CORROSION CONTROL IN GAS AND OIL PRODUCTION

A CASE STUDY OF

SHELL PETROLEUM DEVELOPMENT COMPANY

BY

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DECLARATION

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DEDICATION

DEICATED TO ALMIGHTY GOD,AND THE LORD JESUS CHRIST THE SAVIOUR REDEEMER OF MY SOUL FOR HIS MERCY AND GRACE THAT HAS SEEN ME THROUGH TO THIS DAY.

ALSO,ITIS DEDICATED To MY LATE MOTHER MRS ELIZABETH E. ANTHONY.

ACKNOWLEDGEMENT

A bove all I am grateful to Almighty God for granting me the privilege to be alive and hearthy and the ability and insparation Granted me to succefully carry out this project.

ABSTRACT

Corrosion is one of the common cause of failure in oil and gas production equipment. such failure includes leakages in tank, casing, tubing, pipilines, pumps and other equipment. In the course of the research of corrosion control in gas and oil production, a case study of (SHELL PETROLEUM DEVELOPMENT COMPANY)

Five Methods oF corrosion control as implemented by the company.

The case study of where corrosion was being implement by the company was carried out. The first case study was on corrosion test, samples were taken from three fields from the test it was deduced that corrosion in the field were negligible, because iron content was less than 5ppm and the pH was above 7 for (CO_2, H_2S MAINLY).

while in the second case, Corrosion control measure implemented were the use of inhibitor(COAT-C 1815) for the two wells and to be monitored for 10 years. The corrosion control measure implemented for the two wells were effective.

The third case study which was also carryout on oil well and inhibitor was used which resulted in 13 failure in 12 months. This was attributed to rod or tubing failure which was a consequence/fallout of the highly corrosive nature of the well. It could be therefore be concluded that wells having a high degree of corrosion required a combination of different inhibitors. And a design of cathodic protection equipment or process to protect a buried pipe of 50 kilometer against corrosion was carried out.

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CHAPTER ONE

1.0   INTRODUCTION

CORROSION

This word corrosion means the degradation of a metal by it's chemical combination with a non-metal such as oxygen, sulphur or the destruction of a material under a chemical or electro-chemical action of the surrounding environment. This means that electrical current flows during the corrosion process.

Corrosion is one of the most common causes of failures in the production of oil and gas equipment; such failures include leaks in tanks, casing, tubing pipelines; pumps and after equipment. This involves a number of process where by a metal changes as a result of interaction with the environment. For example the rusting of steel involves a conversion of metallic iron to a mixtures of oxides and other compound which will not only changes the appearance of the metal but also seriously reduces its cross section.

Corrosion and corrosion engineering constitute a science that has only developed within the lifetime of many people working in the field today. This does not mean that corrosion is strictly a modern phenomenon, for it has on the contrary existed since man first discovered ways to make metal ores. It does however, mean the prior to this half-century, the existence of corrosion was passively accepted, along with depth and taxes, as inevitable. In fact, many plants managers in this early period insisted that there was no corrosion. Such evasive attitude however, have changed over the years due to an awareness of replacement economics. This in turn, has created a demand for corrosion prevention specialist now known as corrosion engineers.

Corrosion processes are in many cases predictable from thermodynamic consideration. For example when a metal and some compound of much lower free energy, the interaction is very likely to take place, since system universally tend to seek a lower energy situation.

In the case when Iron is exposed to water and oxygen and corrosion in their presence is certain to occur.

In view of this, it is important for a designer to consider whether a material will corrode in a particular environment and to determine the rate of which it takes place.

It is difficult to predict the rate of corrosion reaction by energy because many factors may intervene in such a way as to restrain its progress. An example of this is afforded by aluminum and its alloys which do not rust when exposed to air and water but give satisfactory performance in many domestic and Engineering application. The main difference between the corrosion of aluminum and Iron is that in the case of aluminum, there is a rapid production of a tough adherent film of oxide which protect the metal from further attack, so that corrosion substance which affords little protection against continued corrosion.

The environment of corrosion in practice is difficult and will consist of more than one corrosive medium.

The method of product fabrication, such as welding, cold working on mechanical fastening will introduce changes in composition and work hardening which can effect the susceptibility to aid rate of corrosion.

The in-services wear can remove protective films and allow accelerated corrosion. Some of the factor that can affect corrosion include; oxygen, carbondioxide, hydrogen sulphide, wate, dissolve salts, bacteria,metallurgy and environment factors such as temperature, pressure, pressure and $_pH$ of solution.

When corrosion is not controlled in the various system, a lot of damage can be done to the system.

The different forms of attack are: uniform attack, pitting concentration cell, Erosion - corrosion and several other forms.

Having known the different forms of attack involved ,the corrosion can now be controlled. This is done effectively by the use of corrosion inhibitors, cathode protection method and other ways of controlling corrosion.

1.1   OBJECTIVES AND SCOPE OF WORK

Corrosion is one of the most common causes of failures in the production of oil and gas being the major source of income in Nigeria, therefore corrosion control can not be over emphasis.

THE MAIN OBJECTIVE OF THIS WORK OR RESEARCH ARE:

i.   To find out the different corrosion control methods implemented by (SHELL PETROLEUM DEVELOPMENT COMPANY WEST).

ii.   And how effective the measures are.

TO ACHIEVE THIS OBJECTIVES

Case studies were taken of where the corrosion are been implemented by the company.

A detail design of one of the corrosion control method cathodic protection was carried out.

1.2   IMPORTANCE OF CORROSION CONTROL

The importance of corrosion control are in three folds:-

I.   Economic

ii.   Improved safety

iii.   Conservation

ECONOMIC

The first area of significance is economic, including the objective of reducing or material losses resulting from the corrosion of piping, tanks and metal component of machines, casing and tubings.

ECONOMIC LOSSES are divided into:

a.   Direct losses

b.   Indirect losses

Indirect losses. it involves the cost of replacing corroded structure and machinery or their component such as pipelines, tanks, values & the labour employed.

Other example are repainting of structures where prevention of rusting is the primary objective. Direct losses also include the extra cost of using corrosion resistant metal and alloys.

INDIRECT LOSSES

Are the losses which are difficult to asses.

Examples of indirect losses are as follows.

a.   **SHUT DOWN:** The replacement of corroded equipment in an industry causes a few thousand Naira, but shut down of the unit while repair is underway may cost the company millions of Naira per hour in low production.

b.   **LOSS OF PRODUCT:** Losses of all oil and gas through corroded pipe systems units while repairs are made. But leakage of gas may cause fire outbreak of which equipment are burnt down.

c.   **CONTAMINATION OF PRODUCT:** A small amount of copper picked up by slight corrosion of copper piping or of brass equipment will contaminate the liquid passing through it.

    i.   **IMPROVED SAFETY** of operating equipment which through corrosion may fails with castatrophic.

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ii.   The third is conservation applied mostly to metal resources e.g. the wastage of this includes corresponding losses of energy associated with the production and fabrication of metal structures and human effort entering into the design and rebuilding of corroded metal equipment.

CHAPTER TWO

2.0   CORROSION PRINCIPLES

Four things are necessary for corrosion to occur.

1. This provides an electrolytically conductive electrolyte will not support the corrosion process.

2. Anode Area: In which oxidation reaction occurs causing Iron to go into solution.

3. CATHODE AREA: In which a reduction reaction ,occurs with the environment.

4. METALLIC PATH: Electronically connecting the anode - cathode areas. Interfering with oxidation - reduction reaction processes or breaking the metallic between the anode and cathode will contact corrosion. The dynamic of the corrosion process are explained from the illustration in fig 1.

