

Current and Potential Relations for the Cathodic Protection of Steel in Salt Water

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A laboratory investigation was made pertaining to the cathodic protection of steel specimens that were exposed for 60 days to both stagnant and aerated city water, to which was added 3 percent by weight of sodium chloride.

Major consideration was given to the significance of potential as a criterion for protection. Optimum protection was achieved when specimens were controlled at -0.77 volt with reference to the saturated calomel half cell. Although a good degree of protection was obtained at controlled potentials more noble than -0.77 volt, that is, at the potentials associated with the breaks in cathodic polarization curves, this lesser degree of protection could not be obtained at lower mean current densities.

1. Introduction

Cathodic protection is applied primarily to iron and steel structures exposed to corrosive soils and waters. Despite the numerous publications on this subject, there still remains a diversity of opinion concerning the criteria for such protection. The fundamental requirements for cathodic protection were established by Mears and Brown [1, 2]¹ who concluded that in solutions of high conductivity a metal must be cathodically polarized to the open-circuit potential of the most anodic element on its surface in order to have complete protection.

In an earlier study of cathodic protection at the Bureau, it was observed that the potential of steel exposed to one relatively air-free soil (pH 9.5) was about -0.77 v with reference to a saturated calomel half cell [3]. It was also observed that a composite curve of pH versus potential of steel, as obtained from measurements in 20 air-free soils, intersected the pH -potential curve of the standard hydrogen electrode at pH 9 and approximately -0.77 v. In tests which followed, steel maintained for 60 days at about -0.77 v lost very little weight in 5 severely corrosive soils. This potential is equivalent to -0.85 v referred to the copper-copper sulfate electrode. These laboratory results thus confirmed the field experience of Kuhn [4] and many others. A pertinent observation was made by Sudrabin [5] in that iron in an air-free sea water environment was found to have a potential of -0.77 v with reference to the saturated calomel half cell.

Some engineers are of the opinion that -0.85 v with reference to a copper-copper sulfate electrode sometimes represents overprotection and excessive current demands. In order to investigate the matter further, the present work was undertaken. Cathodic polarization curves are logically associated with any study in cathodic protection. The current at the break (change-in-slope) in the curve, which occurs at the open-circuit potential of the anode of a corrosion cell or at the composite open-circuit potential of all the anodes on a corroding steel surface, has been found to bear a relatively direct relationship to the corrosion current [6]. This current is the

minimum value necessary for cathodic protection, based on the corrosion rate existing at the instant of measurement and has been previously discussed in connection with the cathodic protection of steel in soils [3]. The minimum current for cathodic protection has also been discussed by Pope [7]. In order to relate the current at the break in the curve with the currents and the potential required to maintain optimum protection, an investigation was conducted with a water environment containing 3 percent of sodium chloride. This environment was chosen as the IR drop is negligible in such a medium and therefore potentials measured with the equipment used would be significant.

2. Experimental Procedures

2.1. General

All specimens used in these experiments were cut from one piece of 0.5 in. diameter cold-rolled steel to lengths of 16 in. They were degreased, smoothed with emery cloth, washed in hot water, and then weighed to the nearest 5 mg.

The exposure medium was Washington, D. C., city water to which had been added 3 percent by weight of sodium chloride, each specimen being exposed for a period of 60 days. Exposure was under two conditions, one with the electrolyte in Pyrex jars (approximately 12 in. in diameter by 12 in. high) representing a stagnant condition, and the other in the electrolyte in an aerated condition when contained in a wooden vat about 66 in. in diameter and 18 in. high. Air was continually passed into the salt water in the vat from a perforated rubber hose which rested on the bottom. In both cases, water lost by evaporation was replaced weekly. No attempt was made to control the temperature of the electrolyte, and exposure of the specimens in the jars was not simultaneous with exposure of those in the vat. All of the specimens were positioned normal to the surface of the electrolyte with 0.1 ft² of bare surface under exposure. Specimens were protected from waterline corrosion by plastic insulating tape extending about 1.5 in. above and below the waterline thus allowing about 9 in. of the steel to be exposed. The surface of the specimens above the tape was protected

¹ Figures in brackets indicate the literature references at the end of this paper.

against atmospheric corrosion with a thin coating of oil.

