PRACTICAL WORKBOOK

MY-413 Corrosion Engineering

Name__________________________

Roll No________________________

Batch__________________________

Year___________________________

Department_____________________

Department of Metallurgy Engineering
NED University of Engineering and Technology
Karachi-75270, Pakistan

Practical Workbook

MY- 413 Corrosion Engineering

PREPARED BY
Dr. Muhammad Ali Siddiqui (Asst: Professor, MYD)

This is to certify that this practical book contains _____________ pages.

Approved by:

Dr. Ali Dad Chandio
Chairman

Department of Metallurgy Engineering
NED University of Engineering and Technology
Karachi-75270, Pakistan

<u>CERTIFICATE</u>

It is certified that Mr. / Ms. ____student of class ______Batch______, bearing Roll No. MY ______ has completed his / her coursework in **<u>CORROSION ENGINEERING (MY-413)</u> as** prescribed and approved by the Board of Review of the Metallurgical Engineering Department.

His/her performance is reflected by the performance rubrics of his/her practical workbook. The student's overall performance will address the assigned learning attribute.

____

Course Teacher

TABLE OF CONTENTS

MY-413: CORROSION ENGINEERING

Experiment No. 1

Aim of the Experiment
To study the safety precautions

Materials /Apparatus
A wide variety of equipment is being used in MDL. Most of the equipment is delicate, sensitive and expensive. Before you use any equipment you must learn about its operation and its safety implications. Misuse of equipment can lead to injury delay in project work and substantial cost in repair bill.

Gases
A variety of compressed gases are used, some of which may be toxic, corrosive, flammable, or explosive. These hazards have been minimized by the use of proper equipment, proper confinement, ventilation, safety valves, etc., and by procedural controls. You must learn about the safe handling of gases before embarking on their use. An accident with any of these could be catastrophic.

Chemicals
Acids, bases, etching solutions and solvents are commonly used in materials chemistry and device fabrication. These are "hands on" hazards which are hard to control by engineering controls only. These chemicals can cause severe burns, tissue damage, organ damage, asphyxiation, and genetic damage if used improperly. You must take chemical safety instructions before using any chemical.

General Safety Awareness

- Familiarize yourself with all aspects of safety before using any equipment.
- Be alert to unsafe conditions of the equipment, procedures and actions, and call attention to them so that corrections can be made as soon as possible.
- Label all storage areas, appropriately, and keep all chemicals in properly labeled containers.
- Date all chemical bottles when received and when opened.
- Note expiry dates on chemicals.
- Note storage conditions and adhere to them.
- Familiarize yourself with the appropriate protective measures.

Safety precautions for Gamrey – Potentiostate
Gamrey is highly delicate machine equipped with glass cell, it works on three anode system and electrochemical reactions are involved ,during its operation following precautions must be taken,

- Do not touch the working table during the running of any operation.
- Must check the clips and placed to right sensor& provide moderate temperature.

Questions

Q1. What are personal safety precautions?

Q2. Why it is necessary to take measure precarious during working on Potentiostate?

Q 3. What could happen if we will use hot nitric acid?

Experiment No. 2

Aim of the Experiment

To **practice** Gamry Echem Analyst Software and determine the corrosion rate of steel in tap water by linear polarization resistance (LPR) Method.

Theory

Linear Polarization Resistance monitoring is an effective and a quick, nondestructive testing technique and electrochemical method of measuring corrosion rate. Monitoring the relationship between electrochemical potential and current generated between electrically charged electrodes in a process stream allows the calculation of the corrosion rate. LPR is most effective in aqueous solutions, and has proven to be a rapid response technique. This measurement of the actual corrosion rate allows almost instant feedback to operators. LPR monitoring has seen wide industry use for nearly 50 years.

Electrical conductivity (the reciprocal of resistance) of a fluid can be related to its corrosiveness. A two or three electrode probe is inserted into the process system, with the electrodes being electrically isolated from each other and the process line. A small potential in the range of 20mV (which does not affect the natural corrosion process), is applied between the elements and the resulting current is measured. The polarization resistance is the ratio of the applied potential and the resulting current level. The measured resistance is inversely related to the corrosion rate.

The electrical resistance of any conductor is given by:

$$\mathbf{V = I\,R}$$

Where **R** = Effective instantaneous resistance

V = Applied voltage

I = Instantaneous current between electrodes

If the electrodes are corroding at a high rate with the metal ions passing easily into solution, a small potential applied between the electrodes will produce a high current, and therefore a low polarization resistance. This corresponds to a high corrosion rate.

Electrode and Cell Setup

Polarization resistance is most commonly run in 3 electrode mode. In this configuration there is a working electrode (your material sample), CE (graphite and platinum are commonly utilized), and an independent reference electrode--Saturated Calomel Electrodes (SCE) and Silver/Silver Chloride (Ag/AgCl) are most common.

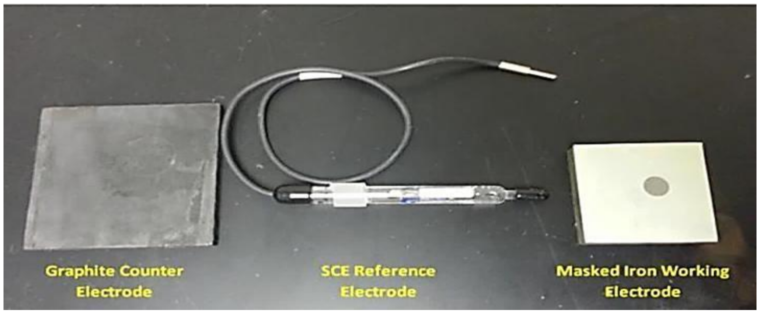

Figure 1: Materials used for a 3 electrode LPR experiment. The iron sample has been masked to reduce surface area. Masking is an optional step

LPR probes and instruments interact with the electrochemical corrosion mechanism in order to determine the rate at which metal ions are passing into solution (corroding). If it were possible to directly measure the corrosion current density, I_{corr}, passing between the anodic and cathodic areas it would be possible, by knowing the corrosion anodic reaction.

