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Reliability of coupons for AC/DC interference monitoring

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ABSTRACT

Coupons are available in different configurations, dimensions and shapes. Monitoring AC and/or DC interference requires a small surface area of the bare steel coupon sample with a reference electrode tip as close as possible to the steel surface for minimizing the IR-drop error in the measurement. Furthermore the effect of a coating surrounding the defect is often neglected or simplified which may have influence on the measured current densities, and thus corrosion rates.

Current standards such as NACE Standard SP0104-2014[1] does not address sufficient details to make AC/DC coupons sufficiently sensitive and reliable for interference monitoring. This article discusses results from a benchmark study on commercially available coupons. Deviations in the current density and IR-free readings through computational modelling are reported.

Keywords: AC/DC interference, coupon configuration, modeling, monitoring

INTRODUCTION

The use of coupons has significantly increased the last decades because remote monitoring devices allow better managing of the corrosion threats caused by interference sources while significantly reducing field interventions. It is the aim of coupons to represent as good as possible the protection level or corrosion behavior of a coating defect on the pipeline. Coupons are used for IR-free potential measurements but with the latest knowledge in AC and DC interference corrosion mechanisms there is a growing interest in measuring the AC and DC current on coupons for proper risk assessment. Especially under interference conditions, high current densities and potential fluctuations occur and reliable readings are of particular interest.

As coupons are available in different configurations, dimensions and shapes, significant variations in the current response are expected. Furthermore correct installation of coupons near pipeline sections under AC/DC interference might be challenging due to the large variations in the ground potential around the pipeline. The reliability of the coupons was therefore verified in CPMaster™ computational modeling software. Special attention is made for:

- Effect of coupon geometry on monitored current density
- Effect of coupon position

This work is intended to provide more general guidance on appropriate coupon design selection and installation.

CURRENT STANDARDS

The criteria for determining the CP status of a buried pipeline are mentioned in the standards NACE SP0169[2] and EN12954[3]. More details on the use of coupons for CP monitoring are described in NACE SP0104[1] and EN13509[4] standards. However the information on the design is limited and not dedicated to interference phenomena in particular. Separate guidelines for DC interference assessment are provided in the EN50162[5] and, for AC corrosion interference, in EN15280[7] and NACE Standard Practice under development by TG430[6].

As stated in the standards various types of coupon designs may be used depending on the specific circumstances. A proper coupon design must be selected for the monitoring program. However the sensitivity of the coupon design and the installation on the measured current density or corrosion rates is not discussed. Some examples are given in the standards related to CP and DC interference as shown in figures 1 to 3. For AC corrosion no examples of coupon designs are provided in the standards but some are found in literature[8] as shown in figure 4. In order to be representative for a pipeline coating defect, coupons should be installed close to the structure and in the same electrolyte around the pipeline.

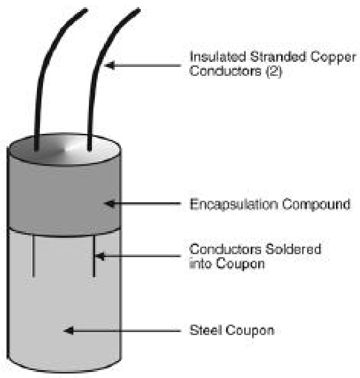

Figure 1: Coupon with cable connection[1]

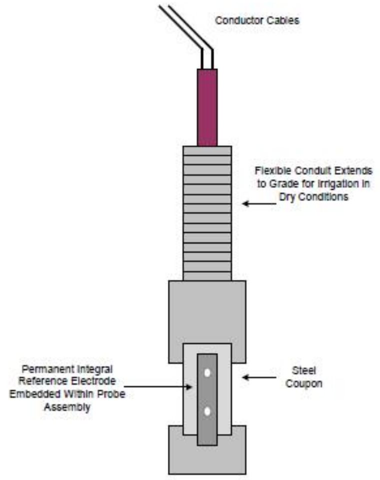

Figure 2: Coupon with built-in reference electrode[1]

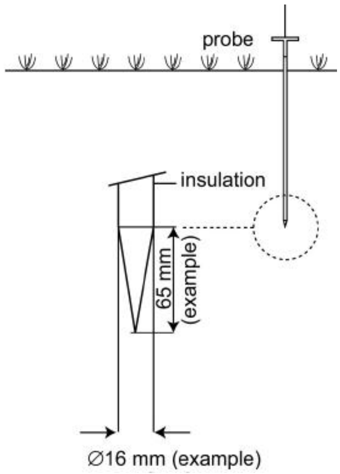

Figure 3: Coupon for DC stray current interference[5]

