CEOCOR CONFERENCE

FLORENCE 2013

TITLE: IR Free Potential Measurement Techniques in common use

AUTHORS: Ken Lax FIET, FICorr, NACE Corrosion Specialist. Technical Director Corroconsult UK Ltd

ABSTRACT: IR Free potentials are a requirement of many European and International Standards but how they are measured and interpreted varies considerably. The paper will very briefly discuss why IR free potentials can be useful and the main sources of error in IR free potential measurements.

Different techniques used around the world will be illustrated and the pros and cons discussed. These techniques will include:

- Galvanic system on/off measurements
- Impressed current on/off measurements
- Coupon on/off measurements
- CP Analyser measurements
- ER Probe IR Free potential measurement calculation.

What are IR Free Potentials?

The term IR derives from Ohms Law where the product of the current (symbol I) and the resistance (symbol R) produces a voltage. If a potential measurement is made whilst the cathodic protection current (I) is flowing through the circuit resistance (R) then there will be an element of the potential measured that is due to the IR voltage as well as the actual structure potential. This is discussed in more detail in other presentations at the conference.

Why do we need IR Free Potentials?

Almost all standards define the structure to electrolyte potential at which cathodic protection can be considered effective. These values vary depending upon circumstances (e.g. electrolyte resistivity, bacterial activity). Operators and regulators depend upon the measured potentials as an indication that the external corrosion has been reduced to acceptable levels by the cathodic protection. This acceptable level has been defined as 10 $\mu m\ a^{-1}$ (10 microns per year).

The standards state that the potential measurements have to be made without the effect of the IR component (e.g. EN 12954:2001 "All potentials are IR free..").

Unfortunately the structure-to-electrolyte potential is not always a good indication that the structure will not corrode even if the potential criteria are met. For example, where there is AC influence, where the potentials are fluctuating wildly due to DC interference, and when the potential is measured incorrectly (e.g. wrong placement of the reference electrode).

EN 12954 also allows the use of the actual measured corrosion rate as an alternative to a potential measurement. This topic is covered elsewhere in the conference.

Typical structure-to-electrolyte potentials are inherently inaccurate for the following principle reasons:

1. The electrode might not be close to the bare steel of the structure.

2. The electrode might not be close to the actual structure.

3. There may be galvanic couples that affect the measured value.

4. Electrolyte pollution can affect the measured value.

5. Criteria values given in the standards are not absolute.

6. Even if the cathodic protection current sources are interrupted it is not always possible to know what errors are introduced by the stored energy in the circuit. (the stored energy discharges during the OFF period and produces an IR error)

