Evaluation of Aqueous Film Forming Foam

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ABSTRACT: The corrositivity of a set of aqueous film forming foam (AFFF) agents was investigated. A stagnant , aerated 3% hydral solution was used as corrosive media in order to simulate firefighting systems. The investigation was carried out using linear polarization (LPR) and Weight loss methods. The results indicate that only some of them were able to prevent localized attack and others caused accelerated localized attack when 304 stainless steel is used.

Keywords : Aqueous Film, weight loss, linear polarization.

Introduction:

HYDRAL is a fluorosynthetic film forming liquid commonly known as Aqueous film forming foam (AFFF) which is a highly efficient type of fire suppressant agent, used to attack flammable liquid pool fires.[1]

AFFF available in three concentrations:(1,3, and 6)%. The numbers refer to the concentration percentage of the foam concentration mixed with either fresh or sea water by a proportion nozzle[2]. A.F.F.F is effective against a wide variety of corrosion. Generally, increased corrosion resistance can only be obtained at increased cost. At a fundamental level , corrosion resistance materials often tend to be more susceptible to localized corrosion which is often difficult to detect and to monitor effectively.

AFFF concentrates used for fighting fires on hydrophobic liquids are generally diluted with water at a 3-part concentrate to 97-part water ratio. This dilution step is called proportioning. The resulting mixture is then mixed with air and the resulting foam is then applied to the burning hydrophobic liquid. A concentrate which is effective at a 3% dilution level is desired over a weaker concentrate, such as a concentrate which is diluted at a 6 part concentrate to 94 part water ratio [3] .

The AFFF coats a pool of hydrocarbon fuel with a layer of foam, which acts as a thermal and evaporation barrier to inhibit and eventually extinguish combustion. The "film-forming" characteristic refers to the fact that, even after the foam has dissipated,the aqueous layer formed from the water/concentrate mixture can coat a liquid hydrocarbon surface[4]. Three fire extinguishments mechanisms are in effect when using ANSULITE 3% (AFC-3A) AFFF Concentrate. First, an aqueous film is formed which works to help prevent the release of fuel vapor. Second, the foam blanket from which the film-forming liquid drains effectively excludes oxygen from the fuel surface. Third, the water content of the foam provides a cooling effect [5] .

EXPERAMINTAL WORK

The experimental work was to investigate the corrosion susceptibility of Type 304 stainless steel to aqueous film forming foam (AFFF) where linear polarization resistance technique and Weight loss method were used to evaluate those compounds.

Electrodes

The material used was 304 stainless steel according to ASTM, this standard is issued under the fixed designation G102[6]. The chemical composition is given in table (1) below:Table1. chemical composition of used coupons

Element	C	Mn	P_{max}	S_{max}	Si	Cr	Ni	Fe
maximum Percent	0.08	2.00	0.045	0.030	0 .75	19	9.5	Balance

1- Electrochemical technique

1.1 Preparation of Coupons

Coupons with the dimensions of 1 cm² in area of Stainless steel for testing,samples were grinded using a 100, 220, and 600 μm emery paper,then the samples were washed with distilled water and fainly dried by jet air drying.

1.2 Electrochemical Test Cell

Electrochemical experiments were performed using a standard three- electrodes cell of 500 cm^3 volume. The working electrode was stainless steel (304) embedded into epoxy resin, the counter electrode was platinum net and reference electrode was a saturated calomel electrode (SCE) as shown in Figure 1.

1.3 Procedure

Polarization Resistance (R_P) values were measured by stepwise potentiostatic (the technique for maintaining a constant electrode potential) using a single small potential step, ΔE, usually either ±10mv are usually commonly used[7]. R_Ps (Polarization Resistance) were taken after 24 hours from immersing the specimens in the test solution, the results obtained were presented in the form of potential current relations.

