GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 10, NO. 2, MARCH 2004: 301 - 305
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THE STUDY OF EPOXY POLYAMIDE AND POLYVINYL RESINS AS CORROSION PROTECTIVE COATING ON LOW CARBON STEEL

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(Received 15 October 2003; Revision accepted 3 December 2003)

ABSTRACT

The corrosion resistance of two commonly used protective coatings (epoxy polyamide and polyvinyl resins) in the Niger Delta area of Nigeria has been assessed. The coatings on low carbon steel were subjected to varying conditions of pH, temperature and exposure time and the corrosion rates calculated. At a pH of 2, 3, 4, 5 and 6 the corresponding calculated corrosion rates in mpy for epoxy polyamide resin were 0.677, 0.660, 0.392, 0.345 and 0.336 respectively and that for polyvinyl resin were 0.345, 0.336, 0.315, 0.298 and 0.272 respectively. At temperatures of 30°C, 40°C, 50°C, 60°C and 70°C, the corresponding calculated corrosion rates in mpy for epoxy polyamide resin were 0.169, 0.399, 0.572, 0.856 and 0.971 respectively and that for polyvinyl resin were 0.112, 0.227, 0.402, 0.572 and 0.741 respectively. At an exposure time in hours of 672, 1008, 1344, 1680 and 2016, the corresponding calculated corrosion rates in mpy of epoxy polyamide resin were 0.014, 0.018, 0.034, 0.044 and 0.059 respectively and that for polyvinyl resin were 0.0001, 0.009, 0.021, 0.44 and 0.046 respectively. The results showed polyvinyl resin to have a better coating performance than epoxy polyamide resin.

KEY WORDS: Corrosion, coatings, temperature, polyamide, polyvinyl.

INTRODUCTION

Most metals in their refined state are inherently unstable and therefore have the natural tendencies to return to their original state of lower energy to attain thermodynamic stability. The process accompanying the conversion of refined metal to their ore is termed corrosion. The petroleum industry in Nigeria has over the years experienced a number of corrosion problems. For example, between 1994–2002 Nigeria National Petroleum Corporation (NNPC) reported 162 cases of failure due to corrosion (Ajayi, 2003).

Corrosion is always a function of environmental conditions and its control is always concerned with preventing contact of the surroundings with the metal. This has led to the usage of inhibitors and protective coatings in the control of corrosion. Eldredge and Warner (1982) stated that any substance which when added in small amounts to the corrosive environment of a metallic material and effectively decreases the rate of corrosion is called an inhibitor. Videla (1996) stated that a coating is any thin material applied firmly and continuously attached to the structure, which it is designed to protect and prevents contact of the environment with the structure. The use of protective coatings is one of the oldest and most frequent methods of protecting metals from corrosion (Peabody, 1967).

For a protective coating to effectively and efficiently protect a metal against corrosion, it is necessary that it must possess stability, resistance against impact, chemical resistance to the environment to which exposed, resistance to permeation by moisture and the temperature to which the coatings are exposed. Roche et al (1987) and Zaki et al (1990) confirmed the variations in performances of certain coatings in different environments. Corrosion of asphalt, certain tape adhesives and components binders fillers used in pipeline wrappers due to the activities of bacteria and fungi have been reported (Harris, 1960).

This paper reports on the corrosion resistance of two commonly used protective coatings on low carbon steel in the Niger Delta area of Nigeria (epoxy polyamide resin and polyvinyl resin) when exposed to varying conditions of temperature, pH and exposure time.

MATERIAL PREPARATION

Sheets of low carbon steel (0.1 – 0.2 percent carbon content and of density 7.82g/cm^3 as was reported by the manufacturer) were obtained from a corrosion company in Port Harcourt and cold cut to the dimension of 4 x 4 x 1cm. The cold-cut technique was used to maintain the integrity of the steel and hence avoided the probable effect of heat-affected zone (HAZ) on corrosion. Each coupon was perforated with hole of the same diameter at the side to allow the passage of a

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thread. The average weight of coupons ranged from 18.0g to 20.0g. Thirty pieces of coupons were prepared for the study.

