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Cathodic Protection in Onshore Pipe Networks Gas Pagardewa Receiving Station

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ABSTRACT

The use of pipelines is one element that plays an important role as a production chain The pipeline network is used as the main component to distribute gas from the producer to the shipper and then distributed to industrial and household customers. In accordance with the regulations of the Ministry of Mines and Energy No. 300. K / 38 / M.PE / 1997 concerning the Occupational Safety of Petroleum and Gas Pipeline Pipes that the gas and main pipe transmission pipes held on land must be planted with a depth of at least 1 (one) meter above ground level. However, the placement of steel pipes in the ground can cause pipe material to be threatened by corrosion due to interaction with the environment. This happens in the Pipeline Line of the Gas Pagardewa receiving station. To prevent corrosion from continuing on the pipeline, a precautionary step is needed where one of them is by applying the cathodic protection method. At Pagardewa Gas Receiver Station, which has the role of distributing gas to PLN's power plan in South Sumatra by using a 4875 m pipeline that is embedded in the ground so it needs to be designed for a cathodic protection system to be corrosion resistant. The purpose of this study is to design a cathodic protection system that uses sacrificial anodes so that the analysis can be obtained to be applied in the field.

Keywords: *pipe transmission, cathodic protection, sacrificial anodes, pitting corrosion*

1. INTRODUCTION

The National Gas Company is a company engaged in the transportation and distribution of natural gas, the use of pipelines is one element that plays an important role as a production chain he pipeline network is used as the main component to distribute gas from the producer to the shipper and the shipper is distributed to industrial and household customers. In accordance with the regulations of the Ministry of Mines and Energy No. 300. K / 38 / M.PE / 1997 concerning the Occupational Safety of Petroleum and Gas Pipeline (Simpson, 2017; Sudarsan, 2017; Bahadori, 2017).

Pipes that the gas and main pipe transmission pipes held on land must be planted with a depth of at least 1 (one) meter above ground level. However, the placement of steel pipes in the ground can cause pipe material to be threatened by corrosion due to interaction with the environment. To prevent corrosion of the pipe network, a precautionary step is needed where one of them is by applying the cathodic protection method (Brock et al., 2017; Bu.Y et al., 2018)

Pagardewa Gas Receiver Station has the role of distributing gas to the power plan of the State Power Plant in South Sumatra by using a 4875 m long pipeline embedded in the ground so that a cathodic protection system needs to be designed to protect against corrosion attacks. In conducting this design the researcher will design a cathodic protection system that uses a sacrificial anode (Sacrificial Anode Cathodic Protection) so that the analysis can be obtained to be applied in the field.

2. LITERATURE REVIEW

Pipes are engineering structures that are widely used for the collection, transportation, and distribution of fluids in various regions from rural and urban areas to marine areas. Most pipes are placed underground, charged by land weight and traffic load. Buried pipes are affected by chemical and mechanical loads in the service environment and these pressures cause expensive failure to repair. In many cases, underground pipes are needed to withstand certain environmental hazards. Corrosion of pipe material is the most common form of pipe damage and must be considered both in the analysis of strength and service of the pipe being planted (Mahmoodian, 2018).

High-strength steel pipes operating in the Arctic and sub-Arctic regions experience complex stress and strain conditions. In addition to the circular stress resulting from internal operating pressure, ground motion can produce a significant longitudinal strain on the pipe which can increase corrosion, if it occurs, on steel (Sing R.2014). CP has proven in the past 70 years that it works in a variety of applications, from soil and seawater to concrete, both active and passive metals (Lazzari, 2017). Corrosion is not only an engineering problem but also an economic problem. A study supported by NACE International estimated global corrosion costs to reach US $ 2.5 trillion in 2013, which is equivalent to 3.4% of global Gross Domestic Product (GDP).

