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Corrosion Under Insulation (CUI) Monitoring: Prediction of CUI Using Electromagnetic Wave

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Abstract: Corrosion Under Insulation is a major problem for oil-and-gas industries, as it costs loss of billions of dollars annually. The problems associated with CUI are that the corrosion occurred beneath the insulation layer, thus not visible for human eye and visual inspection. The objectives of this study are to identify the amount of water ingress in insulation and to identify the corrosion rate of low carbon steel pipe under insulation over a period of 6 months. The scopes of the study are limited to low carbon steel pipe, with length of 2m, pipe thickness of 10mm, and the range of wireless network among electromagnetic sensors are 20m, and the study is carried out at an uncontrolled environment. The material of the pipe used is low carbon steel pipe, while the insulation material is rockwool. The cladding, which is the weather barrier is made of zinc. The method used to detect the amount of water ingress in insulation is by using a pair of electromagnetic sensors, by using pipe-guided wave. The data gathered from the pipe-guided wave was then transferred and stored at a PC through wireless connection. The fourth sentence presents key findings and trends that can be observed from the data. The findings through 128 days observation have shown that the average amount of water ingress in insulation was -50.25mℓ, CUI rate of 0.36 mm/year, and maximum estimated wall loss was 0.47mm. The findings on the amount of water ingress in insulation and CUI rate allowed maintenance staff at oil-and-gas facilities to forward planning the maintenance work and the study may be carried out under controlled environment for future work.

Keywords: Corrosion Under Insulation, Non-Destructive Evaluation, Corrosion Rate

1. Introduction

In general, corrosion means a material reacts with their environment. As a material continues to react with the environment, the properties of the materials such as tensile strength and appearance will decrease over time as the material deteriorates. There are three regions or state for any materials, which are corrosive, passivity, and immune. Thus, to prevent or mitigate corrosion, we can carry out adjustments on the properties of a material to bring it to the region of passive or immune. Corrosion Under Insulation (CUI) is a severe form of localized external corrosion. CUI is a major problem in oil-

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and-gas industries, resulting in loss of billions of dollars every year [1]. CUI usually occurred when the fluid flow in insulated pipe is around 60 ºC to 200ºC. The existing method of monitoring the corrosion of insulated pipe carried out by oil-and-gas industry was by using corrosion coupon, where intrusive probe was added at various distance of pipeline. The limitation of this method was that it takes 3 to 12 months of exposure time. Because of this, lab work may not be carried immediately and had to wait 3 to 12 months. Also, this method was not able to detect any specific corrosion activity that happens through the period of exposure. Besides that, this method was not able to record any peak activity of corrosion happening and their duration, since it was important to note the activity of corrosion, whether during operation or off-duration. The objectives of this study are to identify the amount of water ingress in insulation and to identify the corrosion rate of low carbon steel pipe under insulation over a period of 6 months. The expected outcome of this study shall be the identification of the amount of water ingress in insulation and CUI rate for an offline insulated low carbon steel pipe.

1.1 Factors of CUI

There are 4 environmental factors that cause CUI, which were coating, temperature, chlorine, and microbial [2]. When the coating of the insulated pipe failed, CUI may occur [3]. Also, when the fluid temperature inside the insulated pipe is between 60 ºC to 200ºC, the tendency for CUI to happen is high. Besides that, the presence of chloride in the environment, such as at offshore plant, chloride stress corrosion cracking may occur. Some of the methods to detect chloride in metals were by using near- and far-field microwave non-destructive methods [4]. Also, microbes found in the seawater may degrade the pipe and caused microbial influenced corrosion (MIC).

1.2 Type of Corrosion Happening Under Insulation

There are 4 types of corrosion that happened beneath insulation, which were uniform corrosion, pitting corrosion, stress corrosion cracking, and microbial influenced corrosion [5]. Uniform corrosion is the degradation of a metal over all areas exposed to the environment. Materials such as carbon steel do not form passivation layer, thus is vulnerable to uniform corrosion. Protective coatings are usually applied to protect the surface of carbon steel.

Besides that, pitting corrosion a form of corrosion where the degradation of the material is localized to small areas rather than over the entire surface uniformly and usually occur at mild steel [6]. Pitting corrosion occur when the protective film of metal surface failed, and contaminants and salt particles penetrate the metal surface. Tiny holes may be observed on the surface while Deep pits were formed within the material. The pits were formed due to contaminants and salt particles.

