EVALUATION OF CATHODIC PROTECTION AND STRAY CURRENT CORROSION ON A FLOATING DOCK

by

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SUMMARY

In order to evaluate the generation and control of corrosion of the floating dock, tests were carried out to determine the degree of cathodic protection and the effect of stray currents sources.

It was found that the cathodic protection is more than adequate and may possibly have caused deterioration to the piers through descaling. It is recommended that this current be reduced to ensure that such deterioration will no longer be possible.

It was also found that the rate of deck corrosion is severe and that the probable cause is a combination of natural corrosion due to exposure and to the presence of stray currents due to ac arc welding. It is recommended that the remedial measures already in existence be continued to eliminate stray currents and that the entire pontoon deck be covered with zinc filled paint (CATHA COAT 302) The dock was inspected lately in October and December 1972 and the remedial measures suggested are working perfectly with amount of deck corrosion below accepted averages even for temperate climates.

THE ELECTROLYTIC CORROSION PROCESS

When a metal such as iron is immersed in an electrolyte such as ea water, there is a tendency for positive ions of the metals to lissolve into the electrolyte where they are then oxidised. pecifically this is the process of corrosion. An impressed electric urrent from the electrolyte into the metal will slow this process and the magnitude of the current is sufficient the corrosion process ill be completely stopped and a protective polarization potential ill be produced at the surface of the metal. This polarization otential will persist even when the externally impressed protection current is interrupted. If on the other hand, an electric current is impressed from the metal to the electrolyte then the process of corrosion will be accelerated. In the case of the floating dock the corrosion as proved by chemical analysis of scale is a physical electrochemical corrosion associated with marine environment and also aggravated by strong currents. Under ambient conditions, it is highly unlikely that any other forms of corrosion are taking place.

To protect metal in contact with an electrolyte from corrosion it is generally recommended to

(1) Eliminate stray currents which may be directed from the metal into the electrolyte.

(2) Provide a protection current from the electrolyte into the metal. This is called cathodic protection.

To provide cathodic protection an anode (that is, a positively charged electrode) is placed near the metal to be protected, the latter then becoming a cathode (that is, a negatively charged electrode). There are two methods of supplying the necessary electric current, namely:

(1) by impressing an external dc supply between the anode and cathode, or

(2) selecting a metal for the anode which in conjunction with the cathode and electrolyte forms an electric battery of sufficient potential.

In the second case, as a result of the required electro-chemical reaction, the anode will corrode away and will have a limited life. In the case of steel this protection is supplied, either by a zinc coating such as a galvanize or zinc filled paint, or by attaching blocks of zinc to the steel surface. These blocks are called sacrificial anodes and must be replaced from time to time.

In the first case, a noble metal such as platinum may be used for the anode and will have an indefinite life.

THE EVALUATION OF A CATHODIC PROTECTION SYSTEM

The effectiveness of a cathodic protection system is determined by the magnitude of the polarization potential existing. In order to obtain an accurate measurement of this potential, great care must be taken to properly account for the electro-chemical reaction which will take place at the measurement electrode. Specifically, a half cell which is a type of special reference electrode with stable and accurately known characteristics must be used.

As half cells are not commercially available locally, it was necessary to construct and test a set in the Engineering laboratories. Samples of those constructed were found to have electrode resistances ranging between 100 and 200 ohms which is sufficiently low to assure accurate measurements.

Tests were carried out at the floating dock using a copper/copper sulphate half cell. For this type of half cell corrosion protection of steel just takes place when a half cell potential of - 0.85 volts is measured relative to the steel.

The geometry of the floating dock and its cathodic protection system was used to determine the points of least protection and measurements were made at these points. These points are shown on Figure 1. These measurements and the corresponding excess protection potentials are tabulated in Table 1. The current density corresponding to these potentials is approximately 37 ma per sq. ft. at points where bare metal is exposed and is sufficient to cause the formation of hydrogen gas bubbles. Although this current density is excessive and can be reduced to as low as 4 ma to maintain protection, it is not sufficient to cause damage to the floating dock. This may not be true, however, of the pier next to the dock where the current may cause descaling of the steel reinforcing resulting in a separation of the concrete from the steel rods. Unfortunately, it is not possible to make a more comprehensive check of the pier without resorting to destructive tests.

