

Inhibition of Zinc Corrosion under Variable Conditions

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Abstract

A study of the zinc behavior under specified conditions of corrosion was done. The conditions in which this study was held are 0.1N HCl solution for three values of temperature for each media viz 20, 40 and 60°C.

The inhibition of zinc corrosion in 0.1N HCl solution was performed using thiourea at the concentrations of (0, 300 and 600 ppm), while for 0.1N NaCl solution, it was NaNO₃ for three values of concentration (0, 150 and 300ppm).

It was noticed that the thiourea inhibition in the acid media approaches up to 90%, while for 0.1N NaCl solution in the presence of NaNO₃ was up to 78%.

All the experiments were carried out using the weight loss method as well as polarization technique. It was seen that the corrosion rate increased and the corrosion potential becoming more negative with the increase in temperature. Increasing inhibitor concentration tends to reduce corrosion current and corrosion potential goes to more positive values.

البحث يهدف إلى دراسة سلوك معدن الزنك تحت ظروف معينة حيث اعتمد مبدأ الاستقطاب

0.1N NaCl

0.1NHCl

درجات حرارية لكل وسط (20 40 60). تم تثبيط تآكل معدن الخارصين في الوسط الحامضي بواسطة استخدام الثايويوريا ولثلاث تراكيز (0 300 600 /) اما في الوسط الملحي فتم استخدام NaNO₃ وبتراكيز (0 150 300 /). قد لوحظ ان مثبط الثايويوريا يعمل بشكل جيد في الوسط الحامضي وقد تصل 90% ومثبط نترات الصوديوم 78%. كما لوحظ ان معدل التآكل يزداد وجهد التآكل يصبح اكثر سالبية مع زيادة درجات الحرارة. اما زيادة تركيز المثبط تعمل على تقليل معدل التآكل وجهد التآكل يصبح سالبية. بينت دراسة الاستقطاب ان كثافة التيار المحدد تزداد مع زيادة درجة الحرارة ويقل بزيادة تركيز المثبط.

Introduction

Zinc is one of the most common elements in the earth's crust. It is found in air, soil, and water, and is present in all foods. Pure zinc is a bluish-white shiny metal.

Zinc has many commercial uses as coatings to prevent rust, in dry cell batteries, and mixed with other metals to make alloys like brass, and bronze. A zinc and copper alloy is used to make pennies in the United States. Zinc combines with other elements to form zinc compounds. Common zinc compounds found at hazardous waste sites include zinc chloride, zinc oxide, zinc sulfate, and zinc sulfide. Zinc compounds are widely used in industry to make paint, rubber, dyes, wood preservatives, and ointments⁽¹⁾.

Experimental work

The experimental work as well as the laboratory design of zinc corrosion inhibition system.

The experimental work was divided into two main parts:

1. Weight loss measurements of single metals (free corrosion) to determine the average corrosion rates and corrosion potential under static, without and with inhibitor at different temperatures.
2. Electrochemical polarization measurements of the instantaneous potential corrosion under a variable temperature for clean surfaces and different inhibitor concentrations.

Experimental work was carried out to determine the corrosion rate of zinc under static conditions, at a variable temperature of 20, 40 and 60°C using weight loss and electrochemical polarization methods. Specimens were cut from zinc with dimensions $6 \times 2.25\text{cm}$. After cleaning and preparing, the specimens were placed in the test solution (0.1N HCl solution) for one hour at several temperature values via 20, 40 and 60°C and with addition 0, 300 and 600 ppm of thiourea inhibitors and also in 0.1N NaCl solution at 20, 40 and 60°C with addition 0, 150 and 300ppm NaNO_3 inhibitors. The polarization measurement were carried out using zinc plate as a working electrode of the above dimensions, a Saturated Calomel Electrode was used as a reference electrode while the auxiliary electrode was graphite. The whole polarization circuit was monitored manually and figure (1) represents the circuit. The temperature was controlled by a water bath with accuracy of $\pm 1^\circ\text{C}$.

