DESIGN OF TEMPORARY CATHODIC PROTECTION SYSTEM

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May, 2010

DESIGN OF TEMOPARY CATHODIC PROTECTION

A Thesis submitted in partial fulfillment of the requirements of the Degree of Master of Technology

(Pipeline Engineering)

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May, 2010

CERTIFICATE

This is to certify that the work contained in this thesis titled "**Design of Temporary Cathodic Protction**" has been carried out by **Imthadulla.M** under my supervision and has not been submitted elsewhere for a degree.

10/5/10

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ABSTRACT:

Corrosion is a natural process which cannot be egested but can be kept under control. The natural process in which the metals get converted to lower energy levels. In this project we designed Temporary Cathodic Protection for span of 684 km to Chennai-Trichy-Madurai Pipeline (CTMPL). The system has spur line from Asanur-Sankari for span of 158 km.

The Temporary Cathodic Protection is designed for pipeline of section-1 (Chennai-Asanur) with a span of 255 km and section-2 (Asanur-Sankari) with a span of 158 km, and section-3 (Asanur-Trichy) with a span of 115 km, and section-4 (Trichy-Madurai) with a span of 156 km.

This project focus on the systematic approach to calculate the total anode ground bed requirement for the pipeline. Calculation in finding out the spacing of anode ground bed as also been done and is presented kindly.

ACKNOWLEDGEMENT

I take this opportunity to express my gratitude to my project guide **Prof. Mr. Ajay Kumar** College of Engineering Studies, University of Petroleum and Energy Studies, for his valuable advice, inspiring instruction, resourceful guidance, active supervision and constant encouragement through out my project period.

I would like to express my grateful thanks to **Mr. Adarsh.K.Arya Assistant professor,** College of Engineering studies, University of Petroleum and Energy studies, for his timely suggestions and help in completing this project.

I wish to acknowledge my sincere thanks to **Prof.Dr.Srihari**, Dean, College of Engineering Studies, for his timely support and help.

I take this opportunity to express my gratitude to my parents, whose blessings, support and constant encouragement has fetched me success in all my activities.

I wish to acknowledge my thanks to all my friends and colleagues for the support and encouragement.

IMTHADULLA.M

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NOMENCLATURE

NACE---- National association of corrosion engineers

CP ------ Cathodic protection

TCP ---- Temporary Cathodic protection

API – --- American Petroleum Institute

DNV---- Det Norske veritas

BS ------ British standards.

CTMPL --- Chennai Trichy Madurai Pipeline.

CPCL ----- Chennai Petroleum Corporation limited.

PSP ------- Pipe to soil Potential.

CTE ------ Coal Tar Enamel

HT ---- High transmission lines.

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

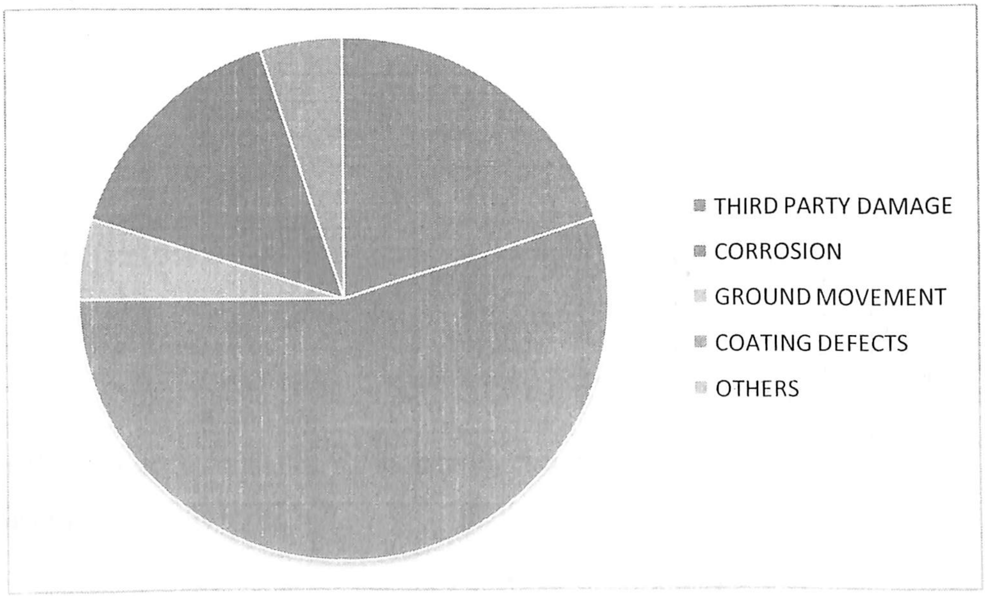
Pipelines are utilized to transport valuable products like oil, gases and water. In pipelines the major problem are corrosion. The corrosion can be controlled by cathodic protection. Successful application of cathodic protection depends upon the selection, design, installation and maintenance of the system.