CL

Fe^{++}

SO$_4^{--}$

ELECTROLYTE

ANODE

e -

e -

METALLIC PATH

H$^+$

e -

H$^+$

$\bar{e}$

CATHODE
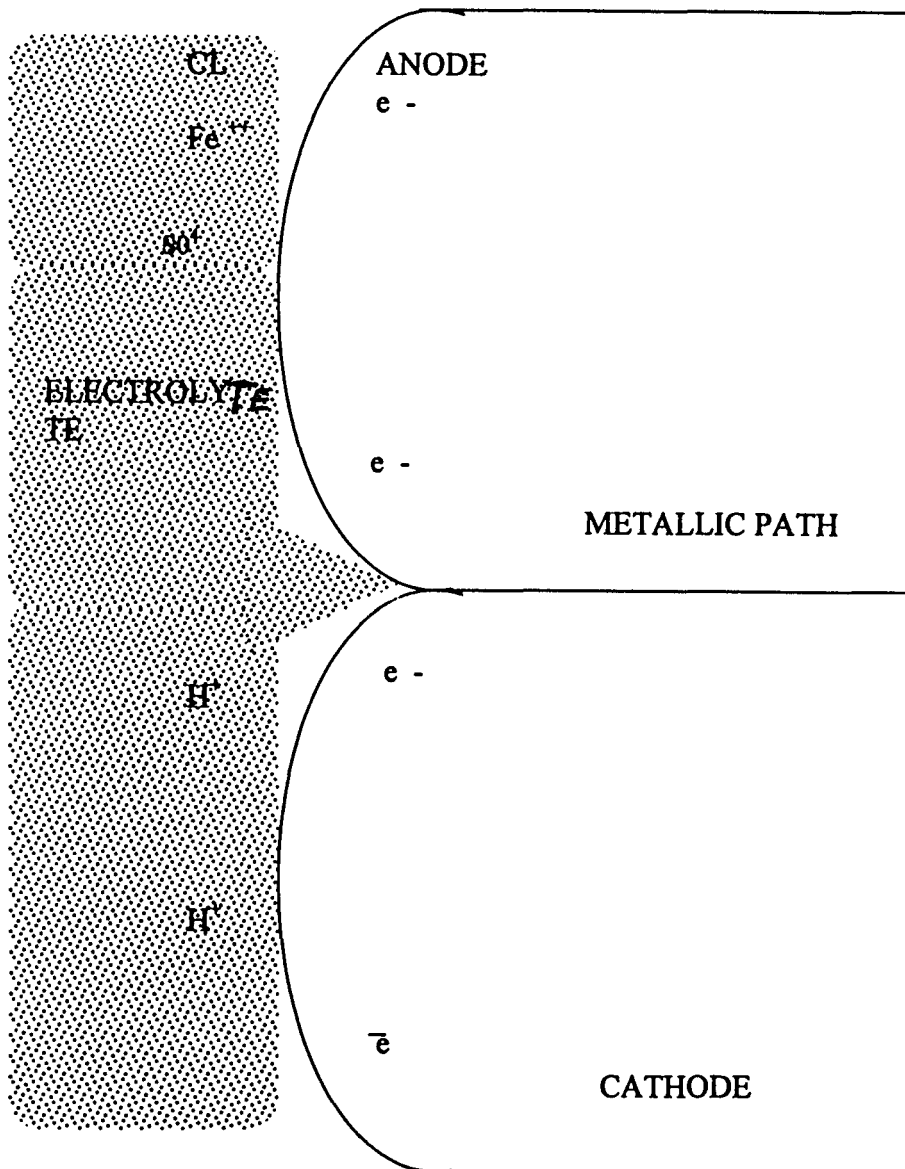
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2.1 TYPES OF CORROSION

There are four types of corrosion namely

1. Sweet corrosion

2. Sour corrosion

3. Oxygen corrosion

4. Electrochemical corrosion

SWEET CORROSION

This type of corrosion occurs as a result of the presence of carbon dioxide and fatty acids oxygen and hydrogen sulphide are not present.

Carbon dioxide is non corrosive in the absence of moisture when moisture is present, carbondioxide dissolves and forms carbonicoxide (H_2So_4)

$$Co_2 + H_2O \dashrightarrow H_2Co_3$$

The carbonic acid causes a reduction in $_pH$ of the water and increases its corrosively.

$$Fe + H_2Co_3 \dashrightarrow FeCo_3 + H_2$$
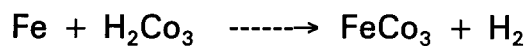
In addition to the acidly produced by carbon dioxide,low molecular weigh organic acids such as acetic acid,contribute to the corrosion. These acids are seldom considered the primary cause of sweet corrosion. Most metals that come in conduct with it e.g.

$$H_2s + Fe \dashrightarrow FexSx + H_2O$$

The Iron Sulphide produced by this reaction generally adheres to the surface as a black powder or scale, water soluble. The released hydrogen ions can react further to the $_pH$ of the water, or they may migrate to the cathode, gain an election and be converted into hydrogen atom end enter the metal at the cathode The presence of carbon dioxide with hydrogen sulphide will increase corrosiveness of the water above that experimented by hydrogen sulphide atom.

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SOUR CORROSION

This corrosion is a corrosive condition that exit where hydrogen sulphide can be detected by analytical means or by odour. Any system that contains hydrogen sulphide is regarded as a sour system even though carbon dioxide or oxygen may be present in higher concentration. Hydrogen sulphide is corrosive in the presence of moisture and becomes severely corrosive when carbondioxide or oxygen is present.

When hydrogen sulphide dissolves in water, the $_pH$ of the water decreases Ionized hydrogen sulphide and entrained H_2S will readily dissolves or corrode most metals that come in contact with it e.g.

$$H_2S + Fe + H_2O \longrightarrow Fe_xS_x + H_2 + H_2O$$

The iron sulphide produced by this reaction generally adhere to the surface as a black power or scale, writer soluble .The released hydrogen ions can react further to reduce the $_pH$ of the water, or 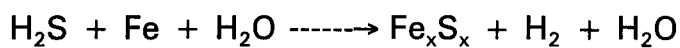they may migrate to the cathode. Gain an electron and converted into a hydrogen atom and enter the metal at the cathode.The presence of carbon dioxide with hydrogen sulphide will increase corrosiveness of the water above that experienced by hydrogen sulphide alone.

OXYGEN CORROSION

Dissolved oxygen in water can cause severe corrosion at very low concentration. The most common form of oxygen corrosion is rusting. Oxygen reacts with steel to form oxide which reduces the metal to its native state.

$$3Fe + O_2 \longrightarrow Fe_2O_3$$
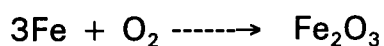
Oxygen, plays three major roles in corrosion

a.   <u>AS A VAPOLIRIZER:-</u>

This means that it will remove electrons from the cathode and cause the corrosion reaction to proceed a rate limited by the ability of oxygen to diffuse to the cathode. More energy is required to evolve hydrogen gas at the cathode when oxygen is not

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present. When oxygen is present the oxygen acts as an additional acceptor of electrons at the cathode, reducing the energy requirement and allowing the reaction to speed up. This can be further explained. As the oxygen dissolves in the water combines with hydrogen, oxygen is consumed, but if the water is in contact with air, oxygen from the air will enter the water to maintain the oxygen concentration.

Therefore it will continue to depolirizer the hydrogen and corrosion continues. If however, the water is in a closed system as in a hot water heating system, the little oxygen dissolved in the water is soon consumed and then corrosion stops.

b.   AS A SOURCE OF PASSIVITY:-

Oxygen in higher concentration can retard corrosion: It does this by forming invisible protective films on the metal surface This film can be formed directly by oxygen uniting with metal or it can be formed by oxidizing agents, like nitric acid (HNO_3). In most cases of Iron corrosion, the initial rate of Iron corrosion is much greater than the rate after a short period of time. The chemistry of the reaction of oxygen is explained as follows.

$$2Fe + 3/2O_2 + H_2O \quad 2Fe(OH) \longrightarrow Fe_2O_3 + H_2O$$
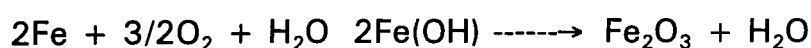
This shows that iron combines with oxygen and water to form rust. This type of corrosion can be identified by the $FeO(OH)$ yellow and Fe_2O_3 (orange) corrosion products.

c.   AS A RUST FORMER

When iron goes into a solution as ions (when it corrodes) as indicated below

$4Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3$ Ferrous ions are formed. Some of the ions will combine with the hydroxyl ions(OH) in the water to form Ferrous oxides $Fe(OH)_2$. This is the black or green deposits next to the corroding metal. On continue   exposure   to   oxygen   and   moisture,   this   change   to   ferric

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hydroxide,$Fe(OH)_3$. Ferric hydroxide is the red rust which forms on the outer layers with mixtures of the two in between.

ELECTROCHEMICAL CORROSION

Electro chemical corrosion is designed as that which occurs when corrosion current can be readily measured or when corrosion can be mitigated by the application of current. In Electrochemical corrosion, oxygen and acids have been referred as the corrosive agent. Let us consider the electrical effects, that can be produced, a simple experiment to determine effects is this - when a piece of Zinc(Zn) is immersed in dilute hydrochloric acid.

2.2 CAUSES OF CORROSION

Corrosion is mainly caused by hydrogen sulphide, carbondioxide and oxygen. These contaminants includes naturally occurring hydrogen sulphide, carbon dioxide.

