STUDIES IN THE CORROSION OF ALUMINIUM ALLOYS IN DILUTE HYDROCHLORIC ACID SOLUTIONS WITH ORGANIC INHIBITORS

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ABSTRACT

The influence of various organic inhibitors (1 gm to 2 gm/litre) on the corrosion of some commercial and experimental aluminium alloys in 0.1N and 1N HCl solutions has been studied by weight loss and electrochemical methods. Amongst various inhibitors studied acridine appears to be an effective inhibitor for most of the commercial and experimental aluminium alloys in HCl solution, the inhibitor efficiencies being over 60%. Some of the commercial aluminium alloys exhibit certain similar characteristics in the cathodic polarisation curves in 0.1N and 1NHCl with different concentrations of acridine and also in its absence. The corrosion process is essentially under cathodic control in the absence of inhibitors for all the aluminium alloys studied and in the presence of inhibitors is under cathodic control in most of the cases, except a few being under mixed control.

Several investigators have reported earlier on the effect of certain organic inhibitors on the corrosion of selected aluminium alloys in dilute hydrochloric acid.[1-3] In this paper, similar study by wsight loss and electrochemical measurements on a few commercial alloys and some experimental alloys in 0.1N and 1NHCl at 30°C in the presence of 1 to 2 gm/litre of inhibitors like acridine, dextrin, gelatin among several others has been presented. Some of the experimental alloys[4] investigeted are also considered as of potential interest as cladding material for fuel elements in reactors.

Experimental

Specimens of commercial aluminium alloys 1S, 2S, 3S, 24S, 52S and 57S and experimental aluminium alloys of nominal compositions Al-1%Mn-0.7%Fe, Al-1%Ni-0.7%Fe, Al-9% Si-1% Ni and Al-9%Si-1%Ni-1%Mg were polished on successive grades of water-proof emery paper. They were than degreased in benzene and acetone, dried, weighed and their surface areas measured accurately. The organic inhibitors added to the acid solutions are of chemically pure quality. The specimens were immersed in solutions of selected concentration of HCl containing various organic inhibitors at 30°C. The anodic and cathodic polarisation studies in these solutions have been carried out using a Wenking Potentiostat with platinum as the auxiliary electrode.

The specimens on removal from the solutions after immersion test, have been washed well in running water, degreased in acetone, dried and weighed. The weight loss in milligrams has been converted to milligrams per square decinetre per day (MDD) on the basis of 6 hours of immersion test.

Rama Char and co-workers[1] have determined the relation between weightloss of aluminium alloy versus concentrations of inhibitors in various HCl solutions upto at least 6 hours of immersion in the presence of inhibitors of concentrations ranging from 0.25 gm to 5 gms/litre. In the present studies, corrosion of various commercial and experimental aluminium alloys in 0.1N and 1NHCl solution containing 1 g and 2 gms/litre of various organic inhibitors (added separately) at 30°C have been carried out. It is observed in general[1] that there is fairly large value of MDD after 6 hours of immersion test, hence the corrosion tests are carried out for 6 hours to obtain a proper evaluation of corrosion rates in definite concentrations of HCl and inhibitor.

Results and Discussion

Table 1 gives the corrosion rate of the different alloys on the basis of weight loss measurements in the absence of inhibitors in 0.1N & 1NHCl at 30°C. In the Table 2 the inhibitor efficiencies (expressed as percent) of the several inhibitors with regard to corrosion of the