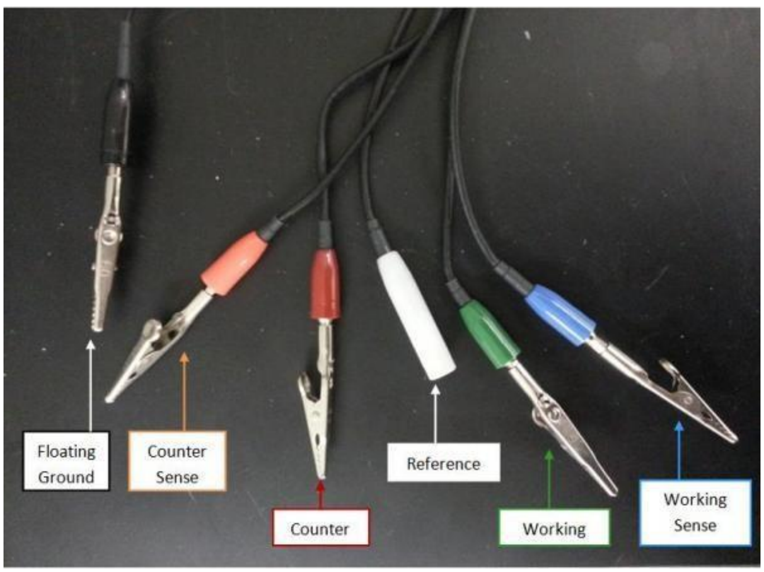

Figure 2: For LPR experiments the Counter, Reference, Working, and Working Sense leads will always be used

Experimental procedure

1. First prepare the sample take steel bar and cut the square piece of 10 cm x10 cm , roughly grind and solder it with copper wire and mounted it . After that do complete grinding and polishing of mounted sample**.**
2. Clean the corrosion cell and assemble it. Fix the mounted sample as working electrode, reference electrode and counter electrode at their specified holes on lid of Cell.
3. Now connect orange banana clip to Red clip then connect to counter electrode, white to reference electrode, connect blue alligator clip to green clip then connect it working electrode and ground the black clip.

Analysis of LPR data via Echem Gamry Analyst

Result

Experimental	**values**
Initial E	
Final E	
Scan Rate	
Sample area	
Equivalent weight of sample	
Density of sample	

Corrosion rate of sample

Questions

Q1. What are key advantages of LPR?

Q2. What is conventional method to determine corrosion rate?

Q3. What other testing we can do using potentiostate?

Q 4. What is purpose of using counter electrode?

Q5. What is effect of temperature on corrosion rate?

NED University of Engineering & Technology
Department of Metallurgical Engineering

Course Code and Title: MY-413 Corrosion Engineering

Laboratory Session No. ___________________________ Date: ______________________

Rubric for Assessment of Electrochemical Testing Software						
S.NO.	**Criterion**	**Extent of Achievement**				
		Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
1	**Technical Skills:** Identification and correct use of Gamry Echem Analyst /Zsimp win software menus	Cannot identify the software icon from desktop	Identify but rarely uses software menus	Occasionally use software menus correctly.	Often uses software menus correctly.	Uses software menus correctly and effectively.
2	**Response:** Skills to use analysis tab of LPR/ PD/EIS etc	Not able to use any analysis commands.	Uses analysis commands from software help option	Partially uses analysis commands with help	Fairly uses all analysis commands without help.	Exhibits full use of all analysis commands.
3	**Observation's:** Correct identification of observed result of software menus for LPR/ PD/EIS etc.	Not able to identify the results	N.A	N.A	Moderately able to identify the results	Skillfully identified
4	**Use:** Use of Observed values to re-verify the corrosion values via mathematical formula given in standard	Do not remember the formulas	Partially remember the formulas	Partially remember the formulas and understand the meaning of result to draw conclusion	Moderately remember the formulas and understand the meaning of result to draw conclusion	Skillfully verified & understand the meaning of results to draw conclusion

Weighed CLO	
Remarks	
Instructor's Signature with Date:	

Experiment No. 3

Aim of the Experiment

To **practice** Gamry Echem Analyst Software, analyze and present the Potentiodynamic polarization plot (PD) (ASTM G-03 and G102).

Theory

Potentiodynamic polarization measurement (PDP) belongs to one of the most commonly used DC electrochemical method in corrosion measurements. In the PDPs, the potential in a wide range is applied on the test electrode (depends upon the alloys pourbaix or E-pH diagram), due to which on the metal surface dominantly oxidation or reduction reaction happens (depending on the direction of polarization) and as a result of that, an adequate current is generated. The presentation of the potential in the function of current density (I) (or log I) for each measured point results in obtaining the polarization curve. The polarization curve can be used to determine the corrosion potential and the corrosion rate of the metal in the given condition (Tafel slope).