IR Free Potential Measurement Techniques in common use

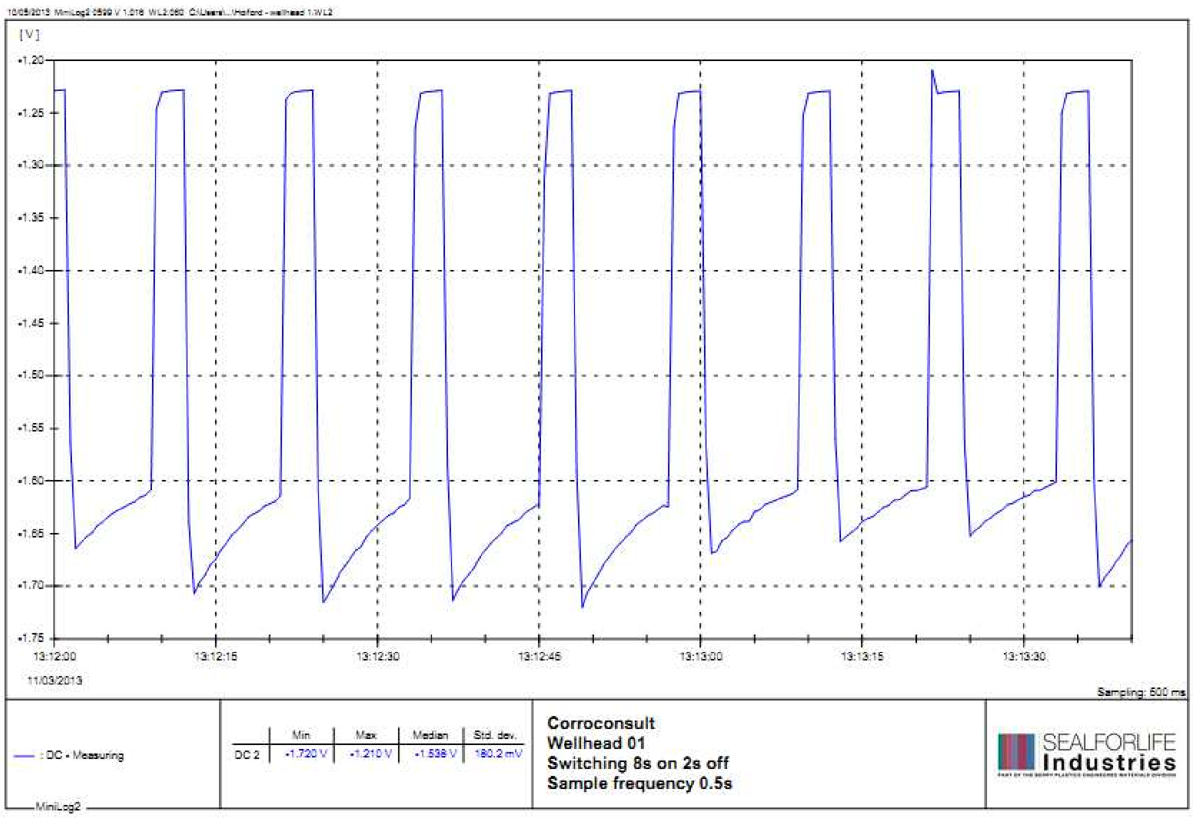
There are a number of techniques employed through the world to measure IR Free potentials. Very few of them are really accurate and are often undertaken by unqualified personnel.

1. Switch off the cathodic protection current source and measure with a DVM

This is a popular technique because it is easy to do and usually produces a potential that looks reasonable. The technician will observe several cycles and select a potential that he likes the look of. Using this method it is not usually possible to know exactly when the current source has been switched off. The operator will usually accept the most negative potential as the ON potential and the most positive potential as the OFF potential.