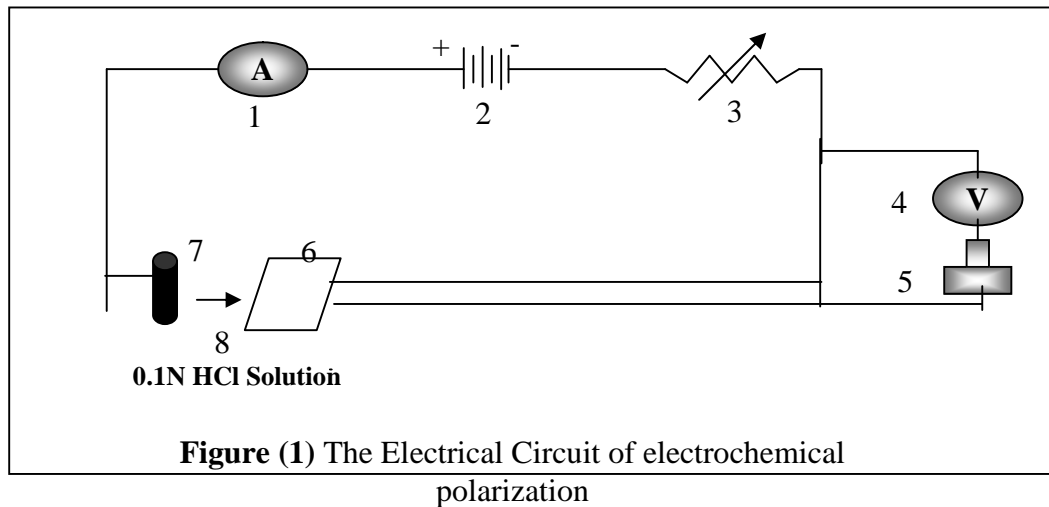


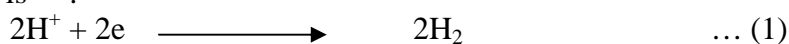
Table (1) gives the item number with its details as illustrated in Fig.1

Item No.	Details
1	Multirange Ammeter.
2	D.C Power Supply.
3	Resistance Box.
4	Multirange Voltmeter.
5	Saturated Calomel Electrode (SCE)

6	Cathode
7	Anode
8	Test Solutions

Results and Discussion

Tables (2) and (3) represent the effect of temperature (20, 40 and 60°C) and inhibitors concentration 0, 300 and 600 ppm of thiourea inhibitor in acid media and 0, 150 and 300ppm of NaNO₃ inhibitor in salt media on corrosion rate by the weight loss method. It is obvious that as the temperature increases, the corrosion rate increases accordingly and corrosion potential became slightly more negative (see Figs 3 to 20). This increasing in corrosion rate is attributed to the increasing of oxygen mass transfer and effected the activation polarization. Since in such solutions the basic cathodic reaction is^[2,3]:



Tables 2 and 3 show that efficiency of inhibitors increases with increasing inhibitors concentration leading to decrease in the total cathodic reaction current of oxygen and hydrogen. Hence inhibitors lead to a decrease in the corrosion rate. Also anodic current (at the higher efficiency of inhibitor) is increasing slightly even at high temperature^[3,4].

Table (2) Effect of inhibitor (thiourea) concentration and temperature on corrosion rate (by weight loss) of zinc specimen ($27 \times 10^{-4} \text{ m}^2$) in air-saturated 0.1N HCl solution and $t=1\text{hr}$.

T (°C)	C (ppm)	w(g)	CR(gmd)	CR(mm/y)	CR(mpy)	%
20	0	0.0196	174.222	352.087	8.943	-
40	0	0.0320	284.444	543.504	13.805	-
60	0	0.0450	400	720.236	18.294	-
20	300	0.0032	28.444	57.441	1.459	83.7
40	300	0.0163	144.888	276.850	7.032	49.1
60	300	0.0241	214.222	385.709	9.797	46.4
20	600	0.0011	9.777	19.764	0.502	94.4
40	600	0.0018	16	30.571	0.7765	94.4
60	600	0.0072	64	115.236	2.927	84

Table (3) Effect of inhibitor (NaNO₃) concentration and temperature on corrosion rate (by weight loss) of zinc specimen ($27 \times 10^{-4} \text{ m}^2$) in air-saturated 0.1N NaCl solution and $t=1\text{hr}$.

T (°C)	C (ppm)	w (g)	CR(gmd)	CR(mm/y)	CR(mpy)	%
20	0	0.0008	3.555	7.185	0.1825	-
40	0	0.0013	5.777	11.894	0.3021	-
60	0	0.0052	23.111	50.697	1.2877	-
20	150	0.0005	2.111	4.206	0.1084	41.46
40	150	0.0007	3.111	6.406	0.1627	46.14
60	150	0.0031	13.777	30.220	0.7676	96.46
20	300	0.0002	0.888	1.795	0.0456	75.02
40	300	0.0004	1.777	3.657	0.0929	69.25
60	300	0.0006	2.666	5.846	0.1485	88.47

However, in all cases, a preliminary stage of adsorption of the inhibitor can be envisaged and to the extent, the adsorption theory has fulfilled its purpose. Another theory which says those inhibitors are adsorbed on the metal surface forming a protective layer. The adsorption was considered either a physical adsorption or chemisorptions^[5].

From figures (3 to 20), one can notice that the value of potential will be less negative with increasing value of inhibitors concentration this due to the inhibitors is affected on anodic reaction i.e. anodic inhibitors for two cases.

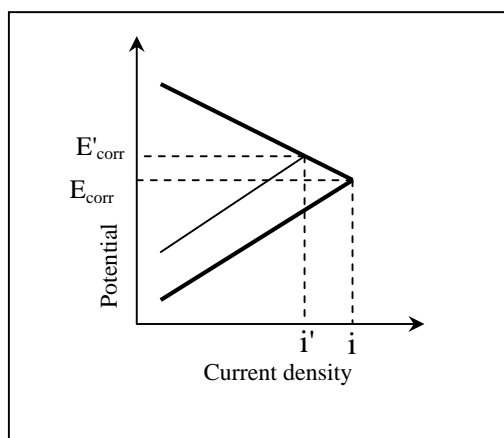


Figure (2) Mechanism of action of anodic corrosion inhibitors based on polarization effects ⁽⁵⁾.