At the conclusion of exposure all specimens were removed from the electrolyte, washed under hot running water, and examined. Tightly adherent corrosion products were loosened by cathodically cleaning the specimens in the same electrolyte at a current density of 1 amp/ft² for periods ranging from 1 to 3 hr. This was followed by brushing with a stiff brass bristle brush under hot running water. When dry, the specimens were again wire brushed and reweighed to measure the loss of metal.

2.2. Arrangement for Stagnant Exposure

Five jars were filled to within 1 in. from the top with the sodium chloride solution. Four of the jars were each fitted with three 0.5 in. diameter carbon anodes mounted vertically 0.5 in. from the inner wall so as to form the corners of a triangle and extending about 3 in. above the waterline. One specimen was located at the vertical center line of each jar and held by a perforated rubber stopper with a clamp, so that its lower end did not quite reach the bottom of the jar. Electrical connections to the anodes and specimens were made with battery clips, the 3 anodes being interconnected. Wires from the clips were securely fastened to the outside of the jars so as to avoid disturbing the specimens when making electrical connections. The fifth jar was not fitted with carbon anodes but contained two control specimens, No. 1 centrally mounted and No. 6 off to the side about 1 in. from the inside wall of the jar. Three of the four jars with the carbon anodes contained specimens that were held under different degrees of cathodic protection. The fourth jar contained control specimen No. 2. Sleeves of insulating material were vertically mounted near the inner wall of each jar with one end of the sleeve extending about 5.5 in. below the waterline in order to hold an agar salt bridge. The bridge consisted of a flexible plastic tube containing a cotton string saturated with potassium chloride and filled with a saturated potassium chloride-agar mixture. This connected the test solution with the reference cell.

2.3. Arrangement for Aerated Exposure

The location of specimens Nos. 8 through 12 in the wooden vat, A, is shown in figure 1. They too were fitted with perforated rubber stoppers for clamping to a supporting bar which spanned the open top of the vat. The electrolyte, B, was maintained to a depth of 17 in. and the exposed ends of the specimens were about 6.5 in. from the tank bottom. Anodes, C, consisting of 0.5 in. diameter steel rods mounted as shown, were used to supply current for the specimens as needed. Two anodes were used in conjunction with each specimen as indicated by the arrows. Steel rather than carbon anodes were used in order to avoid excessive anodic polarization of the anodes when obtaining cathodic polarization curves automatically on the specimens. Electrical connections with the specimens and anodes were made as previously described. The air hose,

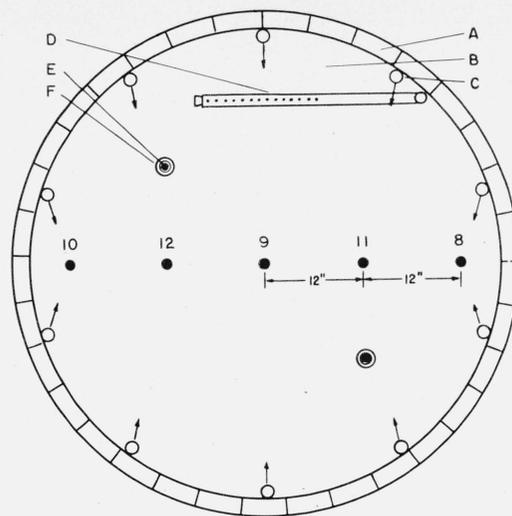


FIGURE 1. Experimental arrangement in the wooden vat. Control specimens, Nos. 8, 9, and 10; cathodically protected specimens, Nos. 11 and 12.

D, end sealed, contained 15 holes 1 in. apart. In anticipation of the likelihood of uneven water movement around the 5 specimens, the cathodically protected specimens (Nos. 11 and 12) were symmetrically arranged with respect to the air supply. Visual observation and later experimental results indicated maximum agitation in the center of the tank, with decreasing agitation toward the tank wall. The flexible agar-salt bridges, E, used in conjunction with the potential-control equipment for specimens Nos. 11 and 12, were held by insulated sleeves, F, as previously mentioned.