General corrosion can occur such as pitting corrosion, and environmentally assisted cracks for plant equipment which in turn can cause loss of containment of hydrocarbon liquids and other process fluids (Arwati, 2016). However, several studies, such as ASM, Kruger, and NACE concluded that between 15 and 35% of the loss corrosion can be saved by applying existing technology to prevent and control corrosion (Shekari et al., 2017). About 40% of all major accidents occur during transportation. Risks associated with this activity can be estimated along the transportation route (Casal, 2018). This problem affects the economy and industrial stability and endangers the lives of employees. Of the total, the oil and gas industry takes up more than half of which is related to the processes of petrochemical processes and refining (Makhlouf et al., 2018).

Talang Duku State Power Plant in South Sumatra uses a 4875-meter long pipeline that is embedded in the ground so it needs to be designed for a cathodic protection system to protect against corrosion attacks. This study aims to determine how much the sacrificial anode is needed to protect the pipe from corrosion attack. within twenty years. Can design a cathodic protection system on a 4875 m pipe.

3. RESEARCH METHODOLOGY

3.1 Survey of Soil Resistivity

In simple terms, this measurement method is carried out by using four electrodes which are stuck with the same distance between electrodes. Then do the measurement with a soil resistance measuring instrument that will inject alternating current - back to the ground. The horizontal measurement results can represent vertically, because of the nature of the electrodes which will disperse the current radially or form a ball. Current and voltage measuring devices are in one measuring instrument. With the measurement of current and voltage, you will get an R-value using Ohm's law. The ground resistivity measurement equipment used is like Figure 1.

Fig. 1. Soil Resistance Measuring Instrument; (A) Meter resistance, (B) Copper cable, (C) Pin for plugging into the ground

The scheme of installing a soil resistance measuring instrument using the Four Wenner Electrode method can be seen in Figure 2.

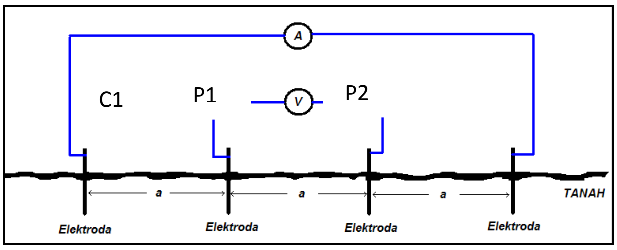

Fig. 2. Measurement of soil resistance with four Wenner electrode (Source: Adi. 2008).

The measurement procedure is as follows (1) Insert four steel pins into the ground at a fixed distance in a straight line. Then connect each pin to the measuring instrument, 2) The distance measured represents the measurement of type resistance from the depth of the electrolyte with variation 0.8; 1.6; 2.4 and 3.2 m. (3) The two outer pins (C1 and C2) are current electrodes, while the two inner pins (P1 and P2) are potential electrodes that measure potential decreases due to the resistance of the electrolyte (ground) when the current is passed between the outer pins, (4) Measuring the resistance value directly to the end system and calculating the resistance value of its type according to the following equation (Dai et al., 2018; Genchev et al., 2017) :

$$\rho = 2.\Pi.A.R. \quad (1)$$

Where:
ρ = soil type resistance (Ohm-cm)
a = distance between pins (cm)
R = measured resistance (Ohm)*Π= 3.14*

3.2 Pipeline Potential Survey and Soil pH

In simple terms this measurement is carried out easily, for pipe potentials it can be done using Cu / CuSO4 (Half CS) Corrosion Test (CSE) and multimeter measuring instruments. Whereas for soil pH measurement using pH Meter. The results of measurements of pipe potential and soil pH can be analyzed using Pourbaix Graph to find out whether the soil is in the immune or corrosion area so that it can determine whether or not a cathodic anode protection installation needs to be done. To make these measurements the equipment is used as follows:

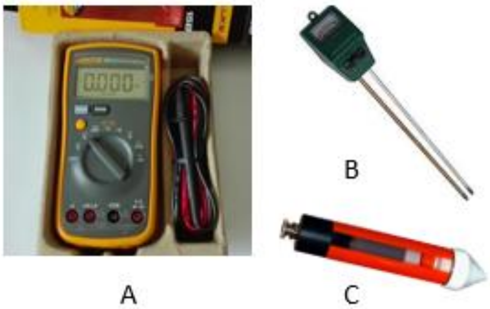

Fig. 3. Pipe potential measuring device; (A) Standard Electrode Cu / CuSO4 (CSE) (B) Multimeter (C) pH meter

Measurements of Soil pH based on Dr. Marcel Purbaix Coating materials using protected layer material: Three Layer Polyethylene (3LPE).

