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THE EFFICIENCY OF CRUDE CORROSION INHIBITOR AND GAS CORROSION INHIBITOR BY USING CARBON STEEL 1018 WITH POLARIZATION METHOD

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ABSTARCT

Carbon Steel 1018 is a low carbon steel having a carbon content (C) of 0.14-0.20% (<0.30% C). Low carbon steel is commercially known as mild steel. Corrosion is one way to prevent corrosion caused by the environment. Corrosion inhibitor are taken between the Crude Corrosion Inhibitor and Gas Corrosion inhibitor on Carbon Steel 1018 using the polarization method. Corrosion inhibitors work by making passive layers in the form of thin films or films on the surface of the material used as a barrier between metals and corrosive media. The analysis method used is polarization. Inhibition Efficiency Results obtained for Gas Corrosion Inhibitors (1A) at 10 ppm 96.86%, 20 ppm 59.74%, 30 ppm 74.48%. The Crude Corrosion Inhibitor (2A) results obtained inhibition efficiency for 10 ppm 99.57%, 20 ppm 77.69%, and 30 ppm 12.63%. The optimum value for the Gas Corrosion Inhibitor and Crude Corrosion Inhibitor is at 10 ppm at 96.86% and 99.57%.

Keywords: carbon steel, crude corrosion inhibitor, corrosion, gas corrosion inhibitor, inhibitor

I. INTRODUCTION

Corrosion is a decrease in the quality of metals due to electrochemical reactions with the environment. Metals that experience a decrease in quality not only involve chemical reactions but also electrochemical reactions.

Corrosion problem is a big and serious problem because it is related to work safety, economy, environmental damage and health, both that occur in industries and in various installations such as in the treatment of clean water, oil and waste (Febrianto, 2010).

The problem of corrosion on metals can be controlled in a number of ways including coating, painting, cathodic protection and adding inhibitor substances into corrosive media. Inhibitors to be one of the most effective ways to prevent corrosion because in its use requires relatively low cost and the process is simple. Inhibitors that can be determined as substances added to the environment will reduce attacks on the environment. Reducing inhibitors from organic and inorganic compounds (Prasetya, 2016).

II. LITERATURE REVIEW

2.1. Corrosion

Corrosion is a decrease in the quality of metals due to electrochemical reactions with the environment. Metals that experience a decrease in quality not only involve chemical reactions but also electrochemical reactions, that is, between the materials involved in the transfer of electrons. The process of material destruction that occurs causes a decrease in the quality of the metal material. Many factors can cause corrosion of a material, one of them is the influence of the concentration of corrosion media (R Kenneth, et.al, 1991).

Corrosion can occur if there are four elements below:

1. Anode
An oxidation reaction occurs, then the area will arise corrosion
2. Cathodes
A reduction reaction occurs, the area consumes electrons

3. There is a relationship (Metallic Pathway)
Where current flows from the cathode to the anode
4. Solution (electrolyte)
Corrosive solutions that can conduct electric current. Corrosion can occur if all four elements are present. If one of the four elements is not present, corrosion will not occur.

2.2. Steel

Pure iron steel (ferrite) certainly does not contain carbon. This iron is relatively soft and tough and is capable of wrought, but not strong. Almost all pure iron has a tensile strength of around 40,000 psi. The addition of carbon into pure iron in amounts ranging from 0.05 to 1.7 percent, produces steel. Carbon steels are usually classified as shown below:

- a. Low carbon steel
Contains carbon between 0.05 to 0.30 wt% C. Has a yield strength of 275 MPa (40,000 psi), tensile strength between 415 and 550 MPa (60,000 and 80,000 psi). Relatively soft and weak but has exceptional toughness and tenacity. Low carbon steel has the characteristics of being malleable, easy to machine, and easy to weld.
- b. Medium carbon steel
It has a carbon concentration ranging from 0.30 to 0.60 wt% C. It has a higher level of strength compared to low carbon steel. Has properties that are difficult to bend, weld, and cut.
- c. High carbon steel
High carbon steels typically contain 0.60 to 1.4 wt% C carbon. It is the most difficult carbon steel to be formed, forged, welded and cut but has the highest level of tenacity. Has very hard and wear resistant properties (Afandi Yudha Kurniawan, et.al, 2015).