2.4. Instrumentation

All potentials were measured with reference to the saturated calomel half cell using an indicating potentiometer. Some specimens were held at a constant current in the stagnant water while others were held at constant potential. The constant current was supplied from 4 series-connected heavy duty 1.5 v dry cells and appropriate series resistance. After the initial polarization of the carbon anodes, the current remained within about 2 percent of the desired value. The constant potential was controlled by the circuit shown in figure 2 to within ± 5 mv of the adjusted value. The voltage divider, A, was set at the desired potential with reference to the half cell, C. Any difference of potential between terminals PS caused the balancing motor, M, to operate the voltage divider, B, until the difference of potential was reduced to zero. As previously stated, the *IR* drop through the electrolyte was negligible. Two agar-salt bridges, E, connected the test solution with the reference cell, C, through a container of saturated potassium chloride, D. When specimens were protected at a designated potential, the polarizing current was continuously recorded by a strip chart recorder, R.

Cathodic polarization curves were obtained on most of the controls at significant times throughout the exposure periods and occasionally on some of

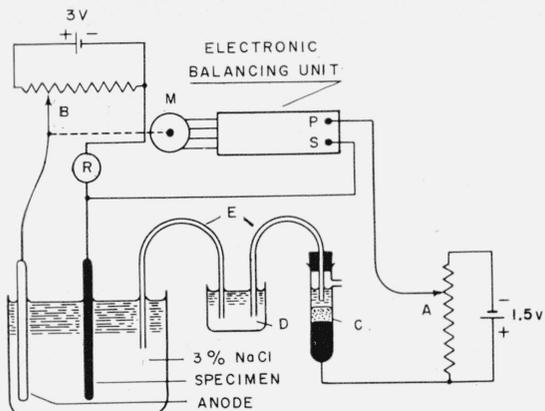


FIGURE 2. Potential-control circuit.

the specimens under cathodic protection. The polarizing current and potential of the specimen were recorded with a two-pen strip chart electronic recorder, the potential measuring circuit of which has a high input impedance. The polarizing current was supplied by a 4 v storage battery shunted by a voltage divider which was manually controlled during stagnant exposure and synchronously driven during aerated exposure.

3. Experimental Results

3.1. Exposure to Stagnant Salt Water

For the first 24 hr of exposure all of the specimens corroded freely. It was assumed that all six would corrode at approximately the same rate as the exposed areas were equal and the environment the same. On the second day, cathodic polarization curves were obtained on the control specimens Nos. 1 and 2. The current, I_p , at the break in the curve, approximately the same value being measured for both specimens, was applied to specimen No. 4. A current equal to 50 percent of this value of I_p was applied to specimen No. 3. Potential control was placed on specimen No. 5, the controller being adjusted to -0.775 v. The potential of specimens 3 and 4 and the current to specimen 5, measured daily or less frequently throughout the exposure period, are plotted in figure 3. Also shown in figure 3 are the values of current, I_p , from curves obtained less frequently on control specimen No. 1 at significant times during the exposure period. The values of current shown in figure 3 and wherever later mentioned have been converted to current densities.

The plots of the potentials of specimens Nos. 3 and 4 and of the current to specimen No. 5 (fig. 3) show that fluctuations such as occurred in the corrosion rates, due chiefly to temperature changes of the electrolyte, happened more or less simultaneously. For example, any depolarization of specimens No. 3 and 4, indicative of increases in corrosion rate, was generally accompanied by increased current to specimen No. 5, while increased polarization of specimens Nos. 3 and 4 was usually associated with decreased current to specimen No. 5. That the current at the break