4 PURPOSE OF OUTCOMES AND DISCUSSION

4.1 Measurement results Pipes Before and after Protection

The results of the measurements before protection to determine the optimal cathodic anode attachment. It was found that corrosion of the Onshore Pipe Network of the Pagardewa Village Gas Receiving Station can be seen in Fig. 4.

Fig. 4. Pipe corroded before corrosion protection

Data structures that will be protected are; Pipe Material: Low carbon steel Pipe specification: API 5L Grade B, NPS 12 "Sch.80, SMLS, Length of API 5L Grade B steel pipe, NPS 12 "Sch. 80, SMLS: 4875 m. measurements include Resistivity based on (Peabody A.W., 2011). Test Results for Soil Resistivity. The measurement process requires the survey location to be a fairly flat plain. At each location four measurements were made with variations in the distance between pins of 0.8 meters; 1.6 meters, 2.4 meters and 3.2 m, this distance represents measurements of type resistances from electrolyte depth. The graph of the results of measurements can be seen in Figure 5.

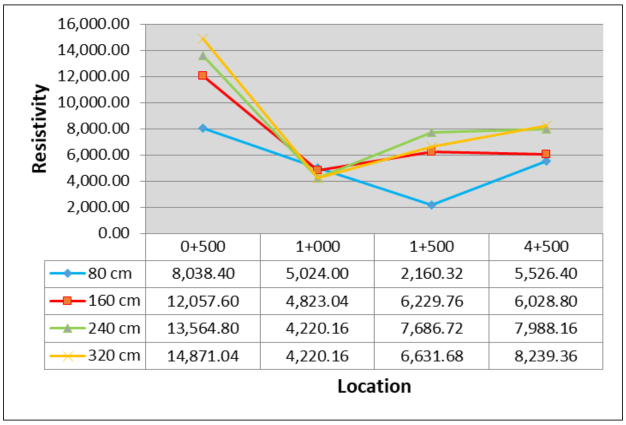

Fig. 5. Graph of Land Resistivity Measurement

From the graph above, it can be found that the measurement results of varying soil resistivity are: (1) a blue curve with a depth of 80 cm, the result of the resistivity of the soil along the pipeline is at least 2160.32 ohm.cm, 2) for a red curve with a depth of 160 cm, the results of the resistivity of the soil along the pipeline line are at least 4823.04 ohm.cm, (3) for a green curve with a depth of 240 cm, the lowest resistivity of the pipeline is 4220.16 ohm.cm (4) for the yellow curve with a depth of 320 cm, the result is the lowest resistivity of the soil along the pipeline 4220.16 ohm-cm.

The data that will be selected is the lowest value of the soil resistivity, which is 2160.32 ohm.cm because according to the criteria of soil corrosion, the lower the resistance the more corrosive the environment.

4.2 Potential Test Results and Soil pH

The survey process measures between potential and pH carried out on the soil as long as the pipe to be planted are 4875 meters long and measured every 500 meters. Determination of this potential involves the reference electrode. The results of measuring soil pH and corroded pipes can be seen in table 1 below

Table 1. Pipe Potential Measurements and Soil pH before Protected Installations

Distance range (m)	Potential value (mV)	pH
0	259.1	5
500	208.4	5
1000	210	5
1500	292.7	5.5
00	311.2	7
2500	305.3	7
3000	302.6	6
3500	317.2	6
4000	315.1	6
4500	315.1	5

Before protecting the inlet pipe in the corroded area, we can see the soil pH value and the pipe potential in Fig. 6 below.

Sacrificial anode uses Magnesium with blanket backfill for the purpose that the anode's performance is better and corroded accordingly. Backfill for feed anodes consisted of a mixture of gypsum, bentonite and natrium sulfate with a composition of 75% gypsum, 20% bentonite (clay), 5% sodium sulfate. The weight of the selected anode is 14.5 kg type 32D5. Length of prepacked magnesium anode 32lbs (m): 0.9 m and Diameter of prepacked magnesium anode 32lbs (m): 0.195 m. To determine the surface area of the pipe structure to be protected pipe diameter is 12".