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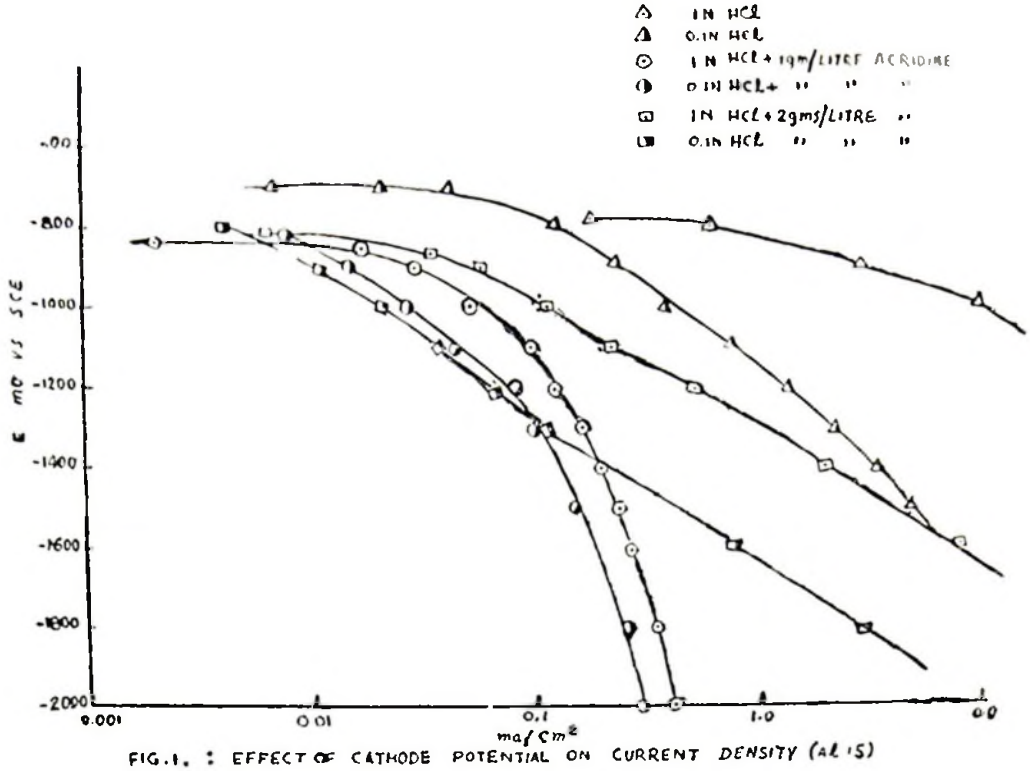


FIG.1. : EFFECT OF CATHODE POTENTIAL ON CURRENT DENSITY (AL 15)

