

**Use of Potential Probes To Monitor Cathodic Protection:
Accuracy of the of the IR free Potential**

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ABSTRACT

Potential probes are sensors consisting of a reference electrode and a metal coupon close to the electrode used for measuring the protection potential of underground metal structures in cathodic protection. They allow the reading of the potential purified by the ohmic drop contribution, the so-called IR-free potential, a useful parameter for assessing the effectiveness of a cathodic protection system. Aim of this work is to compare the accuracy of the potential measurements of commercial probes, which differ in geometry, extension of the porous plug, number and position of the metal coupons. Measurements of reference electrode potential stability in the presence of cathodic protection and ability of the probes to compensate the ohmic drop were performed. The results showed that not all potential probes are able to measure the IR-free potential, as the measurement contains an ohmic drop contribution, greater for more negative cathodic polarization values.

Keywords: cathodic protection, monitoring, potential probe, ohmic drop.

INTRODUCTION

Cathodic protection (CP) is an electrochemical corrosion prevention technique, which is implemented by circulating a direct current between an electrode (anode) placed in the environment and the structure to be protected (the cathode): this current causes a lowering of the potential of the metal and reduces its corrosion rate, until it stops.¹

The general criteria used to verify CP efficiency is based on potential measurement, performed by using a reference electrode placed in contact with the environment surrounding the structure (soil, water, electrolyte or concrete) and a high impedance voltmeter whose positive pole is connected to the structure and its negative one to the reference electrode.

Potential measured through a reference electrode depends on electrode position with respect to the structure. In the presence of a cathodic protection current, I , the measured value, E_{ON} , is the sum of three contributions: the equilibrium potential of the metal (E_{eq}), the overvoltage (η) related to the cathodic current density, and the ohmic drop (IR , where R is the electrical resistance), the latter depending on the reference electrode position, environment resistivity and the circulating current:

$$E_{ON} = E_{eq} + \eta + IR = E_{IR-free} + IR \quad (1)$$

The sum ($E_{eq} + \eta$) is the true polarization of the metallic structures, the well-known IR-free potential. Even in the presence of electrical interference, the measured ON potential may be affected by an ohmic drop contribution.²

When considering underground structures, pipes or tanks, ISO 15589-1³ illustrates the principles of design, installation, testing and management of CP systems. In the section dedicated to plant management and monitoring, the standard indicates two approaches to assess the effectiveness of the CP based on potential reading:

- *general assessment*: a CP plant is properly functioning if the ON potential of the structure is less noble than the free corrosion potential, i.e. a cathodic direct current is entering the metal
- *detailed and comprehensive assessment*: CP is effective if the true polarization of the structure, (the so-called IR-free potential, $E_{IR-free}$) is lower than the protection potential, the latter being a function of the type of metal and the soil characteristics, namely the resistivity. For carbon steel in aerated ground, the protection potential is -0.85 V CSE (CSE is the copper / copper sulphate, Cu/CuSO_{4,sat.}, which potential is +0.32 V compared to the hydrogen standard electrode).

While the ON potential is easy to measure, to have the IR-free potential value the ohmic drop contribution must be eliminated. In principle, there are two main ways to get it:

- reduce the physical distance between the reference electrode and the structure
- use the ON-OFF technique

Potential probes are one of the available methods^{1,4-5}. They consist of a metal specimen (or coupon) connected to the same CP plant of the pipeline and a reference electrode placed in its immediate vicinity. Nowadays, there are commercially available sensors with one or more carbon steel plates of size between 1 and 10 cm², fixed in proximity to a CSE reference electrode inserted in a plastic container. A porous plug guarantees electrolytic continuity between the internal electrode and the external ground. In theory, this device allows eliminating the ohmic drops for two reasons:

- 1) the reference electrode is placed in the vicinity of the specimen whose potential is to be measured
- 2) the presence of the plastic case allows to electrically isolate the internal electrolyte where the reference electrode is housed, thus eliminating the ohmic drops associated with the circulation of current in the soil.

The devices available on the market differ from each other in the number and size of the metal plates, the distance between the plate and the porous plug and the position and size of the porous plug. Therefore, it could be assumed that, with the same electric field induced by a CP plant, the elimination of the ohmic drop contribution is linked to the different geometry of the probe. In this work, some

configurations of commercial potential probes are compared, by evaluating the contribution of the residual ohmic drop measured by the probe itself.

EXPERIMENTAL PROCEDURE

Three configurations of potential probe have been considered. Table 1 shows a scheme of the probes: the plastic container in green, the ceramic porous plug in grey and the metal coupons in black. Probe A has a porous plug with a surface less than 70 cm² and a very small coupon-porous plug distance. Probe B has the largest porous plug and an electrode-coupon distance of about 4 cm. Probe C has a porous plug of intermediate extension but a coupon-to-plug distance equal to 15 cm. In all probes, the coupons are in carbon steel API 5L⁶ and the internal reference electrode is based on copper/copper sulphate.

Table 1: Tested Potential Probes

PROBE	COUPON		Porous plug surface (cm ²)	Distance coupon–plug (cm)	PROBE SCHEME
	N	Surface (cm ²)			
A	2	1 – 10	50-70	< 2 cm	
B	3	2.5 – 2.5 – 5	100-200	4 cm	
C	1	10	80-140	15 cm	

Each probe was subjected to two series of tests: verification of the stability of the reference electrode potential, evaluation of the residual ohmic drop.

The stability of the internal electrode of each potential probe was determined by measuring the potential of the internal CSE reference electrode with respect to an external silver-silver chloride master electrode (SSC: Ag/AgCl/KCl_{sat.}, +0.2 V with respect to the hydrogen standard electrode). The scheme of the cell is depicted in Fig. 1. The measurement was carried out in three conditions:

- CSE reference electrode immersed in solution without any connections (i.e. disconnected from any coupon or other electrode)
- CSE reference electrode connected to a zinc anode, interposing a 10 MΩ electrical resistance simulating the internal impedance of a voltmeter
- CSE reference electrode connected to a magnesium anode, interposing a 10 MΩ electrical resistance, simulating the internal impedance of a voltmeter

The zinc and magnesium anodes are intended to simulate a metal structure under cathode protection at a constant potential of approximately -1.0 V CSE and -1.5 V CSE, respectively. The tests were carried out in a tank containing a solution with a resistivity of 50 Ω m. The duration of the tests is five days. Potential measurements were performed twice a day.

The evaluation of the residual ohmic drop allows verifying the actual ability of the probes to measure the IR-free potential. The tests were carried out in a tank containing 50 litres of a solution with a