Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Technology
Chemical Engineering Department

CATHODIC PROTECTION OF STORAGE TANK

A Project Submitted To The Chemical Engineering Department Of The University Of Technology In Partial Fulfilment Of The Requirements for the Degree Of Higher Diploma In Chemical Engineering - Petroleum And Gas Refining

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SUPERVISOR CERTIFICATION

I certify that this project entitled " Cathodic Protection Of Storage Tank " was prepared under my supervision as a partial fulfilment of the requirements for the degree of Higher Diploma Science in Chemical Engineering at the Chemical Engineering-Department , University of Technology.

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EXAMINATION COMMITTEE CERTIFICATE

We certify that we have read this project entitled " Cathodic Protection Of Storage Tank " and as examining committee examined the student Rana M. Hussain in its contents and that in our opinion it meets the standards of a project for the degree of Higher Diploma in Chemical Engineering Petroleum and Gas Refining .

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Abstract

Cathodic protection is an electrochemical means of corrosion prevention technique which uses the electrochemical properties of metals to insure that the structure to be protected becomes the cathode of an electrolytic cell.

The purpose of present work is to construct cathodic protection (CP) system to prevent structures from corrosion . A case study for protecting 18.000 m^3 crude oil storage tank exists in DURA refinery was investigated .The scope of work included the design and determination of all necessary materials for the internal cathodic protection of tank bottom and one meter height of tank wall. utilizing Aluminum anodes as sacrificial anodes .

The results showed that the cathodic protection required 230 anode rods (N), Current output (one anode) =0.138 Amp , Minimum distance between anodes " L_{min}" = 2.607 m , Protecting diameter for one anode "D_{anode} " =1.471 m .

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Nomenclature

Symbol	Meaning	Unit
D	Diameter of tank	m
h	Water level	m
ρ	Resistivity	Ω.cm
l	Design current density	mAp/m^2
w	Weight (for one anode)	kg
I	Current capacity of anode	kg/Amp. year
ΔE	Potential difference for anode in sea water	mV
S_t	Tank bottom surface area to be protect	m^2
S_r	Tank shell area to be protect	m^2
S_{total}	Total surface area to be protect	m^2
T_{total}	Total current required at design current density	Amp
w	Total weight of anode rods	kg
N	Required number of anode	ea.
S_{anode}	Protected area by one anode	m^2
L_{min}	Minimum distance between anodes	m
D_{anode}	Protecting diameter by one anode	m

Nomenclature

E_{corr}	Corrosion Potential	volt
i_{corr}	Corrosion current density	µA/cm2

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Corrosion is defined as the chemical or electrochemical reaction between a material, usually a metal or alloy, and its environment that produces a deterioration of the material and its properties. According to the characteristics of the environment, corrosion processes are classified as chemical or electrochemical . Corrosion is a costly worldwide problem. In addition to the huge cost in economic terms, corrosion is also blamed for many of the disasters that cause loss of life and devastating pollution to the environment. [1]

Five different main principles can be used to prevent corrosion: appropriate materials selection, change of environment, suitable design application of coatings ,electrochemical i.e. cathodic and anodic protection,. The choice between these possibilities is usually based upon economic considerations, but in many cases aspects such as appearance, environment and safety must also be taken care of. Two or more of the five principles are commonly used at the same time. [2]

Corrosion occurs on all metallic structures that are not adequately protected. The cost of replacing a structure which may have been destroyed or weakened due to excessive corrosion is substantial but avoidable, and means should be taken to consistently prevent or mitigate this added cost through cathodic protection [3]

Cathodic protection (CP) is a technique to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. The simplest method to apply CP is by connecting the metal to be protected with another more easily corroded metal to act as the anode of the electrochemical cell. Cathodic protection systems are most commonly used to protect steel of water or fuel pipelines , storage tanks, steel pier piles, water-based vessels including yachts and powerboats, offshore oil platforms and onshore oil well casings. Today, galvanic or sacrificial anodes are made in various shapes using alloys of zinc, magnesium and aluminium. The electrochemical potential, current capacity, and consumption rate of these alloys are superior for CP than iron. [4]

1.2 The aim of present work

The purpose of present work is to construct cathodic protection (CP) system to prevent structures from corrosion by utilizing Aluminum anodes as sacrificial anodes.

CHAPTER TWO

THE PRINCIPLES OF CORROSION AND CATHODIC PROTECTION

2.1 Introduction

Corrosion refers to the deterioration of a material due to reactions with its environment .[5]

In nature, most metals are found in a chemically combined state known as ore. Ores may be oxides, Sulphides, Cabronates or other complex compounds. In order to separate a metal such as iron from one of its ores, e.g. iron oxide, it is necessary to supply a large amount of energy. Therefore, metals in their un combined condition are usually high-energy states. It is this tendency of metals to recombine with components of environment that the phenomenon known as corrosion. Deterioration by physical causes is not called corrosion, but is described as erosion, galling, or wear. In some instances, chemical attack accompanies physical determination as described by the term: corrosion-erosion, corrosion wear or fretting corrosion .[6]

Cathodic protection (CP) is a technique to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. The simplest method to apply CP is by connecting the metal to be protected with another more easily corroded metal to act as the anode of the electrochemical cell. [7]

Cathodic protection (CP) has been known for about 170 years. Primarily it has been used for protection of ordinary structural steel in soil and seawater, more seldom (and under special conditions) for steel exposed to fresh water. Other materials can also be protected by CP, for instance to prevent localized corrosion on stainless steel and aluminium. In recent decades the application of this technology has increased considerably in connection with the expanding offshore oil and gas exploration and production. [8]

Cathodic protection was therefore neglected for 100 years after which it began to be used successfully by oil companies in the United States to protect underground pipelines. It is interesting that the first large-scale application of cathodic protection by Davy was directed at protecting copper rather than steel. [9]

2.2 Corrosion principles &mechanisms

2.2.1 Understanding Corrosion

Corrosion of metallic materials can be divided into three main groups;

- Wet corrosion, where the corrosive environment is water with dissolved species. The liquid is an electrolyte and the process is typically electrochemical.
- Corrosion in other fluids such as fused salts and molten metals.
- Dry corrosion, where the corrosive environment is a dry gas. [10]

2.2.2 Corrosion Cell

From the process of corrosion it should be apparent that there are four fundamental components in an electrochemical corrosion cell.