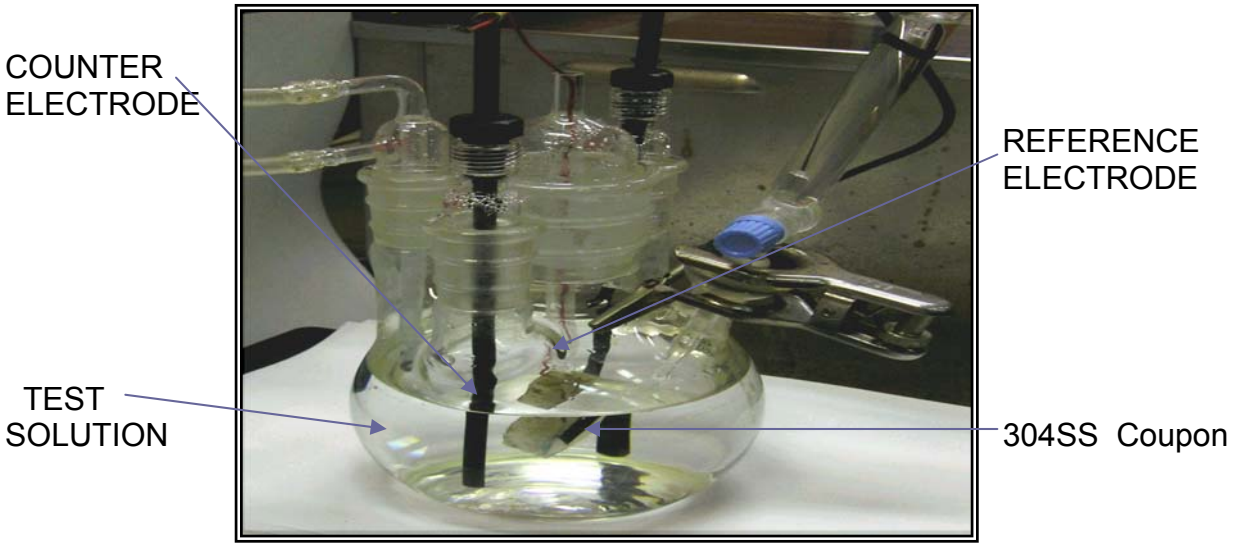

Figure.1 A typical electrochemical corrosion test cell.

Test Media: 3%Hydral fluorosynthetic A.F.F.F has the chemical physical properties as shown below:

Table 2. Typical Physiochemical Properties

Appearance	Clear yellowish liquid
Specific gravity at 15°C(gr/cm	10.02±.0.02
Viscosity at 0°C (mm²/sec)	Max 25
PH at 20°C	7.5±1
Pour Point	-10 to -15
Sediments centrifuging at 20°	0.2% vol.max.
Solubility (sediment)	0.1% max.

Table 3. list of chemical compounds symbols

Sample name	Symbol
Q1 area tank No.552A	A
NC 41 tank No.1170	B
G1 area tank No.553A	C
Fire truck No.2	D
Eni oil tank No.1422B	E
Eni oil tank No.1422A	F
Foam storage tank A	G
NC 41tank No.1171	H
Q, area tank No. 552B	I
Fire truck No.1	J
G,area tank No.553B	K
Foam storage tank B	L
Deck tank	M
Helideck tank	N

2- Weight Loss method

Coupons Preparation

Coupons made from 304SS were used in the experimental work with size 13mm×75mm ×3mm then the specimens were rinsed with distilled water, and cleaned with acetone in ultrasonic bath then dried with alcohol [8].

Cleaning of specimens before weighing and exposure is critical to remove any contaminants that could affect test results [9].The specimens are then marked by stamping grades and kept in desiccators for 24hours.

2.1 Procedure

Each coupon was immersed completely in a bottle and covered with the foam concentration 3% by volume, the temperature of concentrate was 18-25 ºC, The exposure time of coupon exposure is important since quick tests (3days) will give results which could be misleading [10] . The coupon is then cleaned of all corrosion products using benzene,dry with a clean cloth, and passivate by immersing in nitric acid-dichromate solution at 43 to 49°C for 15 to 30 min; rinse with water, then benzene,dry with a clean cloth and is reweigh [11] . The weight loss is converted to a corrosion rate (CR) or metal loss (ML), as follows:

$$\text{Corrosion Rate(CR)} = \frac{\text{weight loss of metal coupon(g)} \times (1000\text{mg/g}) \times (100\text{cm}^2/\text{dm}^2)}{\text{Area (cm}^2\text{) x exposure time (days)}}$$

Where W= weight loss, g

D = density, g/cm^3

A = surface area, cm^2

t = time, days

Results and Discussion

Corrosion rate of 304SS samples under Aqueous Film Forming Foam (A.F.F.F) at 3% concentration conditions was measured at 24 hours for each sample at room temperature. it's clear from figure(3) that the compounds (B, D, F, K,N) show higher corrosion rate values compared to the other compounds (E, G, H, J, and M).