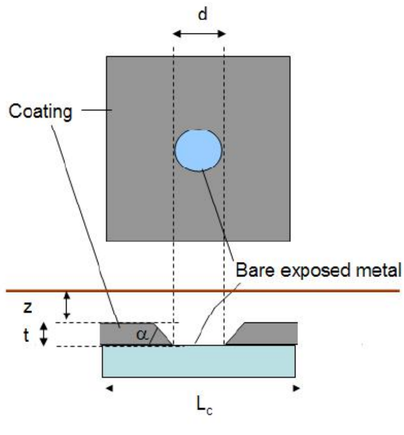

Figure 4: Coupon for AC corrosion monitoring[8]

MODELLING RESULTS

Effect of coupon geometry

Since the current density is determined by the spread resistance, which in turn is determined by the coupon geometry and soil resistivity, the coupon design may play a role in its efficiency for monitoring purposes. Different geometries of commercially available coupons and probes have been investigated through modeling. A polarization level of 15V AC superimposed on a -1.2V CP level was simulated for two different soil types, namely saturated sand and saturated clay with a specific resistivity of 8.5 and 14.9 Ω m respectively. The polarization data was measured in a laboratory cell and used as input for the modeling software.

Figure 5 and 6 show the simulated current density for different coupon geometries. The value is obtained by averaging the current density distributed on the coupon surface at peak AC voltage. The coupons are grouped per surface size and ordered per increasing current density. It can be seen that there is no much variation in response on CP coupons of 10 cm^2 meaning that the geometry has less impact on the measured current density. Smaller coupons of 1 cm^2 show a higher current density than the larger ones. The geometry has a larger impact as well. Cylinder type coupons and ER probes (wire flush and strip flush) show the highest current density. The presence of an (artificial) coating increases the spread resistance of the coupon and as a consequence reduces the current density. The angle of the coating cutting edge (45° - 75° - 90°) plays a role as well. A cutting angle of 90° results in a lower current density (higher spread resistance) than in the case of 45°. Note that for the same set of investigated 1 cm^2 coupons the average current density differs a factor 1.40 and 1.85 for respectively sand and clay. The difference in the average current density between sand and clay can be explained by the fact that clay is a more corrosive soil leading to more pronounced electrochemical reactions and thus resulting in a decrease in local soil resistivity at the metal surface of the coupon.

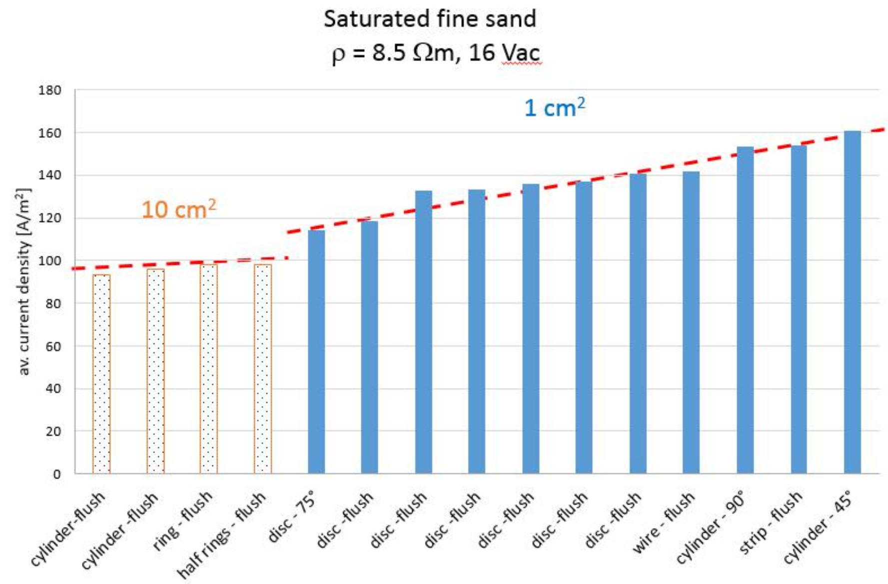

Figure 5: Average value of simulated current density on AC coupons in saturated fine sand