SULPHATE REDUCING BACTERIA

The most prevalent type of sulphate reducer is the genus desulfovibrio.

Sulphate - reducing bacteria contribute to corrosion by two means

i.   Production of sulphate and

ii.   Removal of hydrogen from the cathode thus allowing the corrosion process to continue which result to a loss of metal at the anode.

These wide spread organism are physiologically unique in that they reduce sulphate ion to sulphide ion. Sulphide is well known for its role in the corrosion process. The second way that sulphate reducing bacteria cause corrosion is that they contribute to condition favourable for electrochemical (oxygen - free) environment.

The Electrochemical basis of this corrosion process is shown below:

Anode reaction Fe Fe^{2+} + $2e^-$

Cathode reaction $2H^+$ + $2e^-$

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The above two reaction occurs stimultaneouly. A reaction of the cathode cannot proceed without a reaction at the anode where the iron goes into solution.

HYDROGEN SULPHIDE

Production of hydrogen sulphide gas by the sulphide reducing bacteria results in a decrease in the $_pH$ of the produced water. The ionized hydrogen sulphide and the entrained hydrogen sulphide gas in water will accelerate metal corrosion .The resulting corrosion by products iron sulphide, a black, water insoluble precipitate.

The reaction of hydrogen sulphide with electrochemical reaction, the presence of dissolved salts accelerates corrosion by increasing the electrical conductivity of the environment .Further more, some are often present in the surface and produces water. These iron interacts in the chemistry of the processes by combining with the metal or forming deposits on metals surfaces. Since most corrosion processes are essentially electrochemical reactions, the presence of dissolved salts accelerates corrosion by increasing the electrical conductivity of the environment. Further more,some salts accelerates certain form of corrosion, such as pitting and stress corrosion cracking.

ACIDS

Organic acids(Formic, Acetic e.t.c) can be formed by bacterial action or thermal degradation of organic addictive/Organic and mineral (hydrochloric, hydroflouric, etc) acids are used as stimulating treatments. Acids cause general corrosion by lowering the $_pH$ and by removing protective films, and a source of hydrogen embrittlement. Dissolved oxygen appreciably accelerates the corrosion attack of acids.

2.3   FORMS OF CORROSION

Corrosion can be classified by the forms in which it manifest itself, the basis for this classification being the appearance of the corroded metals. Each form can be

is often sufficient. Attack is limited to specific areas or part of a structure .As a result they tends to cause unexpected or premature failure of plants; machines, or tools.

GALVANIC OR TWO METAL CORROSION

When dissimilar metals with great potential differences are coupled in the same system or when the crystalline structure of a portion of a metal surface is changed of these metals are placed in contact (or otherwise electrically connected) this potential difference produce electron flow between them. Corrosion of the less corrosion - resistant material is decreased as compared with the behaviour of the metal when they are not in contact. The less resistant metal becomes anode or cathode and the move resistant metal cathode. Usually the cathode or cathodic metal corrodes very little or not at all in this type of couple. Because of the electric current and dissimilar metal involved, this form of corrosion is called galvanic, or two metal -corrosion.

CREVICE CORROSION

Intensive localised corrosion frequency occurs within crevice and others welded areas on metal surface exposed to corrosion. This type of attack usually associated with small volumes of stagnant solution caused by holes, gasket surface. Lap joints, surface deposits, and crevices under bolt and rivet heads. As a result, this form of corrosion is called crevices corrosion is called crevices corrosion, or sometimes, deposits or gasket corrosion.

Example of deposits that may produce crevices (or deposit attack)are sand, dirt, corrosion product, and other solids. The deposits act as a solid and creates a stagnant condition there under. The deposits could also be a corrosion product contact between metal and non - metallic surfaces and can cause crevices corrosion as in the case of a gasket wood, plastics, rubber, glass, concrete

identified by mere observation. In most cases the naked eye is sufficient but sometimes magnification is helpful or required.

Some of the eight forms of corrosion are unique, but all of them are more or less interrelated.

The eight forms are:

    i.   Uniform or general attack

    ii.   Galvanic or two metal corrosion

    iii.   Crevice corrosion

    iv.   Pitting

    v.   Intergranular corrosion

    vi.   Selective leaching or parting

    vii.   Erosion corrosion

    viii. Strees corrosion

UNIFORM ATTACK

Uniform attack is the most common form of corrosion .It is defined as the form of corrosion occurring to the same degree over the exposed metal surface .The metal becomes thinner and eventually fails. For example, a piece of steel or zinc immersed in dilute sulphuric acid will normally dissolve at a uniform rate over its entire surface. A steel iron roof will show essentially the same degree of rusting over it entire outside surface. The figure below shows a steel tank in abandoned gold smelting plant. The circular section near the center of the photograph was thick than the rest of tank. The section is now supported by a "lace curtain" of tank bottom metal.

Uniform attack represent the greatest destruction of metal on a tonnage basis. This form of corrosion, however is not of too great concern from the technical stand point, because the life of equipment can be accurately estimated on the basis of comparatively simple test merely immensely specimen in the fluid involved

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asbestos, wax and fabrics are examples of materials that can cause this type of corrosion.

PITTING

Pitting corrosion is a localized attack resulting in an even surface on holes in the metal surface. The holes may be small or large in diameter, but in most cases they are relatively small . Pits are sometimes isolated or so close together that they look like a rough surface. Generally a pit may be described as a cavity of hole with the surface diameter about the same as or less than the depth.

Pitting is one of the major destructive and isidous form of corrosion. It causes equipment to fact because of perforation with only a small percent only a small percent weigh loss of the entire structure .It is often difficult to detect pits because of their small size and because the pit are often covered with corrosion products. In addition, it is difficult to measure quantitatively and compare the extent of pitting because of the varying depth and numbers of pits that may occur under identical conditions. Pitting is also difficult to predict by laboratory test. Some times the pits require a longtime - several month or a year - slow up in actual service. Pitting is particularly vicious because it is localized and intense forms of corrosion, and failure often occur with extreme suddenness.

INTERGRANULAR

In the process of welding, all metals especially stainless steel are susceptible intergranular corrosion. Proper metals composition, welding procedures and heat treatment are necessary to avoid this form of attack. For example, the Duraluminium type alloy(Al - Cu) are strong because of precipitation of the compound $CuHL_2$ substantial potential differences between the copper depleted areas and adjacent materials have being demonstrated. When these alloys are solution quenched to keep the copper in solution, their susceptibility to intergranular corrosion is very small but they possess low strength.

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SELECTIVE LEACHING

Selective leaching is the removal of one element from a solid by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Similar processes occur in other alloy system in which aluminum, Iron, cobalt, chromium, and other elements are removed.Selective leaching is the general term and describe these processes and it uses precludes the creations of term such as dealuminification, decobaltification etc parting is a metallurgical term that is sometimes applied, but selective leaching is preferred.

EROSION CORROSION

Erosion is the attack on a metal because of relative moment between a corrosive fluid and the wall surface. The cycle of erosion and corrosion if continues presents a very serious problem. All types of production equipment exposed to moving fluids or gases containing suspended solids are subjected to erosion. Generally this movement is quite rapid and mechanically wear effects or abrasion are involved. Metal is removed from the surface as discussed iron, or it forms solid corrosion products that are mechanically swept from the metal surface. Sometimes movement of the environment decrease corrosion, particularly when localized attack occurs under stagnant conditions, but this is not erosion corrosion because deterioration is not increased.

Erosion corrosion is characterized in appearance by grooves, gullies waves, grounded holes and valleys and usually exhibits a directional patterns.

STRESS CORROSION

Stress and corrosion can work together to cause decrease in corrosion resistance allowing acceleration corrosion to occur, or crack. Applied and residual stress in a metal affects the molecular structure which alters the metal corrosion resistance.

During stress corrosion (SCC) the metal or alloy is virtually unattacked over most of its surface while fine cracks progress through it. This cracking phenomenon has serious corrosion cracking are "season cracking" of brass and the "caustic embrittlement" of steel, both of these obsolete terms describe the environmental conditions presents that led to stress corrosion cracking. Season cracking refers to the stress corrosion cracking factor of brass cartridge cases .During periods of heavy rainfall, especial in the tropics, cracks were observed in the brass cartridge cases at the points where the case was crimped to the bullet .It was later found that the important component in season cracking was ammonia resulting from the decomposition of organic matters

CHAPTER THREE

3.0   FACTORS AFFECTING CORROSION

WATER

The liquid form is necessary to support corrosion processes. The electrolytic conductivity of water is increased as dissolved inorganic salts increase corrosion reaction almost always increase with an increase in salt concentration. The type of salt or ions influence the degree and form of corrosion attack. As an example chloride as combine with steel forming; corrosion reaction may proceed on a continuous basis. Electrochemical reaction promotes chloride ions and hydrogen ions in pits which form hydrochloric acids and accelerates corrosion. This process is known to occur in crevices under deposits or in pits sea water has a mixtures of salt which enhances corrosion and promote mineral scaling and bacterial corrosion attack.