- An anode.
- A cathode.
- A conducting environment for ions (electrolyte).
- An electrical connection between the anode and cathode for the flow of current.

If any of the above components is missing or disabled, the electrochemical corrosion process will be stopped. Clearly, these elements are thus, fundamentally important for corrosion control.[11]

corrosion mitigation techniques are based on the principles of corrosion cell as shown in Fig. (2.1) .[12]

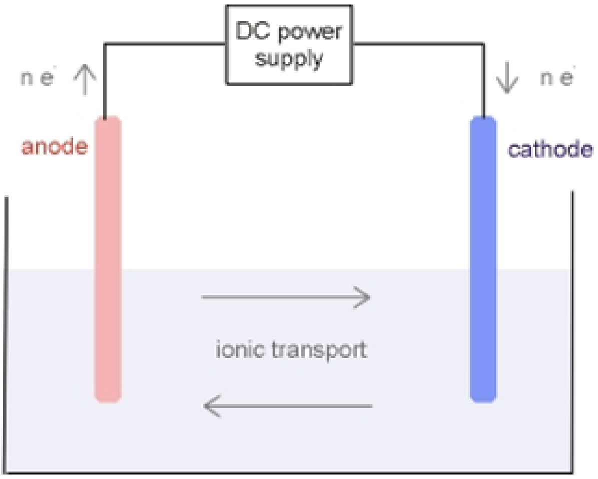


Fig. (2.1) Corrosion cell [12]

2.2.3 Cathodic & Anodic reactions

Corrosion of most common engineering materials at near-ambient temperatures occurs in aqueous (water-containing) environments and is electrochmical in nature. The aqueous environment is also referred to as the electrolyte and, in the case of underground corrosion, is moist soil. The corrosion process involves the removal of electrons (oxidation) of the metal [Equation (1)] and the consumption of those electrons by some other reduction reaction, such as oxygen or water reduction [Equations (2) and (3), respectively]:

$$\mathrm{Fe} \longrightarrow \mathrm{Fe}^{++} + 2e^{-} \qquad \text{-----------} \ (1)$$

$$\mathrm{O_2} + 2\mathrm{H_2O} + 4e^{-} \longrightarrow 4\mathrm{OH}^{-} \qquad \text{-----------} \ (2)$$

$$2\mathrm{H_2O} + 2e^{-} \longrightarrow \mathrm{H_2} + 2\mathrm{OH}^{-} \qquad \text{-----------} \ (3)$$

The oxidation reaction is commonly called the anodic reaction and the reduction reaction is called the cathodic reaction. Both electrochemical reactions are necessary for corrosion to occur.

The oxidation reaction causes the actual metal loss but the reduction reaction must be present to consume the electrons liberated by the oxidation reaction, maintaining charge neutrality. Otherwise, a large negative charge would rapidly develop between the metal and the electrolyte and the corrosion process would cease.[13]

2.3 Common forms of corrosion

It is suggested that a corrosion case should be described at least by its form, the corrosion reactions and corrosion products. A type of corrosion is expected to characterize, and describe more profoundly the circumstances leading to a corrosion or a failure of a certain material and complement the more vast divisions of the six forms of corrosion Modes of Corrosion. Fontana defined eight forms of corrosion, as general corrosion, pitting corrosion, inter granular corrosion, parting, galvanic corrosion, crevice corrosion, stress–corrosion cracking and erosion–corrosion. In refining these eight forms, there are really two broad categories of modes of corrosion: Intrinsic and extrinsic. The intrinsic modes of corrosion which occur independent of design are: [14]

- General corrosion
- Pitting
- Intergranular corrosion
- Parting
- Stress–corrosion cracking

The extrinsic modes affected by the design include:

- Crevice or under-deposit corrosion
- Galvanic corrosion
- Erosion–corrosion
- Fretting corrosion
- Corrosion fatigue

2.4 Corrosion damage

Broader application of corrosion-resistant materials and the application of the best corrosion-related technical practices could reduce approximately one-third of these costs. Advances have been made in the use of stainless steels, coated metals, and more protective finishes. Moreover, several substitutions of materials made primarily for reasons of weight reduction have also reduced corrosion. The industry is estimated to have eliminated some 35 percent of its “avoidable” corrosion by its improved practices.[15]

Corrosion mitigation becomes important which adds to the costs of the plant operation. The other alternative is to choose corrosion-resistant materials, which may be expensive, resulting in high initial costs. It is also possible to use coatings or cathodic protection, resulting in additional costs. The economic considerations and factors such as plant life dictate the choice of materials and the corrosion prevention strategies used.[16]

2.5 Corrosion Prevention

Although enhancing the materials selection process to pay closer attention to corrosion prevention and control may cost more initially, there are many potential benefits that will result including improved reliability, reduced maintenance, increased availability, improved performance and efficiency, improved safety, increased service life, and reduced life-cycle cost

In addition, extending the life of a fielded system is far easier and less costly if excessive corrosion is prevented from occurring in the first place.[17]

2.5.1 Material Selection:

The right choice of material in relation to corrosive medium .[18]

Then material must be selected to the design stage with consideration given to corrosion resistance, mechanical strength, workability, and cost. For example, carbon steel is the almost exclusive choice of pipelines designers. [19]

2.5.2 Design Considerations:

The use of acceptable engineering practices to minimize corrosion is fundamental to corrosion control. This is accomplished by engineering design .