The main objective of my project work is to design and control corrosion by using cathodic protection system for [Chennai - Trichy - Madurai] pipeline using (galvanic anodes) in the Temporary cathodic protection system.

1.2 How pipeline get affected:

Pipelines are the safest means of transportation for transporting hydrocarbon fluids over long distances. The statistics of pipeline failures reveal that the fatalities are meager in relation to other forms of transportation. However, pipelines as engineered facilities do fail from time to time. The failures are caused by various mechanisms such as external and internal corrosion, stress corrosion cracking, third-party damage, soil movement/instability, materials defect, construction practice and operating problems.

The pie chart shows the potential of various failures in pipeline.



So the above shows importance to corrosion control process. Let first understand the corrosion process.

1.3 CORROSION FUNDAMENTALS AND CORROSION PROCESS

1.3.1 CORROSION

One general definition of corrosion is the degradation of a material through environmental interaction. This definition encompasses all materials, both naturally occurring and man-made and includes plastics, ceramics, and metals. Corrosion processes are usually electrochemical in nature. Basically it means loss of electrons of metals on reacting with surrounding in presence of oxygen. This type of damage produces oxides or salts of the original metal. Most structural alloys corrode merely from exposure to moisture and air, but the process can be strongly affected by exposure to specific substances. Corrosion can be concentrated (Pit or crack) or it can be extend across the whole body of the metal to produce deterioration. Localized corrosion that leads to pitting may provides sites for fatigue initiation and, additionally, corrosive agents like seawater may lead to greatly enhanced growth of the fatigue crack. Pitting corrosion also occurs much faster in areas where micro structural changes have occurred due to welding operations.

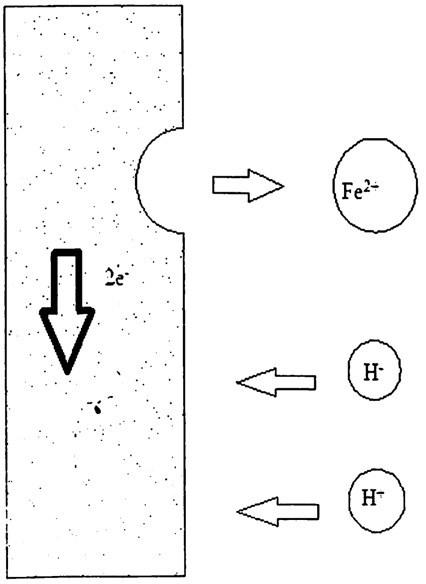


Figure 1 Corrosion process or anodic reaction of the metal dissolving as ions generates some electrons.

1.3.2 FUNDAMENTALS OF CORROSION

Flow of electricity between certain areas of metal surface through an electrolyte is a basic fundamental of corrosion. This electrochemical action causes deterioration of a metal at areas (called as anodes). The electric current leaves the metal at anodic sites and enters the electrolyte. The bonds between metal ions contain an abundant amount of free potential energy, which has a tendency to be released through the process of corrosion (i.e. oxidation) converting the metal to its natural state. The difference in the binding energies between the metal atom is what provides the driving potential towards the oxidation of metal atoms (M), resulting in the loss of one or more electrons and the production of the ionic form of the metal shown in equation 1.

