RENEWABLE ENERGIES

CATHODIC PROTECTION TRAINING BENCH

DL MK1

The Cathodic protection is a technique to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell. This is achieved by placing in contact with the metal to be protected another more easily corroded metal to act as the anode of the electrochemical cell. Cathodic protection systems are most commonly used to protect steel, water or fuel pipelines and storage tanks, steel pier piles, ships, offshore oil platforms and onshore oil well casings.
The theoretical study that precedes the experiments to undertake over the bench is reported into the modular manual book. In this book it is easily explained the background and moreover the target of the experiment.
The bench provides facilities to study the case of isolated systems, as well as the case of systems where different metals are coupled together. Particular attention is given to the presence or not of several kinds of insulating materials over the surfaces of the samples, in order to demonstrate the different behavior of the same material when coated or bare.
The bench provides suitable devices to highlight the concept of the free corrosion potential, measured with easy to use reference electrodes and means suitable to build with a certain accuracy the polarization curves.
Protective techniques are represented as per sacrificial anodes systems of several type of metals as per impressed current Cathodic Protection systems with the possibility to see which is the explanation of the use of constant voltage, constant current and constant potential feeders.
The bench is provided with measuring facilities characterized by suitable sensitivity and accuracy, in order to introduce which must be the basis of the laboratory tests to be executed, to recognize which is the correct way in order to determine the behavior of a metal in contact with the electrolyte in different conditions of temperature (thermostatic bath) and in high oxygen concentration (air insufflations pump).
A suitable multi-channel interface can connect the bench to a PC in order to record the experiment results and give the trace for further studies.

LIST OF THE EXPERIMENTS

The following list reports the proposed experiments and it corresponds to the manual structure. The manual is a document addressed to the teacher in order to prepare the lesson and reports the bibliography and links for further investigations on the matter.

1) The use of the voltmeter

The most important instrument in the field of the Cathodic Protection is the Voltmeter; typically, the digital type is the most common. Because of the great impedance, it allows the measurement of voltages (the potentials) due to sources with very high internal impedance. The measurements follow the introduction to the electrical measurements and to the introduction to the Ohm's law that regulates the passage of the current into the first as well as into the second species conductors (metals and electrolytes).

2) The measurement of the difference of potential of a sample into an electrolyte

This experiment introduces to the subject of the Cathodic Protection. The target of the discipline is to modify the potential (versus the reference cell) of the structure to protect by slowing the natural tendency of the metal to pass in solution. This experiment emphasizes the electrochemical approach to the corrosion phenomena.

3) The reference cell

This experiment puts in relation the practical use of the three types of reference cells most common in the discipline that are the Cu/ $CuSO_4$ reference cell, the Ag/AgCl reference cell and the Zinc reference cell.

4) The Daniel Cell

In the Daniel cell, copper and zinc electrodes are immersed in a solution of copper (II) sulphate and zinc sulphate respectively. At the anode, zinc is oxidized per the following half reaction: Zn(s) Zn^{2+}(aq) + 2e-

At the cathode, copper is reduced per the following reaction: Cu^{2+}(aq) + 2e-   Cu(s)

In the Daniel cell which, due to its simplicity, is often used for demonstrations, electrons that are "pulled" from the zinc travel through the wire, providing an electrical current that illuminates the bulb. In such a cell, the sulphate ions play an important role. Having a negative charge, these anions build up around the anode to maintain a neutral charge.

Conversely, at the cathode the copper (II) cations accumulate to maintain this neutral charge. These two processes cause copper solid to accumulate at the cathode and the zinc electrode to "dissolve" into the solution.

5) The first and second species conductors

By using a simple circuit it is possible show the equivalence between the electrolytes and the common conductors as far the passage of the electrical current concerns.

6) Introduction to the Cathodic Protection Criteria

By using the electrolytic cell of the bench it is possible reproduce the application of the NACE criteria that confirm the status of Cathodic Protection of a structure.

7) Introduction to the sacrificial anodes in Zn, Mg, and Al

By using the electrolytic cell of the bench it is possible reproduce the application of the sacrificial anode to a steel structure and see in the same time the comparison in between two specimen, one in Cathodic Protection regimen, the other in free corrosion regimen.

8) Introduction to the Cathodic Protection Impressed Current System

By using the electrolytic cell of the bench it is possible reproduce the application of the impressed current to a steel structure and see at the same time the comparison between two specimens, one in Cathodic Protection regimen, obtained by means of sacrificial anodes, the other driven with the impressed current system.

9) The consumable impressed current anode (Fe)

By using the electrolytic cell of the bench it is possible to reproduce the application of the impressed current to a steel structure and see in time the effect of the consumption of the anode due to its passage in solution.

10) The inert impressed anode (Ti-Pt and MMO)

Not all the anodic materials pass in solution, two examples can be seen by using the Titanium Platinized anode and the Metal Oxide covered Titanium anode.