In design the structure care must be taken to avoid such as crevices, contact between different metals, welding practice and easy installation of cathodic protection .[20]

2.5.3 Corrosion Inhibition

Inhibitors are chemicals that act to slow down corrosion they are the preferred methods of corrosion control in closed and recalculating cooling and heating system using water as the heat transfer medium and are the only cost-effective method for corrosion control of steel pipelines in the oil and gas industry. [21]

2.5.4 Coating Control Corrosion

Coating control corrosion placing a barrier between the pipe and the surrounding environment, eliminating the electrolyte. The effectiveness is dependant upon the integrity of the coating. i.e. how many holes are present, strength of bond with the metal, and ability to insulate the pipe from electrical current. Example of common coating as asphalt, concrete, epoxies, polyvinyl chloride (PVC), and poly ethylene.[22]

2.5.5 Cathodic Protection

Cathodic protection is a common and successful form of corrosion control in a variety of situations, for example, submerged marine structures, pipelines, chemical plant, oil storage and rebars corrosion in concrete.

Current research is focusing on a number of areas including aluminum anodic, magnesium anodic, potential mapping, influences of defects on coated steel, monitoring of cathodic protection system and protection of oil field water.[22]

2.6 Cathodic protection & its relation to the electrochemical theory of corrosion

Cathodic protection is a method to reduce corrosion by minimizing the difference in potential between anode and cathode. This is achieved by applying a current to the structure to be protected (such as a pipeline) from some outside source. When enough current is applied, the whole structure will be at one potential; thus, anode and cathode sites will not exist. Cathodic protection is commonly used on many types of structures, such as pipelines, underground storage tanks, locks, and ship hulls.[23]

Cathodic protection is an electrochemical method allowing control of the kinetics and mechanism of electrode processes proceeding on the metal/electrolyte phase boundary by DC current polarisation.

The generally accepted principles of this initially empirical method can be explained by kinetics of electrode processes, the foundations of which are given by the Wagner and Traud mixed potential theory. The principle of cathodic protection in a potential . current density system is explained in Fig (2.2) .

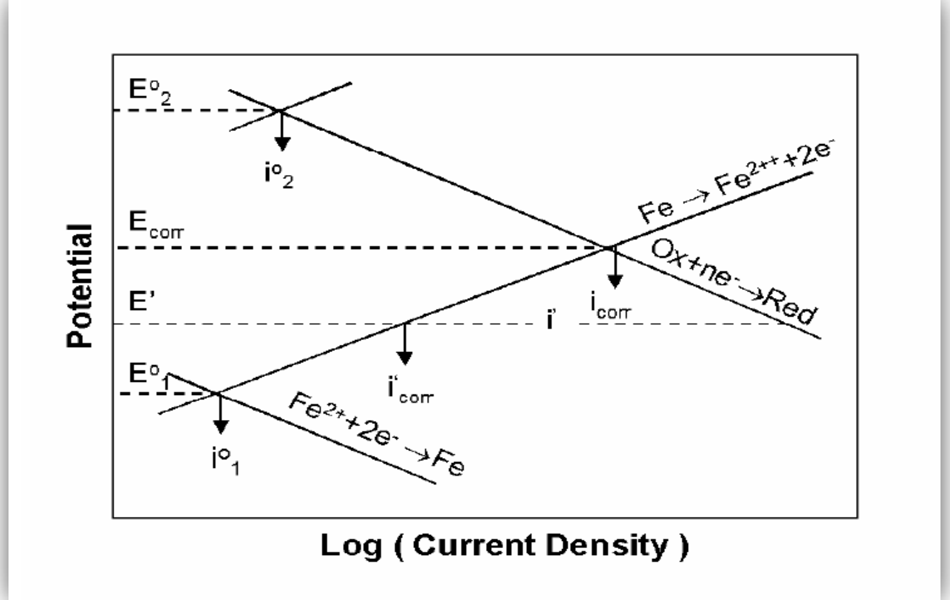


Fig (2.2) Current density system [25]

It presents the relation of anodic and cathodic reaction partial currents accompanying the steel corrosion process, i.e., their rate from the imposed potential. In zero current conditions an equilibrium state is established on the surface of steel, in which the anodic (oxidation) process rate is equal to the cathodic (reduction) process rate. This state is characterised by corrosion potential *Ecorr* and corrosion current density *icorr*.

By cathodically polarising the pipeline with a DC current, hence appropriately changing the potential from the corrosion potential in the negative direction, one may slow down or hinder the anodic reaction of iron ionisation responsible for the corrosion process.

Partial cathodic protection is ensured, for example, by polarisation of steel to potential *E.* with a current *i.*, at which the corrosion current decreases to value *icorr*. Full hindering of the corrosion process requires polarisation of the metal to the reversible potential of the anodic reaction *Eo*.[24]