$M \rightarrow Mn+ \quad + ne-$ ------------------------ Eq.1

The above reaction is known as the anodic reaction occurring on the corroding metal's site (Anode)

Specifically, the positively charged atoms of metal detach themselves from the solid surface of the metal and enter the electrolyte as ions while the negatively charged electrons remain behind in the metal. The negatively charged electrons travel through the bulk metal to a "location "where the undergo a secondary reaction known as cathodic reaction, where either a non –metallic atom or ion (Nm or nm^+, respectively) or another metallic ion (p^+) is reduced, resulting in the accumulation of these electrons. The process of which is shown in equation 2, 3 and 4

$Nm + ne- \rightarrow Nm^{n-}$ ----------------- Eq. 2

$Nm^{n+} + ne- \rightarrow Nm$ ----------------- Eq. 3

$P\,n+ \quad + ne- \rightarrow P$ ----------------- - Eq. 4.

1.3.3 CORROSION MECHANISM

- Corrosion occurs in aqueous (water containing) environments and is electrochemical in nature.
- Corrosion process in totality involves oxidation as well as reduction reactions & proceeds as per the following equations:

  $Fe \rightarrow Fe^{++} + 2e^-$

  $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

  $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

- Oxidation reaction is commonly known as anodic reaction & the reduction reaction is called cathodic reaction

1.3.4 CONDITION OF CORROSION

The necessary components of a differential corrosion cell are

- There must be an anode
- There must be a cathode
- There must be a metallic path electrically connecting the anode and cathode. (Normally, this will be the pipeline itself.)
- The anode and cathode must be immersed in an electrically conductive electrolyte
- (Normally, moist soil).

1.4 TYPES OF CORROSION

1.4.1 CHEMICAL CORROSION

This type due to the contact of a pipe with a corrosive substance such as an acid, which attack or reacts with the surface of the pipe to cause damage. It happen to both metallic and non metallic pipes and it can damage either the pipe interior or exterior surfaces depending on whether the corrosive chemical is inside or outside the pipe. A number of chemicals exists that can corrode pipes. Metal pipes can be damaged various acids, halogens and salts; concrete pipes can be corroded various acids and salts; and plastic pipes can be damaged various acids, hydrocarbons and chlorine. Generally steel pipes require no lining for transporting hydrocarbons such as petroleum, but they do require a lining for transporting water unless oxygen is removed from the water. Corrosion resistant metals include copper, brass, nickel, stainless steel, titanium and man alloys. Plastic pipes cannot be used for transporting hydrocarbons, but they are inert to water even when containing oxygen. Chemical corrosion happens only when a pipe transports or otherwise comes into contact with a corrosive chemical. Chemical corrosion can be controlled by either avoiding contact with corrosive chemicals, selecting a pipe material inert to the corrosive chemical that the pipe will be in contact with, or b using a pipelining or coating inert to the corrosive chemicals. Special type of corrosion take place and a metal pipe is in contact with water containing dissolved oxygen. For steel or cast iron pipe, the metal (Iron) react chemically with the water and oxygen to form various hydrated ferric oxide, which form rusts. This type of corrosion can be prevented b using the deoxygenated water, which is common practice for protecting boiler for power plant.

1.4.2 ELECTROCHEMICAL CORROSION (WET CORROSION)

This is the most common type of corrosion that occur in metal pipes, and it is of electrochemical origin, such corrosion can be subdivided into two types.

1. Galvanic Corrosion
2. Electrolytic Corrosion

1.4.3 GALVANIC CORROSION

Galvanic Corrosion is based on the same principle that Galvanic cells. A piece of Zinc (Zn) and a piece of copper (Cu) are immersed in a electrolyte, and the two metals (Electrodes) are connected b a wire that is a good conductor, such as copper. Zinc has a higher electrical potential than copper. Consequently, a current will flow from the copper to zinc through the connecting wire. To complete the electric circuit, the current of same magnitude will flow through the electrolyte, form zinc to copper. This electrical; current through the electrolyte removes molecules from the surface of the zinc electrodes, causing galvanic corrosion to the zinc. The foregoing galvanic cells are one used commonly in car batteries. Same type of reaction can happen when a two different metals, such as Iron (Fe) and copper (Cu), Come in contact with each other, and when they are immersed in a electrolyte. Furthermore, the connecting wire between the two metals serves only one purpose, which is to bring the two metals into electrical contact. Thus the phenomenon will happen without the connecting wire, as long as the two metals are in direct contact with each other.