SA = πDL (2)

D = 12 "= 0, 0254 x 12 = 0,32385 m

L = 4875 m

The surface area of a protected structure is:

SA = 3,14 x 0,3 2385m x 4875 m = 4957,33 m

Protection Flow Requirements;

Id = Icoating . coating breakdown (3)

Id = 20 mA/m2 x 3 % = 0,6 mA/m2

Total Protection Flow Requirement

IReg = Id . Sa

(4)

IReg= 0,6 mA/m2 x 4957,33 m2 = 2974,39 mA

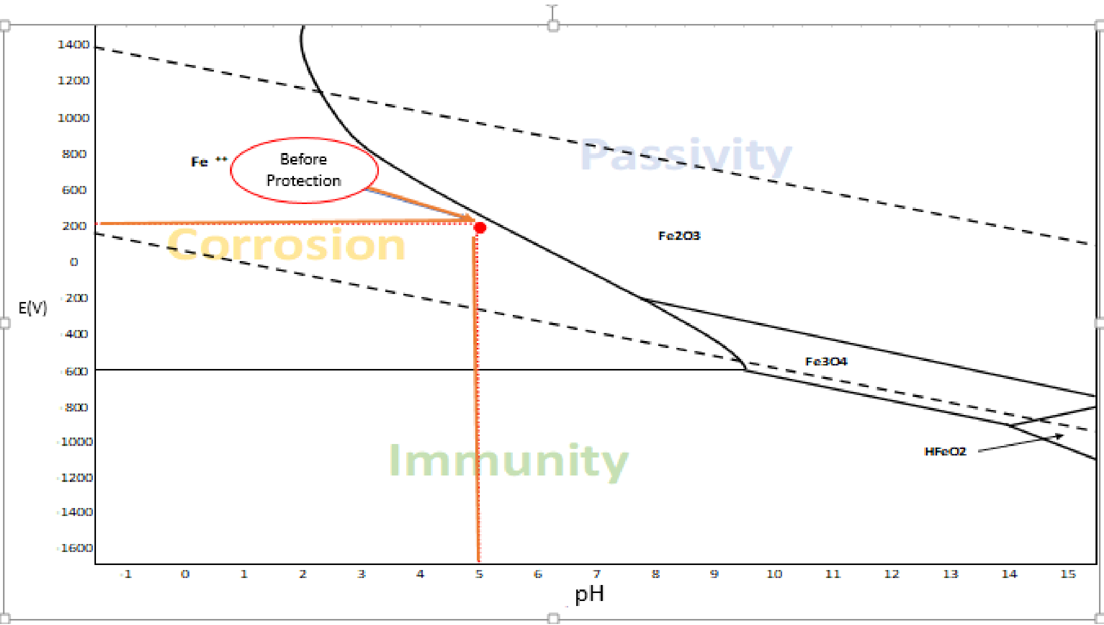

Fig. 6. Graph of Pourbaix measurement results before installed Cathodic Protection

From the calculation above, it is found that for the ginning, but in the middle and the end of the protection flow will vary greatly with time, the longer the increase. This indicates that the coating has begun to deteriorate. To determine the Total Need for Anodes

$W = (I_{Req} . t . 8760)/(\eta.u)$ (5)

W = (2,97 A x 20 x 8760) / (1100 Ah/Kg. year x 0,8)

W = 591,3 Kg

Total weight of the anode needed during the design time is 975.54 Kg. the weight requirement of the anode depends on the size of the protected structure, the greater the structure, the greater the anode used. To determine,

$N = W/W_{anoda}$ (6)

N = 591,3/14.5 = 40,78 ~ 41

The number of anodes to protect the pipe during the design life is 68 Magnesium anodes. For construction purposes, the standard requires a spare 25 - 50% of the number of anode calculations for conditions if there is a river crossing or road crossing. To determine the location of the anode installation. The distance between the anode = 4875/41 = 118.9 ~ 119 m.