CARBON DIOXIDE AND HYDROGEN SULPHIDE

These two acid forming gases represent the most difficult corrosion problem in oil and gas producing wells. These gases accelerates corrosion, promote pitting attack and form insolute corrosion by product that result in equipment failing and formation plugging hydrogen. Hydrogen sulphide greatly increase hydrogen embrittlement corrosion attack.

OXYGEN

Oxidation of metal is considered the largest worldwide corrosion problem. In production operation oxygen presents a series of difficult to control problem oxygen combines directly with steel causing corrosion. Forming Iron oxide corrosion products. Irons in solution also combines with oxygen resulting in insoluble precipitates. The precipitates causes fouling and plugging oxygen

strips protective hydrogen from metal which indicates corrosion reaction under deposit and crevices. These electro - chemical reaction often causes severe pitting that can become self - perpetual if not controlled. The presence of oxygen also reduces the protective qualities of corrosion acceleration.

Careful analysis of trace qualities of oxygen is critical in keeping system closed to oxygen entry.

Increased corrosion usually occurs when oxygen combines with carbon dioxide and hydrogen sulphide.

MICRO ORGANISM

Bacterial corrosion problems are receiving more attention in production operation as improved analysis methods aid in measuring their effects .

Sulphate-reducing, slime forming and Iron oxidizing bacterial are the most common types recognized . They produce and gases (CO_2 H_2s)remove protective hydrogen films and form slime which fouls equipment and plugs injection wells.

METALLURGY

Impurities in a metal created during the refining and forming of that metal and irregularities or had spots, make susceptible to the effects of corrosion mill scale which remains on the metal can contributes to localized attack as well.

OTHER FACTORS

Temperature, pressure and flows rate directly affects corrosion processes. Increased temperature almost always increase corrosion as it tends to accelerates chemical reaction .Exception to this trend do exist such as reduced corrosive gas solubility with increased temperature thus reducing corrosion. Pressure is related o the solubility of corrosive gases in a liquid. The greater the pressure, the greater the tendency of a gas to go into solution and cause corrosion.

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This condition is expressed as partial pressure and relates to CO_2 and H_2S and oxygen corrosion attack. Flow rate cause physical removal of protective films and increase corrosion attack.

3.1 CORROSION DETECTING AND MONITORING

An effective corrosion prevention program in oil and gas production operation requires continual analysis and evaluation of the corrosion problem and selected treatment programmed. While some techniques have significant limitation to be considered several metallic can effectively be used to detect various corrosion problems and top determine the severity to these problems.

ANALYSIS OF PRODUCED FLUIDS AND GASES

Analysis of the produced oil for the water for $_pH$ and dissolved gases and of the produced acids gases can give an indication of other corrosion.

EQUIPMENT INSPECTION

Visual inspection of production equipment failed in service provides date on the existence and severity of a corrosion problem. The form of corrosion can also be determined .

Visual inspection is particularly useful in gas condensation well where corrosion is aggravated by turbulence. Unless inspection is conducted on a total system, the extent of the problem throughout the system may not be known.

3.2   CORROSION CONTROL METHODS

(IN SHELL PETROLEUM DEVELOPEMENT COMPANY)

The most comon techniques used to minimise corrosive attack are as follow:

1.   Removal of water and oxygen from the process stream

2.   Use of material which resist the corrosive environment.

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3.   Coating metal surface with, for example, plastic,cement and paint.

4.   Cathodic protection.

5.   Use of inhibitors to retards the chemical reaction between the metal and the corrosive environment.

CONDITIONING OF THE PROCESS STREAM

DRYING

The long life diameter pipeline which transport gas from offshore to land will be subject to serious internal corrosion by carbondioxide and /or hydrogen sulphide unless the gas is dried. (Experiment have shown that a sweet gas should be dried even if the CO_2 partial pressure is as low as 1PSI). Gas transport line are often protected by an offshore drying installation.

OXYGEN REMOVAL

Where possible, the oxygen content of the process stream is reduced by gas stripping. A lower limit of 0.3 to 0.4 ppm can be reached. This followed by injection of an oxygen scavenger (e.g sodium sulphite Na_2co which futher reduces the oxygen content to about 0.005ppm.

CHOICE OF MATERIALS

Of all the regular API grades, the indications are that J-55 low alloy steel is more resistant to sweet corrosion than the higher grades, although there is no objection to using the latter (assuming there is no possibility of future H_2O corrosion) If considerations dictate.

The sulphide stress corrosion cracking which may occur,in a sour environment is more severe in high strength than in low strength materials or materials with a high strength but heat treated to keep their hardness below a critical level is Rc22 (or a maximum allowable tensile strength of about 110000psi) It has been shown that 'fully quenched and tempered' heat treatment (Q + T) gives the best protection against H_2O attack. API grade L-80, which has a specified maximum hardness of

Rc23, has been accepted by the industry for sour enviroment service because of its specified pyhsical and chemical properties and its Q + T heat treatment. For more detained information on the selection of materials four service, refrence should be made to the least edition of NACE Standard MR -01-75.

To aviod local stress concentrations in exsess of the critical value, the following rules should be observed:

1. Joints should be carefully handled while making up, avoiding dents and teeth marks by tongs and wrenches.

2. Cold die stamps are prohibited; all markings should be painted on.

3. Used, cold-straightened tubulars are not acceptable for H_2S ser vice below $80^{0}c$ ($175^{0}F$).

4. Oxy-acetylee cutting of cadsing and tubing is not permitted.

COATING

PIPE COATINGS

Conventional hot-applied bitumen or coal tar coatings (containing iner filler such as talc or slate dust) are the most widely used for buried and underwater pipelines. Coatings are applied at the pipe mil, in a coating yard, or 'over-the-ditch'. For submarine lines greater than 25cm (10in) diameter, a layer of dense concrete (containing barytes or other heavy materials) is often applied over the coating to provide negative buoyancy and additional protection during the offshore laying operation.

Plastic tapes have sometimes been used, especially for on-site work,due to their ease of application using relatively simple wrapping equipment. The duplex type of tape consisting of an outer layer of PVC with an inner layer of butyl rubber (total thickness 0.625mm), applied either in one or two applications over an adhensive primer, is normally recommended for buried lines. The applied tape is susceptible

to mechanical damage and consequently is preferably laid 'over-the-ditch'. Laying and back filling of the coated pipe must be done with care.

Extruded plastic coatings consist of polyethylene extruded directly on to primed pipe lengths. The special soft adhesive primer layer is used not to ensure good adhesion but also to seal any perforations in the outer coating caused by mechanical damage. Coating thickness varies with the pipe diameter from about 0.6mm for small diameter pipe to about 4 to 5mm. For 12in to 16in diameter pipe. sintered polyethlyene coatings (i.e pipe coatings based on powdered polyethylene 'sintered' or fused on to the heated blast cleaned pipe) are finding increased use, their performance being similar to that of the extruded system mentioned above.

INTERNAL PIPE LININGS

Concrete linings may be applied to line pipe at the pipe mill or on site by centrifugally spinning. Cement linings are used for salt water supply and return lines, salt water ballast lines, fresh domestic water lines, industrial and domestic sewer lines as well as tanker discharge lines.

The thickness of the concrete lining depends mainly on pipe diameter and range from 1/8in to 1/2in. Concrete lining may also be carried out on existing pipelines by in-situ methods. Such processes, which must be carried out by specialist contractors, are particularly suitablefor badly corroded or even leaking lines. Lining up to one inch thickness can be applied in such cases. The method has been usedon existing tanker discharge lines which have been perforated as a result of line clearance with salt water.

Hot applied bituminous linings give satisfactory results in water service; however, they cannot be recommended if extreme turbulence is encountered, or if there is a risk of barnacle growth. These linings are normally applied at the pipe mill.

Similarly, hot applied coal tar linings may also be used, except that in general these are not suitable for drinking water service.