For a galvanic cell to form, two conditions must be satisfied.

1. There must be two dissimilar metals in contact with each other or connected together by a conductor.
2. Two metals immersed in an electrolyte.

Galvanic corrosion is common in metal pipes due to existence of many dissimilar metals in a pipeline, such as a valve made of a different type of steel then that used for the pipe, or a pump having an impeller made of or coated with bronze. The severity of galvanic corrosion depends not only on the potential difference between the two connecting metals but also on the contacting electrolyte. The higher the conductivity of the electrolyte, the more current flows through the galvanic cell, and the more severe corrosion becomes. Therefore, wet soil and soil and soil that contain salts are highly corrosive to pipeline and other metal structures. A modified type of galvanic corrosion also exists. In the modified type, the entire pipe can be a single metal of uniform potential. However, the electrolyte (such as soil) in contact with one part of the pipe is different from soil potential for one part of the pipe is different from the pipe-to-soil potential for another part of the pipe. This also creates a galvanic cell that corrodes pipeline.

1.4.4 ELECTROLYTIC CORROSION

Electrolytic corrosion is based on the same principle of electrolysis (i.e. electric plating). If two metals are immersed in an electrolyte, and if an outside direct current (DC) source, such as a battery, is connected between the two metals, a current will flow through the electrolyte, causing metal to be lost from metal which is the anode and be transported to and plated on which is cathode. This causes anode to corrode.

This type of corrosion can occur in metal pipes for one of two reasons.

1. Using a pipeline to ground any dc source of electricity such as a battery, a rectifier, a DC generator etc.
2. Stray currents are generated through the soil in the neighborhood of an underground pipeline.

For both types of electrochemical corrosions, it is always the anode that is corroded, and the cathode that is protected.

Electrochemical can occur in

- **Dissimilar environment**-As pipeline passes through different types of soil. Pipeline material exhibit different potential in different soils, the electric potential in different soils determines which areas become cathodic and which becomes anionic. Since both the anode and cathode are electrically is in contact with both of them, thereby resulting in the flow of current & hence resulting in oxidation and chemical reaction.
- **Oxygen concentration**- pipelines that are exposed to an electrolyte with a low oxygen concentration are generally anodic to same material exposed to an electrolyte with high oxygen content. As backfill and excavation operation contains a high amount of oxygen pipeline can be frequently affected by this type of corrosion as there are different levels of oxygen content.

1.5 OTHER TYPE OF CORROSION

1.5.1 BACTERIAL CORROSION

It is caused by the presence of certain bacteria or algae, which can produce substance that corrode pipe. These bacteria's produce acid that corrode pipe and other underground structures. Examples anaerobic sulphate- reducing bacteria thrive in poorly aerated soils such as clay which corrodes the pipelines. Many bacteria's produce mineral or organic acid that may also breakdown structure coating. The breakdown products lead to accelerated corrosion

1.5.2 PITTING CORROSION

It is special type of electrochemical corrosion that occurs at certain points along a pipe where the paint or coating is damaged, and where metals are exposed to the environment (electrolyte). Because the exposed areas are small, current densities caused by electrochemical corrosion cell going through these areas are high, causing high corrosion rates and rapid damages of pipe.

1.5.3 CREVICE CORROSION

When the ion concentration in the electrolyte is different at different locations, a concentration cell is established. The area of electrode in contact with the low concentration electrolyte becomes anodic and corrosion is observed. For example under the washers in an assembly, usually the corrosion is observed. In the stagnant solutions, localized depletion of dissolved oxygen causes this type of crevice corrosion, to avoid the crevice corrosion; sometimes riveting is replaced by welding.