The location of anode installation or anode spacing is assumed at the beginning with a normal distribution. But in practice, the results of calculations will be largely determined by conditions in the field. Anode resistance is determined by several factors, namely the anode dimension, soil resistance, and installation position. Anodes that are installed

vertically and horizontally will have different prisoners

$R_h = (\rho/2\pi L)[\ln (4L/D)-1]$ (7)

= (2160.32/90.π.2.)[ln(4.90/19.5) -1] = 7.32 Ohm

Anode Output Flow;

$R_v = (\rho/2\pi L)[\ln (8L/D)-1]$ (8)

$R_v = (2160.32/90.\pi.2)[\ln(8.0/19.5)-1]$

$R_v = 9.97$ Ohm

$$I_h = (E_{anode} - E_{proteksi})/R_h \quad (9)$$

$= (1.55 – 0.85)/ 7.32 = 0.09$ A

$$I_v = (E_{anode} - E_{proteksi}) /R_v \quad (10)$$

$= (1.55 – 0.85)/9.97 = 0.06$ A

The horizontal installation will give a larger output current, so the installation is chosen horizontally. Total Flow of Amount of Anoda

$$\text{anoda total} = I_{anoda}. X N \quad (11)$$
$$= 0.09. 41 = 3.69 \text{ A}$$

from the calculation of the protection current requirements above, it is found that the total output of the anode (applicable protective current) exceeds the required protection current so that this analysis may be applied for protection in the pipeline network on the Pagardewa Gas Receiving Station. The excess of anode protection current is caused by the calculation of anode factor of 80%, but this is not a problem because, in the river crossing and crossroad, the need for anode protection current becomes larger as a capital modification in the field. To determine the age of homogeneous protection of anode

$$t_{anoda} = (I_{anoda\ total} / I_{req}) . t_{design\ life}. \quad (12)$$

$t_{anoda} = (3,69/2,97) . 20. 0.8 = 19.8$ year

Based on the anode calculation it will run out (80% of the weight per anode) within 20.28 years or more than the design time of this with the assumption of constant current output current. Whereas in practice anode will only issue current according to the need, the output current will depend largely on the extent of the coating damage (at the initial condition of the need for a very small current), then wet or dry soil conditions will also affect how much damage the coating itself

4.3 Anode Cultivation Design

Installation of the cathode anodic cathode protection installation refers to KEPMEN 370K / 1997 for its depth and distance with the pipe in accordance with technical considerations. the anode installation was chosen horizontally with consideration of the value of resistance obtained more than 7,32 ohm which has an effect on the outflow of the anode of the victim and the resulting current is greater than 0,09 ampere. The design of the sacrificial anode can be seen in Fig. 7.

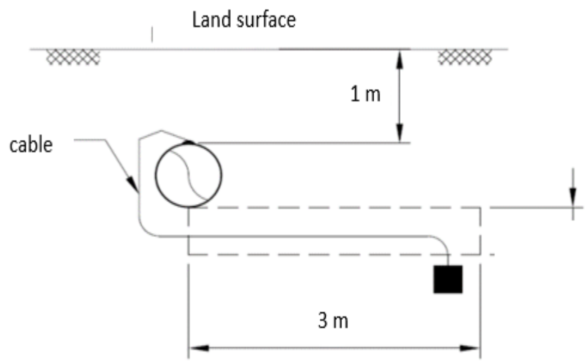

Fig. 7. Cultivating Anodized Surfaces

The installation of the anode victim was installed with the distance of each 119-meter victim's anode into 50 cm deep from the embedded pipe with the distance from the 3-meter pipe and connected with the cable connected by using a thermite welding then made a test cable directed to the test box used to monitor the pipes that are in protection.

4.4. Test Results After Corrosion Protection

The measurement process between pipe potential and pH is carried out again after the installation of the sacrificial anode on the ground along the 4875-meter pipe and measured every 500 meters. For the measurement results can be seen in table 2 below.