Next, stress corrosion cracking occurred when the 3 conditions, which were susceptible material, applied or residual tensile stress, and at corrosive environment [7]. Also, the chloride accumulated from seawater at offshore environment will cause chloride stress corrosion cracking. The location of the corrosion usually happened at the base where stress was concentrated, and the crack growth was due to enhanced electrochemical conditions.

Lastly, Microorganisms including bacteria are found in sea water and these organisms can contribute to material degradation. Biofilms may form at the surface of marine structures and influence corrosion rates, initiate corrosion, or change the mode of corrosion [8].

2. Materials and Methods

In the study, low carbon steel was the chosen material for pipe, while rockwool was chosen as the insulation material. Zinc was selected as the material for cladding. The material used on the support structure was also low carbon steel, that include I-beam and square hollow steel bar. Silicon sealant was used to seal the gap between insulation layer and pipe.

2.1 Materials

The length of the pipe used was 2m, with a wall thickness of 10mm. The diameter of rockwool insulation wrapped on the pipe was 50.8mm. The diameter of pipe was 100mm. The electromagnetic sensors were added to the insulation layer, at a depth of 20mm. Humidity sensors were also added to the insulation layer at a depth of 10mm. Both electromagnetic and humidity sensors were powered and connected to transceiver. The detailed dimension and alignment of components of pipe setup was shown in Figure 1.