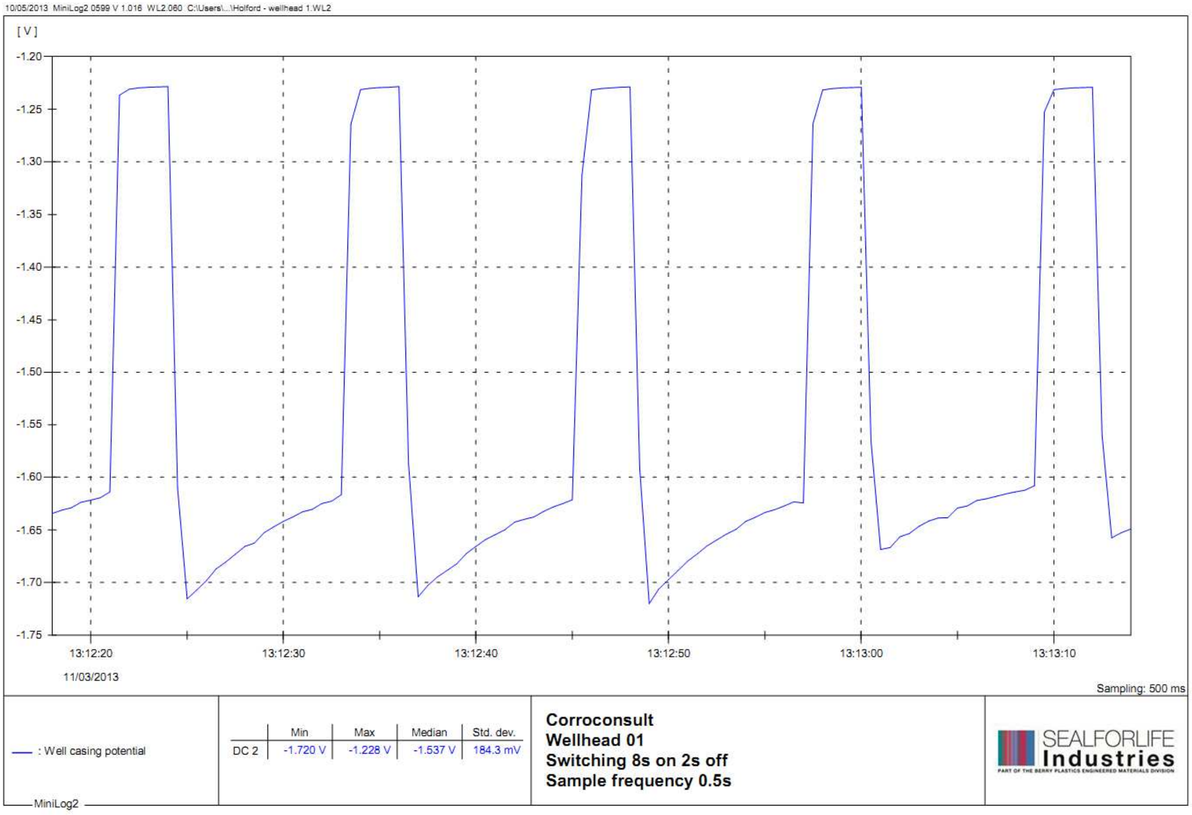
Example of ON/OFF potential measurements using a data logger

Well casing potential measurement showing the actual waveform and stored energy charge and discharge effects.



Example of ON/OFF potential measurements using a data logger

Well casing potential measurement showing just 5 cycles and stored energy charge and discharge effects.



2. Synchronously interrupt the cathodic protection current sources and measure with a DVM

As for method 1, but the current sources are synchronously interrupted. The measurement principles and uncertainties are also the same as for method 1.

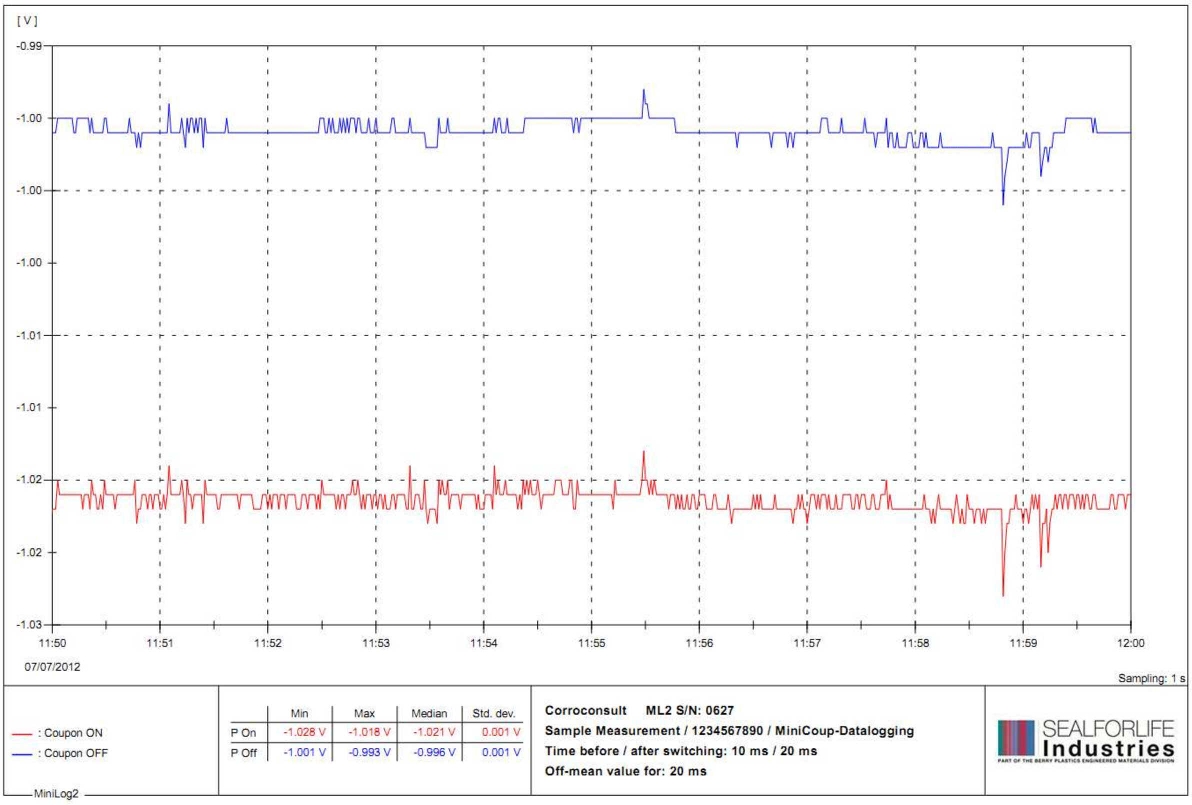
3. Synchronously interrupt the cathodic protection sources and measure with a DVM that is synchronized with the interrupters.