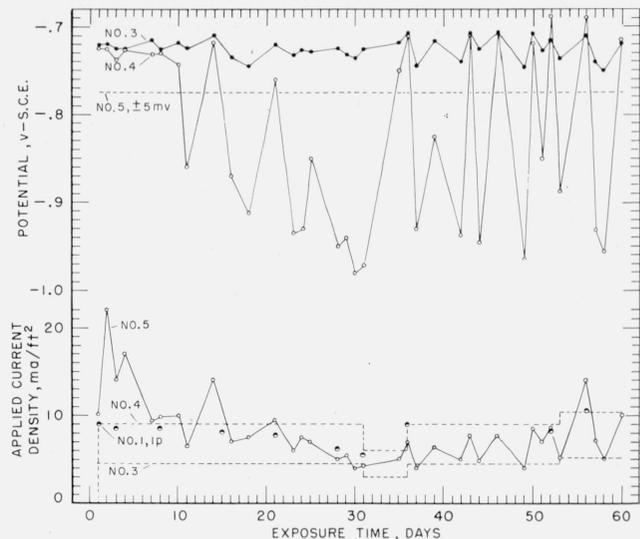


FIGURE 3. Relationship between potential and applied current density for different degrees of cathodic protection on steel specimens Nos. 3, 4, and 5 exposed to stagnant water containing 3 percent of sodium chloride.

I_p , protective current requirement as indicated by control specimen No. 1; No. 5, specimen at constant potential -0.77 volt; No. 4, specimen at constant current, except as indicated; No. 3, specimen at constant current equal to 50 percent of that on No. 4.

in the polarization curve is a critical value, as related to polarization, is shown by the values of current I_p (No. 1 specimen) and the potential changes of specimen No. 4, presumably held fairly close to a mean value of I_p considered applicable to all specimens. It will be observed that an over-all lowering of the corrosion rate occurred up to about the 31st day of exposure, as indicated by the decreasing values of I_p for specimen No. 1. The low rates of corrosion on the 28th and 31st days of specimen No. 1 are reflected in the potential of specimen No. 4, which at the time had more protective current applied than was then required. Accordingly, it was decided to reduce the current to specimen No. 4 and also to specimen No. 3 as shown (fig. 3). On the 36th day, it was noticed that considerable depolarization had occurred on specimen No. 4, some on specimen No. 3, and that the current to specimen No. 5 had increased. That these observations were indicative of increased rates of corrosion was verified by an increase in current I_p from the curve on control specimen No. 1, obtained on the 36th day, to approximately its original value. Accordingly therefore, the currents to specimens Nos. 3 and 4 were again raised, No. 4 to the value indicated by the then currently measured I_p and No. 3 to 50 percent of that value. On the 52d day, an unusually large amount of depolarization had occurred on specimen No. 4. Therefore, on the following day, the current applied to this specimen was again raised slightly. During the remainder of the test, the potential of specimen No. 4 and the current to specimen No. 5 continued to fluctuate. However, a cathodic polarization curve obtained on control specimen No. 1 on the 56th day indicated I_p to be very nearly the same as the current applied to specimen No. 4. During this period the current to specimen No. 3 was increased accordingly.

All specimens were subject to fluctuations in temperature of the salt water because the room temperature varied from 60° to 92° F during the exposure period. As would be expected, increases in temperature were accompanied by increased rates of corrosion and decreases in temperature resulted in lower rates of corrosion. The effect was particularly noticeable by the potential changes that occurred on specimen No. 4. Although these effects were not premeditated, the changes in corrosion rate on specimen No. 4 made it possible to observe the effects, on potential, of applied current less and greater than the critical value, I_p , as this value fluctuated above and below the applied value.

At the end of the 60-day exposure period, in turn, protective currents were removed from specimens Nos. 3, 4, and 5 and depolarization allowed to proceed to the most noble potentials. In each instance, the depolarization time was about 20 min, specimen No. 5 reaching the most noble potential of the three specimens, followed in the order of potential by specimens Nos. 4 and 3. Based on previous experience with the cathodic protection of steel in soils [3], these relative changes in potential indicated that specimen No. 5 had probably received the best degree of protection. That this was true will be shown later with reference to the weight losses measured on these specimens.