When the value of potential will be more negative with increasing value of temperature of metals this due to increasing corrosion rate to increasing bulk oxygen concentration.

The results of Figures(3 to 20) show that the potential is moved with time to more negative values, where the potential is recorded at each minute for an experimental run of sixty minute long (each experiment). Precisely the potential became rapidly more negative in the first ten minutes, and then the curve converged to slower rate, that is because of the formation of the OH^- ions in a high rate and grouping around the electrodes^[4]. Later on its formation rate will revert to smaller nominal values^[5,6].

In figures (21 to 38) The data are supported by the polarization curves (next paragraph) which its represented potential vs. saturated calomel electrode against current for cathodic region and anodic region at 0.1N HCl solutions (a variable temperature and thiourea concentrations) and 0.1N NaCl solutions (a variable temperature and Na_2NO_3 concentrations) where the corrosion current density is a limiting (salt solution) one, therefore, it is obvious that as the temperature increases, the limiting current density increases accordingly and corrosion potential became more negative. This increasing in limiting current is attributed to the increasing of oxygen mass transfer and effected the activation polarization^[5,6,7].

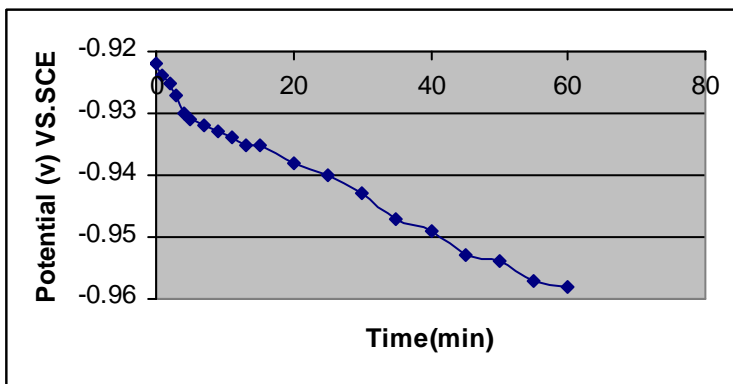


FIG.(3) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N HCl SOLUTION AT T=20°C

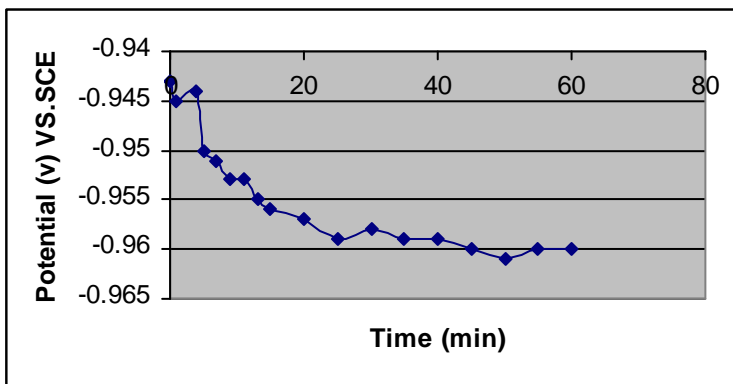


FIG.(4) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N HCl SOLUTION AT T=40°C

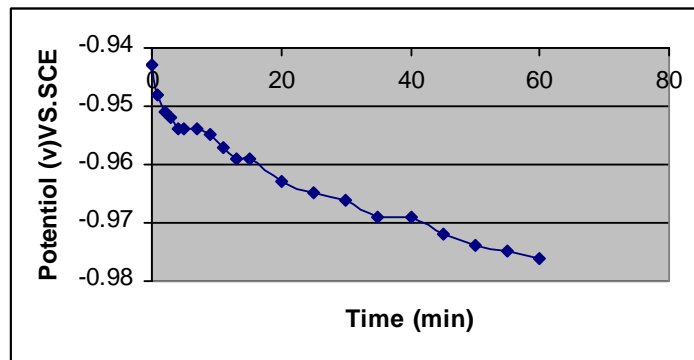


FIG.(5) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N HCl SOLUTION AT T=60°C

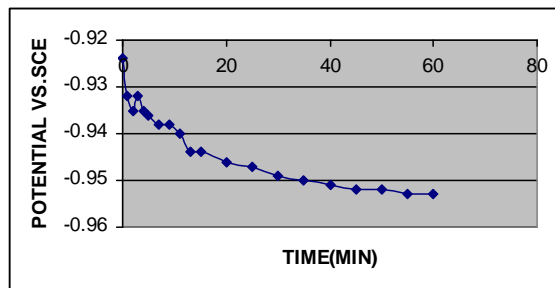


FIG.(6) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N HCl SOLUTION & C=300 PPM AT T=20°C