The coupons were surface finished by scrubbing with sand paper, sterilized by dipping in absolute ethanol and degreased by washing in acetone. These coupons were then dried in an oven at a temperature of 60°C for 15 minutes. They were allowed to cool over night in a dessicator. Coatings were carefully wrapped on the surface of the coupons. The methods of coupons preparation and the application of coatings on the coupons were consistent with International Paint Protective Manual (1990) and Avwiri and Tay (1999).

The prepared coupons were then weighed before and after the application of coating. The weights were to the nearest 0.0001g (Mettler Balance Model AE 166).

METHODOLOGY

Corrosion rates are a measure of the extent of a corrosion reaction. Bradford (1993), related corrosion rate to weight loss as stated in equation 1.1

$$R = \frac{KW}{A_o T D} \quad 1.1$$

Where: R = Corrosion Rate in mils per year (mpy)

W = Weight loss in grams

A_o = Original surface area of coupon (cm^2)

T = Exposure time (hours)

D = Density of coupons (g/cm^3)

K = Constant (3.4×10^6)

But: $W = W_o - W_f$ 1.2

Whereas: W_o = Original weight of coupon before testing

W_f = Weight of coupon after testing

Also, $A_o = 2(LW + LH + WH)$ 1.3

Where;

LW = Length of the coupon

LH = Height of the coupon

WH = Width of the coupon

The parameters that were investigated are, pH, temperature and exposure time. Horn (1978) stated that parameters, such as temperature, pH and exposure time are good environmental indicators in the testing of coating resistance.

pH: To assess the effect of pH on the corrosion resistance of the selected coatings (epoxy polyamide and polyvinyl resins) the coated coupons were dried, weighed and immersed in identified air-tight (with the aid of petroleum jelly) plastic containers containing sulphuric acid of pH 2, 3, 4, 5 and 6 for a period of 12 weeks. At 12 weeks the coupons were removed, washed in absolute ethanol, oven dried and weighed. Corrosion rates for each coupon were calculated.

Temperature: To assess the effect of temperature, the coated coupons were dried, weighed and immersed in identified air-tight (with the aid of petroleum jelly) stainless containers containing sea water of pH 8 previously collected from the sea in Brass near Brass oil terminal (a facility of Nigerian Agip Oil Company). The immersed coupons were placed inside an autoclave for two weeks at temperatures of 30°C, 40°C, 50°C, 60°C and 70°C. After two weeks, the coupons were removed using a hand clip, washed in absolute ethanol, oven dried and weighed. Corrosion rates for each coupon were calculated.

Exposure time: To assess the effect of exposure time, the coated coupons were immersed in airtight (with the aid of petroleum jelly) plastic containers containing seawater of pH 8. The test periods were 4, 6, 8, 10 and 12 weeks and the experimental condition (of constant pH of 8) was maintained throughout the tests. At the end of the tests, the coated coupons were washed in absolute ethanol, dried, weighed and corrosion rates were calculated for the coupons.

RESULTS AND DISCUSSION

The plots of the calculated corrosion rates with pH, temperature and exposure time for the protective coatings (epoxy polyamide and polyvinyl resins) are presented in Fig. 1.0 to 3.0. Tables 1.0 to 3.0 showed the result of the effects of pH, temperature and exposure time on the studied coatings performance.

Table 1.0: Effect of pH of corrodent (Sulphuric acid) on coating performance

Type of coating	W_o(g)	W_f(g)	$W=W_o-W_f$	pH	Exposure Time (Hrs)	Corrosion Rate (mpy)
Epoxy polyamide resin	19.861	19.702	0.159	2	2160	0.677
	19.869	19.714	0.155	3	2160	0.660
	19.864	19.772	0.092	4	2160	0.392
	19.863	19.782	0.081	5	2160	0.345
	19.863	19.784	0.079	6	2160	0.336
Polyvinyl resin	19.844	19.763	0.081	2	2160	0.345
	19.846	19.767	0.079	3	2160	0.336
	19.847	19.722	0.075	4	2160	0.319
	19.844	19.774	0.070	5	2160	0.298
	19.848	19.784	0.064	6	2160	0.272