Electrode and Cell Setup

In this configuration there is a working electrode WE (study material sample), CE (graphite or platinum are commonly utilized), and an independent reference electrode--Saturated Calomel Electrodes (SCE) or Silver/Silver Chloride (Ag/AgCl) are most common. (Setup is showing in Figure-1)

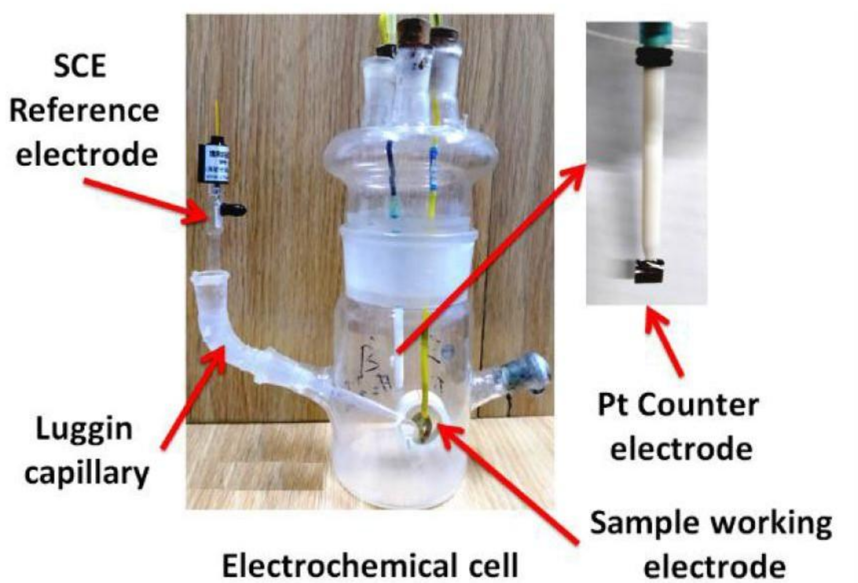

Figure 1: Electrochemical flask showing 3 electrode setup.

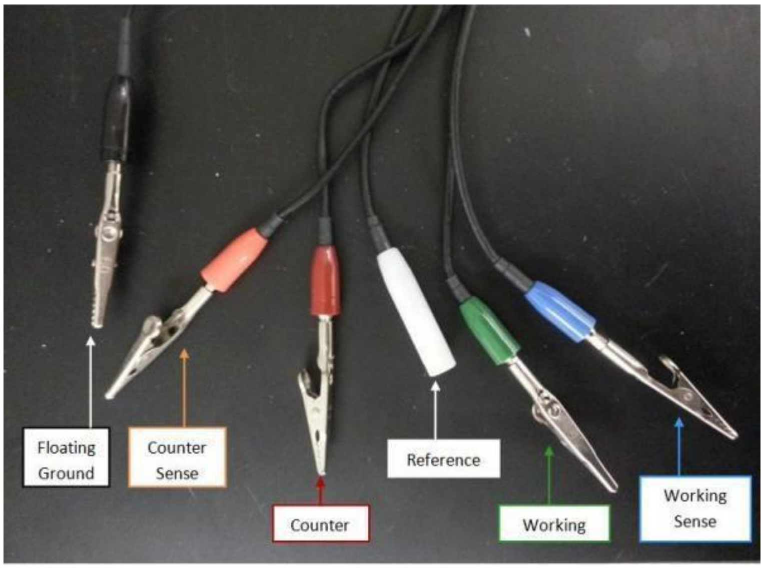

Figure 2: Electrochemical workstation (Gamry) experiments the counter, reference, working, and working sense leads will always be used

Experiment
Performing experiments (Via Gamry Framework) (write in your own words)

Analysis of PDMs data via Echem Gamry Analyst (write in your own words)

Result

Experimental data	Values (Steel)	Sample 2 (Ti-Cu alloy)
Initial E (V) vs Eoc		
Final E (V) vs Eoc		
Scan Rate (mV/s)		
Sample area (cm^2)		
Equivalent weight of sample		
Density of sample		

Analysis Results	values	Sample 2 (Ti-xCu alloy)
Beta A		
Beta C		
Icorr		
Ecorr		
Corrosion rate		
Passive current density (ip)	Not observed	
Pitting Potential (Ep)	Not Observed	

NED University of Engineering & Technology
Department of Metallurgical Engineering

Course Code and Title: MY-413 Corrosion Engineering

Laboratory Session No. ___________________________ Date: ______________________

Rubric for Assessment of Electrochemical Testing Software						
S.NO.	**Criterion**	**Extent of Achievement**				
		Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
1	**Technical Skills:** Identification and correct use of Gamry Echem Analyst /Zsimp win software menus	Cannot identify the software icon from desktop	Identify but rarely uses software menus	Occasionally use software menus correctly.	Often uses software menus correctly.	Uses software menus correctly and effectively.
2	**Response:** Skills to use analysis tab of LPR/ PD/EIS etc	Not able to use any analysis commands.	Uses analysis commands from software help option	Partially uses analysis commands with help	Fairly uses all analysis commands without help.	Exhibits full use of all analysis commands.
3	**Observation's:** Correct identification of observed result of software menus for LPR/ PD/EIS etc.	Not able to identify the results	N.A	N.A	Moderately able to identify the results	Skillfully identified
4	**Use:** Use of Observed values to re-verify the corrosion values via mathematical formula given in standard	Do not remember the formulas	Partially remember the formulas	Partially remember the formulas and understand the meaning of result to draw conclusion	Moderately remember the formulas and understand the meaning of result to draw conclusion	Skillfully verified & understand the meaning of results to draw conclusion

Weighed CLO	
Remarks	
Instructor's Signature with Date:	

Experiment No. 4

Aim of the Experiment

To **operate** microscope for the analysis of pitting structure of steel.

Theory

Pitting is a form of localized corrosion of a metal surface where small areas corrode preferentially leading to the formation of cavities or pits, and the bulk of the surface remains unattacked. Metals which form passive films, such as aluminum and steels, are more susceptible to this form of corrosion.