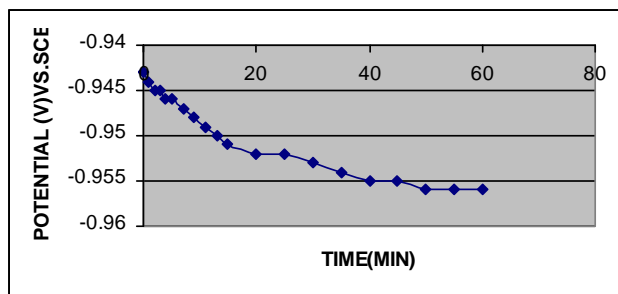


FIG.(7) POTENTIAL VS TIME FOR ZINC METAL IN 0.1N HCl SOLUTION & C=300 PPM AT T=40°C

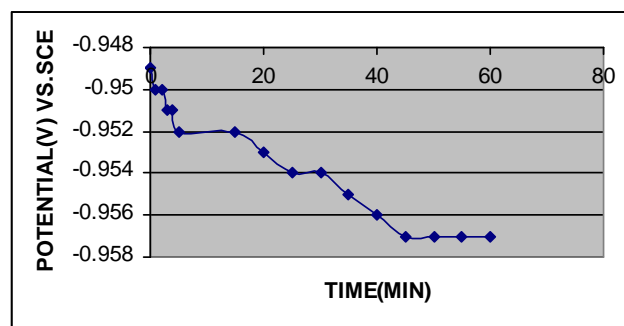


FIG.(8) POTENTIAL VS TIME FOR ZINC METAL IN 0.1N HCl SOLUTION & C=300 PPM AT T=60°C

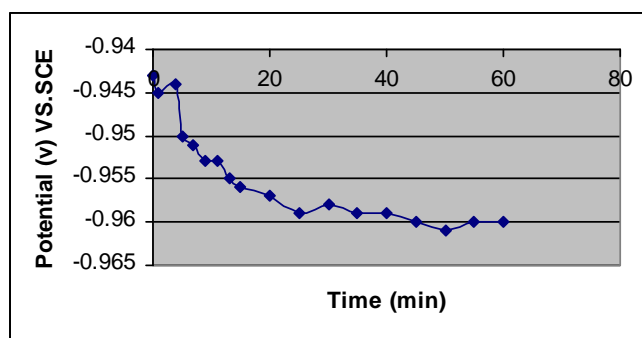


FIG.(9) POTENTIAL VS TIME FOR ZINC METAL IN 0.1N HCl SOLUTION & C=600ppm AT T=20°C

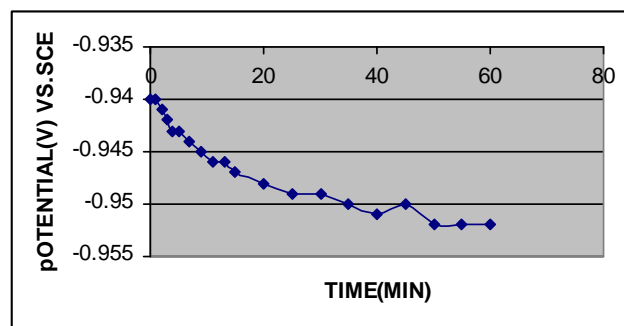


FIG.(10) POTENTIAL VS TIME FOR ZINC METAL IN 0.1N HCl SOLUTION & C=600 PPM AT T=40°C

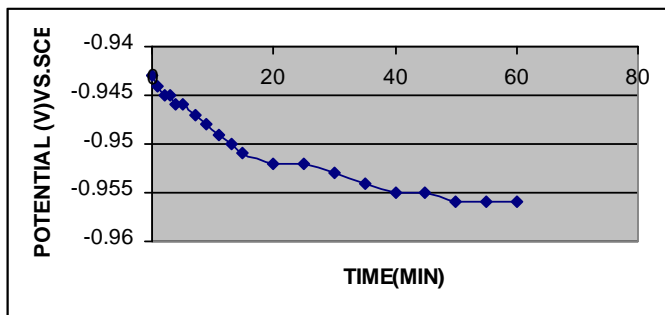


FIG.(11) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N HCl SOLUTION & C=600 PPM AT T=60°C

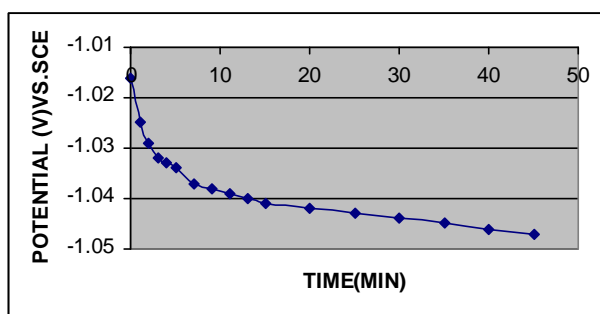


FIG.(12) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1 NaCl SOLUTION AT T=20°C