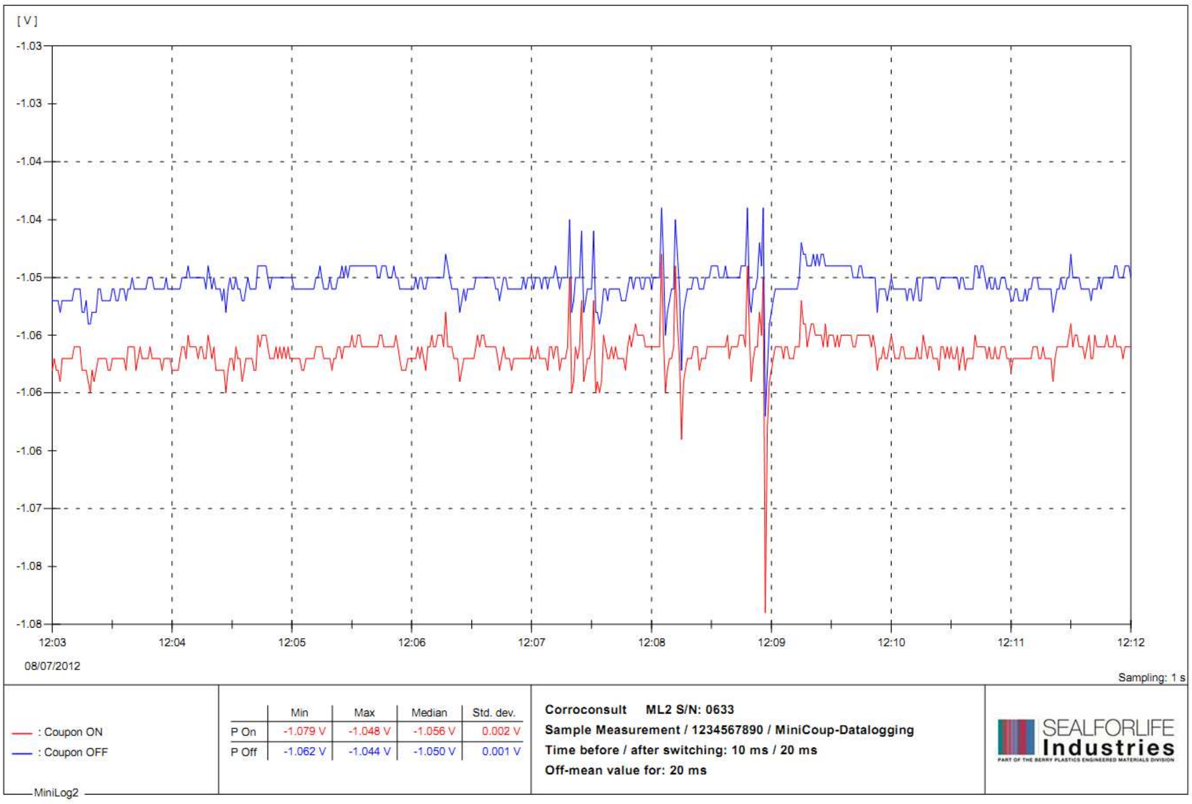
This is a great improvement on method s 1 and 2 since it allows accurate identification of the OFF period. The only IR errors that are still present are those caused by so-called relaxation or balancing currents. These currents originate from the energy that is stored in the electrical circuit. The energy is stored as a result of the circuit capacitance (symbol C) and capacitance (symbol C). The energy stored by the circuit capacitance is proportional to the square of the Voltage (symbol V) (Energy stored = 0.5 x $(CV)^2$). The energy stored by the circuit inductance (symbol L) is proportional to the square of the Current (symbol I) (Energy stored = 0.5 x $(LI)^2$. The length of time that the energy takes to discharge is a function of the circuit resistance. Since the predominant mechanism for buried pipelines is the capacitance discharge the period required for the stored energy in the capacitor to discharge is 5 times the value of capacitance multiplied by the resistance (5 x C x R). The product of C x R is known as the time constant. It is impossible to calculate for a buried pipeline but the effects can be seen clearly on a digital oscilloscope or fast reading data logger.