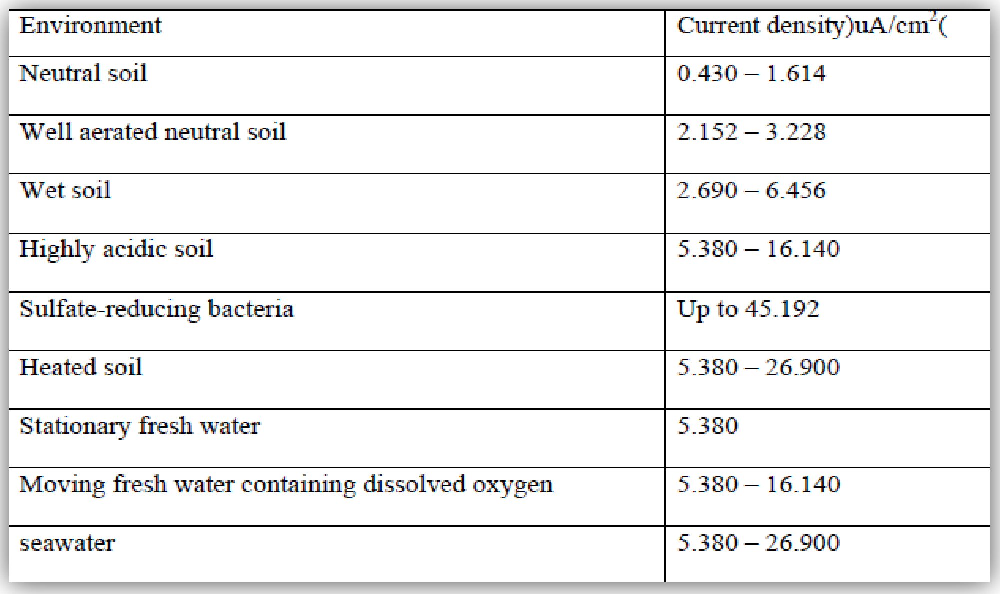
2.6.1 Current density requirement

The current required for cathodic protection depends upon the metal being protected and the environment. The potentials required to determine adequate protection (criteria). To achieve these protective potentials, current must flow from the anode to the structure being protected.

The amount of current required to protect a given structure is proportional to the area of the structure that is exposed to the electrolyte. Therefore, current requirements are usually given as current densities in units of amperes or milliamperes (0.001 amperes) per square meter (foot) of exposed surface.[25]

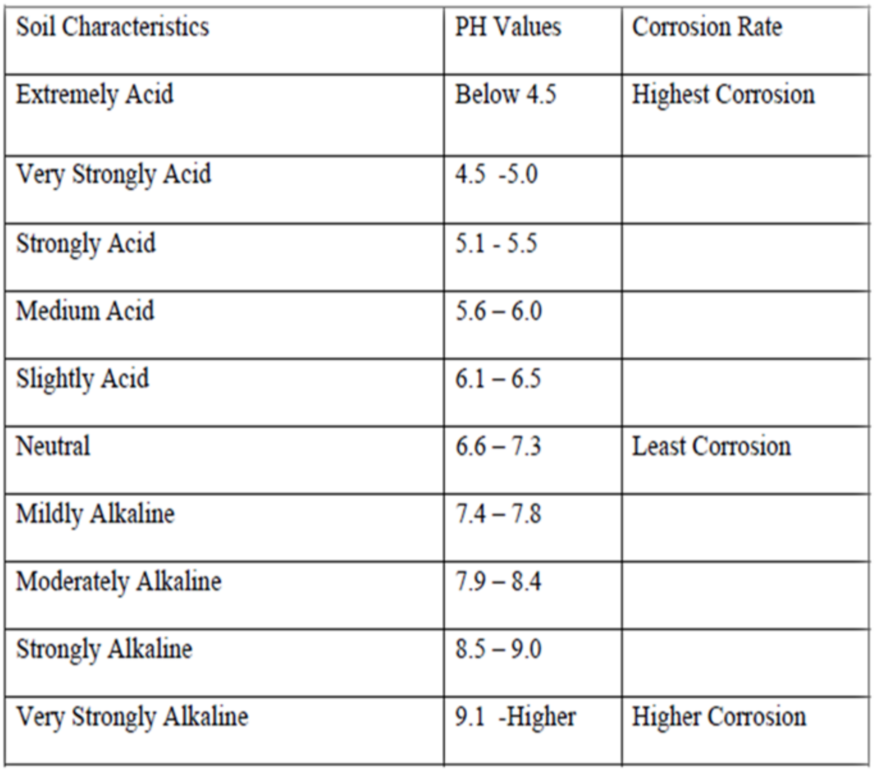
The pH of environment will also be important, the presence of coating, marine fouling, and calcareous deposits will have a profound effect on current density, for economic and technical reasons a low current is desirable Some typical current requirement in a range of different environment is given in Table (2-1) and PH value and corrosion in table (2-2).[26]

Table (2-1)Typical current density required for cathodic protection of uncoated steel[27]



Environment	Current density)uA/cm^2(
Neutral soil	0.430 – 1.614
Well aerated neutral soil	2.152 – 3.228
Wet soil	2.690 – 6.456
Highly acidic soil	5.380 – 16.140
Sulfate-reducing bacteria	Up to 45.192
Heated soil	5.380 – 26.900
Stationary fresh water	5.380
Moving fresh water containing dissolved oxygen	5.380 – 16.140
seawater	5.380 – 26.900

Table (2-2) PH value and corrosion [27]



Soil Characteristics	PH Values	Corrosion Rate
Extremely Acid	Below 4.5	Highest Corrosion
Very Strongly Acid	4.5 -5.0	
Strongly Acid	5.1 - 5.5	
Medium Acid	5.6 – 6.0	
Slightly Acid	6.1 – 6.5	
Neutral	6.6 – 7.3	Least Corrosion
Mildly Alkaline	7.4 – 7.8	
Moderately Alkaline	7.9 – 8.4	
Strongly Alkaline	8.5 – 9.0	
Very Strongly Alkaline	9.1 -Higher	Higher Corrosion

2.7 Sacrificial anode system

2.7.1 Introduction

A galvanic cathodic protection system makes use of the corrosive potential for different metals, one area of the structure exists, at more negative potential than another, and corrosion results if, however, a much less inert object (that is, with much more negative potential, such as magnesium anode is placed adjacent to the structure to be protected such as pipelines; and metallic connection (insulated wire) is installed between the object and the structure, the object will become the anode and the entire structure will become the cathode. That is, the new object corrodes sacrificially to protect the structure . Thus, the galvanic cathodic protection system is called "a sacrificial anode cathodic protection system "because the anode corrodes sacrificially to protect the structure [28], a shown in fig. (2-3)