It is the most insidious form of corrosion. It causes failure by penetration with only a small percent weight-loss of the entire structure. It is a major type of failure in chemical processing industry. The destructive nature of pitting is illustrated by the fact that usually the entire system must be replaced.

Generally, the most conducive environment for pitting is the marine environment or high acidic environment. Ions, such as Cl^-, Br^- and I^-, in appreciable concentrations tend to cause pitting of steel. Thiosulfate ions also induce pitting of steels.

Basically three processes are involved:

(A) Pitting Initiation

(B) Pitting Propagation

(C) Pitting Termination.

Procedure

1. Take a steel sample (clean sample) and observe its surface under stereomicroscope as well as optical microscope after grinding and polishing of sample.
2. Place the polished steel sample in the acid or ferric chloride solution for certain period of time in order to form pits on the surface.
3. Take a pitted steel sample and observe the surface under optical microscope and measure the pitting length.
4. Take stereograph of both sample and compare the surface of both samples.

Result

Observe the micrographs and compare both micrographs (paste the micrographs).

Questions

Q1. What is mechanism of pitting corrosion?

Q2. How pit length is calculated?

Q3. Explain the surface appearance of pitting micro-structure?

F/OBEM 01/05/00

NED University of Engineering & Technology
Department of ____________________Engineering
Course Code and Title: ____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
EquipmentIdentification Sensory skill to ***identify*** equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as itscomponents.
Equipment Use Sensory skills to ***demonstrate*** the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demon strates the use of equipment.	Fully demonstrates the use of equipment.
Procedural Skills ***Displays*** skills to act upon sequence of steps in lab work.	Not able to either learn or perform lab work procedure.	Able to slightly understand lab work procedure and perform lab work.	Able to somewhat understand lab work procedure and perform lab work.	Able to moderately understand lab work procedure and perform lab work.	Able to fully understand lab work procedure and perform lab work.
Response Ability to ***imitate*** the lab work on his/her own.	Not able to imitate the lab work.	Able to slightly imitate the lab work.	Able to somewhat imitate the lab work.	Able to moderately imitate the lab work.	Able to fully imitate the lab work.
Observation's Use***Displays*** skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
Safety Adherence Adherence to ***safety*** procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
Equipment Handling***Equipment care*** during the use.	Doesn't handle equipment with required care.	Rarely handles equipment with required care.	Occasionally handles equipment with required care.	Often handles equipment with required care.	Handles equipment with required care.
Group Work ***Contributes*** in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. ______________ Date: ________________________

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

Experiment No. 5

Aim of the Experiment
To electroplate the steel by copper/Brass/Cast Iron electroplating.

Theory
Electroplating is the application of a metal coating to a metallic or other conducting surface by an electrochemical processElectrodeposition is a well-established process for applying metallic coatings to improve surface properties of materials used in engineering practice

Basic principles
Electrodeposition or electroplating involves making the component to be coated the negative electrode or cathode in a cell containing a liquid or electrolyte which must allow the passage of electric current.
This electrolyte is usually a solution in water of a salt of the metal to be deposited, and is maintained at a controlled temperature which can be up to about 60 "C. The electrical circuit is completed by a positive electrode or anode which is generally made out of the metal to be deposited and is located a short distance away from the cathode. Under the action of a direct current applied at a low voltage, positively charged metal ions in the electrolyte move towards the cathode, where they undergo conversion to metal atoms and deposit on the cathode, i.e. the component surface.

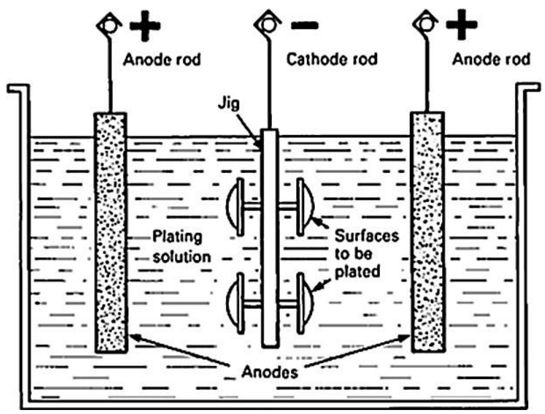

Figure 1: Electrochemical Cell for electroplating

Types of electrodeposition
- Vat Plating
- Selective Plating

Experiment

Typical steps in the electroplating of metals

- Clean the sample in rotary tumbler the clean the sample with organic solvent or aqueous alkaline; to remove dirt or grease.
- Is the surface is covered by oxides as a result of corrosion, clean with acid.
- Rinse with water to neutralize the surface.
- Electroplate metals under controlled condition.
- Rinse with water and dry.
- Pour copper sulphate solution in beaker and attach the sample with wire then clip the sample to negative port of DC power supply.
- Clean the copper anode plate and grind it attach it with positive port of DC power supply.
- Additional step: heat treatment in air or vacuum environment.