2.3. AISI 1018

AISI 1018 is the American Iron and Steel Institute standard, in figure 1018, 1 in the first number is carbon steel (Carbon Steel), number 0 expresses plain (not added sulfur and phosphorus) and 18 shows carbon content (C) around 0.18% .

1. AISI 1018 steel is equivalent to J3 (Japanase Industrial Standards) G3101 SS (Structural Steel) 400, ASTM (American Society for Testing Materials) A283 Grade D and ST 41.
2. This steel can almost all be done in welding, is easily shaped and machined.

The content of the AISI 1018 element on the American Iron and Steel Institute standards is as follows:

- a. Manganese
Manganese content up to 1% will slightly increase the strength of the steel, if above 1.5% the steel will become brittle and very rarely used.
- b. Phosphor
Phosphor serves to add to the molten nature of the steel when it melts, the melting temperature of low carbon steel is 1400 ° C and excess phosphorus adds strength, ductility and resistance to impact.
- c. Silicone
At 0.050% silicon does not affect the steel properties but if the silicon content is more than 0.2% the strength and elasticity of the steel slightly rises without reducing its ductility.
- d. Chromium
Chromium is one of the alloys that must be present in the formation of a passive layer. Passive layers can form in the presence of 10% chromium content. While mild steel has 17-20% Cr, a thicker, more corrosion resistant passive layer is formed in the corrosive environment. Chromium will form a passive layer whose thickness depends on the amount of chromium added (Sudiarti Tety, 2014).

2.4. Polarization Method

Based on ASTM G31-72, to measure corrosion rates there are two methods used to calculate them, the two methods are the weight loss method and the polarization method (Pakpahan Marlina, 2015).

The Polarization Method is a method for determining the behavior of metal corrosion based on the potential relationship and anodic or cathodic currents. Metal corrosion occurs if there is an anodic current of the same magnitude as the cathodic current, even though no current is given

outside the system. Because there is a potential difference between metal and solution as the environment.

The advantages of the Polarization method include:

1. The accuracy of this method is the same even better than conventional methods (weight loss measurement method)
2. To be used to measure very small corrosion rates and can be used to control corrosion rates.
3. Tafel curves can provide a direct picture of the corrosion currents associated with corrosion rates
4. To determine the amount of corrosion rate quickly so that it can be used for research on inhibitors

The rate of corrosion can be determined by this method by using a potentiostat with three electrodes, namely the reference electrode of the calomel type (SCE), auxiliary electrodes in the form of platinum and working electrodes in the form of steel specimens. The data obtained from this method is an anodic / cathodic polarization curve which states the relationship between currents as a potential function (Noviadam M. Riki, Arya Mahendra Sakti,2016).

2.5. Cell Three Electrodes

In this study, the equipment used was three electrode electrochemical cells. Three electrodes used are work electrodes, saturated calomel electrodes and assistive electrodes derived from platinum. The arrangement of electrochemical cells is shown in the following figure:

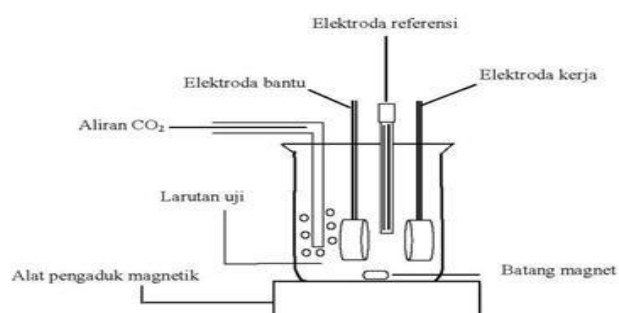


Figure 2.1. Arrangement of three electrode electrochemical cells for electrochemical measurement

a. Working Electrodes

The working electrode is the designation for the electrode being studied. Work

electrodes can be prepared by installing a small specimen in the cooling resin. The specimen must have an electrical connection and can be prepared before installation. After installation, the specimen surface must be grinded or sanded.

b. Auxiliary Electrodes

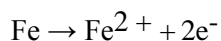
The auxiliary electrode is the second electrode which aims to transport current in the circuit formed in the study. These electrodes are not needed for potential measurements. The material used for auxiliary electrodes is usually carbon rods, platinum.

c. Reference Electrodes

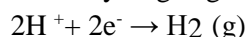
The Reference Electrode aims as a base point to refer to measurements of the working electrode potential. The current flowing through this electrode must be as small as possible so that it can be ignored. If this is not the case, this electrode will participate in the cell reaction and its potential is no longer constant, therefore a reference electrode is needed.