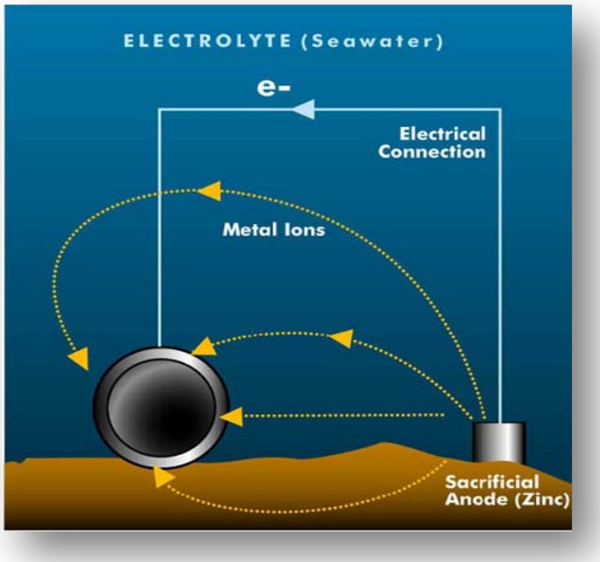


Fig. (2-3) A sacrificial anode cathodic protection system [28]

Cathodic protection in the sacrificial anode system is essentially a controlled electrochemical cell. Corrosion on the protected structure is shifted to the anode. The anode is consumed in the process but is designed and installed so that it is easily replaced when consumed. Anode life of 10 to 15 years is common. Anode life is dependent upon the amount of current emitted by the anodes and their size. [29]

2.7.2 Galvanic anode types

Galvanic anode protection is often called "sacrificial" because the anode is thought of as "sacrificing" itself to protect the structure. This type of protection utilizes a galvanic cell consisting of an anode made from a more active metal than the structure. The anode is attached to the structure, either directly or, to permit measurement of the anode output current, through a test station . [30]

The following three metals are the most common galvanic anode materials and the galvanic anode characterisation in table(2.3)

- Magnesium
- Zinc
- Aluminum

Table (2.3) Galvanic anode characterisation[31]

Material	Theoretical output A-h/kg	Actual output A-h/kg	Eff %	consumption	
				Rate Kg/A-year	Potential to CSE[a]
Zinc					
Type I	860	781	90	11	1.06
Type II	816	739	90	12	1.10
Magnesium					
H-1 alloy	2205	551-1279	25-58	6.8-16	1.40-1.60
Magnesium High Potential	2205	992-1191	45-54	7.3-8.6	1.70-1.80
Al/ Zn/ Hg	2977	2822	95	3.1	1.06
Al/ Zn/ In	2977	2591	87	3.3	1.11

(a) Cu/ $CuSO_4$ reference electrode

2.7.3 Advantages and Disadvantages

2.7.3.1Advantages[32]

- Simple to install.
- Independent of any source of electric power (self-powered).
- Low maintenance requirement.
- Less likely to cause stray current interference problem on neighboring structures.
- When the current requirement is small, a galvanic system is more economical than impressed current system.

2.7.3.2 Disadvantages [32]

- Low driving voltage.
- Limited to use in low resistivity soils.
- Not an economical source of large amounts of cathodic protection current.

2.8 Impressed Current

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2.8.1 Introduction

Impressed current systems are sometimes called rectifier systems because they utilize a device (a rectifier) to convert an external AC power source to the required DC power source. In this type of system, anodes are installed in the soil around the structure to be protected and the DC power is supplied to the anodes through buried wires. [33]

The main difference between galvanic and impressed current systems is that the galvanic system relies on the difference in potential between the anode and structure; whereas the impressed current system uses an external power source to drive the currents shown in fig.(2-4).[34]

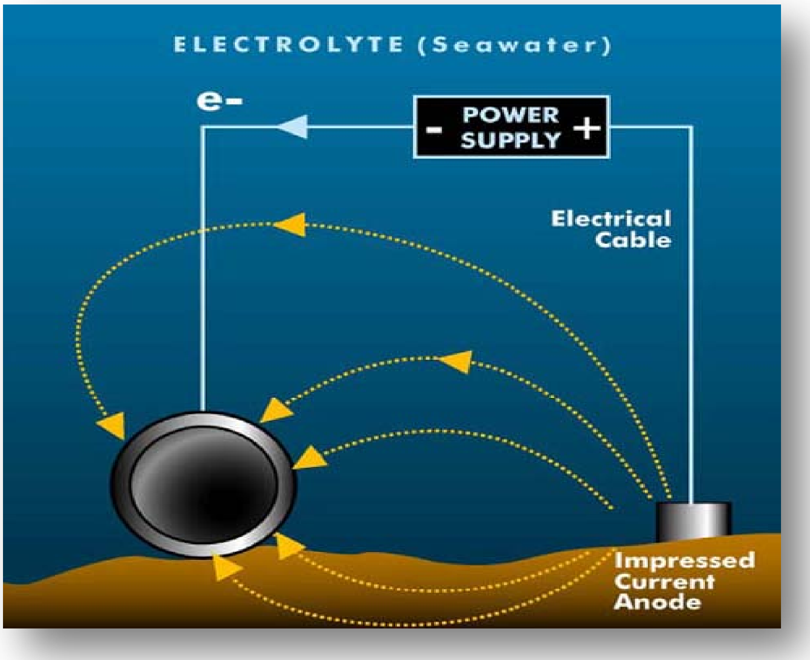


Fig. (2-4) Impressed current system [34]

The external power source is usually rectifier, that converts ordinary AC power to DC, current is carried in the external circuitry as electrons, free electrons do not exist in an electrolyte solution; therefore, the current must be carried by positively and negatively charged ions.The current through the electrolyte solution, equal to that in the external circuit.