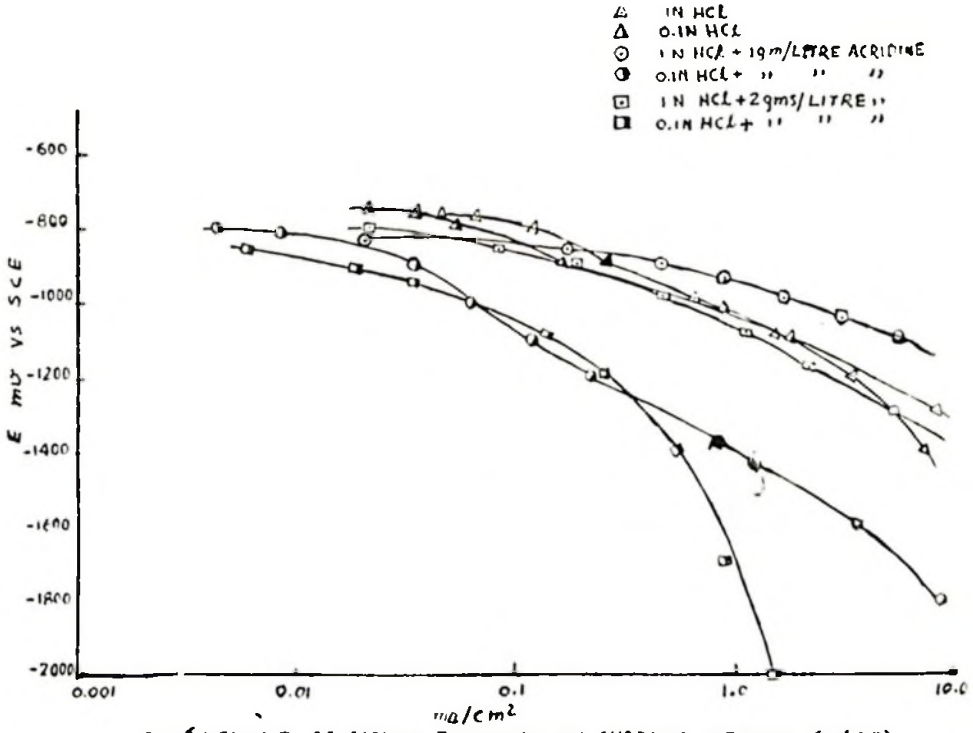


FIG 2 : EFFECT OF CATHODE POTENTIAL ON CURRENT DENSITY (AL25)

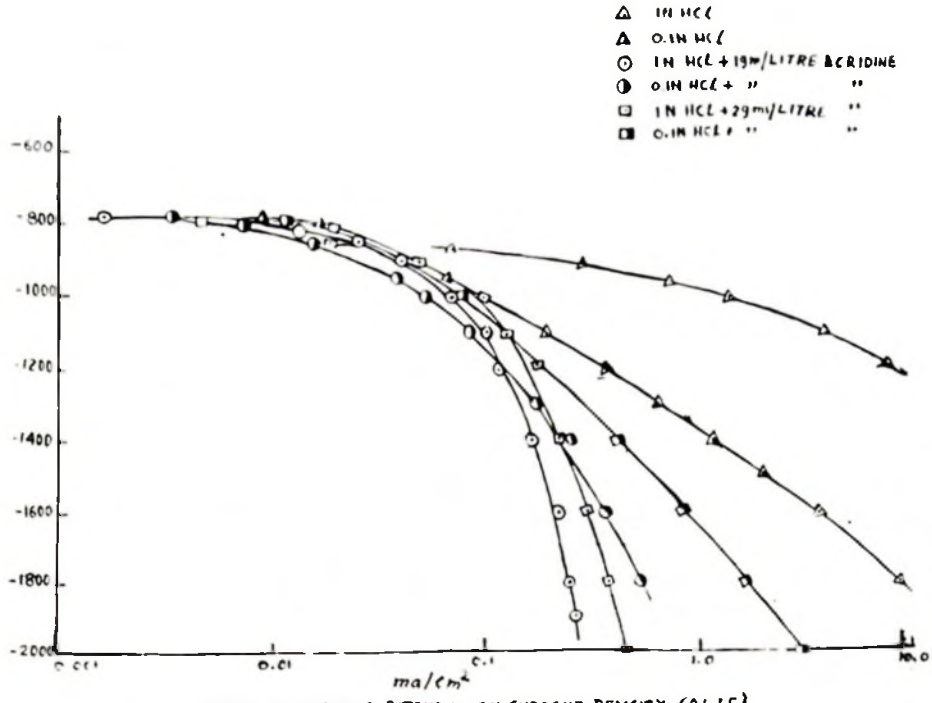


FIG 3 EFFECT OF CATHODE POTENTIAL ON CURRENT DENSITY (AL 35)