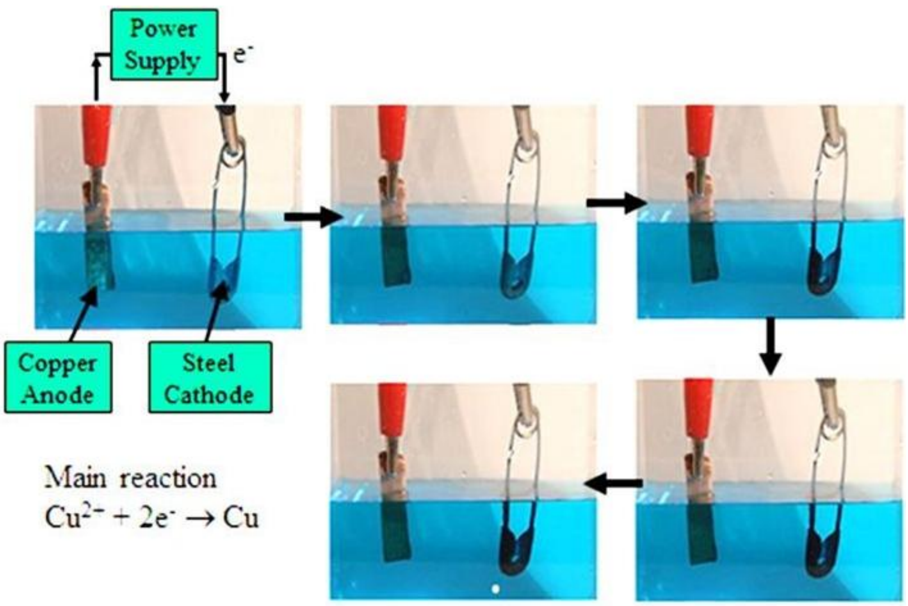

Figure 2: Copper electroplating of Safety Pin

Questions

Q1. What is electroforming?

Q 2. What is brush plating and its application?

Q3. What are advantages of electroplating?

Q4. Name the other methods for plating?

Q5. Can we use this experiment for copper nano powder production?

Experiment No. 6

Aim of the Experiment
To demonstrate the basic principle of cathodic protection

Theory
Metallic structures in contact with water, soil, concrete, and moist air are subject to corrosion. Cathodic protection (CP) is one of the few methods that successfully mitigate corrosion. It can be applied in any situation where the environment surrounding the metal acts as a conductor for electric current. It has been successfully applied to offshore structures, ships, boats, propellers, moorings, pipelines, storage tanks, piers, jetties, bridges, aquaria, instrumentation etc.
Cathodic protection can, in principle, be applied to any metallic structure in contact with a bulk electrolyte. In practice its main use is to protect steel structures buried in soil or immersed in water. It cannot be used to prevent atmospheric corrosion. Structures commonly protected are the exterior surfaces of pipelines, ships' hulls, jetties, foundation piling, steel sheet-piling, and offshore platforms.
Cathodic protection is also used on the interior surfaces of water-storage tanks and water-circulating systems. However, since an external anode will seldom spread the protection for a distance of more than two or three pipe-diameters, the method is not suitable for the protection of small-bore pipework.
Cathodic protection has also been applied to steel embedded in concrete, to copper-based alloys in water systems, and, exceptionally, to lead-sheathed cables and to aluminum alloys, where cathodic potentials have to be very carefully controlled.

Methods of applying cathodic protection
Cathodic protection may be achieved in either of two ways. By the use of an impressedCurrent from an electrical source, or by the use of sacrificial anodes (galvanic action).

Sacrifical anode system
Sacrificial or galvanic anodes rely on the galvanic corrosion of a more reactive metal to produce current, e.g. Aluminum anodes, Zinc anodes, or Magnesium anodes.
Sacrificial anodes are most commonly used to protect metallic structures in electrolytes because of their simplicity of installation and maintenance free operation. Of the alloys available for sacrificial anodes, alloys of aluminum have proven to be the most economical in seawater or very low resistivity muds.
Knowing the total submerged and buried steel areas, the water resistivity and the required system life, a Corrosion Engineer can determine precisely what energy will be required to protect a structure and can design a galvanic system to suit the environmental requirements.

Anode selection

Anodes, for both impressed current and sacrificial anodes, are selected according to their size and chemical composition. Table is given for properties of anodes.

Property	Anode Material Type				
	Magnesium	Zinc	Galvalum 1	Galvalum II	Galvalum III
Density, kg/m^3	1940	7130	2700	2700	2700
Electrochem Equiv, g/coulomb	0.126E-3	0.339E-3	0.093E-3	0.093E-3	0.093E-3
Theoretical Ah/Kg	2,205	819	2,987	2,987	2,987
Current Efficiency %	0.55	0.95	0.95	0.57	0.85
Actual Ah/Kg	1,212	780	2,830	1,698	2,535
Actual Kg / Amp / Year	7.95	11.25	3.10	5.16	3.46
Potential V, ref. Ag/AgCl	-1.75	-1.05	-1.05	-1.04	-1.10

Experimental procedure

Prepare a glass container; fill it with distilled water and HCL or simple tap water.

Then place a sample (mild steel plate grinded) in bath, and clip it with negative terminal of DC power supply.

Then place anode (Mg or zinc) in bath and clip with positive terminal of DC power supply, set the voltage about -1.76 volts. Then note down the current output using ammeter after 2 hours.

Questions

Q1. What are advantages of using zinc over magnesium?

Q2. Calculate the size of zinc anode required for small steel tank?

Q3. Why anode efficacy is essential to analyse before placing it in application?

Experiment No. 7

Aim of the Experiment

To **practice** ZSim Software and present the Electrochemical Impedance Spectroscopy (EIS) (ASTM G-03 and G102).

Theory

The term Impedance refers to the frequency dependant resistance to current flow of a circuit element (resistor, capacitor, inductor, etc. Impedance assumes as AC current of a specific frequency in Hertz (cycles).