THE EFFECT OF STRAY CURRENTS AS A RESULT OF AC ARC WELDING

It is extremely unfortunate that currently, in a majority of welding operations throughout Trinidad, there is a common practice of completing the electrical connection from the work to the welding transformer by laying together miscellaneous scraps of steel. These practices have been used habitually by the welders at the floating dock until October 1968. In particular, the common side of the welding transformer was earthed to the dock; then the electrical circuit to the work, (which was otherwise insulated from the dock), was completed by resting a piece of scrap on the deck of the dock and leaning it against the side of the work. Thus, stray currents passed through the surface of the deck into the overlying surface layer consisting of sand, salt, moisture and miscellaneous impurities and then through the connecting piece of scrap to the work. This stray current has been suspected of causing an increased rate of corrosion of the deck of the floating dock. This clearly would have been the case if there had been a net dc component passing from the deck to the work. However, for this to be the case in ac arc welding, rectification of the ac welding current to produce a dc component of the necessary polarity would have to take place. In fact, rectification at the arc is a reasonable hypothesis in that it is likely that, because of its high temperature, thermionic emission of electrons from the welding electrode takes place. This could neither be confirmed nor denied by the locally available literature on arc welding due to the fact that it dealt only with practical aspects and not with the theoretical details of arc welding. For this reason, it was necessary to seek confirmation in the laboratory.

Tests were duly conducted using electrodes and welding currents similar to those used at the floating dock. A schematic diagram of the test arrangement is shown in Figure 2.

These tests confirmed that a dc component is, indeed, produced and directed from the work to the electrode and in the case of the floating dock, of the magnitude and polarity to have caused deck corrosion. The magnitude of the dc component was found to range between 2 amp and 5 amp when a No. 47 Fleetwood electrode of 5/32 in diameter and a 125 amp ac welding current were used.

Tests have also been conducted to determine qualitatively the nature of the distribution of current density out of the deck. These tests indicate that, due to the porosity of the ferric oxide, stray current densities may be quite large and will be concentrated at the points of contact between the deck and the scrap metal which is used to complete the connection to the work. It is expected that the effective area (i.e. total current divided by maximum current density) was in the range of 0.25 sq. in. to 10 sq. in.