Table 1 shows pertinent data resulting from the experiment. The weight losses of the cathodically protected specimens have been adjusted to allow for the first 24 hr of exposure when all specimens were corroding freely. This adjustment was made by substituting the value of I_p , measured on the controls during the second day of exposure, in the Faraday equation and deducting the calculated weight loss from the total measured weight loss. The data show virtually complete protection of specimen No. 5 maintained at the protective potential and also at a lesser average current than was applied to specimen No. 4, which was not as effectively protected. These data show that steel must be continuously polarized at least to the potential

at the break in the cathodic polarization curve in order to achieve a good degree of protection. Based on the cathodic polarization curves (table 1) this value, E_a , peculiar to the type of environment, was around -0.765 v (mean of specimens Nos. 1 and 2). Although the mean polarized potential of specimen No. 4 was -0.843 v (overprotection), there were times when the potential was more noble than -0.765 v, probably accounting for most of the additional weight loss over specimen No. 5. By referring to figure 3, and considering -0.775 v as a datum line, it will be observed how often the potential of specimen No. 4 reflected insufficient protection. It is believed that the greatest weight loss on specimen No. 4 occurred during the first 10 days when polarization was inadequate. Other important points brought out by these data, which are in agreement with results previously obtained for soil exposure, are that the current I_p is a measure of the minimum value required to produce adequate polarization (with time) and that lesser values initially applied, for example as on No. 3 specimen, result in only partial protection.

The ratio between the corrosion current and the current required to prevent corrosion is about 0.85. This ratio is based on the average corrosion current figured for the three controls and the mean current applied to specimen No. 5 (table 1). For steel in soils, this ratio varied from 0.78 to 0.88, based on the current I_p [6].

3.2. Exposure to Aerated Salt Water

For the experiment in aerated water it was decided to hold one specimen No. 11, at about the potential corresponding to that at the break in the cathodic polarization curve (designated E_a), and the other at -0.77 v. This experiment was designed primarily to determine whether it is advantageous to protect at a potential more noble than -0.77 v, and also to determine the comparative protective currents required in stagnant and agitated waters. The average water temperature during exposure was 74° F, ranging between 66° and 88° F and never varied more than 5 degrees in 24 hr.

TABLE 1. Exposure for 60 days to stagnant water containing 3 percent of sodium chloride

Exposure period	Specimen number	Protective criterion	Cathodic polarization curve						Protective current to specimen			Potential of specimen ^a			Corrosion current ^b I	Weight loss of specimen 60 days	Effectiveness of protection ^c
			Current at break, I_p			Potential at break, E_a			Range		Mean	Range		Mean			
			Range		Mean	Range		Mean	Range			Mean					
			Min.	Max.		Min.	Max.		Min.	Max.	Min.		Max.				
1st 24 hr	All specimens corroding freely																
Re-main-der, 59 days	1	Control	5.5	10.5	8.0	-0.740	-0.775	-0.763	---	---	---	-0.685	-0.735	-0.719	6.1	920	---
	2	do	8.5	10.5	9.1	-.760	-.775	-.768	---	---	---	-.710	-.730	-.722	6.9	1035	---
	3	Current	---	---	---	---	---	---	3.0	5.2	4.4	-.706	-.750	-.726	---	435	54
	4	do	---	---	---	---	---	---	6.0	10.4	8.8	-.688	-.980	-.843	---	120	87
	5	Potential	---	---	---	---	---	---	4.0	22.0	7.4	-.770	-.780	-.775	---	20	98
	6	Control	---	---	---	---	---	---	---	---	---	-.690	-.733	-.720	5.8	865	---

^a Saturated calomel scale.

^b Based on Faraday's law, $W = KI$, where $K = 2.8938 \times 10^{-4}$ grams per coulomb, $W =$ wt loss of control.

^c Effectiveness of protection = $\frac{W_c - W_p}{W_c} \times 100$, where $W_c =$ avg. wt. loss of controls, $W_p =$ wt. loss of the cathodically protected specimen.

^d Based on hourly values from the strip chart record.

^e Corrected for freely corroding period.