The following types of epoxy resin linings are suitable for lines carrying salt water:

a.   Amine-cured Epikote

b.   Epikote coal tar

c.   Epikote phenolic stoving lining

It is recommended that all Epikote lining of pipes for salt water services should be carried out at the pipe mill; the first two Epikote linings mentioned may be applied on site if adequate equipment is available. In this instance the lines should be blast cleaned and lined in sections.Internal welds should be blast cleaned and coated for each length of line laid. Epikote lined pipes cannot be welded without damaging the coating. This damage may not be important when the purpose of the coating is to reduce contamination of a product by rust, but lines carrying salt water or other aggressive materials should be flange-jointed..

Hot dipped galvanized pipe is used to a limited extent but mainly for small diameter domestic water, lines and as an alternative to concrete lining for product lines cleared with salt water.

TANK LININGS

The various epoxy resin coatings mentioned above may also be used for tank. Application is easier in view of the greater accessibility, especially in preparing and coating internal welds. In general, the coal tar Epikote linings are used for crude oil and water service, where as the amine-cured epikote is more frequently usedto prevent contamination of refine products.

PROTECTION OF OFFSHORES STRUCTURES

The area of offshore platform to be protected can be divided into four broad zones.

a.   Mud zone

b.   Under water

c.   Splash and tidal zone

d.   Above water

The mud and under water zone of north sea platforms installed and not coated but are cathodically protected with aluminium sacrificial anodes design to provide protection of the uncoated structures for twenty to twenty five years. Other oil company blast clean and coat the under water jackets with epoxy coal tar as applying cathodic protection. This techniques reduces the overall current density required, at least in the early years of the platform life. Subsequent maintainance of under water coating is not very practicable. In the case of shell/ Esso structures it is felt that the higher cost of cathodically protecting an uncoated platform is more than offset by the saving on the blast cleaning and coating.

For those areas in the splash zone and above the splash zone, a number of different types of coatings are used (including monel, zinc silicates, epoxy, epoxy tar, vinyls, e.t.c) Two requirement are essential in every case, viz. a high standard of blast cleaning and the proper application of an adequate film thickness to the selected system.

PAINTING

A paint is any material apply as a liquid whichon solidification is firmly and continuously attach to the structure which is designed to protect and which prevent contact of the environment with the structure. Painting may be applied to enhance appearance of the structure and also prevent corrosion of a metal surface. There are certain basic factor which must receive careful attention if satisfactory

protective life is to be obtained from a coating application: These are:

1   Condition of exposure

2.   Nature of base metal to be protected.

3.   Environment

4.   Surface preparation

5.   Selection of coating Materials.

6.   Application of coatings.

7.   Inspection.

8.   Maintainance of the coating surface.

In general the conventional on-shore paint system consists of red lead/ red oxide (oil based) primer (2 layers) and 2 layers of top coat. The latter is often an oil based aluminium paint of alkyd enamel paint pigmented in the required colour. To reduce maintainance it is found economical to sand blast or pickle tank plates prior to paint application.

Structural steel is usually only mechanically cleaned prior to painting. Unburied pipes in oil fields are usually not painted as they are often in a non-corrosive atmostphere, an appearance is not very important. For more corrosive atmospheric conditions.

Experiments have shown that in certain circumstances, corrosion at the sea proceeds about five times faster than it does 400meter in land. Although this result is obviously dependent on winds direction and climate, it is clear that paint system for offshore platforms and installations very near the sea must be more corrosion resistant than those used in land. This system have to be apply on blast-clean steel.

In the tidal zone of an offshore platform, the structural steel is thicker than elsewhere (an extra 3/4in for 25 years), is faced with monel, and is coated with Epikote coal tar paint. The reasons for the extral thickness of steel are that paint is easily damaged, cathodic protection is not fully effective and the corrosion rate is high in this zone (although cathodic protection moderates corrosion in the splash zone.

Above water, i.e in the atmostpheric zone, offshore structures are coated with Epikote coal tar paint overcoated with conventional paint (alkyd enamel) where a lighter colour is required for the sake of appearance. It is recommended that equipment on the platform should be protected by a zinc primer, preferably zinc-rich Epoxy,plus two coats of high-build epoxy. Equipment under cover is often painted with the conventiOnal paint system .

CATHODIC PROTECTION

Cathodic protection is perhaps the most important of all approaches to corrosion control. By means of an extremally applied electric current, corrosion is reduced virtually to zero, and or metal surface can be maintained in a corrosive environment without determination for an indefinite time.

When a metal is immersed in an electrolyte, a multiplicity of galvaniccell is set up and metal ions go into solution at the anode of each cell, i.e. corrosion takes place at anodic site. If a so call sacrificial anode i.e a sheet or block of calculated size of some metal whose electrode potential is positive with respect to that of the metal of the structure is attached to the latter, the entire structure becomes cathodic wuth respect to the sacrificial anode. The result is that corrosion of the structure cease or is reduced at the expense of loss of metal from the sacroificial anode. The under water zone of an offshore platform is not usually painted but is provided with cathodic protection. Blocks of aluminium alloy are weld to the steel

structure, their size and number been calculated (Knowing the current flow) to provide protection of the structure for a numbers of year, after which they are renew.

i.   SACRIFICIAL ANODE METHOD

In this case the electrolyte is provided by the damp earth in which the pipe is buried. The sacrificial anode is consumed. It must be replaced periodically

ii.   IMPRESSED CURRENT METHOD

A minimum current density (current/ unit surface area) is necessary for adequate protection of the pipe. The resistance of the electrolyte may be a factor in preventing this density from being conventionally obtained. A quantity of metal (e.g. steel scrap) is buried near the pipe and connected to it through a d.c power supply which maintains a difference sufficient to ensure that the pipe is cathodic to the 'ground bed' which is the name usually given to the burried metals.

GENERAL APPLICATION OF CATHODIC PROTECTION

Cathodic protection requires a source of direct current and auxillary electrode (anode) usually iron or graphite located some distance away from the protected structure. The d.c source is connected with its positive terminal to the auxillary electrode and its negative terminal to the structure to be protected.In this way current flows from the electrode through the electrolyte to the structure. The applied voltage is not crtical it needs only be sufficient to supply and adequate current density to all part of the protected structure. In soil or water of high resistivity, the applied voltage must be higher than in environment of low resistivity.

It is now believed that almost every offshore structure used in the petroleum industry is now under cathodic protection, since is relatively easy to polarise steel

in sea water. The calcareous deposit formed by polarization is effective in reducing the exposed area of steel so that there is little advantage in coating the submerged portion of the structure. Cathodic protection is an effective and economical way of corrosion control in oil and gas production.

CORROSION INHIBITORS

An inhibitors is a substance which retards or slows down a chemical reaction. It is a substance when added to an environment, decreases the rate of attack by the environment on a metal. It is a retarding catalyst.

CHAPTER FOUR

4.0   SELECTION OF CORROSION INHIBITORS

In selection of corrosion inhibitors must take into account the many different well condition. The type of well completion and the fluid level of the well can dictate the method of application. The type of production also determine the treatment method. The rate of production as it relates to economic and efficiency and produced oil/water ratio influence the selection of an inhibitor.

Analyzing produced water, acid gasses, crudes and distillates will play an important part in determining which inhibitor will be most effective.

Selection of an inhibitor for field use requires a general knowledge of the characteristics of corrosion inhibitors. The degree of protection is affected by many factors including the composition of the fluid environment and the type of metal or alloy.

The molecular structure of the inhibitor should enable it to absorb strongly to a surface there by producing a uniform film. Film persistances or the ability to resist film removal from the metal surface, is affected by composition of the fluid environment, fluid velocity,type of surface, temperature of the system and the length of time the inhibitor is in contact with the metal.

COMBINATION OF INHIBITORS

This chemical inhibitors are formulated to control two or more problems. Corrosion inhibitors/ microbisides and corrosion/scale inhibitor combination are available. These and other formular also provides excellent surface properties.

4.1   CORROSION TEST

It is a known fact that oil does not cause corrosion, but the associated substances do, such as water, carbondioxide and hydrogen sulphide.

The test below were carried out. The samples were obtained from three different locations owned by shell petroleum development company.