Impedance : $Z\omega = E\omega/I\omega$, where $E\omega$ = Frequency dependant potential and $I\omega$= Frequency dependant current. Electrochemical impedance spectroscopy is used to study the corrosion systems for measuring corrosion rates. Three graphical formats in common use for reporting electrochemical impedance data are the Nyquist, Bode (Phase and Angle), and Admittance formats. These formats are discussed for a simple electrode system modelled by an electrical equivalent circuit (EEC) as shown in Fig. A. This simple model is used to describe different corrosion characteristic which includes double layer capacitance (Cdl) or Q, Constant Phase Element(CEP), charge transfer resistance *Rt* or polarization resistance *Rp,* which is proportional to the corrosion rate (CR) at the monitored interface and the solution resistance (Ru). As the corrosion system becomes complex, these EEC also become complex. The necessary calculation formulas are presented in ASTM G- 102. EIS may be able to distinguish between two or more electrochemical reaction taking place.

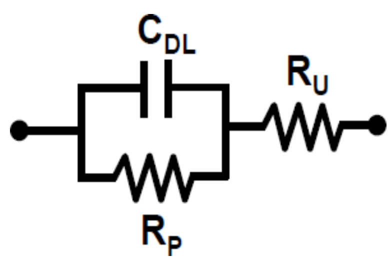

Figure1 : Equivalent Electrical Circuit Model for a Simple Corroding Electrode

Procedure (Write in your own words)

Result

1. Paste the screen Shot of ZSim software, showing Nyquist, Bode (Magnitude and Phase Plot).

2. Draw Two electrical Equivalent circuits (EECs) used in analyzing the data.

3. Analysis Result

Parameters	Circuit 1		Circuit 2	
R_s, (**Ω cm²**)				
R_{hl}, hydroxide layer (**Ω cm²**)				
R_{bl}, barrier layer (**MΩ cm²**)				
Z_{CPE} (hl), hydroxide layer (**μF cm⁻²**)				
Z_{CPE} (bl), barrier layer (**μF cm⁻²**)				
n_1, hydroxide layer				
n_2, barrier layer				
Chi- squared, χ^2				
Corrosion current density (I corr)				
Corrosion Rate (CR in mpy)				

4. Calculation of Corrosion current density (I_{corr}) and Corrosion Rate (CR in MPY)

Experiment No. 8

Aim of the Experiment
To analyze surface performance of coated surface by salt spray testing.

Materials /Apparatus
The apparatus required for salt spray (Fog) exposure consist of a chamber, a salt solution reservoir, a supply of compressed air, one or more atomizing nozzles, specimen supports, provision for heating the chamber and necessary means of control.

Salt Spray Testing (ASTM B117)
Salt spray testing is a widely recognized method for evaluating the corrosion resistance of metallic materials and coatings in accelerated conditions. This overview explores the principles, procedures, standards, and applications of salt spray testing according to ASTM B117.

Reference documents (ASTM**)**
B368, D1654, D1193, D3359, D609, G31, G85, E691, E70, ISO 9227.

Importance of Corrosion Testing

- Material Reliability: Corrosion can weaken structural integrity, leading to equipment failure, safety hazards, and financial losses.
- Quality Assurance: Testing ensures that materials and coatings meet performance standards and regulatory requirements.
- Lifecycle Cost Reduction: Early detection of corrosion susceptibility helps in designing preventive measures and selecting suitable materials, thus reducing maintenance costs.

Methods of Corrosion Testing
Salt Spray Testing (ASTM B117): Exposes samples to a salt fog to simulate accelerated corrosion in a controlled environment.

Test Setup and Equipment

- Salt Spray Chamber: Salt spray chamber, which generates a controlled salt fog environment.
- Test Conditions: Parameters for setting up the salt spray testing machine, such as temperature, humidity, solution concentration, and exposure durations
- Preparation of Samples: Preparing samples before testing, including surface preparation and masking.
- Solution Preparation: Preparing the salt solution (e.g., sodium chloride) to the specified concentration and pH level as per ASTM B117 requirements.
- Temperature and Humidity Control: Parameters for maintaining stable test conditions, typically 35°C temperature and 95% relative humidity within the chamber.
- Monitoring and Maintenance: Monitoring the test conditions and maintaining the machine to ensure accurate and reliable results.

Operating Procedures

- Sample preparation: Preparing test specimens, including cleaning, surface preparation, and application of coatings if applicable.
- To perform the test: The specimen is place inside the chamber.
- The temperature: inside the chamber is maintained at 35ºC.
- The salt fog solution: Has to have a PH with a range of 6.5 to 7.2 and a sodium chloride concentration of 5% by mass.
- Non-stop operation: The machine is equipped with reservoirs, for non-stop operation.

- Specimen position: The specimen shall be supported or suspended between 150 and 300from the vertical and preferably parallel to the principal direction of fog through the chamber.
- Separate: The specimen shall not contact each other or any metallic material.
- Free settling of fog: Each specimen shall be so placed as to permit free settling of fog on all specimens.
- Salt solution: from one specimen shall not drip on any other specimen.
- Air supply: the compressed air supply to the nozzle or nozzles for atomizing the salt solution shall be free of oil and dirt and maintained between 69 and 172 KP a/m2 (10 to 25 PSI).
- Exposure Period: Duration of exposure to the salt spray, typically ranging from hours to hundreds of hours depending on the material and test objectives.
- Intermittent Spraying: Some tests may include intermittent spraying cycles to simulate realistic environmental conditions more accrue.

Conclusion

Salt spray testing according to ASTM B117 is a critical method for evaluating the corrosion resistance of materials and coatings. By adhering to standardized procedures and criteria, engineers and researchers can effectively assess and improve the durability and performance of materials in diverse industrial applications.

Questions

Q1. What is corrosion & coating?

Q2. What are chemical & physical properties of corrosion?

Q3. What are your observations about salt spray testing (SST)?

Q4. Explain procedure of salt spray machine?