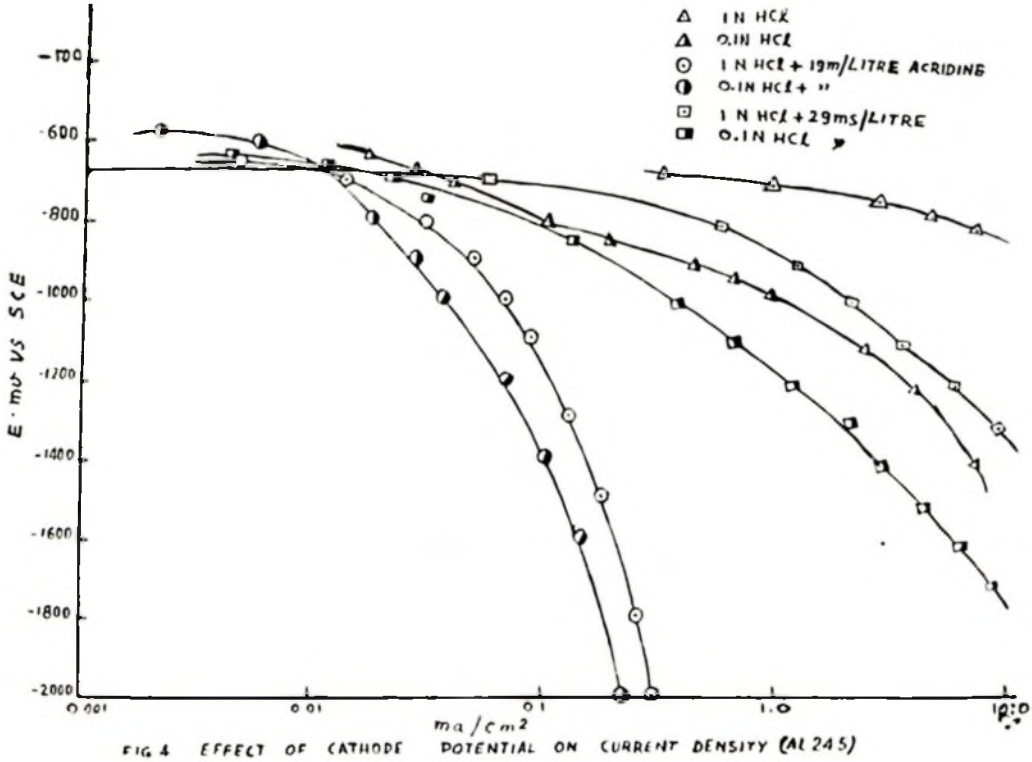


FIG 4 EFFECT OF CATHODE POTENTIAL ON CURRENT DENSITY (AL 24 S)