CORROSION AGENTS	FIRST FIELD	SECOND FIELD	THIRD FIELD
CATIONS			
Total Hardness	2.12 ppm	2.56 ppm	4.00 ppm
Calcium ca^{++}	1.16 ppm	2.0 ppm	2.35 ppm
Magnesium Mg^{++}	0.96 ppm	0.56 ppm	1.65 ppm
Iron Fe^{++}	0.0027 ppm	0.0038 ppm	0.0016 ppm
Barium Ba^{++}	0.0291 ppm	0.0721 ppm	0.0146 ppm
Sodium Na^{+}	107.89 ppm	243.188 ppm	165.7494 ppm
ANIONS			
Chloride	84.254 ppm	219.4366 ppm	146.4789 ppm
Surlphate	0.1458 ppm	0.2083 ppm	0.0417 ppm
Carbonate	1.06 ppm	1.48 ppm	1.24 ppm
Hytroxyl	0.00 ppm	0.000 ppm	0.00 ppm
Sulphide	0.0406 ppm	0.1406 ppm	0.025 ppm
Bi-carbonate	24.57 ppm	24.56 ppm	21.98 ppm
DISSOLVED GASES			
Hydrogen Sulphide	-	-	-
Carbondioxide	-	-	-
Oxygen	-	-	-
PHYSICAL PROPERTY	7.77	7.74	7.81

4.2   CASE STUDY NO.1

INTRODUCTION

A gas well was lost due to corrosion of tubing and casing after only two years on stream. It has been completed at 16,000ft. Corrosion control measure were

recommended for a new well to be drilled to replace the lost one. The cost of the original well and drilling a replacement well was sizeable.

The replace well was completed and from the begining was treated with COAT-C 1815, corrosion rate since then have been minimal and no problem been encountered.

The initial production data for the replacement well were as follows :

Production---gas MMcf/day	5
Condensate, bbl/day	132
Water, bbl/day	145
Bottom hole temperature F	278
Flowing temperature F	92
Flowing pressure, psi	9,000
Shut in pressure, psi	10,000
Packer fluid	lignosulfonate mud plus biocide
Gas composition % co2	2.42

Tubing -$2^7/8$

At the conclusion of testing the new well iron counts were recorded at 78ppm indicating severe corrosion.

Following an initial batch treatment of a drum of COAT---c1815, daily injection of five gallons through a macaroni iron counts were reduced to 38ppm. corrosion probe injection rate of COAT-c1815 was reduced to 0.85 mpy. The injection rate of COAT-C 1815 was reduced to 3 gallons per day after six month.

Following the discovery of a minor corrosion erosion problem in the production, a new choice was made a few months later, the chemical injection rate was increased to 4 gallons daily, a rate which has been maintained to the present.

The table below summarises the available corrosion monitoring data of the new well.

	FE PPM	CL, PPM	CORROSION PROBE, PPM	COAT-C1815 TREATING RATE GAL/DAY
YEAR 1	25	250	0.85	3
YEAR 2	19	250	1.06	3
YEAR 3				
END - FEBRUARY	12	12.5	1.2	3
MID - MARCH	34		1.3	4
MID - APRIL	32	175	0.25	4
BEG - MAY	22	150	0.75	4
END - MAY	28	125	0.75	4
END - JUNE	20	150	0.75	4
MID - AUGUST	17	125	0.65	4
BEG - SEPTEMBER	18	150	0.75	4
MID - OCTOBER	18	1500	0.70	4
MID - DECEMBER	17	125	0.4	4
YEAR 4				
BEG - FEBRUARY	17	125	0.45	4
BEG - MARCH	17	200	0.50	4
BEG - MAY	19	135	0.4	4
YEAR 5				
END - JANUARY	13	125	0.3	4
YEAR 6				
END - FEBRUARY	6	400	0.4 ~~0~~	4
YEAR 7				
MID - JANUARY	18	600	0.19	4
END - JUNE	10	500	0.18	4

The original well has been treated with 55gallons of a weighted competitive corrosive inhibitor by tubing displacement three months after being placed on

production. A second and identical treatement had been given nine moths latter just four months before loss of the well.

CASE STUDY NO 2

Condition of two wells were as follows.

Gas composition	2% H_2S, 3% CO_2
Bottom Hole Temperature	165-170°f
Pressure	25000 psi
Initial Production	3mmcf/day
	50-100 bbl/day condensate
	3-5 bbl/day water
Current Production	0.75mmcf/day
	10-12 ppf/day condensate

Corrosion treatment was initated imediately upon completion of the wells. Each well has been treated by introducing inhibitors into the wells the result of the monitoring of the two wells are as follows:

	WELL No. 1 AVERAGE CORROSION RATE (MPY)	NUMBER OF COUPONS	WELL No. 2 AVERAGE CORROSION RATE (MPY)	NUMBER OF COUPONS
YEAR 1	1.27	4	1.54	4
YEAR 2	1.38	7	2.0	7
YEAR 3	1.37	9	7.05	9
YEAR 4	0.36	7	3.75	7
YEAR 5	0.30	4	1.16	4
YEAR 6	0.66	4	0.30	6
YEAR 7	0.39	4	0.14	3
YEAR 8	0.18	2	1.22	2
YEAR 9	0.06	2	0.13	2
YEAR 10	0.35	8	0.48	8

The wells were never pull down by corrosion inthe ten years of treating them with inhibitors. These excellent result with inhibitors have resulted in the customer using the product for corrosion inhibition in a newly open gas field.

CASE STUDY NO 3

INTRODUCTION

This large independent producer was experiencing aggravated repeat failures on a producing well. At the time some professional were asked to evalute the situation. The well has failed due to rod or tubing failure 13 times in twelve months Well services and related cost during that period were estimated at approximately $94,000. Several factors were identified by the professionals as contributing to the problem. The producing zone contain sour gas. The well produced large volumes ofwater (200 + BWPD)and maintained a fluid level in the annulus.

The well was then treated four times a day with two quarts of inhibitors each time eight months after this program was initiated only one corrosion related failures had occured.

CHAPTER FIVE

5.0   DESIGN PROJECT

PRELIMINARY SURVEY

Corrosion is an electrochemical reaction of a metal or alloy with its environment that results in degradation of the metal or alloy.some parts of the metal(s) tend to become positively charged (anodic) and otherparts negatively charged (cathodic).At the anode areas the metal normaly dissolves and corrosion occurs. This can be eliminated by bring anodic and cathodic areas artificially to approximately the same potential. This technique is called cathodic protection (cp).

In 1823, Sir Humphrey Davy was commissioned to investigate the the corrosion of the copper sheathingof the hills of wooden naval ships, the admiralty were the first user of cathodic protection.

Davy experimented with anodes of tin, iron and zinc to protect the copper. The last two metal were used and in a later later paper (18240) he favour the used of cast iron because it lasted longer and remained electrically more active than zinc remained in used, however, and no doubt it have considerable protection to the the copper sheathing. though there was every reason to be that zinc would successfully protect steel, its continued use seems to have rested more on traditon. The zincs were placed closed to the stern gear and yellow metal parts such as circulating pipe inlets, as these areas proved to be most susceptible to corrosion. zinc were reported as being in sound orders, that is corroded, and this was often regarded as good practise.

Since the begining ofthe present century liquid and gaseous fuels have been pumped through underground pipe lines made of steel or iron.The extensive

network of oil pipe lines that were installed in america in the 1920s presented a vast corrosion problem. To an oil company a single leak from pipe lines can cause numerous losses and many include: loss of commodity,contamination of water supplies and loss of livestock, all of which leads to a detetrioration of public relations. In the early thirties all the major pipelines owners were applying anti - corrosive measures to the external protection of theor pipes including various coating cathodic protection. The schemes were applied to the worst sections where the pipes had been laid. In corrosive soil and great success were achieved. The cathodic protection was derived from zinc anodes or from impressed current supplied either by D.C wind generators or by transformers or copper oxide rectifiers or a.c power supplies.

The other area where oil pipelines were used extensively was the middle East. The first installation protection a group of sea water loading pipelines at Bahram 1939 from early begining cathodic protection has developed rapidly and has become widespread. New material such as artificially alloys of magnesium and aluminium and superior impressed current anodes together with development in eletrical and eletronic engineering have allowed great advances in the techniqu. Cathodic protection in now established as an essential engineering service with a sound.

5.1   DESIGN PROBLEM STATEMENT

This work is to design a cathodic protection equipment or process with a magnesium anode and impressed current system to protect 50km buried pipe line from corroding.