Unlike the test in stagnant water, the protective currents were initially applied to specimens Nos. 11 and 12 immediately upon immersion. A preliminary polarization curve obtained upon a control specimen furnished the basis for the initial control of specimen No. 11 at about -0.7 v while specimen No. 12 was adjusted for control at -0.775 v. After applying protection it soon was observed that the protective currents, automatically recorded, were unusually high. These currents, plotted in figure 4, are daily averages based on hourly values from the strip charts. The potentials shown are the mean measured values. It will be noted that, even after 8 days, the current densities are still high. On the previous day (7th day), cathodic polarization curves had been recorded on the freely corroding controls Nos. 8, 9, and 10. The values of I_p from these curves, tabulated in table 2, showed that protection of the controls could have been accomplished at less than half the current applied to specimens Nos. 11 and 12, even after the latter two had been under cathodic protection for 8 days. On the 8th day of exposure, the current to specimen No. 12 was removed and in a period of 60 sec the specimen potential rose to -0.46 v and then began to slowly drift back again in the less noble direction. After a lapse of 50 min the potential was -0.57 v, changing very little compared to previous changes. A cathodic polarization curve was then obtained on specimen No. 12, resulting in the values of I_p and E_a tabulated in table 2 (1st 8 days). One hour later, an anodic polarization curve was recorded on this specimen (not recorded in table 2). These curves revealed that the corrosion process was cathodically controlled and at a relatively high corrosion rate, as indicated approximately by the cathodic polarization current I_p .

Apparently the protective currents to specimens Nos. 11 and 12 were high, for the first 8 days at least, because no time was allowed for a normal corrosion rate to become established. After obtaining the polarization curves on specimen No. 12, both speci-

mens were left without any protection for 3 days by removing the protective currents. After corroding freely during this time, cathodic polarization curves were again obtained (11th day). The new values of I_p (28 ma/ft², table 2) were more consistent with the values previously obtained for the controls and the intermediate values of I_p seem reasonable when considering the positions in the vat of specimens Nos. 11 and 12 relative to the controls. On the 11th day of exposure, these specimens were again placed under cathodic protection. Because the potentials E_a (table 2), previously obtained from curves of the controls, were all more anodic than -0.70 v it was expedient to readjust the control potential for specimen No. 11. Accordingly, specimen No. 11 was adjusted to -0.725 v and No. 12 again at -0.775 v. The currents applied to these specimens, automatically recorded for 60 days, are tabulated in table 2 and daily averages are plotted in figure 4. The potential of specimen No. 12 was also automatically recorded for the 60 days and, in addition, daily measurements of potential were made on all other specimens, including No. 12. Minimum, maximum, and mean values are tabulated in table 2.

The values of I_p and E_a shown for the controls (table 2, 11th to 60th day) are based on all curves, that is, those recorded on the 7th, 39th, and 57th days of exposure. Judging from the mean values of E_a for the controls, it would be expected that the composite open-circuit potential, E_a , of the anodes of specimen No. 11, and for that matter also specimen No. 12, was probably between -0.715 and -0.728 v. Thus, this range gave assurance that the potential, -0.725 v, to which specimen No. 11 was controlled, was about right, the value -0.73 v shown in table 2 for this specimen being based on only one measurement made the 11th day. On the 60th day, when the protective currents were removed, the rise in potential, as previously described for the cathodically protected specimens in the stagnant water, indicated that specimen No. 12 received the best degree of protection.

TABLE 2. Exposure for 60 days to aerated water containing 3 percent of sodium chloride