1.5.4 THERMAL GALVANIC CORROSION

It is caused by the contact of two pipes of different temperatures, such as a hot-water pipe and a cold pipe. Such contacts cause galvanic corrosion with the hot pipe being the anode and the cold pipe being the cathode.

1.5.5 STRESS CORROSION

It takes place in places experiencing high stress and strain, And in metals subjected to fatigue (i.e. repeated stresses or repeated stress reversals). Such high stresses or repeated stress reversals promote crack of various sizes, which expose the metal to the corrosive environment.

In pipelines this type of corrosion occurs due to a combination of three factors.

1. Presence of tensile stresses.
2. Appropriate environment (minimum temperature).
3. Presence of localized concentrations of particular ions.

1.5.6 EROSION CORROSION

It is combined effects of erosion and corrosion. Without erosion, corrosion will produce a crust to prevent or retard further corrosion. However, with erosion the crust is removed by physical forces of erosion, and new metal is exposed to continue the process. Thus erosion aggravates corrosion.

1.5.7 INTERGRANULAR CORROSION

Under certain conditions grain boundaries are very reactive and intergranular corrosion results. Localized attack at and adjacent to grain boundaries with relative little corrosion of the grains is intergranular corrosion. The alloy losses its strength. It is caused by the impurities at the grain boundaries, enriching one of the alloying elements or depletion of one of these elements. The type of corrosion can be eliminated by correct choice of material and proper maintenance.

1.6 FACTORS AFFECTING THE CORROSION PROCESS

1. **POTENTIAL DIFFERENCE**. The potential difference between the anode and cathode is electromotive forces and can be measured as voltage. The greater the potential of corrosion. The voltage is directly proportional to the current, and therefore the corrosion, in an electrochemical cell.
2. **RESISTIVITY OF THE ELECTROLYTE.** The resistivity of the electrolyte is important factor in determining the rate of corrosion. This is an inheritance characteristic of the soil water. It is inversely proportional to current, and therefore corrosion.
3. **CONTACT RESISTANCE**. The contact resistance of the anode to the electrolyte and of the cathode to the electrolyte has the same effect as resistivity. The lower the contact resistance the greater the current, and hence corrosion.
4. **COATING OF THE STRUCTURE**. Coating of the structure normally raises the contact resistance of the cathode and anode. The coating of the structure depletes ion migration of the structure and hence corrosion.
5. **POLARIZATION OF STRUCTURE.** Polarization is the change of the electrode potential as a electrochemical current flow and results in the formation of a film on the

electrode surface called a "polarization film" which consist parity of thin film of hydrogen on the cathode surface. This polarization film and other changes have beneficial effects at cathode. The layer of hydrogen on the cathode surface. This layer of hydrogen acts as additional coating and increases the resistance of the electrode to the electrolyte increases.

6. **CHEMICAL EFFECT ON THE CORROSION RATE.** Factor which increases the chemical and hence corrosion rate example are temperature (generally temperature increases the corrosion rate)
7. **PH OF THE ELECTROLYTE.** The PH of the soil water electrolyte in a chemical corrosion by speeding or slowing the chemical reactions at anode or cathode. the PH of electrolyte around the cathode may increase the corrosion rate.

1.7 CORROSION CONTROL IN PIPELINES:

There are two types of corrosion which occur in the pipeline, namely the external corrosion and internal corrosion. The external corrosion occurs by the interaction of the pipe external surface with the corrosive environment. The internal corrosion occurs mainly in two forms namely the sour and sweet corrosion. If the product or crude handled by the pipelines have some water traces or H_2S or O_2 etc then the internal corrosion is more likely to occur. This especially occurs in the bends and the downhill area where there is a higher probability of water accumulation.

The **internal corrosion** can be controlled by the removal of water or H_2S or O_2 from the system. This is done by adding corrosion inhibitors namely some polymer and poly peptides which are water soluble react with the element and convert them into a form which does not cause corrosion. The corrosion inhibitors are generally injected in ppm rates in the pump/compressor station. Thus this causes the reduction in internal corrosion of the pipelines. The internal corrosion is checked then and there by internal corrosion direct assessment as prescribed by the NACE codes.