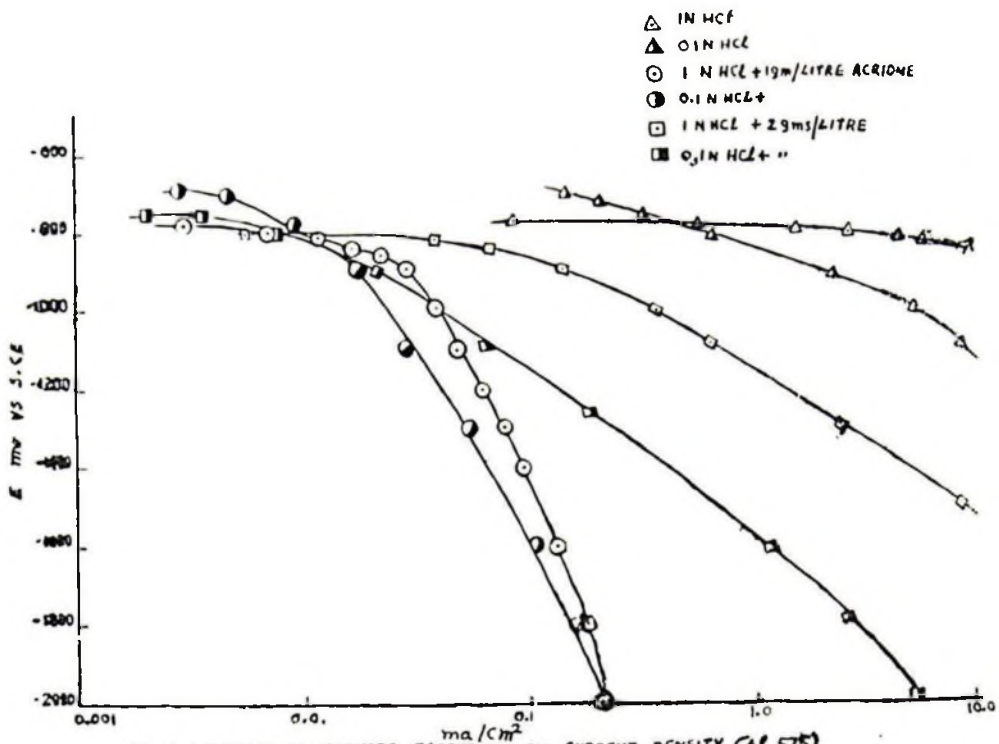


FIG. 5 : EFFECT OF CATHODE POTENTIAL ON CURRENT DENSITY (AL 575)

different alloys listed in Table 1 are tabulated. Two concentrations of acid as also of inhibitors have been selected for study. Results of anodic and athodic polarisation studies in the presence of inhibitors have been presented in graphs (Figures 1 to 5).

The difference in corrosion rates of Al2S and Al3S in 0.5 N and 1NHCl solution has been discussed and explained by Desai at al[3] due to presence of alloying element like manganese in 3S. Their observation that Al3S is more corrosive than Al2S is in agreement with the present investigation. Amongst the commercial aluminium alloys studied, in the abesence of inhibitors maximum corrosion resistance has been observed for Al 1S in 0.1N and Al2S in 1NHCl solution at 30°C and maximum corrosion rates have been recorded for A152S in O. 1N and A12S in 1NHCl. solutions. However, the corrosion rates are much lower in 0.1NHCl than in 1NHCl. Of the four experimental alloys, Al-1%Mn—0.7%Fe has good corrosion resistance both in 0.1N and 1NHCl. With the substitute of Ni for Mn while the corrosion rate is slightly lower in 1NHCl, at the high concentration of HCl the corrosion rate is adversely affected. Alloys containing Si & Ni with or without added magnesium exhibit poor corrosion resistance.

In the presence of acridine of concentration 1 gm/lit. all the commercial and experimental alloys except Al 1S, 2S, 57S and Al—1%Mn.—0.7% Fe show an inhibitor efficiency over 60% in both the concentrations of HCl. Even among these exceptions with 2gms/litre of this inhibitor Al2S, 57S and Al—1%Mn—0.7% Fe have an inhibitor efficiency over 60% in 0.1NHCl. It is however, noteworthy that in 1NHCl while in the case of Al 1S the inhibitor efficiency is high there is no protection for A157S with either concentration of inhibitor. One characteristic observation is that even in the alloys containing Si, Ni & Mg whose corrosion rates are very high, acridine appears to be an effective inhibitor.

No other inhibitor among the ones studied appears to be as effective in protecting Al 1S and 2S the exception being nicotinic acid (1gm/litre) for Al2S in 0.1NHCl.

Dextrin in a low concentration of 1gm/litre is effective for Al24S, 52S and Al—9%Si—1% Ni—1% Mg alloy in 0.1NHCl. with a similar effect at a higher concentration of 2 gms/litre observed for Al3S, 24S, 52S and Al—9%Si—

TABLE 1

CORROSION RATE (MDD) VALUES OF ALUMINIUM BASE ALLOYS IN HCl SOLUTION AT ROOM TEMPERATURE (30°C) BASED ON 6 HOURS IMMERSION TEST

	Type of aluminium alloy.	*Normality of HCl*	*Corrosion rate i.e. weight change (MDD)*
	Commercial aluminium alloys.		
	1 S	0.1N	8.48
		1N	691
	2 S	0.1N	25.28
		1N	63.04
	3 S	0.1N	62.96
		1N	3551
	24 S	0.1N	81.84
		0.1N	308.3
	52 S	0.1N	84.88
		1N	452.4
	57 S	0.1N	54.80
		1N	96.28
	Experimental aluminium alloys.		
A.	Al–1%Ni–0.7%Fe	0.1N	48.32
		1N	30560
B.	Al–1%Mn–0.7%Fe	0.1N	65.88
		1N	106
C.	Al–9%Si–1%Ni	0.1N	2580
		1N	26840
D.	Al–9%Si–1%Ni–1%Mg	0.1N	4016
		1N	48520