Iron which will become an anode when compared to hydrogen ions increases in acid. The reaction equation is:

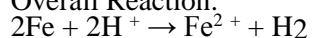
a. When iron is dissolved:



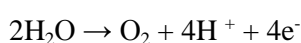
b. When hydrogen gas is formed:



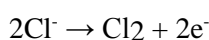
c. Overall Reaction:



The electrode electives chosen are those that will not pollute the answers with the ions. Other reactions must be present on the surface of the electrode if the electrons needed by the platinum cathode must be purchased. The reaction that takes place in an electrolyte is the reaction of the generation of oxygen gas through air oxidation:



Other possible reactions in chloride containing electrolytes are the generation of chlorine gas (Salimor Mario, 2017) :



Carbon steel corrosion rate testing is carried out in an electrochemical cell containing Brine Water and Kerosene test solutions that are bubbled with CO₂ gas. Electrochemical method is a method of measuring the rate of corrosion by measuring the difference in object potential until a corrosion rate is obtained, this method measures the rate of corrosion when measured alone which estimates the rate with a long time (estimating even though the results that occur between one time with another time are different) .

Variation of CO₂ gas injection time for 6 hours, then the carbon steel corrosion rate can be measured. This measurement uses three electrode cells, including the working electrode, namely carbon steel, auxiliary electrode, platinum, and the reference electrode, which is saturated calomel. The three electrodes and the thermometer are immersed in the test solution with the distance between the working electrode and the assist electrode about 1 cm and the comparison electrode being between the surface of the working electrode and the assist electrode. After that, the three electrodes are connected with a potential potentiostat / Galvanostat voltalab type. Corrosion rate testing was carried out using the potentiodynamic polarization method, then with the help of Gamry 600 Software.

The standard electrode used is KCl and the counter electrode used is platinum. All necessary information is entered in the set up program so that a polarization curve is obtained. The potential area for carbon steel corrosion is reached when the carbon steel interface and solution reach a steady state indicated by the value of the Open Circuit Potential (OCP).

2.6. Corrosion Inhibitors

One method of inhibiting the process of corrosion is to use a corrosion inhibitor. Corrosion inhibitors are chemicals that when added to an environment, can reduce the rate of corrosion that occurs in the environment of a metal in it (R Kenneth,1991).

Corrosion inhibitors work by forming a passive layer in the form of a thin layer or film on the surface of the material that serves as a barrier between metal and corrosive media. Many types of inhibitors are available that can be chosen to overcome the problem (Febrianto et.al,2010)

Corrosion inhibitors are added to the media in parts per million (ppm) rate. The choice of corrosion inhibitor depends on the actual conditions of the field. Factors such as temperature and flow rate conditions need to be studied before determining corrosion inhibitors. In the use of inhibitors, manufacturers explain specifically or recommend the amount / dose of use of the product. It is very important to know the product's performance when overdosing or underdosing. The number of inhibitors must be enough to protect the surface of the material from the system.

III. METHODOLOGY

Corrosion testing was carried out electrochemically with potentiodynamic polarization techniques using a potentiostat controlled by the Voltmaster program. Here is how the bubble test works:

A. Tools used

The tools used in this study were: Potentiostat, three electrodes, computers, pH meters, cutting tools, grinding tools, measuring cups, measuring flasks, analytical holes, stirring rods, magnetic stirrers, and carbon steel 1018

B. Material used

The materials used are NaHCO_3 , $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$, $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$, $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$, Na_2SO_4 , $\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$, KCl, NaCl, Kerosene, Aquadest, Crude Corrosion Inhibitor 1A and Gas Corrosion Inhibitor 2A.

C. Work Steps

• Sample Preparation

The specimen is circular cut with a diameter of ± 1 cm. Then the sample is prepared by making a sample of the wire taken with the specimen so that the flow can reach the specimen. The next sample starts from coarse to fine with lattice. After that the sample is cleaned with tissue paper that was previously dipped in acetone, then dried in a desiccator.