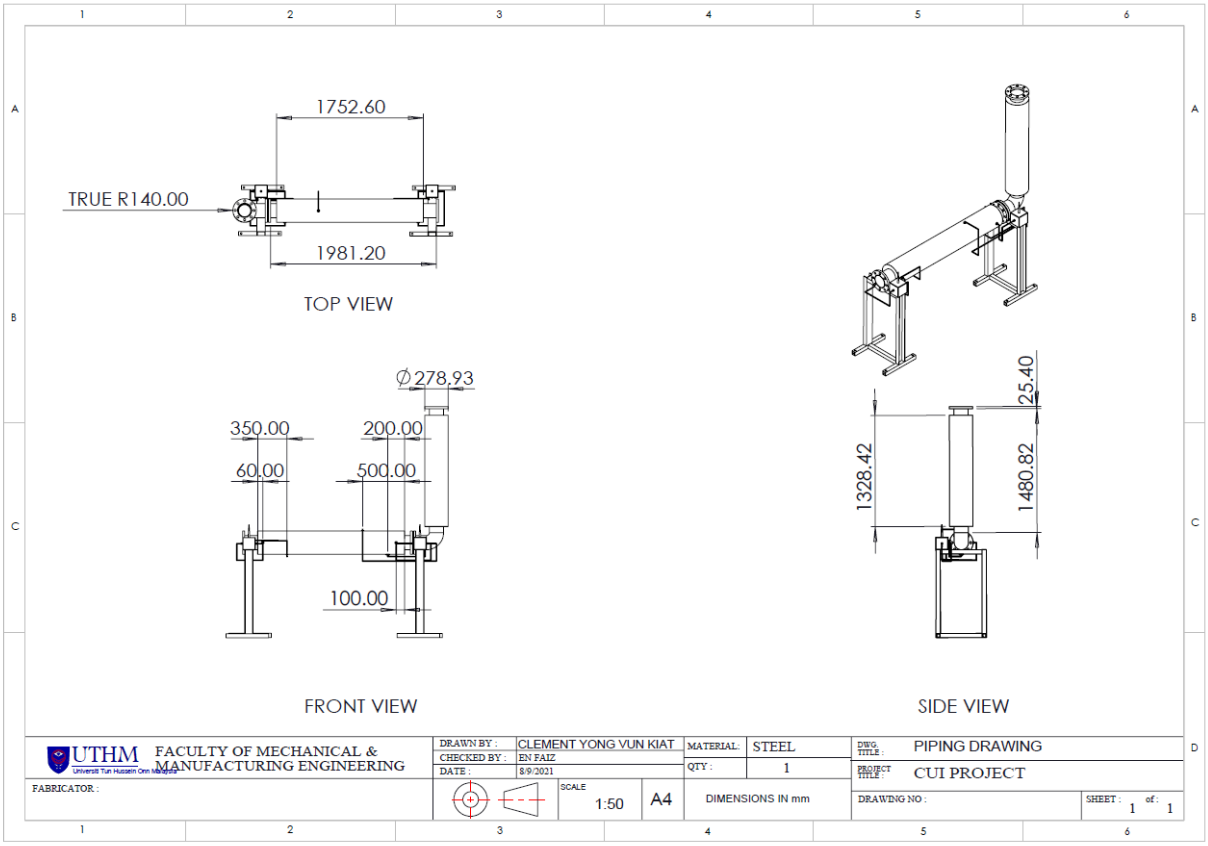

Figure 1: Full drawing of pipe setup

2.2 Methods

Holes were drilled on the cladding and penetrate the insulation layer up to 20mm, to allow space for the installation of electromagnetic sensors. On the left end of the pipe, the drilled hole was 60mm away from the left end of pipe. Another hole was drilled on the right end of the pipe, measuring 100mm away from the right end of pipe. The location of the drilled holes for electromagnetic sensors were at 3 o' clock alignment on the pipe. At 6 o' clock position of the pipe, 2 holes were drilled at a depth of 10mm, to allow the installation of humidity sensor. On the left end of the pipe, the drilled hole for humidity sensor was 350mm away from the left end of the pipe. On the right end of the pipe, the hole was drilled 200mm from the right end of pipe. The length of the horizontal pipe used was 2m, with a wall thickness of 10mm. The diameter of pipe was 100mm. The electromagnetic sensors were added to the insulation layer, at a depth of 20mm. Humidity sensors were also added to the drilled hole on the insulation layer at a depth of 10mm. Both electromagnetic and humidity sensors were powered and connected to transceiver. The transceiver then sends the signal to the PC, with the wireless corrosion monitoring software called WiCorr CUI and WiCorr Trend. The electromagnetic sensors, humidity sensors, transceiver, and software were supplied by 3-SCI, a company founded on England. The detailed dimension and alignment of components of pipe setup was shown in Figure 2.

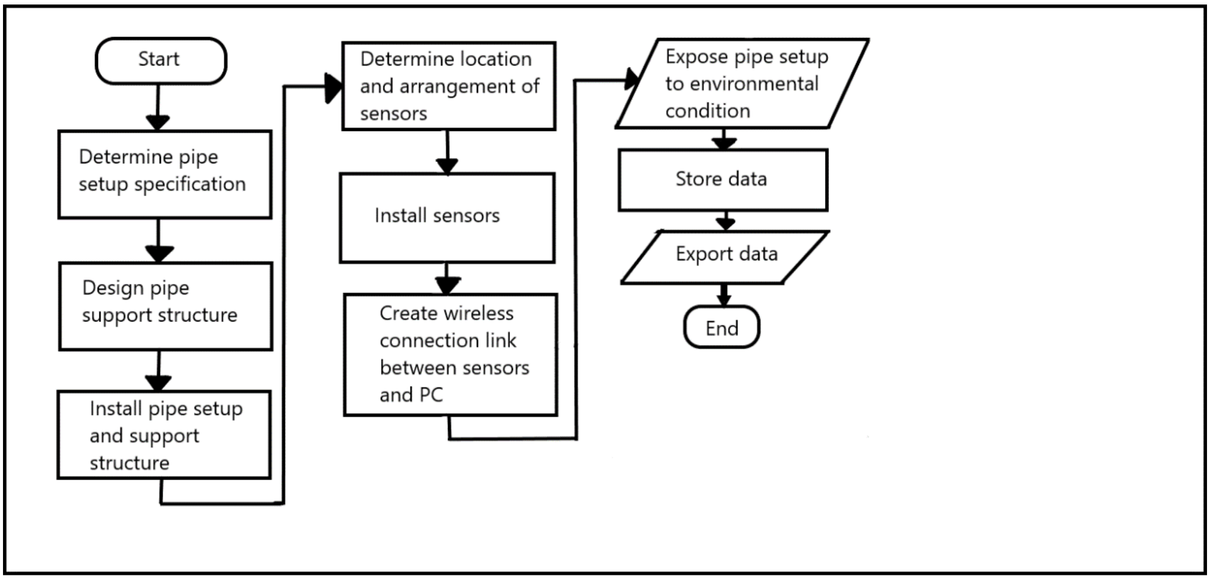

Figure 2: Flow diagram of pipe setup

3. Results and Discussion

In this study, the data obtained through 128 days observation was water ingress in insulation, humidity level, temperature, and corrosion rate. The results and discussion section shall be shown and explained at the subtopic 3.1 and 3.2.

3.1 Results

Figure 3 showed the graph of the amount of water ingress in insulation through 128 days observation, while Table 1 showed the data of relative humidity, temperature, CUI rate, and maximum total estimated wall loss. The explanation and analysis of data will be explained in subtopic 3.2.