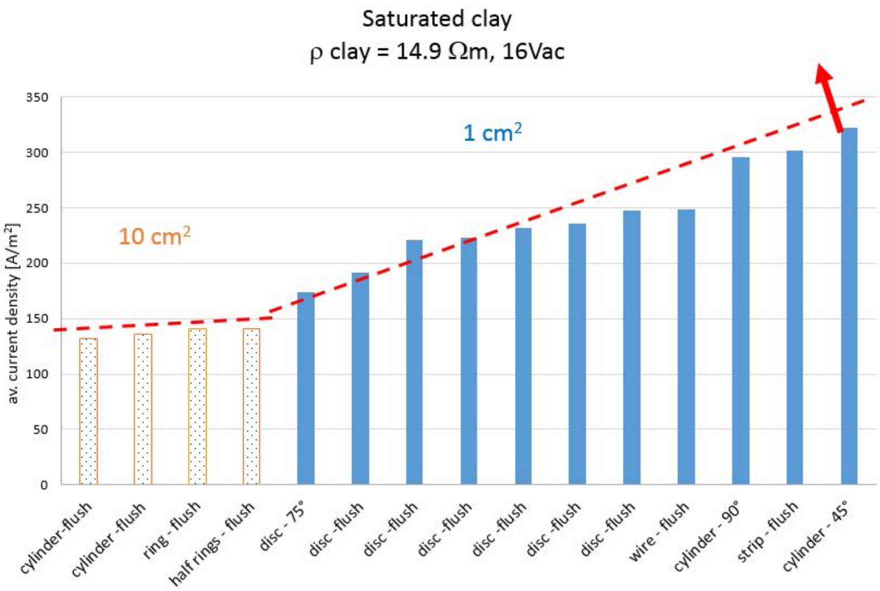

Figure 6: Average value of simulated current density on AC coupons in saturated clay

Monitoring equipments measure the average current density of the coupon. The current density is typically higher at physical edges of the metal surface. These edge effects cannot be measured in the field but only be observed after excavating the coupon. Through modeling the edge effects are visualized as shown in figure 7. A qualification of edge effect is obtained by calculating the standard deviation of the current density distribution on the coupon surface. As can be seen from figure 7 the edge effect becomes more important at higher current densities (see clay versus sand) and on disc shaped coupons. Note that the finish of the coupon housing around the metal may play a role as well. The cylinder type coupons shows the smallest edge effects.

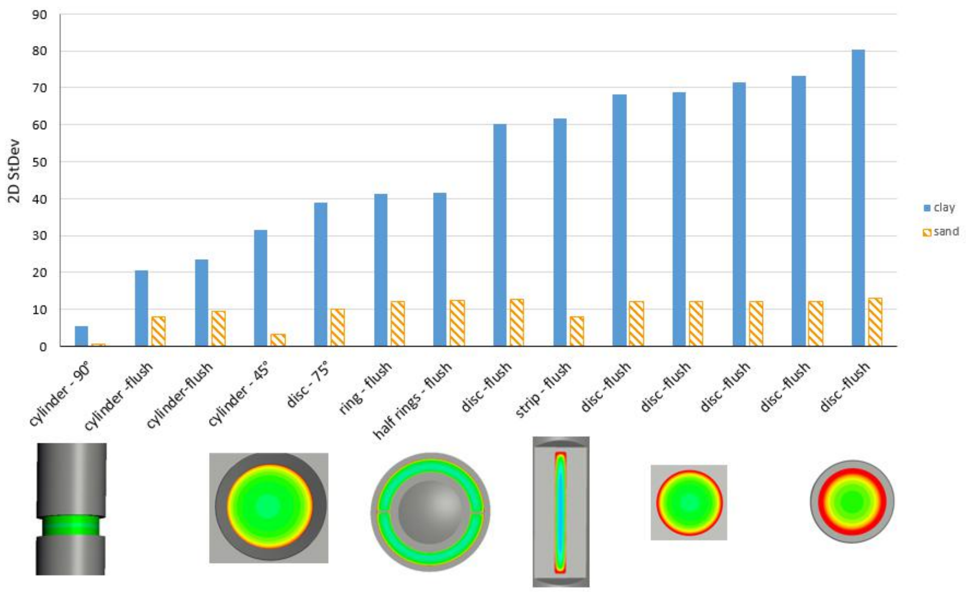

Figure 7: Standard deviation of the simulated current density on AC coupons

Effect of coupon position

Besides the geometry or coupon design to position of the coupon with respect to the pipeline is important, especially in the case of AC/DC interference. In the case of AC/DC interference the potential gradients in the ground are much larger than under normal CP system and may not be symmetrically distributed around the pipeline coating defect. As a consequence the position of the coupon and reference cell are important.

As an example a pipeline crossing with two separate CP systems is given in Figure 8. The clearance between the two pipelines is 10”. A coating defect of 10 cm^2 is foreseen on the lower 20” pipeline while the upper 24” pipeline has no coating defect. Both pipelines have a 10 cm^2 DC coupon installed at 2.5 ft distance left and right of the upper 24” pipeline but are buried at depth of the 20” pipeline. The specific resistivity of the surrounding soil is 250 Ωm. The polarization data for both pipelines is the same but they are polarized differently. The undamaged 24” pipeline has a protection potential of -1350mV while the 20” line with the coating defect has a polarization level of -850mV.