11) Resistance concept, circuit for the first and second species conductors

By using the electrolytic cell of the bench it is possible to produce the passage of current into the bath and in this way to demonstrate the validity of the Ohm's Law in the field of Cathodic Protection.

Ohm's law applies to electrical circuits; it states that the current through a conductor between two points is directly proportional to the potential difference (i.e. voltage drop or voltage across the two points) and inversely proportional to the resistance between them.

The mathematical equation that describes this relationship is: $I = V/R$

Where I is the current in amperes, V is the potential difference in volts and R is a circuit parameter called the resistance (measured in ohms, also equivalent to volts per ampere). The potential difference is also known as the voltage drop, and it is sometimes denoted by U, E or emf (electromotive force) instead of V.

12) Introduction to the specific resistance concept over three different first species conductors (Fe; Cu; Fe-Ni)

To drive the student to the concept of resistivity, an experiment can be executed by using three geometrically identical samples of different material in order to identify the concept of specific resistance that "in fieri" is the resistivity or as inverse the conductivity concept.

13) Introduction to the concept of interference due to the presence of external electric fields on buried or submerged structures (Stray Currents)

The experiment reproduces the effect of an external electric field on a submerged structure with the result of the formation of separated anodic and cathodic areas on the surface of the sample. It is the introduction to the concept of interference due to the presence of an external and interfering electric field on buried or submerged structures (Stray Currents).

14) Air presence influence on resistivity (insufflate air effect)

This experiment explains and demonstrates the change of the resistivity with the increase of the presence of air dissolved into the electrolyte.

15) Current density introduction and Tafel Curves construction

The concept of current density is, like the difference of potential, the main concept in the Cathodic Protection discipline and this experiment allows understanding that with this concept it is possible to predict the amount of current needed to obtain the Cathodic Protection regimen over a known surface structure immersed in the electrolyte.

By using the provided multi channel interface it is possible to record the change of the current values in the time, then build the polarization curves in a plot.

16) Temperature effect over the Current density (thermostatic cell)

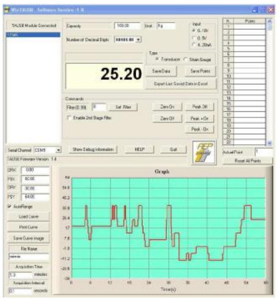
This experiment explains and demonstrates the change of current density as a function of the temperature and introduces the concept of chemical activity.

17) Air presence influence over the Current density (insufflate air effect)

This experiment explains and demonstrates the change of current density as a function of the increasing of dissolved oxygen.

18) Coating and Current density

The use of coated samples allows demonstrating the effect of the coatings over the submerged or buried structures and gives the magnitude of the effect explaining that the synergy between the Cathodic Protection and the Coating of the surfaces to be protected reduces the current density with all the relevant advantages.



LIST OF MATERIALS

- Bench with wheels with electrical console to connect to the mains Vac supply and lockable shelves to contain the hereinafter listed material. Provided with waterproof top surface.
- 3 sets of safety glasses and glows.
- Digital voltmeter.
- PC interface for the measurement and record of 5 different channels.
- Digital voltmeter on console.
- 2 digital ammeters on console.
- 2 Cu/CuSO4 reference cells.
- 2 Ag/AgCl reference cells.
- 2 Zn reference cells.
- 10 copper electrodes, 30 x 140 mm., thickness 2 mm.
- 10 carbon steel electrodes (bare).
- 4 transparent basins to build the electrolytic test bath.
- Simple circuit with sliding resistor and lamp provided with buklets for the insertion into the electrical circuit of the electrolytic cell.
- 20 Zinc electrodes 8 mm., length 140 mm.
- 20 Magnesium electrodes 25 mm., length 140 mm,
- 20 Aluminum electrodes 25 mm, length 140 mm,
- 4 DC feeders (each provided with constant voltage, constant current, constant potential facilities). The relevant instruments are on the front console of the bench.
- 4 Ti-Pt anodes (net anode 50mm x 140mm)
- 4 MMO tubular anodes (25.4 x 140 mm)
- Cu bar 1mm., length 1 m.
- Fe bar 1mm., length 1 m.
- Fe-Ni bar 1mm., length 1 m.
- Resistivity fluid cell.
- Waterproof resistor with thermostatic device.
- Air pump with relevant sprayer.
- 10 carbon steel electrodes (completely coated with epoxy compound)
- 10 carbon steel electrodes (partially coated with epoxy compound)
- 10 various reagents in plastic cans (0,25 kg/each) with technical sheet as per the requirement of CE.
- Set of spare fuses.
- Set of ancillaries and connecting leads (20 pieces).
- 2 paper copies and 1 CD of the manual book for training of the teacher in order to undertake the experiments.