1%Ni—1%Mg alloy in 1NHCl. Gelatin at the lower concentration of 1gm/litre is fairly inhibitive with efficiency over 50% for Al3S, 57S, Al—9%Si—1%Ni and Al—9%Si—1%Ni—1% Mg in 0.1NHCl and at the same concentration for Al24S, and 52S in 1 NHCl. Similar effect is observed at 2 gms/litre concentration for Al24S, 52S, 57S and both the alloys containing silicon and nickel in 0.1NHCl and for Al24S, 52S, and Al—9%Si—1%Ni alloy in 1NHCl. Nicotinic acid apart from its inhibitive efficiency in the case of Al2S referred to earlier is effective at the lower concentration for Al—1%Mn.—0.7%Fe and Al—9%Si—1%Ni in 0.1NHCl and for both alloys containing silicon and nickel in 1NHCl. It is equally effective at the high concentration for Al—1%Mn—0.7% Fe in 0.1NHCl and for Al24S and 52S in 1NHCl. Quinine bi—HCl at the lower concentration is effective for Al—9%Si—1%Ni—1%Mg alloy in both the acid concentrations. At the higher concentration it is beneficial for Al24S and Al—9%Si—1%Ni in 0.1NHCl and for Al24S and Al—1% Ni—0.7%Fe. Tannic acid at lower level is effective for Al24S, Al—1%Ni—0.7%Fe and both the alloys containing silicon and nickel in 0.1NHCl and for Al3S, 24S, 52S, in 1NHCl. At higher concentration it is beneficial for Al52S, Al—1%Ni—0.7%Fe and both Al—Si—

TABLE 2

INHIBITOR EFFICIENCES (PERCENT) OF ALUMINIUM BASE ALLOYS IN HCl SOLUTIONS WITH VARIOUS ORGANIC INHIBITORS AT ROOM TEMPERATURE (30°C) BASED ON 6 HOUR'S IMMERSION TEST

Name of inhibitor	*Commerical Aluminium Alloys*																					
	Normality of HCl and concentration of inhibitor																					
	0.1 *NHCl* + 1 *gm/l inhibitor*						0.1 *NHCl* + 2 *gms/l inhibitor*						1 *NHCl* + 1 *gm/l inhibitor*						1 *NHCl* + 2 *gms/l inhibitor*					
	1S	*2S*	*3S*	*24S*	*52S*	*57S*	*1S*	*2S*	*3S*	*24S*	*57S*	*57S*	*1S*	*2S*	*3S*	*24S*	*52S*	*57S*	*1S*	*2S*	*3S*	*24S*	*52S*	*57S*
Acridine	..	..	67	98.7	90	89.5	..	86.55	68	98	73.50	84.5	88	25.25	96	90	74	31.86	90	..	97	78	76	18.28
Dextrin	..	..	0.63	60	60	16	..	..	..	42	33	66	..	..	22	2.5	..	..	30	..	70	77	78	..
Gelatin	..	..	55	14	..	52	..	..	..	90	77	55	..	..	..	92	65	42	..	..	..	78	56	31
Nicotinic acid	..	69.9	6.3	0.6	24	41	..	..	44	43	2.4	44 5	9	..	..	40	48	..	..	..	..	64	62	..
Quinine bi-hydrochloride	..	..	..	33	8	..	..	..	..	50	..	2	..	..	..	52	..	97	..	..	..	56	..	..
Tannic acid	..	..	..	75	30	..	..	15.19	49.70	..	53	53.70	..	..	98.50	62	62	24	..	..	82.70	..	60	..