• Solution preparation

Table 3.1. Ingredients for making saline solution

NO	Chemical Material	Amount (gram)
1	NaHCO_3	3,7290

NO	Chemical Material	Amount (gram)
2	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$	0,4448
3	$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	0,5038
4	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	0,0027
5	$\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$	0,0362
6	Na_2SO_4	0,0111
7	$\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$	0,0176
8	KCl	0,1947
9	NaCl	7,5896

• Testing

Corrosion testing uses the electroplating method by immersing specimens and electrodes in a solution of artificial brine, inhibitors and kerosene. The variation of inhibitor concentration is 10, 20 and 30 ppm. In the immersion process, electricity is supplied to assist the testing process. The testing time for each specimen is 6 hours. After testing, the specimen is cleaned and then dried. In the test obtained the value of inhibition efficiency with the formula used:

$$\text{Inhibition efficiency (\%)} = \frac{CR_b - CR_i}{CR_b} \times 100\%$$

Explanation :

CR_b = corrosion rate without corrosion inhibitors

CR_i = corrosion rate with the addition of corrosion inhibitors

IV. RESULT AND DISCUSSION

4.1. Characteristics of AISI 1018 Steel

AISI 1018 steel is a low carbon steel having a carbon content (C) of 0.14-0.20% (<0.30% C). Low carbon steel is commercially known as mild steel. This steel is widely used in various types of construction: power plants, building construction, bridge construction, buildings, roof truss buildings and others because of the low price.

The advantages of AISI 1018 steel carbon content is very low but its strength reaches 400 MPa, easy to form and heat resistant. Specimens derived from carbon steel as test samples are formed into cylinders. Specimens that are small or have irregular shapes will be difficult to

handle, especially when sanding and finishing are done. Examples are wire specimens, thin sheet metal specimens, thin pieces. The specimens must be placed on a media (mounting media) to facilitate handling.

In general, mounting using synthetic plastic material. The material can be in the form of resin (castable resin) mixed with hardener. The use of castable resin is easier and the tools used are simpler, because there is no need for heat and pressure applications. This castable resin material does not have good mechanical properties (soft) so it is not suitable for hard materials.

The specimen is then added with an electrode so that only one surface is in contact with the test solution. The test sample was sanded while flowing with distilled water, then the carbon steel surface was cleaned with acetone and then dried and stored in a desiccator, the carbon steel was ready to be used as a working electrode in the corrosion rate test.



Figure 4.1. Specimen AISI 1018

The Polarization Method is a method for determining the corrosion behavior of metals based on the potential relations and anodic or cathodic currents. This method is used to measure the corrosion rate by estimating for 6 hours. The weakness of this method is that it cannot accurately describe the rate of corrosion that occurs accurately because it can only measure the rate of corrosion only at certain times, until the age of use and conditions for treatment cannot be known.

4.2. Efficiency Test Values

Corrosion test results by the Polarization method are listed in the following tables:

Table 4.1. Composition of Test Solutions

Description	Composition
pH at room temperature	7,65
Cations, mg/litre	
Sodium (Na)	4020
Potassium (K)	101,9
Calcium (Ca)	137,3
Magnesium (Mg)	53,2
Barium (Ba)	1,5
Strontium (Sr)	5,8
Total Iron (Fe)	10,7
Anions, mg/litre	
Chloride (Cl)	5116
Bicarbonate (HCO ₃)	2708
Sulphate (SO ₄)	7,5

Table 4.2. Testing Conditions

Description	Proposed Application of Corrosion Inhibitor
Test Solution	As described on Table 1
Test Method	RpEc Trend
Hydrocarbon	Kerosene without additive
Brine/Oil Ratio	90:10:00
Inhibitor Concentration (ppm)	10, 20, 30 ppm
Temperature	60°C
Pressure	Atmospheric
CO ₂ gas	Continuous flowing
Test Duration	6 hours
Test Specimen	C 1018
Test Results	Baseline corrosion rate , mpy
	Inhibited corrosion rate, mpy