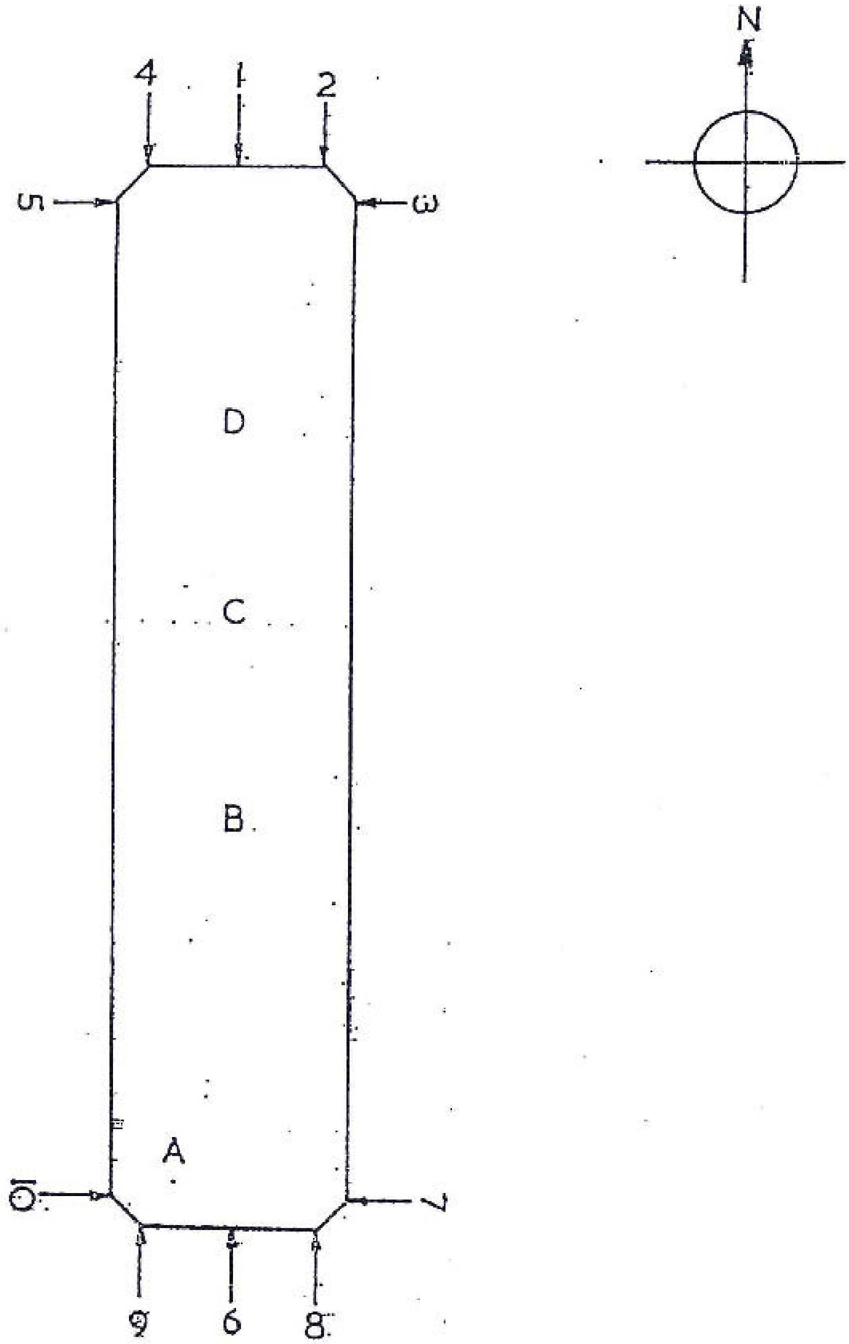

FIG. I Points of Measurement

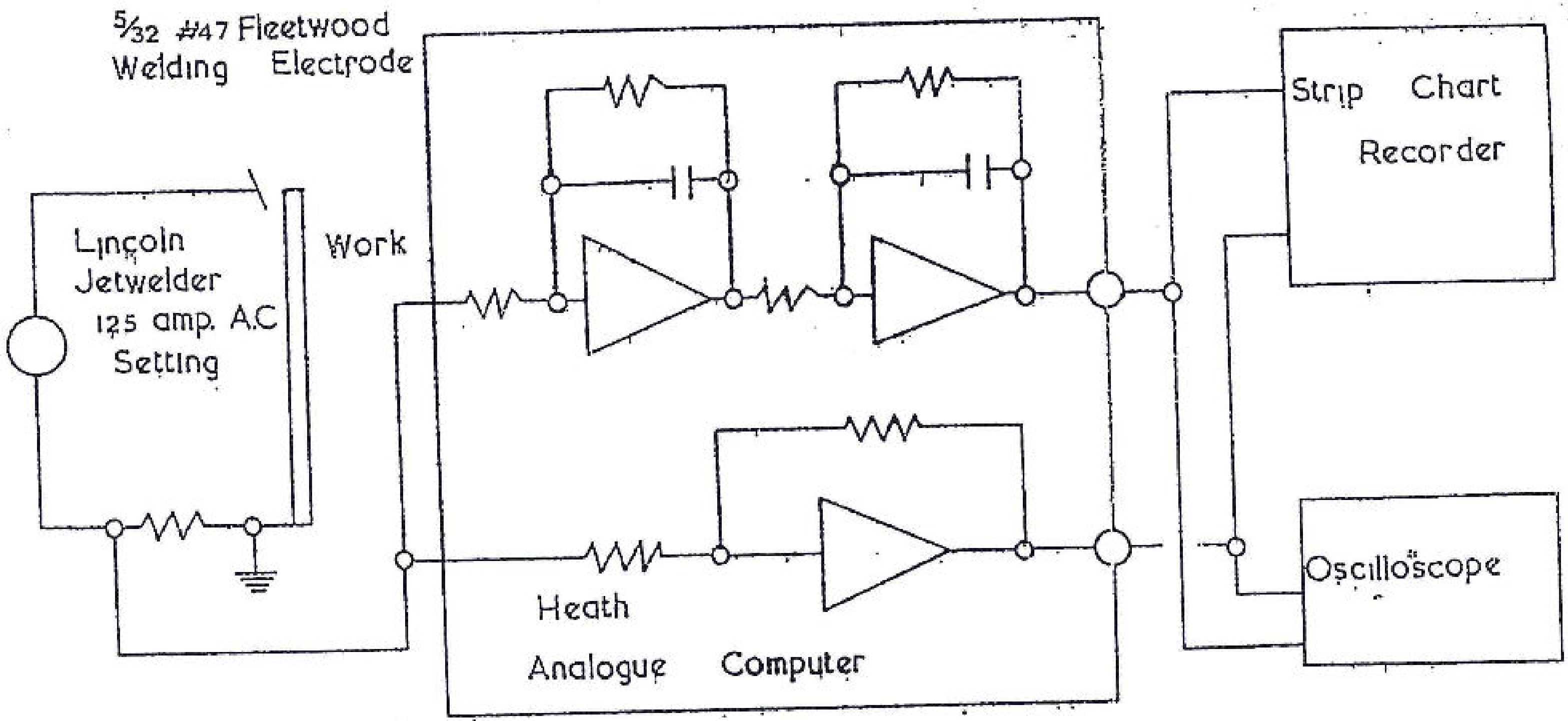

FIG. 2 Schematic Diagram of Test Arrangement

RATES OF CORROSION

In August of 1968 samples of the deck corrosion were taken at four locations (see Figure 1) and were analysed as to chemical composition and weight per square inch of deck surface. Another set of samples were taken in June 1969. From this data the corrosion penetration was calculated (see Table II). It must be kept in mind while evaluating these results that a certain amount of chipping and painting had taken place previously and that it was not possible to make a comprehensive study to determine the maximum and minimum rates of corrosion which no doubt were somewhat larger and smaller respectively than the maximum and minimum values given in Table II.