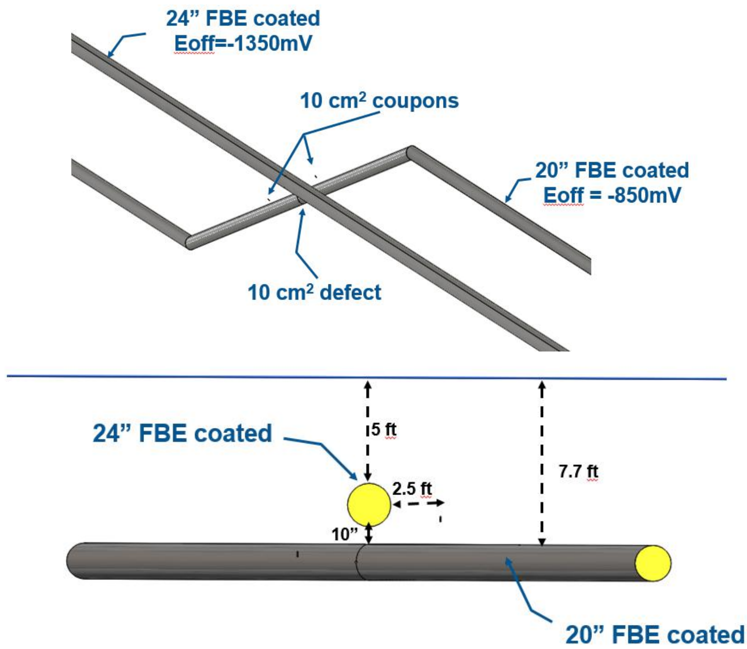

Figure 8: Computational model of pipeline crossing

Simulations results are shown in figure 9 and summarized in table 1. The ON-potential measured at grade is -1342mV as can be seen in figure 9. The coating defect on the 20” pipeline is under protected because of the DC interference at the crossing. Its IR-free potential is -701mV. Worthwhile to mention is that the coupon of the 20” pipeline shows an IR-free protection of -743mV. This means that the coupon over estimates the protection level of the coating defect with 42mV. The coupon of the 24” pipeline underestimates the IR-free with 285mV. The discrepancy is due to the position of the coupon that is influenced by a different ground potential than the coating defect. Note that the current drained by the 10 cm^2 coupon and coating defect is in the range of tens of microamperes.

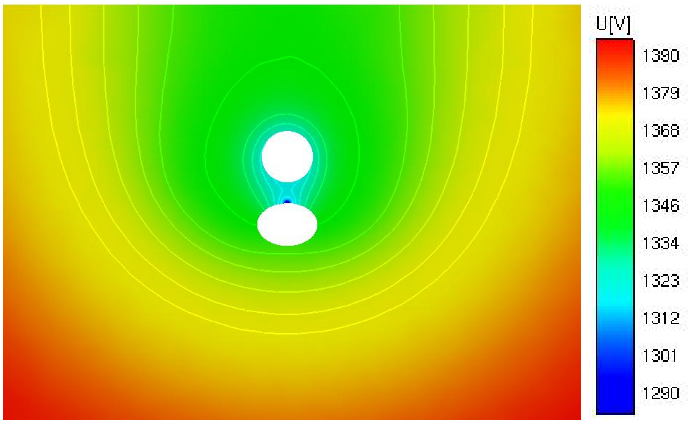

Figure 9: simulated ground potential around the pipeline crossing

Table 1: simulated protection level of pipelines and coupons

Structure	IR-free [mV]	Current [mA/m2]	CP current [mA]
24” pipe	-1320	-0.20	-
20” pipe	-850	-0.06	-
coating defect	-701	-23.00	0.02
coupon of 24”	-1035	-113.00	0.11
coupon of 20”	-743	-34.00	0.03

CONLUSIONS

The reliability of monitoring coupons was investigated through simulations. Under AC and DC interference the geometry (design) and installation is important.

The study shows that the current density between commercial coupons varies with 140% in saturated sand and 185% in saturated clay. The highest simulated current density occurs on cylinder type coupons. However they have the lowest edge effects. The highest current density on the edges was found on flush type disc coupons.

The geometry is less critical for larger coupons (10cm^2) but those are mainly meant for CP monitoring.The larger surfaces underestimate the current density in small coating defects under AC/DC interference.

Installation of the coupons in area with AC and/or DC interference result in an underestimation of the protection level.

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