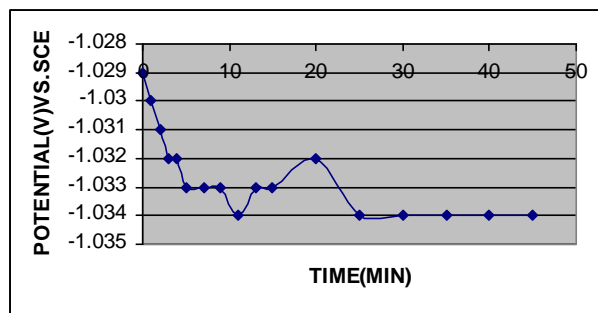


FIG.(13)

POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N NaCl SOLUTION AT T=40°C

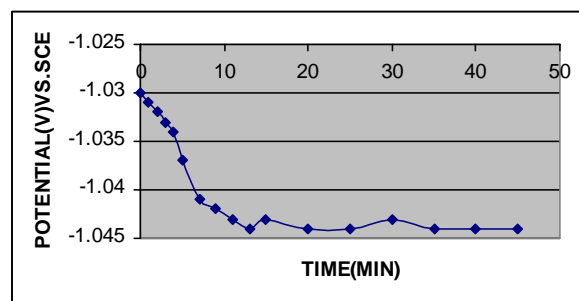


FIG.(14) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N NaCl SOLUTION AT T=60°C

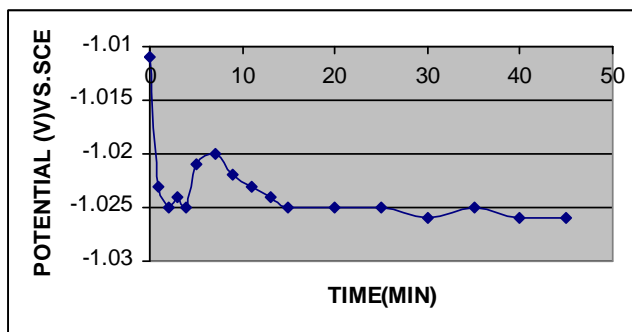


FIG.(15) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N NaCl SOLUTION& C=150 PPM AT T=20°C

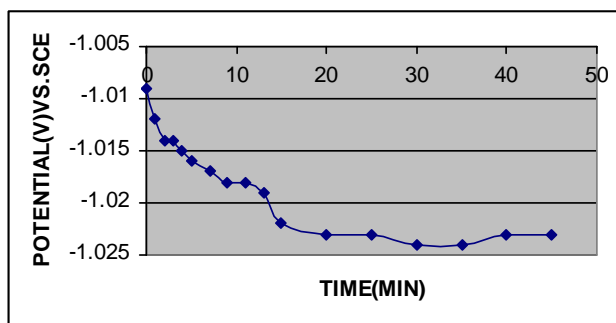


FIG.(16) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N NaCl SOLUTION& C=150PPM AT T=40°C