Table 4.3. Testing Data in the Last 1 Hour with 1A Inhibitors

Blank		10 ppm	20 ppm	30 ppm	
99,58		2,85	39,45	16,67	
99,36		2,63	48,52	28,03	
101,96		3,40	41,46	28,76	
102,95		4,38	43,50	29,49	
100,34		3,24	38,88	24,29	
101,94		3,00	23,79	19,09	
102,30		2,97	41,62	40,01	
100,94		3,12	47,55	24,41	
100,20		3,39	40,32	22,29	
102,23		2,88	47,86	22,92	
101,59		3,12	34,18	24,70	
101,70		3,18	46,53	23,14	
103,27		2,95	36,41	23,92	
Average at Last Hour	101,57		3,19	40,89	25,92
CR_{Blank}	101,57	CR_{Inhibitor}	3,19	40,89	25,92

Table 4.4. Testing Data in the Last 1 Hour With 2A Inhibitors

Blank		10 ppm	20 ppm	30 ppm
99,58		0,63	24,37	104,70
99,36		0,59	19,36	88,46
101,96		0,57	29,29	94,13
102,95		0,47	25,31	96,32

Blank		10 ppm	20 ppm	30 ppm	
100,34		0,46	25,70	92,06	
101,94		0,41	19,66	87,36	
102,30		0,41	22,55	90,01	
100,94		0,40	23,73	86,86	
100,20		0,41	23,42	85,99	
102,23		0,42	20,80	90,99	
101,59		0,37	20,66	84,28	
101,70		0,32	20,43	84,39	
103,27		0,36	20,94	84,00	
Averae at Last Hour	101,57		0,43	22,65	88,74
CR_{Blank}	101,57	CR_{Inhibitor}	0,43	22,65	88,74

Explanation :

1A = Gas Corrosion Inhibitor
 2A = Crude Corrosion Inhibitor

Table 4.5. Testing Results

Description	corrosion rate last 1 hour	% Inhibition Protection
Blank	101.57	
10 ppm 1A	3,19	96,86
20 ppm 1A	40,89	59,74
30 ppm 1A	25,92	74,48
10 ppm 2A	0,43	99,57
20 ppm 2A	22,65	77,69
30 ppm 2A	88,74	12,63

Based on the data that has been attached, the inhibition efficiency values are as follows:

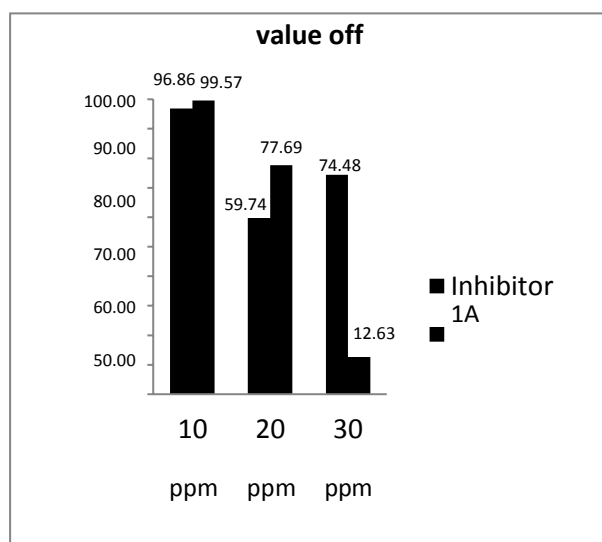


Figure 4.2. Comparison of Inhibitor Efficiency Charts

The inhibitor can work effectively if it is spread to all surfaces and with the condition of the system that must be effective enough to provide protection capabilities. The efficiency of the

inhibitor depends on many factors. The results obtained from the inhibition efficiency for inhibitors with code 1A dose of 10 ppm were 96.86%, 20 ppm dose 59.7%, and 30 ppm dose 74.48%. The results for inhibitors with a code of 2A dose of 10 ppm obtained values of 99.57%, 20 ppm 77.69%, and 30 ppm of 12.63%.

In 1A inhibitors decreased inhibition protection at 20 ppm to 59.74% and again rose at 30 ppm to 74.48%. The cause of the inhibition value is back down, in addition to unstable products as well as compounds in the inhibitor that are incompatible with the material and its environment.