Q5. What is effect of temperature on corrosion?

Q6. Where this technique is used mostly?

Q7. What type of sample is required for this test?

Experiment No. 9

Aim of the Experiment
Humidity Chamber Testing or Environmental Chamber Testing.

Materials /Apparatus
When using a humidity chamber, the requirements typically include:

1. **Temperature and Humidity Control**: Precise settings for accurate simulation.
2. **Calibration**: Regular calibration for accurate measurements.
3. **Sample Placement**: Proper arrangement to ensure even exposure.
4. **Safety Measures**: Compliance with safety protocols.
5. **Monitoring Equipment**: Devices for tracking conditions throughout the test.
6. **Documentation**: Detailed records of all parameters and results.

Humidity chamber specifications typically include:
1. **Temperature Range**: -40°C to 150°C.
2. **Humidity Range**: 10% to 98% relative humidity.
3. **Control Accuracy**: ±0.1°C for temperature, ±1% RH for humidity.
4. **Uniformity**: Consistent conditions throughout the chamber.
5. **Size/Capacity**: Varies from small benchtop units to large walk-in chambers.
6. **Monitoring System**: Digital interface for parameter control and data logging.
7. **Safety Features**: Over-temperature protection and humidity alarms.

Reference documents
International standards for humidity testing include guidelines from organizations like ASTM and ISO. Some commonly referenced standards are:

- **ASTM D2247**: Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity.
- **ISO 6270**: Paints and varnishes — Determination of resistance to humidity.

These standards provide protocols for humidity exposure, test duration, and evaluation criteria to ensure consistent and reliable results across different testing scenarios.

TEST SETUP AND EQUIPMENT
Setting up for humidity testing involves several key components and considerations:

- **Humidity Chamber**

The primary equipment used to control and maintain humidity levels during testing. Chambers vary in size, from benchtop units to large walk-in chambers, and feature precise temperature and humidity controls.

- **Sensors**

Instruments such as hygrometers or psychrometers to measure and monitor humidity levels inside the chamber accurately.

- **Temperature Control**

Equipment to regulate the temperature within the chamber, ensuring it remains stable throughout the test.

- **Sample Holders**

Apparatus to securely hold and position samples within the chamber to ensure consistent exposure to humidity.

- **Data Logging and Monitoring System**

Devices to record and monitor humidity, temperature, and other relevant parameters continuously during the test.

- **Calibration Equipment**

Tools to calibrate sensors and ensure accuracy in humidity and temperature measurements.

- **Safety Features**

Alarms and safety protocols to prevent overheating, excessive humidity, or other potential hazards.

Operating procedures

Operating procedures for a humidity chamber include the following steps:

1. **Preparation**
➢ Ensure the chamber is clean and free from debris.
➢ Verify that all necessary equipment and materials are ready, including samples, sensors, and calibration tools.
2. **Initial Setup**
➢ Power on the humidity chamber and allow it to stabilize.
➢ Set the desired temperature and humidity levels based on the testing requirements.
3. **Loading Samples**
➢ Prepare samples according to the testing protocol.
➢ Place samples inside the chamber in a manner that ensures even exposure to humidity.
4. **Monitoring and Adjustments**
➢ Monitor temperature and humidity levels continuously using the chamber's control panel or monitoring system.
➢ Make adjustments as necessary to maintain stable conditions throughout the test period.
5. **Data Collection**
➢ Record initial readings of temperature and humidity.
➢ Document observations and any changes in sample behavior during the testing period.
6. **Maintenance**
➢ Perform routine checks on the chamber to ensure it continues to operate correctly.
➢ Calibrate sensors and equipment regularly to maintain accuracy.
7. **End of Test**
➢ Once the test duration is complete, carefully remove samples from the chamber.
➢ Record final readings and observations.
➢ Clean the chamber and reset it for the next use.
8. **Documentation:**
➢ Compile all data collected during the test into a comprehensive report.
➢ Include details of the testing conditions, procedures followed, and results obtained.

Following these operating procedures ensures consistent and reliable humidity testing, providing valuable insights into the performance and durability of materials and products under controlled environmental conditions.

➢ **Endurance**: Determining how well materials withstand prolonged exposure to humidity.
➢ **Repeatability**: Ensuring consistency in performance across multiple test cycles.
2. **Comparative Analysis**:
➢ **Control vs. Test Samples**: Comparing results from samples exposed to humidity with those kept under controlled conditions to understand the specific effects of humidity.

By using these evaluation criteria, researchers, engineers, and quality control professionals can effectively assess the impact of humidity on materials and products, guiding improvements in design, manufacturing processes, and product reliability.

Conclusion

In conclusion, humidity testing, as standardized by ASTM D2247 and ISO 6270, plays a critical role in assessing the durability and performance of materials and products under varying moisture conditions. These standards provide robust frameworks for conducting rigorous tests that simulate real-world environmental challenges. By adhering to these standards, manufacturers and researchers can ensure consistency in testing methodologies, facilitate reliable data comparison, and ultimately, enhance the quality and reliability of products. Through comprehensive analysis of humidity effects, insights gained from these tests enable informed decision-making in product development, quality assurance, and regulatory compliance across diverse industries.

Questions

Q1. What is humidity?

Q2. What are chemical & physical properties of humidity?

Q3. What are your observations about humidity testing?

Q4. Explain procedure of humidity chamber?

Q5. What is effect of humidity on environment?

Q6. Where this technique is used mostly?