Positively charged ions carrying the current electrochemical reactions at the electrodes are responsible for the mechanism of cathodic protection and for the transfer of charges from electron to ions at the electrode surface. Impressed current means that a current is impressed between the buried structure and an anode, this force averesal of the current, and causes the anode to be consumed rather than the pipe. [35]

2.8.2 Anodes

Impressed current system anodes include materials such as graphite, silicon iron, Platonized precious metal and lead alloy shown in Table (2-4).[36]

Table (2-4)Impressed Current Anodic Material and their Properties [36]

Material	Consumption $KgAy^{-1}$	Recommended uses
Platonized, titanium and niobium	$8 * 10^{-6}$	Marine environment poTable water, carbonaceous backfill and high purity liquids.
Platonized titanium	$8 * 10^{-6}$	Marine environment poTable water.
High silicon iron	0.2 – 1.0	PoTable water and soil or carbonaceous backfill.

Steel	6.8 – 9.1	Marine environment and backfill carbonaceous.
Iron	Approx 9.5	Marine environment and backfill carbonaceous.
Cast iron	4.5 – 6.8	Marine environment and backfill carbonaceous.
Lead- platinum	0.09	Marine environment.
Lead- silver	0.09	Marine environment.
Graphite	0.1 – 1.0	Marine environment, potable water, and carbonaceous backfill.

The anodes are usually distributed at regular intervals over the whole of structure, rather than in small numbers which must protect large area, there are two main reasons for this.A large current density in the immediate vicinity of an anode is damaging to many types of paint film. The use of more anodes reduces the current output of each anode and lessens the damage to the protective coating.In the complex geometrical arrangement off shore, it is difficult to predict the distribution of potential consequently; it is safer to employ more anodes to protect smaller area. If any doubt exists about the ability of an anode to protect a particular part of the structure.Graphite anode is one of the most commonly used for impressed current system, graphite anode was chosen for of the following reason. [37]

2.8.3 Advantages and Disadvantages

2.8.3.1 Advantages

An impressed current system is used to protect large bare and coated structure and structures in high resistively electrolytes and have the following advantages. [38]

- The large driving force available can protect a large, even uncoated structure in high resistively environments.
- Few anodes are used comparatively with sacrificial anode systems.

2.8.3.2Disadvantages

- Increased maintenance.
- May cause interface on other structures.
- High operating costs.

2.9 Cathodic Protection System Selection

When selecting which type of system to use, the designer should consider the size of the structure to be protected and past project experience in operating and maintaining both types of systems. Early in the selection process, if practical, it is useful to perform a current requirement test to help define the total amount of electrical current needed to protect the structure.

For large structures with significant expanses of bare or poorly coated metal, where the total current requirement tends to be very high, a properly maintained impressed current system can provide 10 to 30 years of effective corrosion protection. Where current requirements are lower and the structure's protective coatings are well maintained, sacrificial anode systems can be very effective. Improved modern coating systems and maintenance practices today allow for a wider use of sacrificial CPSs on large civil works structures than was the case in the past. For both types of systems, preliminary design estimations and comparisons of costs, current output, and overall design life should give an adequate indication of which system is preferable for the specific application. Other factors such as future maintenance needs, reliability, accessibility, and impact on operations may also warrant consideration.[39]

2.10 Application

The connections are similar for the application of cathodic protection to metallic storage tanks, jetties, offshore structures and reinforced concrete structures.[40]

Specifying the use of cathodic protection initially will avoid the need to provide a “corrosion allowance” to thin sections of structures that may be costly to fabricate. It may be used to afford security where even a small leak cannot be tolerated for reasons of safety or environment. Cathodic protection can, in principle, be applied to any metallic structure in contact with a bulk electrolyte (including concrete). 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 on metals. However, it can be used to protect atmospherically exposed and buried reinforced concrete from corrosion, as the concrete itself contains sufficient moisture to act as the electrolyte. Structures that are commonly protected by cathodic protection are the exterior surfaces of:

- Pipelines
- Ships' hulls
- Storage tank bases
- Jetties and harbour structures
- Steel sheet, tubular and foundation pilings
- Offshore platforms, floating and sub sea structures

Cathodic protection is also used to protect the internal surfaces of:

- Large diameter pipelines
- Ship's tanks (product and ballast)
- Storage tanks (oil and water)
- Water-circulating systems.[41]

CHAPTER THREE

CASE STUDY

3.1 Oil Storage Tank

The low carbon steel was used for manufacturing the oil large volume tank which was dismantled after the long-term service. Oil-water level and the range of oil-levels are presented in Fig.(3.1) .Taking it into account, four characteristic zones were chosen from the point of view of the working environment of the material:

zone I – upper part of the wall, absence of contact of steel with oil but with water condensed from oil surface;

zone II – lower part of the wall, constant contact of steel with oil;
zone III – tank wall closer to the bottom – constant contact of steel with residual water;
zone IV – bottom, constant contact of steel with the residual water. Experiments were carried out in the residual water, taken from the exploited storage tank.[42]