Exposure period	Specimen number	Protective criterion	Cathodic polarization curve						Protective current to specimen ^d			Potential of specimen ^a			Corrosion current ^b I	Weight loss of specimen 60 days	Effectiveness of protection ^c
			Current at break, I_p			Potential at break, E_a			Range		Mean	Range		Mean			
			Range		Mean	Range		Mean	Range			Mean					
			Min.	Max.		Min.	Max.		Min.	Max.	Min.		Max.				
1st 8 days	8	Control...	ma/ft ²	ma/ft ²	ma/ft ²	v	v	v	ma/ft ²	ma/ft ²	ma/ft ²	v	v	v	ma/ft ²	mg	%
	9	---do---	-----	-----	20.0	-----	-----	-0.725	-----	-----	-----	-0.655	-0.700	-0.686	-----	-----	-----
	10	---do---	-----	-----	30.0	-----	-----	-0.730	-----	-----	-----	-0.652	-0.695	-0.681	-----	-----	-----
	11	Potential	-----	-----	22.5	-----	-----	-0.730	-----	-----	-----	-0.647	-0.700	-0.684	-----	-----	-----
12	---do---	-----	-----	51.0	-----	-----	-0.680	60.0	95.0	70.7	-0.685	-0.700	-0.697	-----	-----	-----	
								56.0	90.0	70.2	-0.770	-0.780	-0.772	-----	-----	-----	
8th to 11th day	Specimens 11 and 12 corroding freely for 72 hours																
11th to 60th day	8	Control...	20.0	22.5	21.2	-0.725	-0.735	-0.728	-----	-----	-----	-0.690	-0.715	-0.705	13.9	2,090	-----
	9	---do---	27.5	33.0	30.2	-0.705	-0.730	-0.715	-----	-----	-----	-0.670	-0.702	-0.689	19.7	2,955	-----
	10	---do---	19.0	22.5	20.5	-0.725	-0.730	-0.728	-----	-----	-----	-0.690	-0.712	-0.704	15.3	2,300	-----
	11	Potential	-----	-----	28.0	-----	-----	-0.730	13.5	34.2	27.5	-0.729	-0.733	-0.725	-----	^e 238	90
12	---do---	-----	-----	28.0	-----	-----	-0.730	20.0	36.0	27.6	-0.770	-0.780	-0.776	-----	^e 108	95	

See footnotes to table 1.

The weight loss data (table 2) indicate that the effectiveness of the cathodic protection was best on specimen No. 12 and also favorable from the standpoint of applied current over the latter portion of the exposure period (fig. 4). While investigating the reasons for the high currents initially required to protect specimens Nos. 11 and 12, it was decided to hold control specimen No. 8 at a protective potential of -0.775 v overnight and automatically record the protective current required. After 20 hr of cathodic protection, the potential was changed progressively over a period of 10 min to a value of -0.700 v (fig. 5). Within 1 hr, the initially reduced current had increased until it was almost as high as previously. Upon again gradually readjusting the potential to -0.775 v, which required an initial increase of current, a gradual reduction followed, the current once again approaching the original value. This experiment confirmed the comparative currents applied to the cathodically protected specimens Nos. 11 and 12. In fact, the data seem to indicate

that protection at the potential -0.77 v not only assures virtually complete protection but also optimum current requirements.

The average weight loss of the controls in aerated water was about 2.6 times that in stagnant water whereas 3.7 times as much current was required for protection. Had the exposure of the steel in the aerated water been prolonged until the protective current on specimen No. 12 (fig. 4) was stabilized, the ratio of the currents might have been more in agreement with the ratio of the weight losses. It is believed that the higher protective current ratio may be attributed in part, to a difference in the degree of cathodic control of the corrosion rates under the two conditions of exposure. A somewhat analogous comparison of protective currents was made by Waldron and Nelson [8] in reference to the cathodic protection of ship hulls. They found that approximately twice as much current was required to maintain a given potential when a ship was moving as when it was stationary.

4. Summary

Cold-rolled steel specimens were exposed for 60 days to both stagnant and aerated city water, to which was added 3 percent by weight of sodium chloride.

Under both stagnant and aerated exposure, the best degree of cathodic protection was achieved when the specimens were held at a potential -0.77 v with reference to the saturated calomel electrode (equivalent to -0.85 v with reference to the copper-copper sulfate electrode). Although a good degree of protection was obtained at controlled potentials more noble than -0.77 v, that is, at the potentials associated with the breaks in cathodic polarization curves, this lesser degree of protection could not be obtained

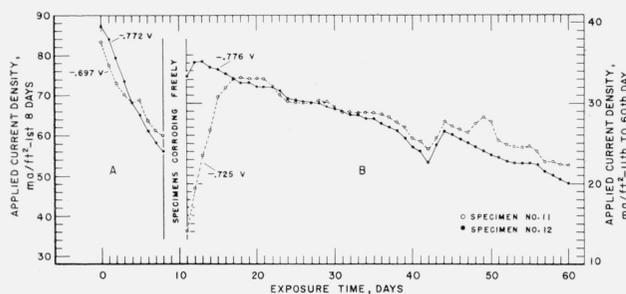


FIGURE 4. Protective current densities on steel specimens exposed to aerated water containing 3 percent of sodium chloride when controlled at constant potentials.