The **external corrosion** is taken care mainly by the coatings in the pipeline. The welded joints are coated in the field by means of heat shrinkable sleeves and the whole pipeline is coated and buried. The coating thickness range from 5mm to 20 mm based on the operating conditions. The coating prevents the direct contact between the pipe outer surface and the soil (corrosive environment) and thereby this reduces the corrosion. Apart from external coatings, the cathodic protection system is also employed to mitigate corrosion. This acts as a supplement to coating and thereby reduces external corrosion.

To protect the buried line pipes from external corrosion, the line pipes are coated. A good quality pipeline coating shall have following characteristics:

- Adherence to pipe
- Non-porous
- Free of defects, pores, flaws, holidays
- Should act as an insulating barrier
- Should be inert to environment
- Coefficient of thermal expansion of the coating film > that of pipe metal
- High resistance to abrasion
- Resistance to UV degradation

1.8 NEED FOR TEMPORARY CATHODIC PROTECTION

After the construction and hydro testing of the pipeline the impressed current cathodic protection might not be commissioned immediately, as impressed current system needs a lot of infrastructure to be built such as transformers and rectifiers and also requires a special Right Of Way for the high transmission lines to be established along the pipeline route. In between after post construction and establishing Impressed Current cathodic protection system. So a Temporary cathodic protection is used.

1.8.1 Temporary Cathodic Protection

It is a technique to reduce the corrosion rate of a metal surface by making it the cathode of an electrochemical cell. At the anodic areas, the current flows from the pipeline & gets corroded. At the cathodic areas, the current flows from the electrolyte on to the pipe surface & corrosion is reduced. This is achieved by connecting an anode to the pipe which corrodes and protects the pipe.

CHAPTER-2

LITERATURE REVIEW

2.1 CATHODIC PROTECTION

2.1.1 HISTORY

The British first uses cathodic protection on copper fitting of wooden sailing vessels in the 1820's. Cathodic protection systems first used extensively in the 1920's for buried steel pipelines transporting petroleum products in the gulf coast oil fields of the U.S.cathodic protection of steel steel-hulled ships became prevalent in the 1950's, to supplement corrosion and fouling resistant coatings.

Cathodic protection is one of the most widely used methods of the corrosion protection. It can reduce or prevent the corrosion of any metal or alloy exposed to any aqueous electrolyte. Corrosion can be reducing to virtually zero and properly maintained system will provide protection indefinitely.

2.2 FUNDAMENTALS OF CATHODIC PROTECTION

All the CP system involves the flow of direct current (dc). The manner in which CP systems involve the flow of direct current from an outside anode through the electrolyte to the metal, the current flows from the electrolyte to the metal, the metal will remain cathodic and therefore will not corrode. Cathodic protection reduces the corrosion rate by cathodic polarization of a corroding metal surface. Considering iron corroding in a dilute aerated neutral electrolyte solution. The respective anode and cathode reaction is as follows

$Fe \rightarrow Fe2^{+} + 2^{e-}$ ----------------- (1)

$O2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}$ ------- (2)