4. Measure a coupon potential when disconnected from the structure.

A properly selected and installed coupon will be representative of a similar sized coating defect on the structure. If the coupon is normally connected to the structure then it will experience the same corrosion, and corrosion protection, conditions as the structure. The issue of coupon potential validity is discussed elsewhere in this conference.

<u>Examples of Coupon potential measurements in stray current area</u>





5. Proprietary instruments and systems

<u>CP Analyser.</u>

The CP Analyzer is a proprietary device that uses an anode, a special electrode and a coupon in a controlled environment. The potentials within the electrode are backed-off with the internal electronics to counteract the contact potential in the electrolyte (rather like a Wheatstone bridge). The value is then processed to display an IR Free potential. The IR Free potentials calculated by this unit are reliably accurate, but the device is expensive and has not won widespread approval.

<u>Wave Form Analyzer</u>

A proprietary system that takes a structure-to-soil potential measurement when the AC from the transformer-rectifier goes through zero. Working on the assumption that if there is no AC then there is no DC and so the IR free measurement can be made. A US government team evaluated the performance of the wave form analyser and the CP Analyzer in 1994 and found that they were both acceptable methods to determine the IR Free potential. The wave form analyser has not won widespread approval.

<u>Correal</u>

The CORREAL system was developed in Belgium and utilises a specially designed probe and integral switcher. Combined with a fast sampling rate this technique enables the IR Free potential to be identified. The device is presented in more detail elsewhere in the convention.