+

−

A

C

B
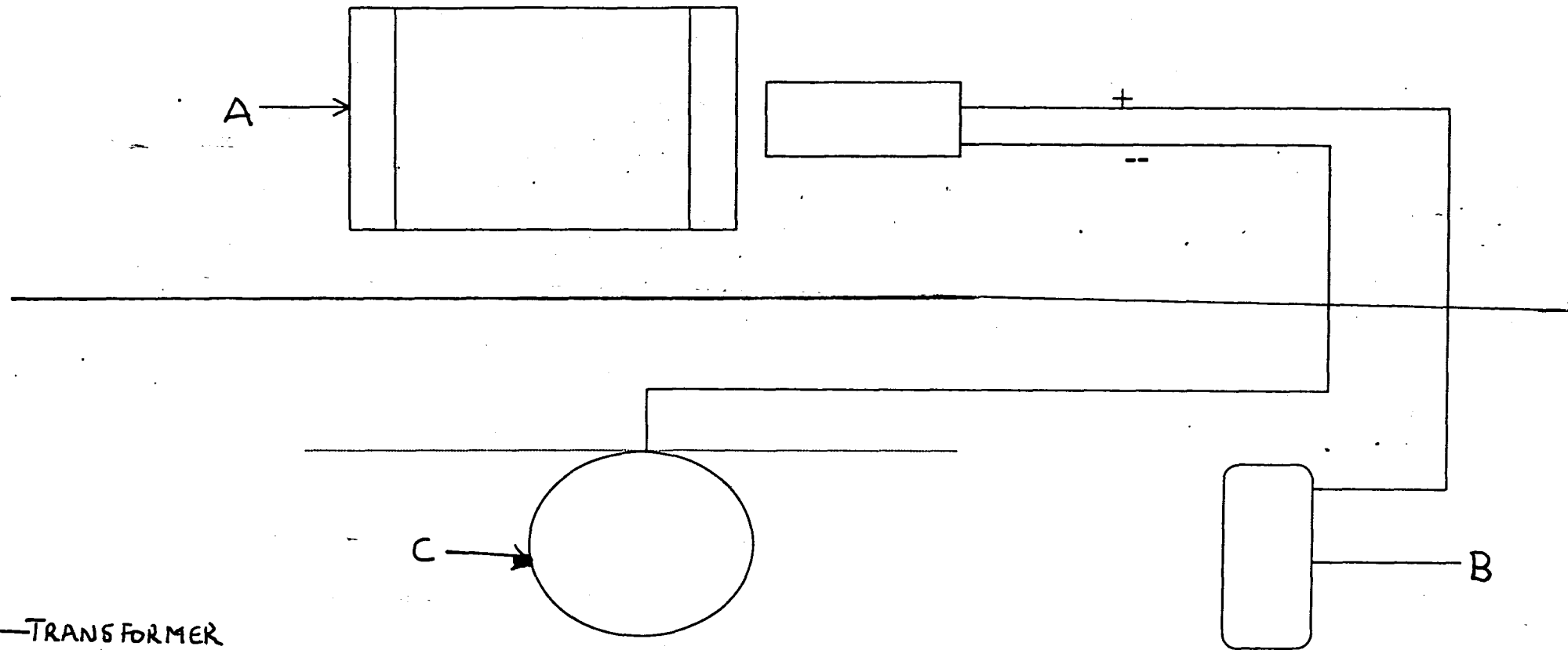
A —TRANSFORMER
RECTIFIER UNIT

B —ANODE MATERIAL

C — CATHODE (PIPE)

SCHEMATIC FLOWSHEET OF CATHODIC PROTECTION

PROCESS OR EQUIPMENT

MATERIAL BALANCE CALCULATION FOR A CATHODIC

PROTECTION EQUIPMENT

5.2 TO PROTECT A BURIED PIPE OF 50KM
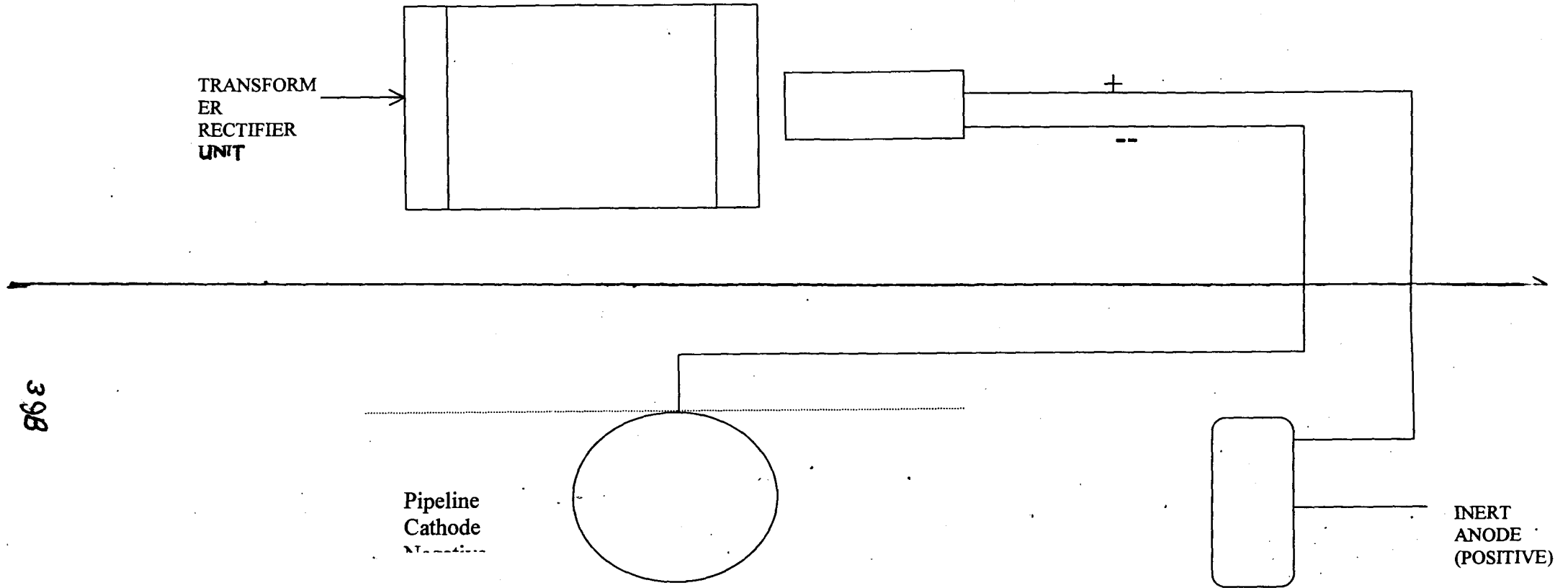
The following data are required

Basis: 50km pipe made of mild iron (at the cathode)

A Diameter of 6000mm = 6m

Basis: $32mA/M^2$ Current

Material for the anode that will be used for the protection: Magnesium

CATHODIC PROCESS DIAGRAM

TRANSFORMER
ER
RECTIFIER
UNIT

+

--

Pipeline
Cathode

INERT
ANODE
(POSITIVE)

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The surface area of the pipe = $2\Pi rL$ = $2 \times \Pi \times 3 \times 5 \times 10^4 m$ = $942600m^2$

Surface Area of the pipe to be protected will be $942600m^2$

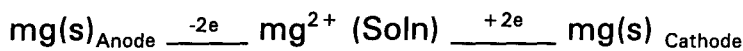The total current needed to protect the surface Area.

I = current = $32mA/m^2$ = $0.032A$.

I = 1 x A. = $0.032A \times 942600$ = **30163.2A**

Total current required for the protection of the pipe = **30163.2A**

Equation of deposition (ionic equation)

$mg(s)_{Anode}$ ___-2e___ mg^{2+} (Soln) ___+2e___ $mg(s)$ $_{Cathode}$

I mole of electron _____ 1 fara day

1 fara day _____ 96500 coulombs

2 moles of electron _____ 2 fara day

2 moles of electron _____ 2 x 96500 coulombs.

Chemical equivalent of magnesium = $\dfrac{molar\ mass\ of\ mg}{no\ of\ mole\ of\ electron}$

$E = \dfrac{24}{2} = 12$

Substance liberated per coulombs of electricity = $\dfrac{1}{96500}$ gm equivalent

Electrochemical equivalent = Z = $\dfrac{1}{96500}$ x $\dfrac{12}{1}$

$= \dfrac{12}{96500}$ = **1.244 x 10⁻⁴**

I = 30 163.2A

T = 1hr = 36secs

Therefore magnesium deposited on the cathodic for 1 hour

mass = Zit = $1.244 \times 10^{-4} \times 30163.2 \times 3600$

= 13503.11g of magnesium is deposited to protect the cathode (pipe)

Mass = **13.503kg**

∴. The mass that will be deposit for 24 hours = 24×13.503 = 324 kg/day

Thickness = $\dfrac{\text{Volume}}{\text{Area}}$

Volume = $\dfrac{\text{Mass}}{\text{Density}}$

Thickness = $\dfrac{\text{Mass}}{\text{Area x Density}}$

Mass = 13.50kg

Density = 1750kg /m^3

$= \dfrac{13.50}{17.50 \times 942600}$ = **8.184 x 10-9 m/nr**

For 1 hour the thickness _____ 8.184 x 10^{-9}m

∴ 24hr _____ 8.184 x 10^{-9} x 24

$= 1.96 \times 10^{-7}$ m

= **0.1964μm**

For the material balance for a cathodic protection equipment for a buried pipe of 50km.

