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Zero resistance microcoulometer for measuring galvanic corrosion current

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An instrument with zero external impedance has been developed to measure directly the total charge passing between the elements of a galvanic couple. The results obtained with mild steel - zinc couple of 1:1 area in sodium chloride solutions from 0.001 - 5.0% were compared with weight loss and potentiostatic measurements. The results are encouraging.

Key words: Microcoulometer, iron-zinc, galvanic corrosion

INTRODUCTION

Studies on galvanic corrosion involve measurement of open circuit potential, assessing weight loss and determination of the galvanic current [1,2]. The latter two methods give quantitative information — the weight loss yields the average galvanic corrosion rate (i_g^{wt}) and the continuous measurement of galvanic current (I_g) shows the corrosion rate variation with time (t). From graphical integration of I_g-t plot, the average galvanic corrosion rate (i_g) is obtained. For measurement of I_g, a Zero Resistance Ammeter (ZRA) is used based on galvanostat, potentiostat, operational amplifier, etc. [3,4]. The effort of the authors to develop a simpler instrument to measure the galvanic current directly is highlighted in this paper.

EXPERIMENTAL

The instrument

Figure 1 shows the block diagram and photograph of the zero resistance microcoulometer. The current being measured is converted into a voltage (I to V converter) using a chopper—stabilized, low noise, low bias current amplifier (ICL 7650S). Its range is extended by changing the feed back resistor. The voltage is amplified by using a noninverting amplifier and is converted into a frequency output by a voltage to frequency converter (VFV-10K). The special feature of this is that the frequency linearity does not fall off near zero input, as is the case with some other converter. Nonlinearity is ±0.005%. The frequency output is counted using a 8 digit decade counter (ICL7226 BIPL). The current can be measured in four ranges from 0.01 μA to 100 mA which gives 0.01 μc to 10 μc integration resolution, respectively.

Electrode assembly

It consisted of three metal strips, two of mild steel (2.5 cm^2 each) and one of zinc (5 cm^2). PVC holders keep the zinc electrode centrally [5]. The test solutions were

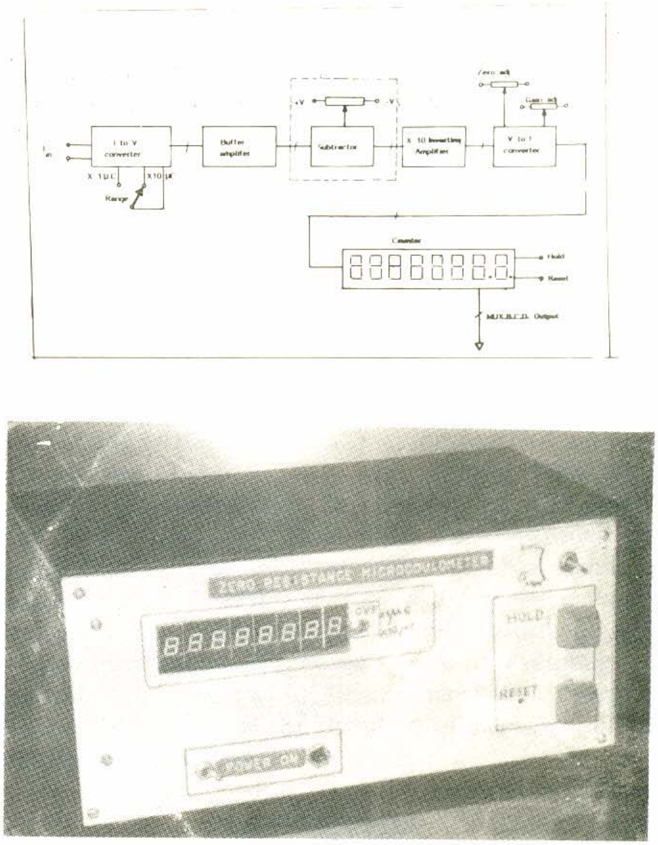

Fig. 1: Block diagram of the zero resistance microcoulometer

sodium chloride of different concentrations, 0.001, 0.01, 0.1, 1.0 and 5.0% with conductivities of 0.016, 0.127, 1.165, 9.89 and 27.9 ms respectively. The test was for 2 hours in quiescent solution at 303K and consisted of measuring the i_g using (i) microcoulometer (ii) potentiostat as ZRA and (iii) directly short circuiting the couple. After the test, the zinc electrode was cleaned in 10% ammonium chloride solution for 5 min at 303K. From weight loss the i_g^{wt} was calculated based on Faraday's law. Also the potential of the electrodes of the couple was measured. The corrosion

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rate of uncoupled zinc was assessed by weight loss.

RESULTS AND DISCUSSION

From Fig. 2, it is evident that the i_g values obtained with the microcoulometer and the potentiostat as ZRA are in good agreement. But, the i_g^{wt} values are 10-40% higher than i_g. This could be due to added corrosion by local cell action. It has been shown by others [6,7] that $i_g^{wt} = i_g + i_{corr}^{anode}$ when the potential of the couple is close to the corrosion potential of the anode, as is the case with M.S. - Zn. The corrosion rate of uncoupled zinc (i_{corr}) was found to be $55 \pm 20\ \mu A.cm^{-2}$ in the different electrolytes and hence the disagreement between the i_g^{wt} and i_g values can be understood. This aspect of the instrument is being taken care of in future work.

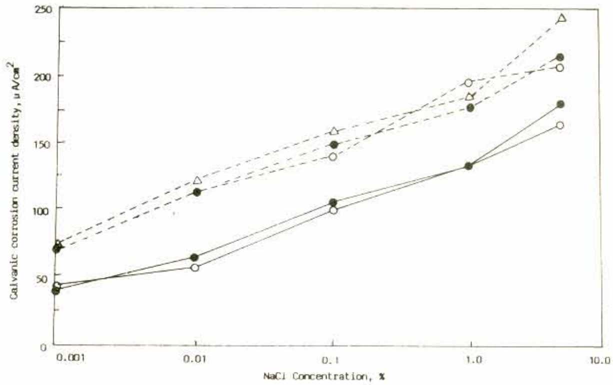

Fig. 2: Galvanic corrosion current density of MS-Zn couple vs NaCl concentrations obtained by different methods; o—microcoulometer, •—potentiostatic ZRA and △ short circuited cell. ——i_g, - - - - - - i_g^{wt}

CONCLUSION

The performance of the instrument is comparable with potentiostat as ZRA in low and highly conducting NaCl solutions.

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