Anions that cause corrosion include Cl⁻, CO⁻. Chloride attacks mild steel and stainless steel. Chloride is usually found in oil-water mixtures in high concentrations that will cause corrosion. Corrosion process can also be caused by an increase in the conductivity of the salt solution, where the more conductive salt solution, the corrosion rate will also be higher. Some types of metal corrosion that can arise include:

- Uniform Corrosion is characterized by electrochemical reactions that are evenly distributed along the surface of the metal so that the surface is eroded and the metal becomes thin.
- Pitting Corrosion, ie localized corrosion attacks produce pits (certain areas) and cause holes in metal surfaces. If the material is exposed to this type of corrosion, the penetration will continue to increase and disrupt equipment life data. Pitting corrosion can occur due to variations in environmental conditions.
- Hydrogen damage, which can occur due to diffusion of hydrogen atoms to the boundary of metal grains and can result in hydrogen blistering, hydrogeninduce cracking.

Carbonate ion (CO²⁻) is often used as a corrosion control where carbonate film is deposited as a protective layer of metal surfaces, but in oil production this tends to cause crust problems. The result of a corrosion attack is local corrosion with a deep pit. The effect of damage is influenced by the nature of the metal and the composition of the inhibitor. The failure of the inhibitor is influenced by the formation of the cementite layer (Fe₃C) in the metal layer.

From a macroscopic perspective it depends on the flow model, chemical solution, temperature. Meanwhile, from a microscopic level perspective, the efficiency of the inhibitor depends on the number of absorption sites, the density of the inhibitor's charge, its molecular size, the way it interacts with the steel surface, the electronic structure of the molecule.

In 2A inhibitors, it is seen that the greater the addition of inhibitors, the less the protection of inhibition. The greater the concentration of the inhibitor added, the less corrosion products are attached to the mild steel surface. This means that the inhibitor attached to the surface functions as a barrier of molecules or ions into or out of the mild steel surface.

There are 2 kinds of inhibitor protection. Primary inhibition is protection due to the addition of compounds (the presence of a thin layer of inhibitors on the mild steel surface) and the second is secondary inhibition, which is protection due to corrosion reaction products. Corrosion continues when inhibitor concentrations are not sufficient to make a film layer.

In type 2A inhibitors, the greater the concentration of the inhibitor, the more film layers of the inhibitor are formed when the amount of corroded area gets smaller with increasing inhibitor concentration. While the thickness of the corrosion product increases the concentration of the inhibitor, the thickness of the corrosion product gets thinner. This causes the corrosion rate to decrease because the film layer of the inhibitor is increasingly covering the surface of mild steel.

From the point of view of the potential difference before immersion shows that the more the concentration of the inhibitor increases the potential difference increases. This shows that the inhibitor has covered the surface of the sample so that the current is blocked by the film layer. While increasing the concentration of the inhibitor potential value tend to go down. The lower the potential value, the less Fe^{2+} ions in solution. This explains that the corrosion rate has decreased.

Based on the comparison results on the inhibitor efficiency chart, for inhibitors with code 1A (Gas Corrosion Inhibitor) effectively used on mild steel at a dose of 10 ppm at 96.86% and for the inhibitor of code 2A (Crude Corrosion Inhibitor) effectively used at a dose of 10 ppm with protection inhibition of 99.57%.

V. CONCLUSION & RECOMENDATION

Crude Corrosion Inhibitor and Gas Corrosion Inhibitor Efficiency Test in Carbon Steel 1018 Using the Polarization Method in the Corrosion Laboratory can be drawn several conclusions, among others :

1. AISI 1018 steel is a low carbon steel having a carbon content (C) of 0.14-0.20% (<0.30% C). Low carbon steel is commercially known as mild steel. Mild steel is 17-20% Cr, so a passive layer that is thicker and more resistant to corrosion in a corrosive environment will form.
2. Inhibition Efficiency Results obtained for Gas Corrosion Inhibitors (1A) at 10 ppm 96.86%, 20 ppm 59.74%, 30 ppm 74.48%. In the Crude Corrosion Inhibitor (2A) the results of inhibition efficiency were obtained for 10 ppm 99.57%, 20 ppm 77.69%, and 30 ppm 12.63%. Optimal inhibitors are used for Gas Corrosion Inhibitors (1A) and Crude Corrosion Inhibitors (2A) at a concentration of 10 ppm with the results of 96.86% and 99.57%.

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