Table 2.0: Effect of Temperature on coating performance

Type of coating	W_o(g)	W_f(g)	$W=W_o-W_f$	T(°C)	Exposure Time (Hrs)	Corrosion Rate (mpy)
Epoxy polyamide resin	19.848	19.8418	0.0062	30	336	0.169
	19.847	19.8324	0.0146	40	336	0.399
	19.849	19.8287	0.0209	50	336	0.572
	19.845	19.8137	0.0313	60	336	0.856
	19.846	19.8105	0.0355	70	336	0.971
Polyvinyl resin	19.848	19.8439	0.0041	30	336	0.112
	19.848	19.8397	0.0083	40	336	0.227
	19.846	19.8313	0.0147	50	336	0.402
	19.847	19.8261	0.0209	60	336	0.572
	19.845	19.8179	0.0271	70	336	0.741

Table 3.0: Effect of exposure time on the corrosion resistance of epoxy polyamide and polyvinyl resins

Type of coating	W_o(g)	W_f(g)	$W=W_o-W_f$	Exposure Time (Hrs)	Corrosion Rate (mpy)
Epoxy polyamide resin	19.857	19.856	0.000	672	0.014
	19.860	19.858	0.001	1008	0.018
	19.860	19.855	0.003	1344	0.034
	19.858	19.850	0.008	1680	0.044
	19.858	19.845	0.010	2016	0.059
Polyvinyl resin	19.856	19.856	0.000	672	0.000
	19.857	19.856	0.001	1008	0.009
	19.856	19.853	0.003	1344	0.021
	19.857	19.849	0.008	1680	0.044
	19.858	19.848	0.010	2016	0.046