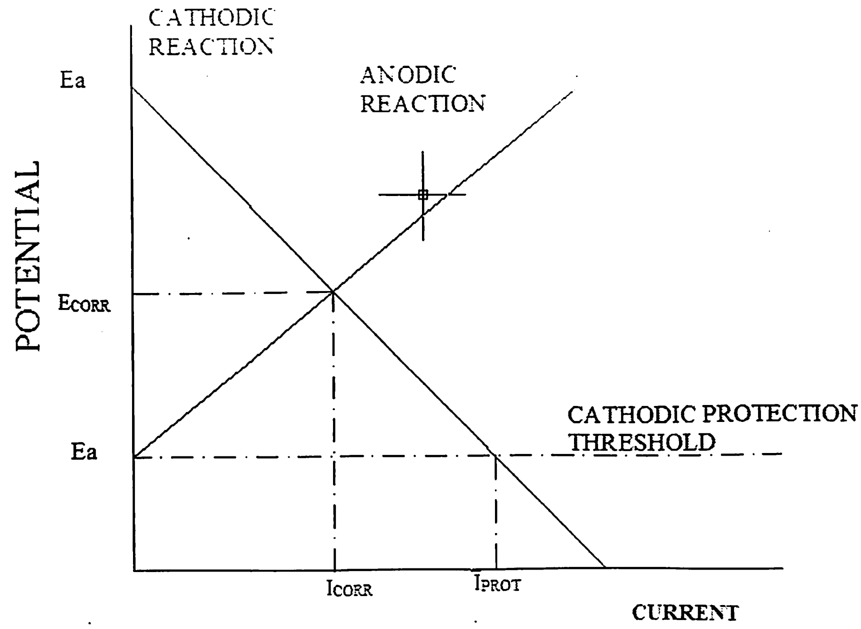


FIGURE 2 EVAN'S DIAGRAM

Figure reprèsents the "EVAN DIAGRAM" which represents potential as a function of current.

It represents following characteristics

- When all the point of the structure have reached the potential Ea, the overall structure will become a single cathode, thereby nullifying the corrosion current (I_{corr}) with a minimal protection current (I_{prot}).
- Iron can be protected fully by shifting its potential to Ea. This required the cathodic current equal to I_{prot}
- The lower level of protection is obtained by shifting the potential to a value between E_{corr} and Ea. This can be achieved with application of the lower current.
- Shifting the potential to a value that is more negative than Ea provides more further corrosion protection, but the result in greater expenditures.

Basically this diagram status the cathodic protection threshold. Praçtically much and less protection both are not desirable.

Table 2.1 Galvanic series of metals

Material	Potential volts (CSE)[a]
Carbon, graphite, coke	+0.3
Platinum	0 to -0.1
Mill scale of steel	-0.2
High silicon cast iron	-0.2
Copper, brass, bronze	-0.2
Mild steel in concrete	-0.2
Lead	-0.5
Cast iron (not graphitized)	-0.5
Mild steel (rusted)	-0.2 to -0.5
Mild steel (clean and shiny)	-0.5 to -0.8
Commercially pure aluminum	-0.8
Aluminium alloy (5% Zinc)	-1.05
Zinc	-1.1
Magnesium alloy (6%Al, 3% Zn, 0.15% Mn)	-1.6
Commercially pure magnesium	-1.75

2.3 TYPES OF CATHODIC PROTECTION

There are two ways in cathodic protection is achieved

1. Sacrificial or galvanic anode cathodic protection system.
2. Impressed current cathodic protection system.

2.3.1 SACRIFICIAL OR GALVANIC ANODE CATHODIC PROTECTION SYSTEM:

Sacrificial anode type cathodic protection systems provide cathodic current by galvanic corrosion. The current is generated by metallically connecting the structure to be protected to a metal/alloy that is electrochemically more active than the material to be protected. (Both the structure and the anode must be in contact with the electrolyte.) Current discharges from the expendable anode, to the electrolyte, and onto the structure to be protected

The basic components of a single. sacrificial anode type cathodic protection installation are the structure to be protected, the anode (with or without a special backfill), and an insulated lead wire connecting the structure to the anode

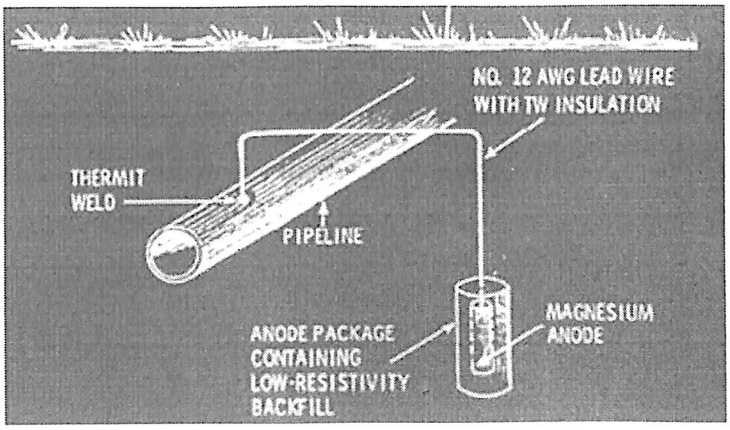


Figure 3 galvanic anode cathodic protection system.