Mass loss by Anode = Mass gain by cathode

Mass loss by the Anode = 324kg /day

Mass gained by the cathode = 324 kg/day.

5.3 ELECTRICAL HEAT ENERGY BALANCE

E_h = IVT

I = Current = 30163 .2A

V = Voltage = 12V

T = Time = 1hr.

E_h = 12 x 30163 x 3600 = 1296000 J = 1296kJ

5.6 SIZING

Length of the pipe 50km $= 5 \times 10^4$ m

Diameter of the pipe $= 6000 \times 10^{-4} = 6$m

Surface Area of the pipe $= 2\Pi rL$

$\qquad = 2 \times \Pi \times 5 \times 10^4 = 942600$m^2

Surface Area of the pipe $= \underline{942600m^2}$

Thickness $= \underline{0.1964\mu m}$

Current required $= 32$mA/m^2

Current required for 24hrs $= 30163.2$A

5.7 COST ESTIMATION AND OPTIMIZATION

Variable Cost 　1 kw Cost ₦20 The Total Current require for the protection of the pipe for 24hrs is 30163.2A	
The Voltage required is 12V	
The Power required will be $P = IV$ 　$= 30163.2 \times 12 = 36195.4$ watt 　　　　　　$= 361.96$ kw	
Load Charge　$361.96 \times$ ₦20 $=$	₦7,239.20
Cable (3 core cable) 　0.45m COST ₦50 　20m of Cables at ₦50 for 0.45m	₦22,222.30k
Anode Material (Magnesium) ₦2,500 per kg 100kg of Magnesium (metal) at ₦2,500 per kg	₦250,000.00
Pipe ₦10,000 per km 50 km of mild iron steel at ₦10,000 per km	₦500,000.00
Fixed Cost for Electricity Supply	₦120
Cost of Labour	₦20,000
Cost of maintenance 5% of Total Cost.	₦39,979.07
Total Cost of Production of a Cathodic Equipment to Protect 50km Buried Pipe from Corroding	₦839,560.46

5.8 PROJECT EVALUATION

Cost estimation is a specialised subject and a profession in its own right. The accuracy of an estimate depend on the amount of design data available, the accuracy of the data available, and the time spend in preparing the estimated will be required, and justified by the amount of information been developed.

The method usually used to update historical cost data makes use of published cost indices. These relates present cost to past cost and are based on data for labour material and energy cost published in government historical digest.

The cost of the design is optimized by using a scrap metal at the anode than magnesium anode. But for the power source the cost is constant.

5·9 ANODE MATERIAL

Generally numerous materials are available for protecting or coating against corrosion. The suitability of those material depend on their properties and the ability of the anode material to protect the cathode effectively

For this process a magnesium Anode is chosen, magnesium can be used in soils with a specific resistivity up to 5000ohm CM it has a relatively low efficiency (approximately 50%) magnesium is used in Sea water only to Polarise steel quickly in case of emergency. The driving voltage in sea is high (approximately 700MV) Typical application are use for protecting the surface of under ground long casing pipes, on roads and railway crossing.

For estimates of current requirement for a magnesium Anode is 32mA/m^2 in soil and 50 - 00 mA/m^2 in sea water. Therefore Anode material can effectively protect an iron pipe surface from corroding. The Anode material to be use must be a less noble metal than the structure to be protected, capable of dissolving slowly and supplying the current for the structure to be protected

5·10 SAFETY

In Cathodic protection Electricity is one of the vital requirement/material needed, therefore safety has to be put into great consideration.

As a rule the equipment should be installed in high rooms with good ventilation. The ventilation system should always take the exhaust air at low level and supply the fresh air above.

Electrical shock can be avoid if necessary precautions are taken

i   Do not forget to put off the main switch and take away the fuse carrier along, while working on an installation.

ii.   Do not forget to earth all metallic covering of the electricity wiring installation. The main objective of earthing is to reduce as much as possible the amount of current available for passage through human body in the event of occurrence of current leaking from the live conductor to the earth.

iii.   Do not allow unauthorised persons to touch or handle electrical apparatus or come within the danger zone of high voltage apparatus. When a person receive an electrical shock; it is the duty of the observer around to disconnect him immediately from the power supply means. This is achieve by switching off the main supply. If it can be easily accessed, or alternatively, the body could be pushed away from the live installation with the aid of a dry stick or rope.

iv   A good electrical connection must be established between the anode and cathode or else if not properly connected it will accelerate the rate of corrosion.

        When carrying out cathodic protection construction to protect the buried pipe following precaution can be taken

1.   Pipelines buried several hundred meters; there handling can cause serious fractures, particularly of the head, the wearing of helmet and protective shoes is compulsory

Dry season is the time when construction goes ahead at it normal pace. The problem of working in heat frequently arise, for instance the climate in Nigeria is characterised by an extremely high day temperature which often exceeds 40^0c in

dry season. This makes than 101 of sweat in 24hrs of the consequent loss of salt between (15 and 20g) can cause muscular cramp.

Therefore it is necessary to provide workers with sufficient quantities of fresh and an appropriate amount of salt at meal times. In very cold climates frequent contact with the meal surface or the earth causes a fall of skin temperature and in particular the local cooling of hands and feet. An electrically heated garment in addition to tradition cold protective clothing may be necessary. Special precaution should be taken for certain types of work, for example trench should not be left uncovered. When trenches are dug there is a further risk of poisoning from snake and scorpion bites. Every work site should be equipped with an emergency medical kit including the anti venom serum: The following are needed, gloves, boots and goggles fire extinguisher and overall are needed at work sites

6.0 DISCUSSION OF RESULTS

Based on the analysis of results from the three fields obtained, that high iron content greater than 5ppm is very corrosive. Any quantity indicates the present of the activity of sulphate reducing bacteria (SRB) which precipitates to give black iron, while $_pH$ below 7 indicates the present of acid gas (i.e. CO_2, H_2S mainly)

From the test results from the three field, one can deduce that corrosion rates in the three field is negligible. For the case studies of oil wells. Two wells were monitored for ten years to find out if the measures were effective for the third well corrosion control measures was also implemented, the well was lost to corrosion thirteen times in 12 months

6.1 CONCLUSION

Firm the test results, one can deduce that corrosion rates in the three field is negligible. This shows that corrosion control methods in their fields are effective, while out of the three case studies, corrosion control is effective in two case for

the third case it fails due to high degree of corrosion which requires combination of different inhibitors.

For the design, of a cathodic protection equipment or process is an effective and economic way of corrosion control in production operation. Adequate inspection is a necessity and should be include in the project total cost.

6·2 RECOMMENDATION

I. **For cathodic protection:** Five basis requirement for an effective corrosion control programe with cathodic protection are design, installation, evaluation monitoring, record and maintenance.

ii. Particular care should be taken to ensure correct connection to pipeline and anode cables as a reversal of the connecting cables can result in the acceleration of corrosion of the pipeline.

iii. The cathodic protection scheme should be conceived at the pipeline design stage, and should not be an after through when the pipeline has been completed. Weighted corrosion inhibitors are recommended for use where adequate buttom hole treatment is difficult with conventional inhibitor in system such as

    i   Gas condensates well with packers

    ii.   High fluid levels flowing oil well packers

    iii.   High fluid level wells where circulation through the annular space is impractical

Water soluble corrosion inhibitors are recommended for corrosion protection against salts, organic acids, carbon dioxide, hydrogen sulphide and small amount of oxygen. Some of the systems where these products have application are.

    i.   Producing oil wells with high water / oil ratios

    ii.   Water flood and salt water disposal system

iii.   Water injection system

iv.   Water supply wells

v.   Crude oil and gas pipeline for corrosion protection in the water phase

vi.   Hydraulic testing of pipelines

Recommendation for treatment program should be made only after a complete well history has being obtained and a through study made of the factors affecting the corrosion problem. Field screening tests such as solubility, dispersibility, emulsion forming tendencies and copper ion test can aid in selecting the selecting the corrosion control measures to be implemented.

Finally adequate inspection is a necessity should be include in the project total cost.

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