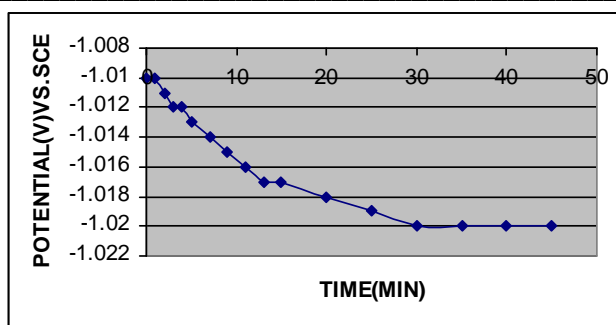


FIG.(17) POTENTIAL VS. TIME FOR ZINC METAL
IN 0.1N NaCl SOLUTION& C=150PPM AT T=60°C

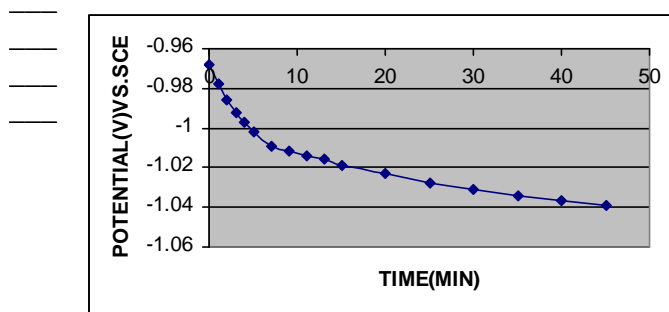


FIG.(18) POTENTIAL VS TIME FOR ZINC METAL
IN 0.1N NaCl SOLUTION& C=300PPM AT T=20°C

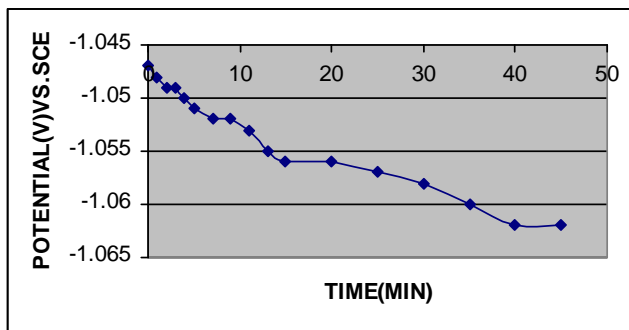


FIG.(19) POTENTIAL VS TIME FOR ZINC METAL IN 0.1N NaCl SOLUTION & C=300PPM AT T=40°C

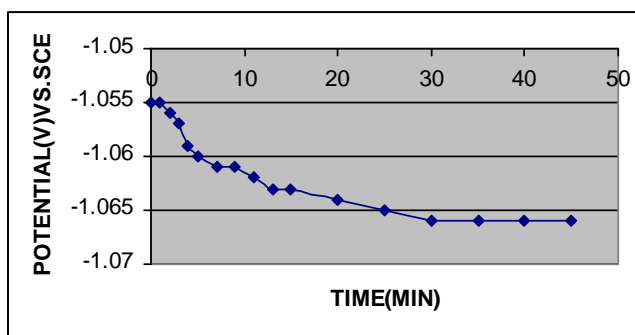


FIG.(20) POTENTIAL VS TIME FOR ZINC METAL IN 0.1N NaCl SOLUTION & C=300PPM AT T=60°C

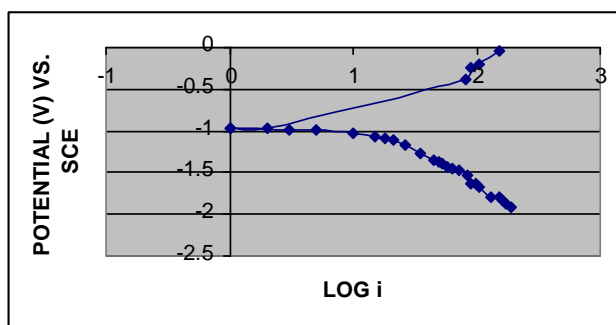


FIG.(21) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N HCl SOLUTION AT T=20°C

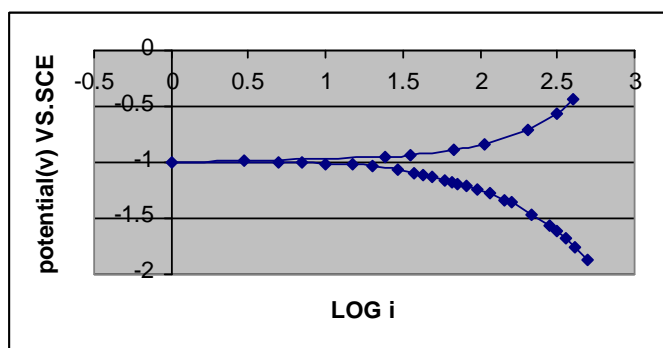


FIG.(22) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N HCl SOLUTION AT T=40°C

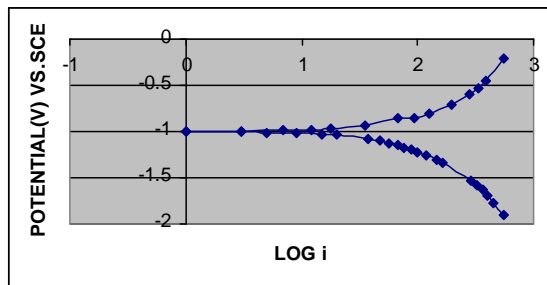


FIG.(23) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N HCl SOLUTION AT T=60°C

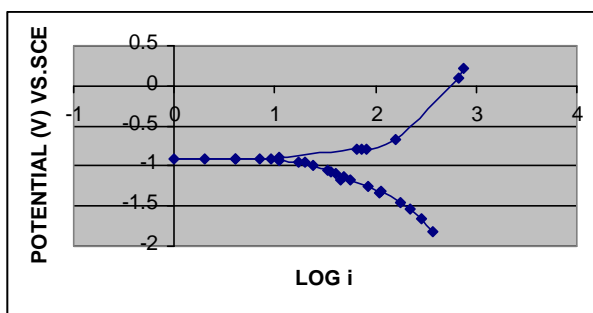


FIG.(24) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N HCl SOLUTION & C=300PPM AT T=20°C

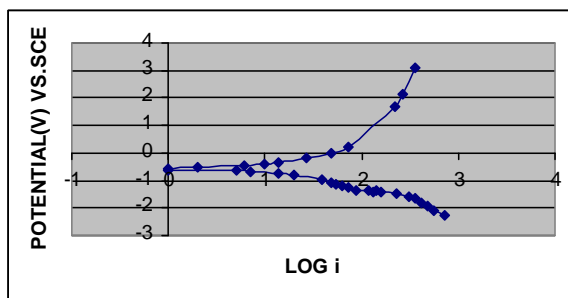


FIG.(25) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N HCl SOLUTION & C=300PPM AT T=40°C