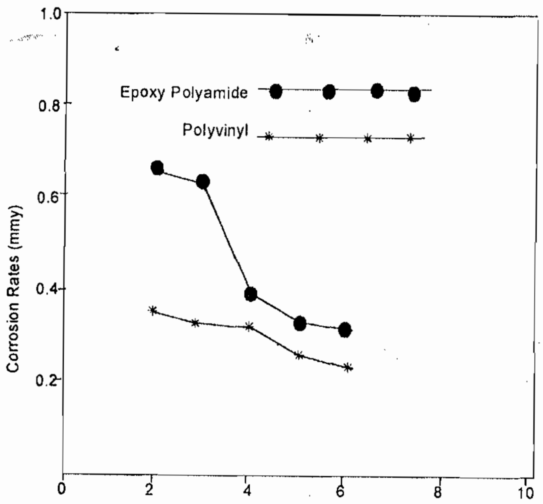

Fig. 1.0 Effect of pH on the performance of coated coupons

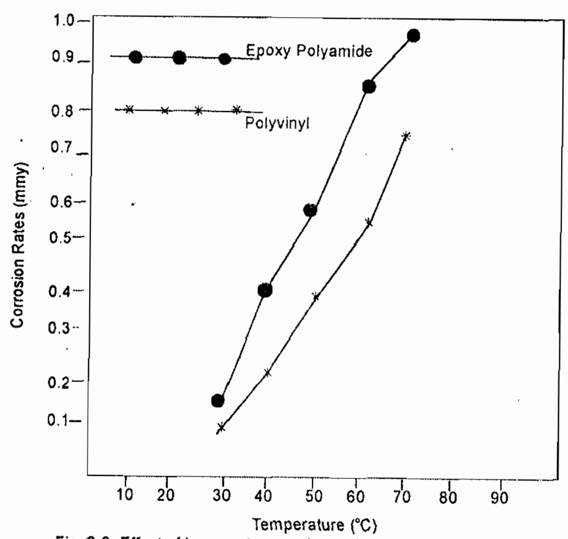

Fig. 2.0: Effect of temperature on the performance of coated coupons

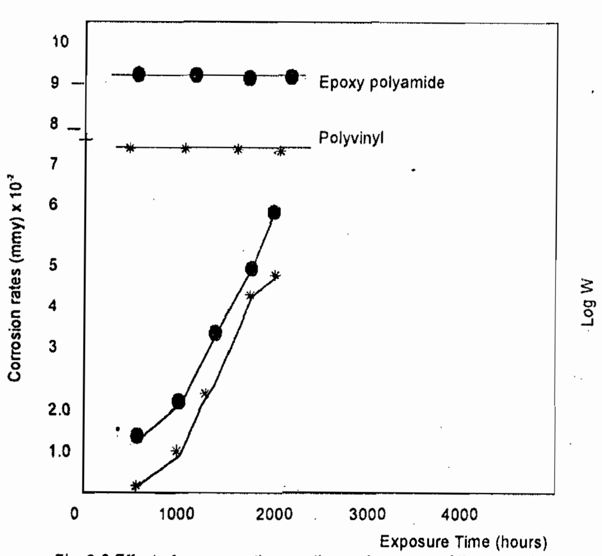

Fig. 3.0 Effect of exposure time on the performance of the coated coupons

The results of the corrosion resistance of epoxy polyamide and polyvinyl resins as protective coatings measured against sulphuric acid of varying pH values of 2, 3, 4, 5 and 6 are presented in Table 1.0. A graphical plot of corrosion rates against the pH values is presented in Fig. 1.0

The surface area for all coupons used in the study was 48.00cm^2. That is A_o = 48.00cm^2.

The Fig.1.0, reveals that corrosion rates tend to increase with increase in acidity for both coatings. This agrees with previous report for steel coupon (Ovri 1998). At the pH of 2, 3, 4, 5 and 6 the corrosion rates calculated for polyamide resin were 0.677, 0.660, 0.392, 0.345 and 0.336 mpy respectively. The calculated corrosion rates for polyvinyl resin at pH of 2, 3, 4, 5 and 6 were 0.345, 0.336, 0.315, 0.298 and 0.272 mpy respectively. From the obtained results, the corrosion resistance of polyvinyl resin is higher than that of epoxy polyamide resin for all mentioned pH values. The higher performance of polyvinyl resin could be attributed to the polymerization of compounds containing the vinyl group and the covalent bond binding the monomeric units together is stronger than the hydrogen bonds found in the epoxy polyamide resin (Morrison and Boyd,1973 and De Renzo, 1985).

The results of the corrosion performance of epoxy polyamide and polyvinyl resins as protective coatings measured against varying temperature of 30°C, 40°C, 50°C, 60°C and 70°C are presented in Table 2.0. A graphical illustration of the effect of temperature on the performance of coated low carbon steel in a closed system containing seawater of pH 8 is shown in Fig.2.0.

The Fig. 2.0 indicates a general increase in corrosion rates with corresponding increase in temperature for the two studied coatings (epoxy polyamide and polyvinyl resins). This increase in corrosion rates with increased temperature is in accordance with the general rule guiding the rate of chemical reactions, which indicates that chemical reactions increase with increasing temperature (Sherwood, 1971). The calculated corrosion rates in mpy for epoxy polyamide resin at temperature of 30°C, 40°C, 50°C, 60°C and 70°C were 0.169, 0.399, 0.572, 0.856 and 0.971 respectively.

The calculated corrosion rates in mpy for polyvinyl resin at temperatures of 30°C, 40°C, 50°C, 60°C and 70°C were 0.112, 0.227, 0.402, 0.572, 0.741 respectively. Comparatively, polyvinyl resin shows a better corrosion resistance to the effect of temperature than epoxy polyamide. When log (weight loss) was plotted against temperature of 30,40,50,60,and 70°C, a linear relationship was obtained (Fig. 4.0). Linearity indicates that the reaction is a first order reaction kinetics. Using the integrated form of

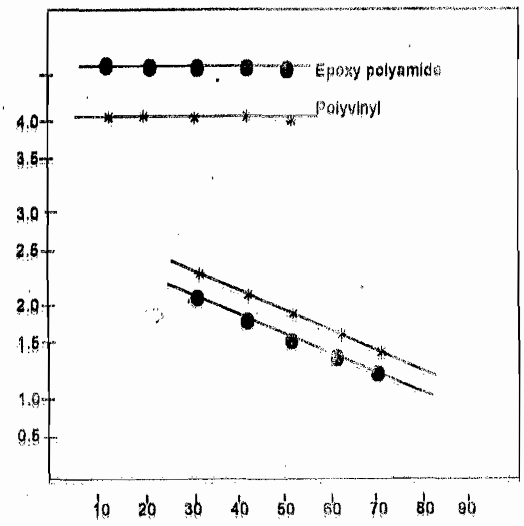

Fig. 4.0 Plot of Log W vs. Temp

Arrhenius equation (equation 1.5) the activation energies (Ea) for the corrosion of epoxy polyamide and polyvinyl resins was calculated as 1.8980 KJ/mol and 2.4180 KJ/mol respectively. The low activation energy values indicate that the process of corrosion of epoxy polyamide and polyvinyl resins was to physiosorption (physical adsorption)(Rase,1977).