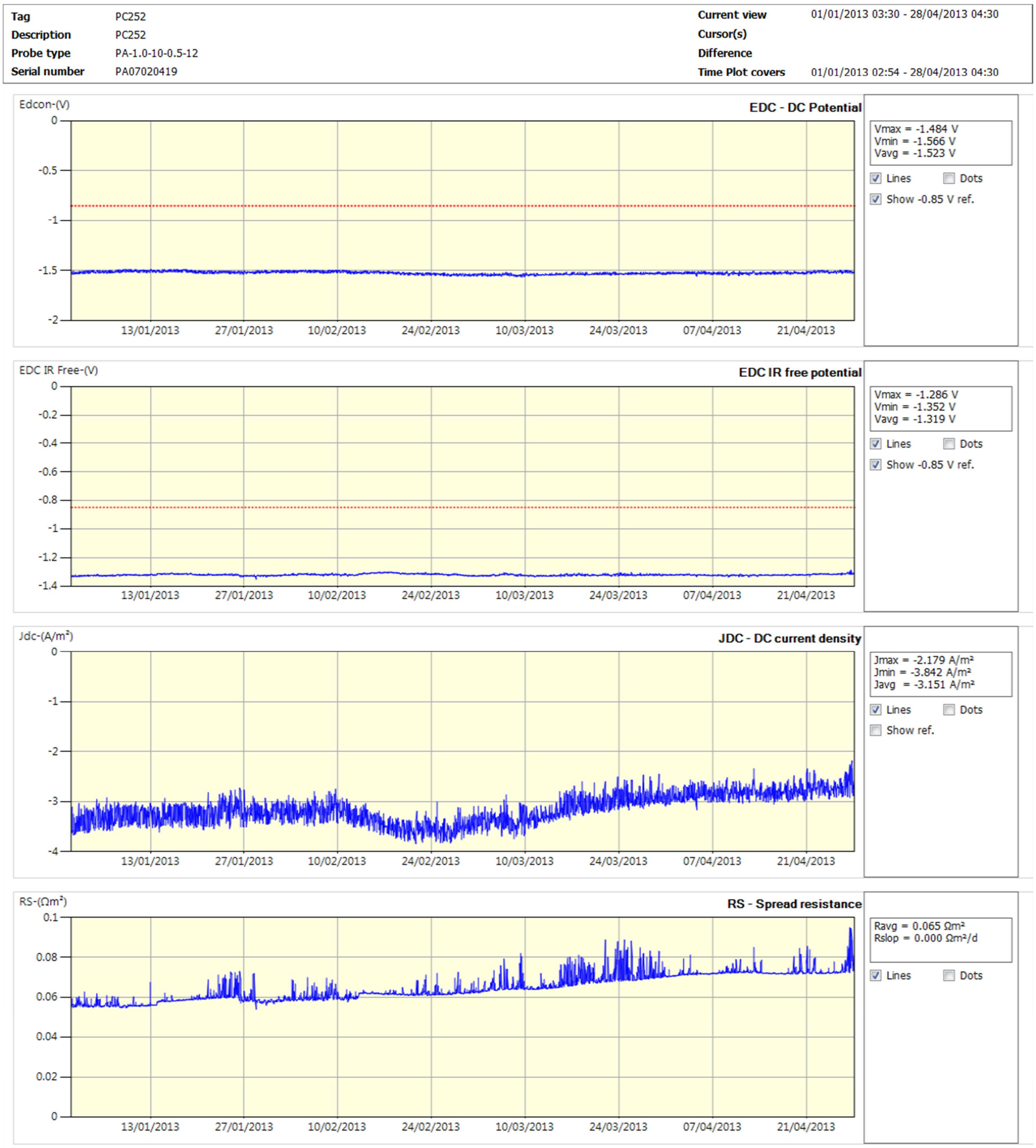
6. Measure ON potential and calculate the IR free potential.

Electrical Resistance (ER) probes are widely used to measure pipe-to-soil potentials and the spread resistance (resistance between the coupon in the probe and remote earth). On the assumption that the most significant portion of the total circuit resistance is the resistance between the probe coupon and remote earth it is possible to calculate the IR Free potential if the current flowing onto the coupon is known.

The coupon measures the current, the ON potential and the spread resistance. From this the IR Free potential is estimated.

<u>Example of ER probe located at pipeline crossing a DC traction system. Potentiostatically controlled transformer rectifier.</u>

Although not shown on the graphs the actual corrosion rate is zero.



Conclusions

IR free potentials can be measured to acceptable levels of accuracy using proprietary measuring systems, coupons and synchronised switching and measurement, and ER probes.

There will always be unskilled technicians who will measure just the most positive and most negative values. Sometimes this may be enough.

Digital oscilloscopes and rapid sampling data loggers are invaluable aids to verify the values reported by simple DVM measurements.