F/OBEM 01/05/00

NED University of Engineering & Technology
Department of ____________________Engineering
Course Code and Title: ____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
EquipmentIdentification Sensory skill to ***identify*** equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as itscomponents.
Equipment Use Sensory skills to ***demonstrate*** the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demon strates the use of equipment.	Fully demonstrates the use of equipment.
Procedural Skills ***Displays*** skills to act upon sequence of steps in lab work.	Not able to either learn or perform lab work procedure.	Able to slightly understand lab work procedure and perform lab work.	Able to somewhat understand lab work procedure and perform lab work.	Able to moderately understand lab work procedure and perform lab work.	Able to fully understand lab work procedure and perform lab work.
Response Ability to ***imitate*** the lab work on his/her own.	Not able to imitate the lab work.	Able to slightly imitate the lab work.	Able to somewhat imitate the lab work.	Able to moderately imitate the lab work.	Able to fully imitate the lab work.
Observation's Use*Displays* skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
Safety Adherence Adherence to ***safety*** procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
Equipment Handling*Equipment care* during the use.	Doesn't handle equipment with required care.	Rarely handles equipment with required care.	Occasionally handles equipment with required care.	Often handles equipment with required care.	Handles equipment with required care.
Group Work ***Contributes*** in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.

Laboratory Session No. ______________ Date: ________________________

Weighted CLO (Psychomotor Score)	
Remarks	
Instructor's Signature with Date:	

NED University of Engineering & Technology
Department of Metallurgical Engineering
BE in Metallurgical Engineering
Complex Engineering Activity (Open Ended Lab)

Subject: MY- 413: Corrosion Engineering **Max. Marks:** 10 **Type:** Group
Title: Investigate the effects of common solutions and pH on the oxidation of aluminum soda can use in everyday life.

Linkage to Course Learning Outcome				
CLO No.	**Description of CLO**	**Domain**	**Taxonomy Level**	**PLO**
CLO-3	Propose and apply the most suitable corrosion protection technique like cathodic protection, anodic protection, type of coating, inhibitor, and alteration in the environment.	Cognitive	C5	Environment and Sustainability

Sr.no.	**Problem Description**
1.	This experiment demonstrates the effectiveness of organic coatings in protecting the most vulnerable metals against corrosion. Organic coatings of various forms (paints, lacquers, wrappings) are used in all sorts of applications to protect metals and alloys against a great variety of environments.
2.	Aluminum is a very reactive metal and easily oxidizes. However, aluminum oxide forms a tough coat on the surface of the aluminum which protects the metal underneath from further corrosion. Certain environments such as low or high pH disrupt the protective oxide coating which allows extensive corrosion of the underlying metal. In certain applications, aluminum must be protected from its environment via coatings.
3.	A common use of aluminum that students will be familiar with is beverage cans. Soda is acidic and can attack the aluminum can; therefore, it has a polymer liner on the inside of the can to protect it from corrosion.
4.	In this open-ended lab, students will investigate the effects of pH on the corrosion of aluminum. Paint is removed from the surface of the can and it is cut into strips. The strips of aluminum are placed into solutions with different pH levels. Some of the solutions will oxidize the aluminum, leaving only the polymer liner. This will help the student in carrying out investigations, constructing explanations, and designing solutions.
Sr.no.	**Constraints/Assumptions**
1.	Assume the production history of aluminum can sample from published literature.
Sr.no.	**Identification of Areas where the use of computational/modern Tools usage is required**
1.	Analysis of the surface before cleaning by using a Stereo Microscope, etc.
2.	Analysis of surface after cleaning by using a Stereo Microscope, etc.
3.	Use of reference management software.
Sr.no.	**Expected Outcomes**
1.	Detail Report with proper formatting and references. The same reference style will be followed as mentioned in the CEP instruction sheet.
2.	Clear pictures of aluminum cam, use in this study with proper marking.
The following assessment questions must also be addressed in the report with proper literature.	
3.	Why are not all aluminum structures or products (such as window frames) coated with paint or a polymer liner?
4.	Why do you think some aluminum structures or products (such as soda) need to be coated with paint or a polymer liner?
5.	Write a chemical equation for a reaction that happened in one of the test tubes or cups.
6.	Which solutions seemed to corrode the aluminum the quickest?
7.	Hypothesize what might happen if the polymer liner on the inside of a pop can was accidentally scratched before it was filled with cola.

Complex Engineering Activities

Preamble: Complex activities mean (engineering) activities or projects that have some or all of the following characteristics listed below:

Sr.no.	Attribute	Description	Apply
1.	Range of resources	Involve the use of diverse resources (for this purpose, resources include people, money, equipment, materials, information, and technologies).	Yes
2.	Level of interaction	Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering, or other issues.	Yes
3.	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	No
4.	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	No
5.	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	No

NED University of Engineering & Technology
Department of Metallurgical Engineering
Course Code &Title: MM-413: Corrosion Engineering
Assessment Rubric for Complex Engineering Activity (OEL)

Student's Name: ____ Roll No.: _____________

Criterion	Level of Attainment				
	Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
Range of resources (literature review)	No use of reference/ unreliable reference	Use of one reference	Use of two references	Use of three references	Use of multiple references
Range of resources (use of equipment)	No use of equipment/apparatus for analysis	Use of equipment/ apparatus but the analysis was wrong	Use of equipment/ apparatus and the analysis was correct	Use of equipment/ apparatus and software of but the analysis was wrong	Use of equipment/ apparatus and software and the analysis was correct
Response of Assessment question	No response in the report	One correct response with reference	Two/Three correct response with reference	Four correct response with reference	Five correct response with reference
Report writing	Do not follow the provided guidelines	Somehow followed the provided guidelines	N.A	Followed the provided guidelines with some mistakes	Completely followed the provided guidelines

Total Score = ____________________________

Instructor's Signature: _____________________