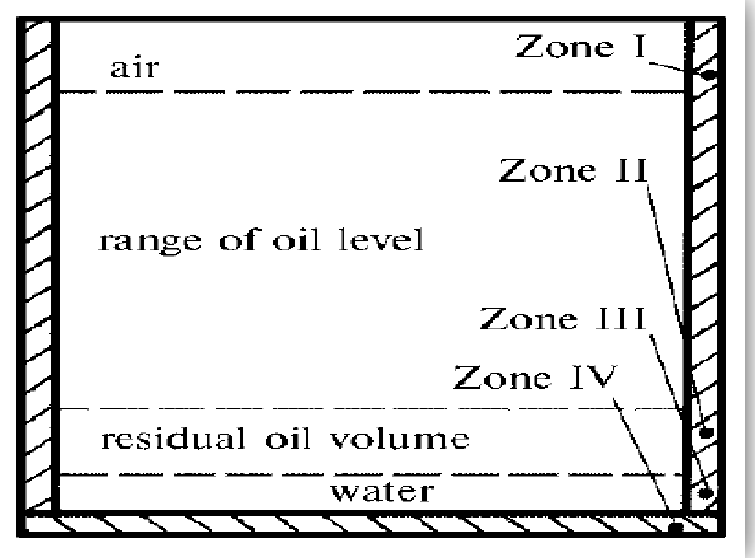


Fig (3.1) Oil storage tank [42]

3.2 Requirements of the internal surface of Oil Storage Tank

18.000 m^3 crude oil storage tank Internal cathodic protection see Fig (4.1) .The scope of work shall include the design and determine of all necessary requirements for the internal cathodic protection of tank bottom and one meter height of the wall at -0,9 Volt versus $CuS0_4$ half-cell.

3.2.1 Design Condition

- The cathodic protection design shall consider formation water resistivity of 100 Ω.cm. Protective current requirements estimated 20 mA /m^2 for this tank.

- The design life time requirement for the internal cathodic protection system 10 years.
- The system shall be based on the use of sacrificial anodes system utilizing aluminum anodes see Fig (3.2) and Fig (3.3).
- A Size and design parameters of 18.000 m^3 crude oil storage tank (Al Anode)

Design Parameter "ALUMINIUM ANODE"	**Value**
Diameter of tank **"D** = 2r"	42.672 meter
Maximum water level *" h "*	1meter
Resistivity **" p "** Res.	100Ω.cm
Design current density " *l*"	20 mA/m^2
Design life time	10year
Al Anode weight (for one anode)	6.362 kg
Current capacity of anode	3.500 kg/A. year
Al Anode current efficiency	90%
Utilization factor	65%
Potential difference for Al anode in sea water ΔE	250mV
Al Anode width	11.700 cm
Al Anode lenght	38cm
Al Anode height	5.300 cm
Al Anode density	2.700 g/cm^3

3.2.2 Calculation

Diameter of tank D =2r
=42.672 m

Tank bottom area $S_1 = \pi \times r^2$

r = D/2 =42.672/2= 21.33 m

$$S_1 = \pi \times r^2$$

$$= 3.14 \text{ x } (21.33)^2$$

$$=1429.406 \text{ m}^2$$

Tank shell area $S_r = 2 \times \pi \times r \times h$

Maximum water level " h "=1M

=2 x 3.14 x 21.336 x 1

S_r =133.99 m²

Total area $S_{total} = S_1 + S_r$

=1429.406 +133.99

=1563.396 m²

Total current required $I_{total} = S_{total} \times I$

Design current density " I" = 20 mA/m^2

=1563.396 x 0 .02

= 31.268 Amp

Required anode weight [43]

$$w= \frac{Design\ life \times Total\ required\ current \times Current\ capacity}{Current\ efficiency \times Utilization\ factor}$$

Design life=10 year

Current capacity = 3.500 kg/A. year

Al Anode current efficiency= 90%

Utilization factor= 65%

w = (10 x 31.268 x 3.500) / (0.9 x 0.65)

= 1430.559 Kg

Required anode quantity

$$N = \frac{\text{Total required anode}}{Weight\ of\ once\ anode}$$

weight for one anode= 6.362 kg

$$N = 1430.559 / 6.362$$

$$= 224.852 = 230 \text{ ea.}$$

Protect area for one anode $S_{anode} = \frac{S_{total}}{N}$

$$=1563.396 /230$$

$$= 6.797 \text{ m}^2$$

Minimum distance between anodes $L_{Min} = \sqrt{S_{anode}}$

$$= \sqrt{6.797}$$

$$= 2.607 \text{ m}$$

Protecting diameter for one anode $D_{anode} = \sqrt{\frac{S_{anode}}{\pi}}$

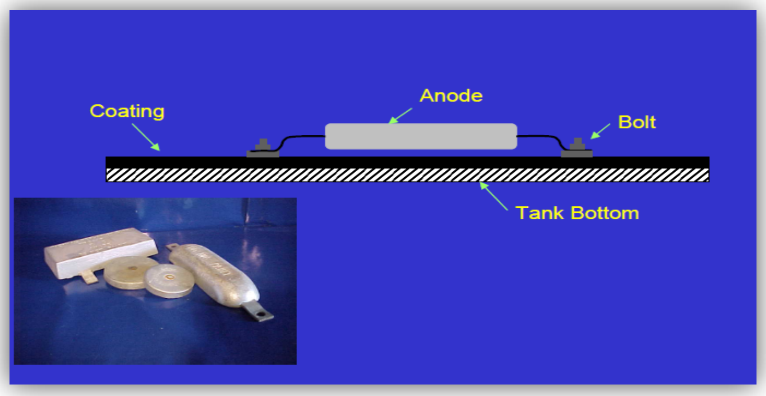
$$= \sqrt{\frac{6.797}{3.14}}$$

$$= 1.471 \text{ m}$$

Calculation Results "ALUMINIUM ANODE"	**Value**
Tank bottom surface area to protect	1429.406 m^2
Tank shell area to protect	133.990 m^2
Total surface area to protect	**1563.396 m^2**
Total Current Required at design current density	31.268 Amp
Total required anode weight	1430.559 Kg
Calculated anode quantity	**224.852**
Required anode quantity " N "	**230 ea.**
Anode to Electrolyte Resistance	1.818 Ohm
Current Output (One anode)	0.138 Amp
Total current output	31.625 Amp
Protect area for one anode " S_{anode} "	6.797 m^2
Minimum distance between anodes "L_{min} "	2.607 m
Protecting diameter for one anode "D_{anode}"	1.471 m

Description of material	**Quantity**	**Unit**
Aluminum Anode (Al-indium)	230	ea.