Table 2. Pipe Potential Measurements and Soil pH after Protected Installation

Distance range (m)	Potential value (mV)	pH
0	-931	5
500	-902	5
1000	-902	5
1500	-970	5.5
2000	-1045	7
2500	-1072	7
3000	-1072	6
3500	-1082	6
4000	-1105	6
4500	-1105	5

In the pourbaix diagram the value of soil pH and pipe potential after cathodic protection can be seen as follows (Fig. 8).

After cathodic protection of the sacrificial anode in the pipe, the Pourbaix diagram shows a potential decrease to the immunity area from this indicating that the pipe condition is in a cathodically protected condition.

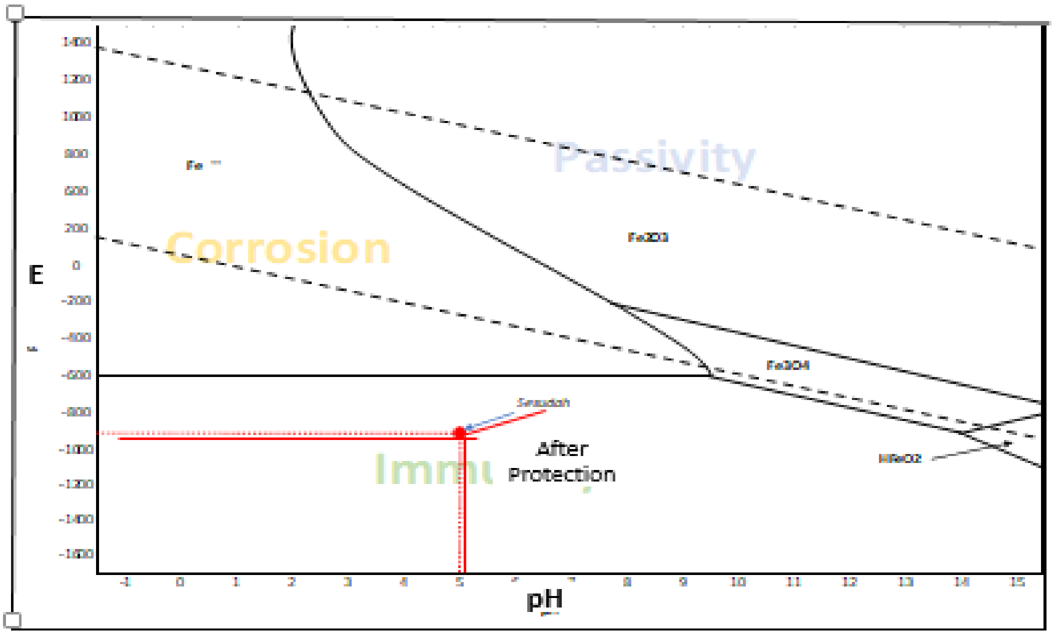

Fig. 8. Graph of Pourbaix measurement results after installed Cathodic Protection

5 CONCLUSION

From the analysis of the sacrificial anodic cathodic protection system above it can be concluded that; The required sacrificial anodes are 41 for the age of cathodic protection 19.8 years fulfilling the time of the 20-year pipe design with a length of 4875 m pipe, this is evidenced by the potential decrease from -121 mV to -902 mV. The best design of anode installation from the calculation results with a pipe length of 4875 m is horizontal with the value of the resistance obtained is smaller and the current is greater when compared to the vertical installation.

6 REFERENCES

Bahadori, A. 2017. Chapter 4 - Transportation Pipelines Pressure Testing. *Oil and Gas Pipelines and Piping Systems*, 93–117. https://doi.org/http://dx.doi.org/10.1016/B978-0-12-803777-5.00004-6

Brock, J., & Zaroog, O. S. 2017. Copper Alloys: Corrosion. *Reference Module in Materials Science and Materials Engineering*, (February 2016), 1–4. https://doi.org/10.1016/B978-0-12-803581-8.02892-7

Bu, Y., & Ao, J.-P. 2017. A review on photoelectrochemical cathodic protection semiconductor thin films for metals. *Green Energy & Environment*. https://doi.org/10.1016/j.gee.2017.02.003