Name of inhibitor	*Experimental Aluminium Alloys*															
	Normality of HCl and concentration of inhibitor															
	0-1*NHCl* + 1 *gm/l inhibitor*				0-1*NHCl* + 2*gms/l inhibitor*				1*NHCl* + 1*gm/l inhibitor*				1*NHCl* + 2*gms/l inhibitor*			
	*A**	*B**	*C**	*D**	*A**	*B**	*C**	*D**	*A**	*B**	*C**	*D**	*A**	*B**	*C**	*D**
Acridine	66.8	..	99	99	63	95.28	97	99	99	..	99	90	99	84.90	91	98
Dextrin	..	..	48	84	..	..	38	..	..	..	..	..	..	..	54	71
Gelatin	..	23.68	85	83	80	..	97	87	85	56.9	45	22	20	..	75	8
Nicotinic acid	..	95	59	25	..	67.51	..	..	15	..	58	90	..	..	39	..
Quinine bi hydrochloride	..	7.58	25	89	..	12.75	58	95	..	..	..	54	53	..	..	..
Tannic acid	70	..	88	86	52	..	86	90	..	..	23	..	..	..	95	..

*A** Al-1%Ni-0.7%Fe *B** Al-1%Mn-0.7%Fe *C** Al-9%Si-1%Ni *D** Al-9%Si-1%Ni-1%Mg

.. Indicates that the corrosion rates are higher than in the absence of inhibitor.

Ni alloys in 0.1NHCl and for Al3S, 52Sanfd Al—9%Si—1%Ni in 1NHCl.

Polarisation Studies

The cathodic polarisation curves for some of the alloys in the presence and absence of a typical inhibitor acridine have been plotted in Figures 1 to 5.

Aluminium alloys 1S, 24S, 57S exhibit several similar characteristics in the cathodic polarisation curves in 0.1N and 1NHCl in the absence of inhibitor or different concentrations of the inhibitor. The cathodic polarisation curve in 0.1NCl is generally steeper than in 1 NHCl with however, some variation in the degree of slope. In the presence of 1gm/litre and 2gms/litre acridine the cathodic polarisation curves are similar. The inhibiting effect in 0.1NHCl is expected to be better than in 1NHCl. However, the inhibiting effect is better with 1gm/litre o acridine than with 2gms/litre of the inhibitor in both the acid concentrations. It is observed that the observations of inhibitor efficiency with respect to Al 1S from the nature of the polarisation curves are not in complete agreement with the results of weight loss measurements.

In the case of Al2S the cathodic polarisation curve is similar in 0.1N and 1NHCl for the most of the C.D. range but the curve in 0.1 NHCl is slightly steeper than in 1NHCl at higher values of C.D. With 1gm/litre of acridine the inhibiting effect in 0.1NHCl is better than in 1NHCl, a behaviour similar to the alloys considered above. However, in 1NHCl there appears to be no inhibition at all as seen from the curve for most part of the range of C.D. With 2gms/litre of acridine the inhibiting effect in 0.1NHCl is better than in 1NHCl similar to the alloys considered earlier but 1NHCl the effect seems to be very slight. However, the inhibiting effect of 2gms/litre of acridine is better than 1gm/litre in both the acid concentrations. A13S ex hibits cathodic polarisation curves similar to the other alloys in 0.1N and 1NHCl in that the curve is steeper in 0.1NHCl compared to the one in 1NHCl. With 1 gm/litre of acridine unlike in other cases the inhibiting effect in 1NHCl is better than in 0.1NHCl. Similar is the effect of 2gms/litre of acridine. However, as in the case of other alloys except Al2S the inhibiting effect is better with 1gm/litre of acridine compared 2gms/litre in both the concentrations.

Anodic and cathodic polarisation studies with different inhibitors indicate that the corrosion process is generally under cathodic control and in a few cases under mixed control. The straight plot of the potential versus current density cruves (anodic and cathodic) with and without inhibitors is observed to be linear in most of the cases. Polarisation behaviour has in most cases lead to observations similar to results of inhibitor efficiency judged by weight loss measurements.

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