Distance Between Lines			2. 33m
	Anode Count	Anode Angle	Circle Diameter
1. Line	50	7.20	38.07
2. Line	44	8.18	33.47
3. Line	38	9.47	28.87
4. Line	32	11.25	24.27
5. Line	26	13.84	19.67
6. Line	19	18.94	15,07
7. Line	13	27.69	10.47
8. Line	7	51.42	5.87
9. Line	1	360	1.27
Total Anodes	230		



Figure(3.1)Anode installation[43]

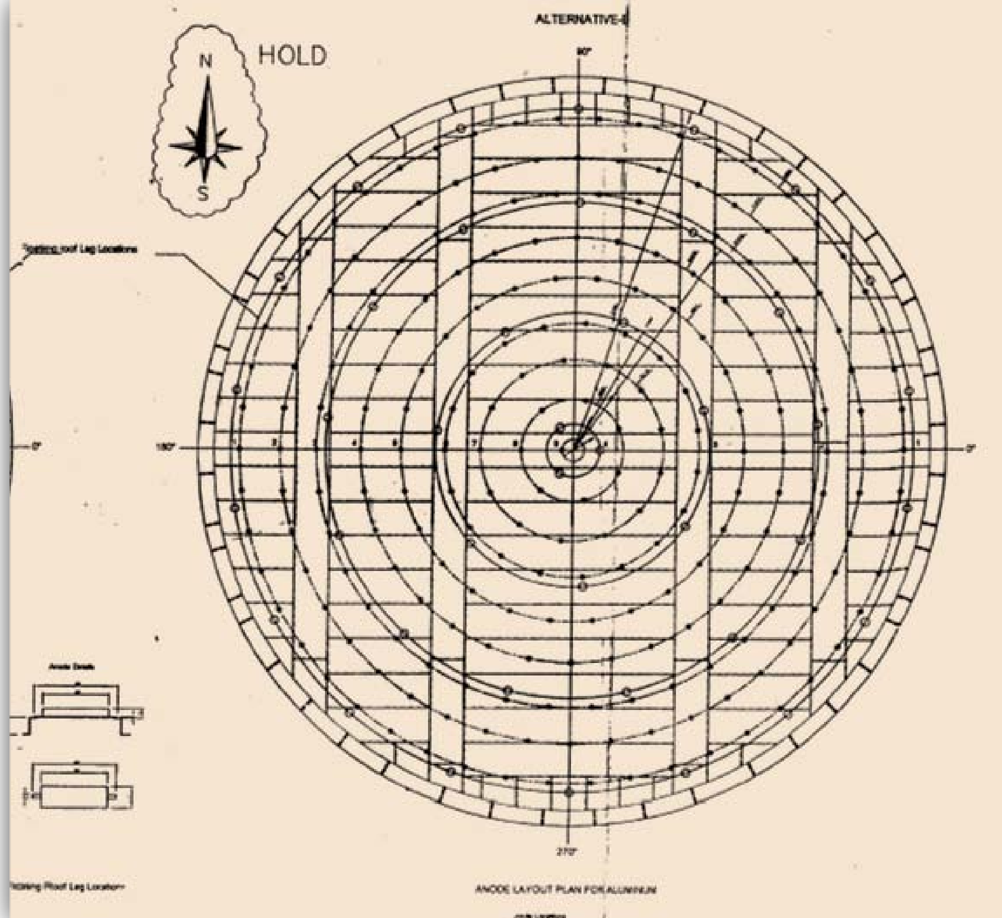


Fig (3.2) Anode layout plan for ALuminum

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الخلاصة

الحماية الكاثودية هي تقنية فعالة للحماية من التآكل التي تستخدم الخواص الكهروكيميائية للمعادن لجعل المعدات المراد حمايتها كاثود الخلية الالكتروليتية.

الغرض من البحث هو دراسة كيفية تقليل التأكل للتراكيب المعدنية بأستخدام الحماية الكاثودية , فالحالة التي تم دراستها لخزان موجود في مصفى الدورة بسعة (١٨٠٠٠) متر مكعب لمادة النفط الخام .

يتضمن العمل تصميم وحساب كافة النقاط المهمة للحماية الكاثودية الداخلية لقاعدة الخزان و ارتفاع متر فوق القاعدة بأستعمال أنودات مضحية من نوع مادة الألمنيوم.

النتائج التي تم الحصول عليها تتطلب (٢٣٠) انود , قيمة التيار الخارج من الأنود الواحد(٠.١٣٨) امبير, اقل مسافة بين الانودات هي (٢.٦٠٧) متر , وقطر الحماية التي يوفرها الانود(١.٤٧١) متر .

وزارة التعليم العالي والبحث العلمي
الجامعة التكنولوجية
قسم الهندسة الكيمياوية

الحماية الكاثودية للخزانات

بحث مقدم الى قسم الهندسة الكيمياوية في الجامعة التكنولوجية كجزء من متطلبات الدراسة لنيل الدبلوم العالي في علوم الهندسة الكيمياوية- تصفية النفط وتكنولوجية الغاز

اعداد
رنا مهند حسين
بكالوريوس في الهندسة الكيمياوية- تكنولوجيا النفط والغاز

بأشراف
د. شذى احمد سامح
٢٠١٢ **شباط**