A, protective current applied immediately upon exposure; B, protective current applied to the same specimens after an intermediate freely corroding period of 3 days.

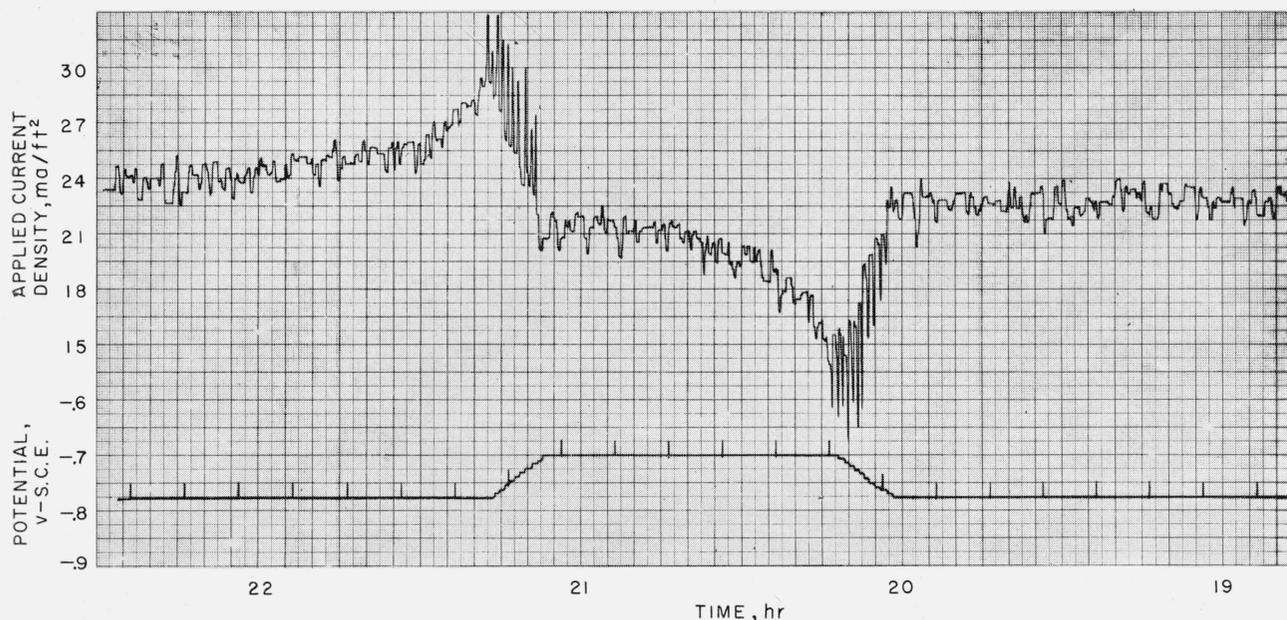


FIGURE 5. Recorded chart showing the variation of the cathodic current density on a steel specimen when changing from potential control at -0.775 volt to control at -0.700 volt and back again.

The potential was initially -0.775 volt for 20 hours.

at lower mean current densities. Therefore, -0.77 v was found to be the optimum protective potential.

Applied currents indicated by the breaks in cathodic polarization curves agreed reasonably well with the currents required to maintain polarization at the optimum potential. The break current, therefore, which was observed to be related to the rate of corrosion, is considered a good measure of the current required for optimum protection.

A short preliminary period of exposure without protective current was observed to greatly reduce the amount of current initially required for cathodic protection.

WASHINGTON, August 14, 1957.

5. References

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