If the life of the deck is taken as the time required for the maximum penetration to equal one third the thickness of the deck (131 mils) then, under conditions existing to August 1968, the life of the deck would be less than 10 years. Recent tests, however, indicate that the rate of corrosion has significantly decreased and that at the present rate the life may be as much as 48 years. This cannot be considered conclusive, though, since samples were taken only at one location.

CAUSES OF CORROSION

There are two primary causes of corrosion taking place:

1. Natural corrosion, i.e., corrosion caused by the presence of moisture and salt.

2. Excess corrosion due to stray currents.

ites of natural corrosion of steel in a marine atmosphere range from 5 to 3.3 mils per year*. When steel is immersed in sea water this rate about 5 mils per year. The most extreme corrosion occurs when the el is subjected to salt spray from severe surf and may be as high as 37 s per year.

Corrosion due to stray currents will progress at a rate of from 15 imp-year to 40 lb/amp-year which corresponds to penetrations of mils/(amp-hr/sq.in.) to 16.5 mils/(amp-hr/sq.in.). Thus, the osion penetration due to one welding machine operating at an ac ling current setting of 125 amp will be at least 12 mils per hour and er severe conditions may be as much as 264 mils per hour.

RECOMMENDATIONS AND CONCLUSIONS

The rate and broad distribution of corrosion of the deck of the dock definitely indicates that a major cause is exposure. On the other hand, stray currents due to improper arc welding practices will cause a high rate of local corrosion. Either of these circumstances alone will cause a significantly shortened pontoon deck life and the combination is, at least, additive. The apparent reduction in corrosion since August of 1968, in fact, indicates that stray currents may have been the major cause of degradation.

Cathodic protection was found to be more than adequate and in fact may be causing deterioration of the piers next to the dock.

* 1 mil = .001 in.

Our recommendations are, therefore,

(1) Protection of the entire deck with a zinc impregnated paint, e.g. British Paints "Torpedo" Catha-Coat 302. This will provide a type of cathodic protection to the deck and may be expected to suppress to a high degree corrosion due to natural causes. This paint may be covered by a neutral material (like asphalt) though special care should be taken to reaction between the zinc and covering material. Such a reaction would nullify the protection offered by the paint.

(2) Elimination of stray currents through the maintenance of proper arc welding standards such as those instituted in October of 1968. Specifically, a high quality connection must be provided directly between the work and the welding transformer so that none of the welding current passes through the pontoon deck. It must be emphasized that such stray currents, if present, can nullify and make ineffective the protection to be given by a zinc paint. Therefore, it is imperative that both recommendations be put into practice.

(3) The cathodic protection current should be decreased until a polarization potential of between .9 and .95V is realized to ensure that descaling of the steel reinforcement of the piers does not result. To do this, it is recommended that the total current should be reduced from the present value of 180 amp to 60 amp. Evaluation of the result of this change should be made and further adjustments should be made as necessary.

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TABLE I

CATHODIC PROTECTION MEASUREMENTS

Location of Measurement (see Figure 1)	Measured Polarization Potential ($Cu/CuSO_4$ Half Cell)	Excess Polarization Potential
1	1.10 V	0.25 V
2	1.09 V	0.24 V
3	1.08 V	0.23 V
4	1.11 V	0.26 V
5	1.10 V	0.25 V
6	1.10 V	0.25 V
7	1.07 V	0.22 V
8	1.08 V	0.23 V
9	1.10 V	0.25 V
10	1.09 V	0.24 V

TABLE II

Sample Location (see Figure 1)	Total Steel Loss (lb/sq. ft.)	Corrosion Penetration Total mils	Mils per Year
A (Aug. 68)	0.788	19.3	14.5 x
B (Aug. 68)	0.625	15.3	11.5 x.
C (Aug. 68)	0.434	10.6	8.0 x
C (Jun. 69)	0.530	13.0	2.7 xx
D (Aug. 68)	0.577	14.1	10.6 x

x over the period Apr. 67 till Aug. 68

xx over the period Aug. 68 till June 69