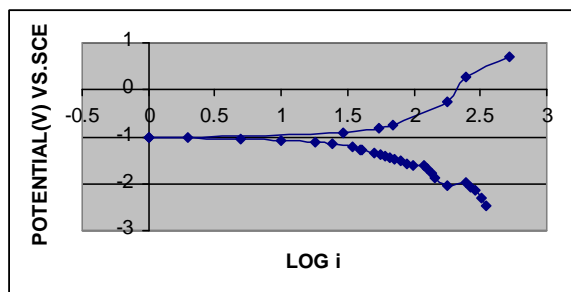


FIG.(26) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N HCl SOLUTION & C=300PPM AT T=60°C

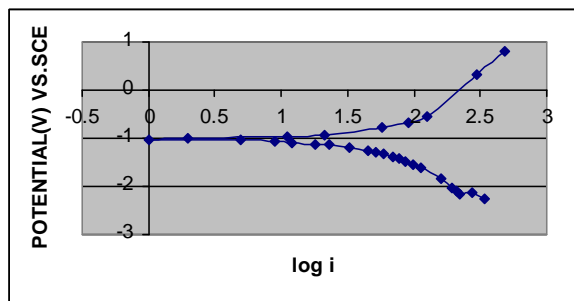


FIG.(27) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N HCl SOLUTION & C=600PPM AT T=20°C

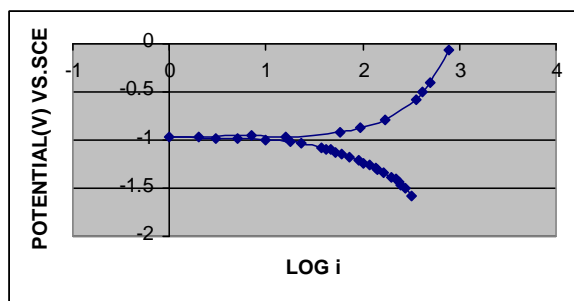


FIG.(28) POTENTIAL VS. CURRENT FOR ZINC IN 0.1N HCl SOLUTION & C=600PPM AT T=40°C METAL

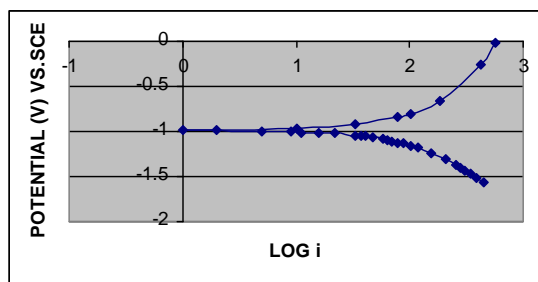


FIG.(29) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N HCl SOLUTION & C=600PPM AT T=60°C

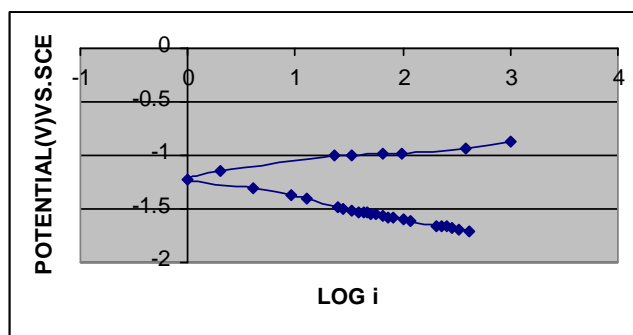


FIG.(30) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N NaCl SOLUTION AT T=20°C

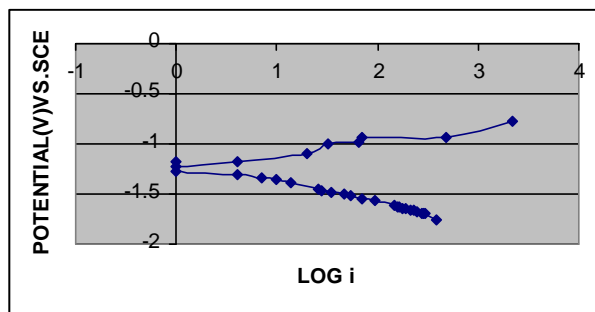


FIG.(31) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N NaCl SOLUTION AT T=40°C

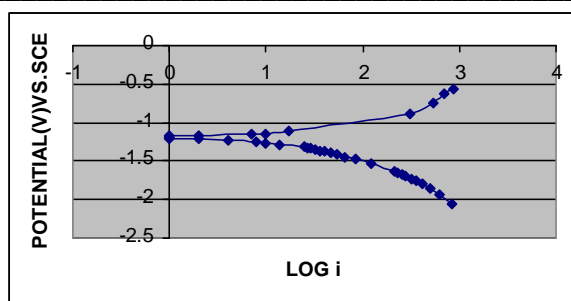


FIG.(32) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N NaCl SOLUTION AT T=60°C