Bu, Y., Chen, Z., Ao, J., Hou, J., & Sun, M. 2018. Study of the photoelectrochemical cathodic protection mechanism for steel based on the SrTiO3-TiO2composite. *Journal of Alloys and Compounds*, *731*, 1214–1224. https://doi.org/10.1016/j.jallcom.2017.10.165

Buchheit, R. G. 2018. *Corrosion Resistant Coatings and Paints. Handbook of Environmental Degradation of Materials* (Third Edit). Elsevier Inc. https://doi.org/10.1016/B978-0-323-52472-8.00022-8

Casal, J. 2018. *Transportation of Hazardous Materials. Evaluation of the Effects and Consequences of Major Accidents in Industrial Plants*. https://doi.org/10.1016/B978-0-444-63883-0.00012-5

Dai, M., Liu, J., Huang, F., Zhang, Y., & Cheng, Y. F. 2018. Effect of cathodic protection potential fluctuations on pitting corrosion of X100 pipeline steel in an acidic soil environment. *Corrosion Science*. https://doi.org/10.1016/j.corsci.2018.08.040

Genchev, G., & Erbe, A. 2017. *Sour Gas Corrosion—Corrosion of Steels and Other Metallic Materials in Aqueous Environments Containing H 2 S. Reference Module in Chemistry, Molecular Sciences and Chemical Engineering*. Elsevier. https://doi.org/10.1016/B978-0-12-409547-2.11546-X

Lazzari, L. 2017. *Cathodic Protection: Basic Principles*. *Reference Module in Chemistry, Molecular Sciences, and Chemical Engineering*. Elsevier. https://doi.org/10.1016/B978-0-12-409547-2.13445-6

Mahmoodian, M. 2018. *Introduction*. *Reliability and Maintainability of In-Service Pipelines*. https://doi.org/10.1016/B978-0-12-813578-5.00001-9

Makhlouf, A. S. H., Herrera, V., & Muñoz, E. 2018. *Corrosion and protection of the metallic structures in the petroleum industry due to corrosion and the techniques for protection*. *Handbook of Materials Failure Analysis*. Elsevier Ltd. https://doi.org/10.1016/B978-0-08-101928-3.00006-9

Shekari, E., Khan, F., & Ahmed, S. 2017. Economic risk analysis of pitting corrosion in process facilities. *International Journal of Pressure Vessels and Piping*, *157*, 51–62. https://doi.org/10.1016/j.ijpvp.2017.08.005

Simpson, D. A.. 2017. *Surface Engineering Concepts*. *Practical Onshore Gas Field Engineering*. https://doi.org/10.1016/b978-0-12-813022-3.00004-3

Singh, R. 2014. *Hazards and Threats to a Pipeline System*. *Pipeline Integrity Handbook*. https://doi.org/10.1016/B978-0-12-387825-0.00005-3

Singh, R. 2017. Corrosion and Corrosion Protection. *Pipeline Integrity Handbook*, 241–270. https://doi.org/10.1016/B978-0-12-813045-2.00017-X

Sudarsan, V. 2017. *Materials for Hostile Chemical Environments*. *Materials Under Extreme Conditions*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-801300-7.00004-8

Sutton, I. 2017. Inspection. *Plant Design and Operations*, 335–352. https://doi.org/10.1016/B978-0-12-812883-1.00011-5

Sutton, I. (2017b). *Transportation*. *Plant Design and Operations*. https://doi.org/10.1016/B978-0-12-812883-1.00007-3

Sagir Alva1, Aiman Sajidah, Mohd Ismahadi bin Syono3, and Wan Adil bin Wan Jamil.2018. Ag/Ag Cl Reference Electrode Based on Thin Film of Arabic Gum Membrane. *Indonesia. J. Chem. 18 (3), 479 - 485*

Arwati, I. A., Majlan, E. H., Daud, R. W., & Alva, S. (2016). *Pengaruh Arabic Gum Terhadap Laju Korosi Pada Aluminium 5052 Menggunakan Teknik Elektroforesis.* Malaysia: Universitas Kebangsaan Malaysia