$$K=K_o^{exp}(-E/RT) \quad \text{.......................................} 1.4$$

$$\text{Log}K_2/K_1=Ea/2.303[T_2-T_1/T_1T_2] \quad \text{......} 1.5$$

The results of the corrosion resistance of epoxy polyamide and polyvinyl resin as protective coating measured against exposure time in hours of 672, 1008, 1344, 1680 and 2016 is presented in Table 3.0. A graphical representation of corrosion rates against exposure time is shown in Fig. 3.0.

The calculated corrosion rates in mpy of epoxy polyamide resin (Table 3.0) for exposure time in hours, of 672, 1008, 1344, 1680 and 2016 were 0.014, 0.018, 0.034, 0.044 and 0.059 respectively. The corrosion rates in mpy of polyvinyl resin for exposure time in hours of 672, 1008, 1344, 1680 and 2016 were 0.0001, 0.009, 0.021, 0.044 and 0.046 respectively. Generally, corrosion rates for the studied protective coatings increased with increase in exposure time. This is consistent with the findings of Tiller (1970) that every material and structure will deteriorate with time. The rate of deterioration of polyvinyl resin is slower than epoxy polyamide resin and hence polyvinyl resin is a better protective coating.

CONCLUSION

Corrosion resistance of coatings depends on certain variables, which include temperature, pH and exposure time. Results obtained in this study show that coating performance of polyvinyl resin is better than that of epoxy polyamide resin. It can be concluded that in an environment where the studied parameters are prevalent, the use of polyvinyl resin as protective coating for pipeline and other structures is strongly recommended.

REFERENCES

Avwiri, G. O. and Tay, G., 1979. Corrosion resistance of various types of roofing sheets in acid rainwater. Nig. Journal of Physics. 11: 199: 68-72.

Ajayi, O., 2003. Oil Spillage: Corrosion versus Sabotage. NNPC Bulletin no 6:8-10

Bradford, S. A., 1993. Corrosion Control. New York: Van Nostrand Reinhand.

De Renzo, D. J. Ed. 1987. Corrosion Resistant Materials Handbook. 4th Ed. Park Ridge: Noyes Corp.

Elderedge, B. C. and Warner, C., 1982. Kirk – Othmer Encyclopaedia of Chemical Technology. 3rd Edition, U.S.A.

Harris, J. O., 1960. Soil Microorganisms in Relation to Cathodically Protected Pipe Corrosion 16: 441-448.

Horn, B. C., 1978. Construction Materials. New York: John Willey and Sons.

International Paint Protective Coating Manual, 1990.

Morrison, R. T. and Boyd, R. N. C., 1973. Organic Chemistry. London: Allyn and Bacon, Inc.

Ovri, J. E. O., 1988. The Corrosion of Steel Reinforcements in concrete acidic and freshwater environments: Nigerian Corrosion Journal II(i)1-10

Peabody, A. W., 1967. Control of Pipeline Corrosion. NACE Houston.

Rase, H. F., 1977. Chemical Reactor Design for Process Plants. London: John Wiley and Sons.

Roche, Mand Samaran, T. P., 1987. Pipeline Coating Performance: Field Experience of an Operating Petroleum Company. NACE.

Sherwood, D. C., 1971. Introductory Chemical Thermodynamics. London: Longman.

Tiller, M. G., 1970. Corrosion resistance of some selected materials, corrosion 82 Paper No. 164 NACE Houston.

Videla, H. A., 1996. Manual of Biocorrosion. Florida: Florida CRC Lewis Publishers.

Zaki, Y and Harori, K. U., 1990. Monitoring short-term corrosion rates in some oil wells. Comments. Journal of Petroleum Technology. 47 (3):19-21