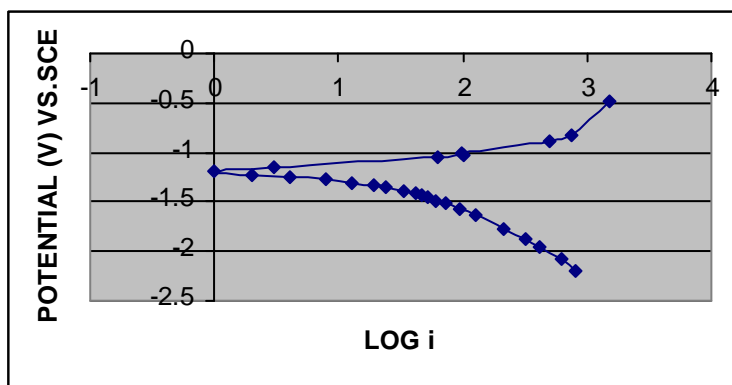


FIG.(33) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N NaCl & C=150 PPM SOLUTION AT T=20°C

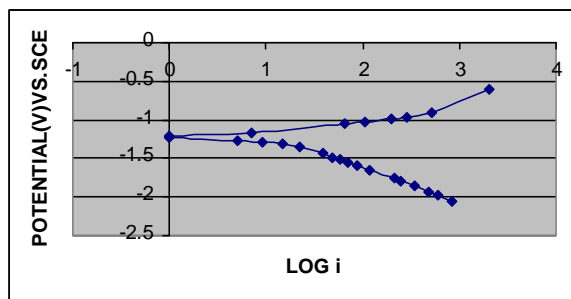


FIG.(34) POTENTIAL VS. CURRENT FOR ZINC METAL
IN 0.1N NaCl & C=150 PPM SOLUTION AT T=40°C

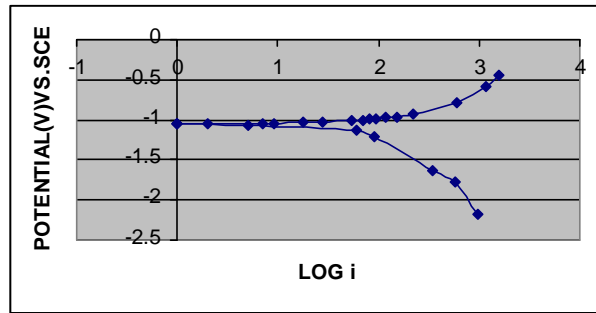


FIG.(35) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N NaCl & C=150 PPM SOLUTION AT T=60°C

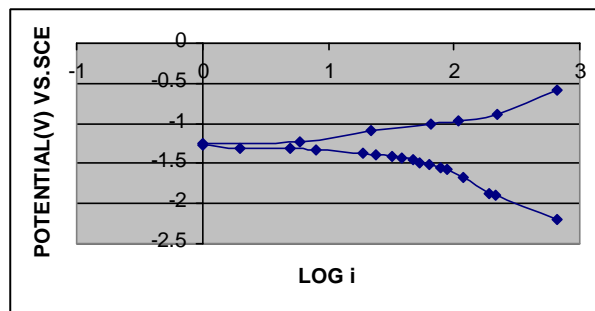


FIG.(36) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N NaCl & C=300 PPM SOLUTION AT T=20°C

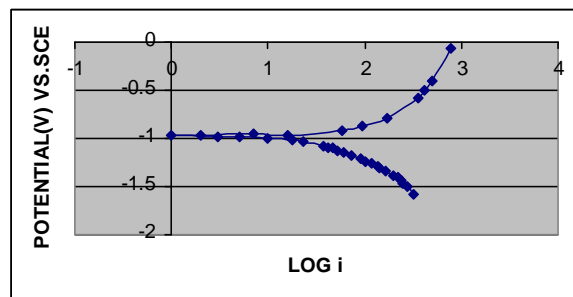


FIG.(37) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N NaCl & C=300 PPM SOLUTION AT T=40°C

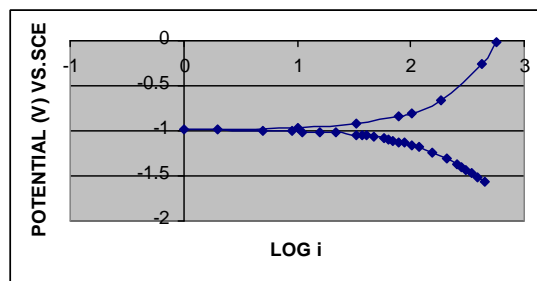


FIG.(38) POTENTIAL VS. CURRENT FOR ZINC METAL IN 0.1N NaCl & C=300 PPM SOLUTION AT T=60°C

Conclusions

- 1- Thiourea is a good inhibitor in acid media with efficiency may reach 90%.
- 2- Na_2NO_3 is a good inhibitor in salts media with efficiency may reach 78%.

- 3- Corrosion rate increase with increasing temperature of solution.
- 4- Potential of corrosion is less negative with increasing inhibitor concentration in solutions and it is more negative with increasing temperature.
- 5- Limiting current density increase with increasing temperature of solution.

Recommendations for Future Work:

The following suggestions are to be considered or to be examined in greater detail for future work:

1. Investigating potential and corrosion rate with longer time and variable velocities of solutions under different isothermal conditions.
2. Investigating the benefit of other types of inhibitors to reduce corrosion rate.

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