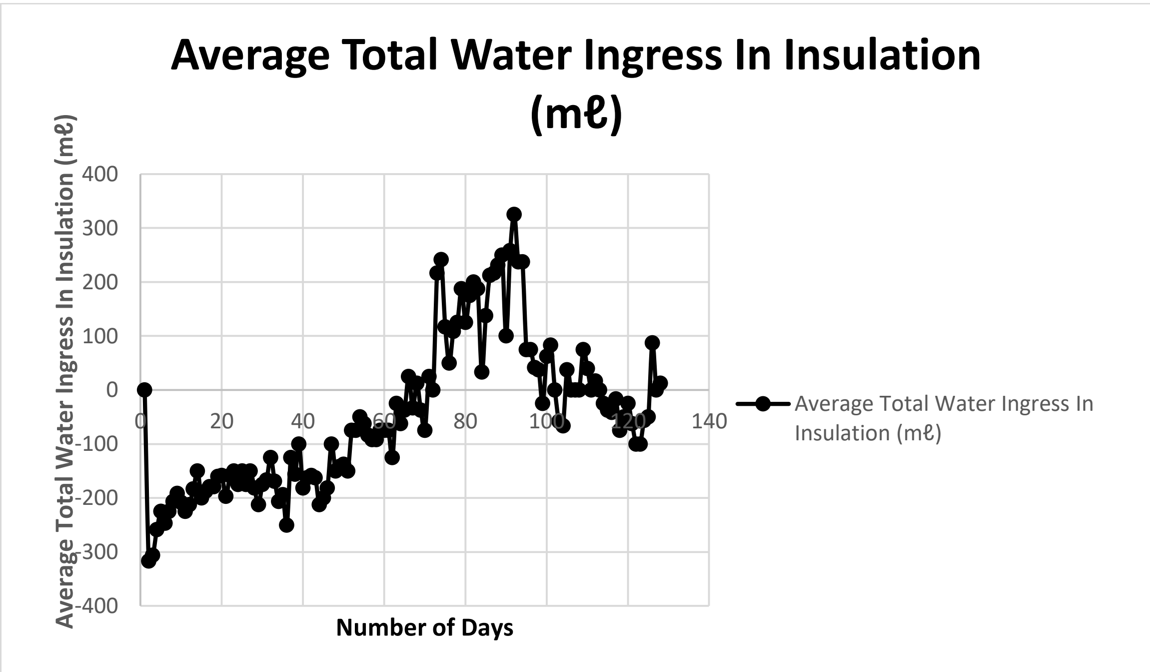

Figure 3: Average total water content in insulation (mℓ) for 128 days observation

Table 1: Humidity level, temperature, CUI rate, and maximum total estimated wall loss data

Item	Parameter Name	Variable Value	Unit or Dimension	Reading
1	Humidity sensor 1	0.01	%	99.62
2	Humidity sensor 2	0.01	%	92.84
3	Humidity sensor 3	0.01	%	96.21
4	Temperature in insulation	0.01	Degree Celsius (ºC)	29.89
5	Ambient temperature	0.01	Degree Celsius (ºC)	29.11
6	CUI rate	0.01	mm/year	0.36
7	Maximum total estimated wall loss	0.01	Millimeter (mm)	0.47

3.2 Discussions

Based on Figure 3, the average total water ingress in insulation slowly shifted from negative towards positive, with an average value of -50.25 mℓ. The slow increase of reading was due to the rainy season, as more water molecule sipped into the insulation layer. Next, the reading from the three humidity sensors were higher than the average humidity based on [9], which was between 74% to 86%. The reason was because moisture was trapped in the insulation layer and not able to escape to the environment. Also, there were relationship between water content in insulation and humidity level. Redox process took place between water and carbon steel, in the presence of humidity. The CUI rate showed the reading of 0.36mm/year and was calculated based on [10]. This reading may be taken as future reference for offline insulated pipe. For the reading of maximum total estimated wall loss, the study has recorded a wall thickness reduction of 0.47mm over 128 days observation. This reading was then verified by conducting ultrasonic test.

Also, the temperature differences between temperature in insulation and ambient temperature were negligible and acceptable since the pipe setup was an offline pipe, as no additional heat source was added to the pipe setup.

4. Conclusion

The main findings of the study were concluded where the average amount of water ingress in insulation for an offline insulated pipe was -50.25 mℓ. The study also discovered that for an offline pipe, it has a CUI rate of 0.36mm/year and maximum total estimated wall loss of 0.47mm through 128 days observation. The presence of humidity also allowed uniform corrosion to occur. The pipe setup may be done in a lab, where temperature, humidity, and the addition of some heat source flow may be done to simulate the industrial environment and process in future work.

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