The corrosion rates in corrosive media (3% A.F.F.F) for all Coupon which used in different experimental work were carried out. Figure(4) shows the corrosion values in corrosive media(3% A.F.F.F) using weight loss method and these results indicate that low corrosion rate values are acheived with only some of compounds (A,C, E,G,H,J,L,M). However, all the results showed that the corrosion rate values were below 1.0 mpy (5.52 mdd) [11] . Comparing the results of two methods (weight loss and electrochemical measurements) , aqueous film forming foams are indicated higher corrosion rates in weight loss were observed compared with the polarization resistance technique and this result attributed to the effect of observed compounds onto the metal surface[12]. The combination of weight loss and electrochemical measurements in the laboratory appears to be a suitable procedure for the evolution of compounds products. Although the weight loss tests have been done for only a short time (3days) [13] .

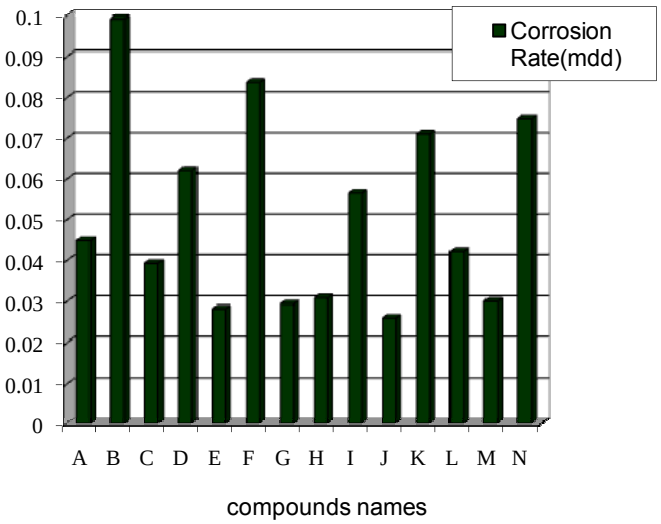

Fig.3 corrosion rates (mdd) for different chemical compounds by using (LPR).

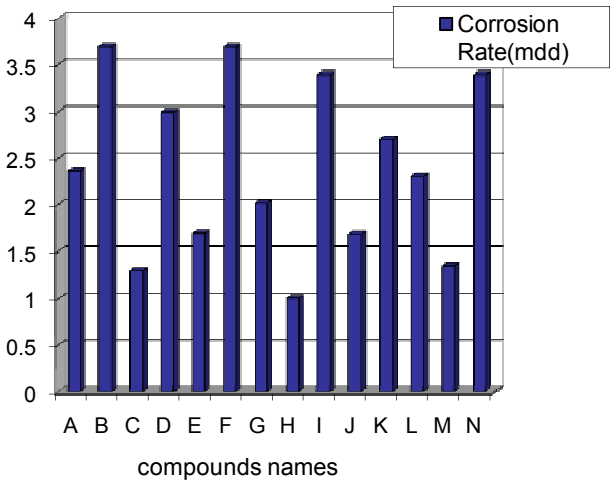

Fig.4 corrosion rates (mdd) for different chemical compounds by using (weight loss).

Conclusions:-

1- Close agreement has been found between weight loss data and electrochemical measurement (LPR) with reference to the ability of chemical compounds action against the corrosion of 304 stainless steel in 3% (AFFF) solution under stagnant condition.

2- In the laboratory tests the compounds (A, C, E, G, H, G, and M) products exhibited the best performance.

3- The compounds (D , I ,L) exhibited the same relative performance, thus ,compounds(B , F, K , N) that might cause localized corrosion after a longer exposure times is likely to be detected by low pitting occurs on specimen surface.

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