ANODE MATERIAL

ZINC

They are available in many weights 5 pounds to 250 pounds. They are basically used to protect the interiors of heat exchanger, water tanks etc. They are used in immersion services in fresh as well as saline water. The efficiency for zinc is higher than magnesium. And its consumption rate is 10.6 kg per ampere year. Zinc alloys are the only anode materials permitted without restriction for the internal protection of exchange tanks on tankers. For the external protection of pipelines in seawater, zinc anodes in the form of bracelets are installed; in the length direction these are welded on to clips attached to the pipe or in the form of half-shells. Zinc anodes are only used for soil resistivities below10 ohms-m. in order to reduce passivation and lower the grounding resistance, the anode have to be surrounded with special bedding material as backfill.

ALUMINUM

Pure aluminum cannot be used as an anode on account of its easy passive ability. For galvanic anodes, aluminum alloys are employed that contain activating alloying elements that hinder or prevent the formation of surface films. These are usually up to 8% Zn and/or 5% Mg. In addition, metals such as Cd, Ga, In, Hg and TI are added; as so called lattice expanders, these maintain the long term activity of anode. To optimize the current yield, so called lattice contractors are added that include Mn, Si, and Ti.

MAGNESIUM

Magnesium is considerably less passive than zinc and aluminum and has the highest driving voltage. On account of these properties and .its high current content, magnesium is particularly suitable for galvanic anodes. Magnesium, however, is prone to self-corrosion of considerable extent, which increases with increasing salt content of the medium the available current content of pure magnesium is therefore much less than the theoretical current content. Magnesium anodes usually consist of alloy with additions of Al, Zn, and Mn.. they are used for protection of interior of water tanks and heaters.

BACKFILL MATERIALS

Backfill is done so as to reduce the grounding resistance; anodes in soil are surrounded by bedding materials, so-called backfill. Such material, besides restricting the formation of surface films and preventing electro osmotic dehydration. Act to provide uniform current delivery and uniform material consumption. The backfill is either poured into the borehole, or the anodes are enclosed in sacks of permeable material filled with backfill. Such anodes are sunk into the borehole and backfilled with water and fine soil. Anodes installed in the way deliver their maximum current after only a few days. Galvanic anodes must not be backfilled with coke.

Table 2.2 Properties of sacrificial anodes

Anode Material	**Density g/ cm^3**	**Potential volts $Cu/CuSO_4$ Ref Electrode**	**Amp-hrs per kg**	**Typical anode current density A/m^2**
Zn	7.1	-1.10	780	0.5 - 2
Al	2.7	-1.15	2700	0.6 – 2.5
Mg	1.7	-1.55	1230	1.5 – 1.6

ADVANTAGES:

- Simple design and easy to install
- No need for an external power source
- Highly suitable for localized protection
- Cheap and easy to trouble shoot
- Maintenance costs are minimal
- Interference problems like stray current phenomenon are absent

- Less liable for interaction with the neighboring structures

DISADVANTAGES:

- In case of places where over protection is needed, this system cannot be utilized
- Small driving force which restricts the versatility of the use in conductive environments.
- Depends largely on coating effectiveness
- For a longer distance CPs thousands of sacrificial anodes are needed and demands more installation facilities

2.3.2 IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM.

In the impressed current cathodic protection the buried pipe receives current from auxiliary power source usually an inert electrode buried inside the soil near the pipe. The DC source keeps the pipeline catholically protected. The auxiliary electrode is usually scrap iron. The iron will dissolve from the anode by reaction and the electrode is described as a consumable anode. If the anode is a noble metal or an electrochemically inert material, the surrounding environment will be oxidized. There are range of materials have been used as non-consumable anodes for impressed-current systems.

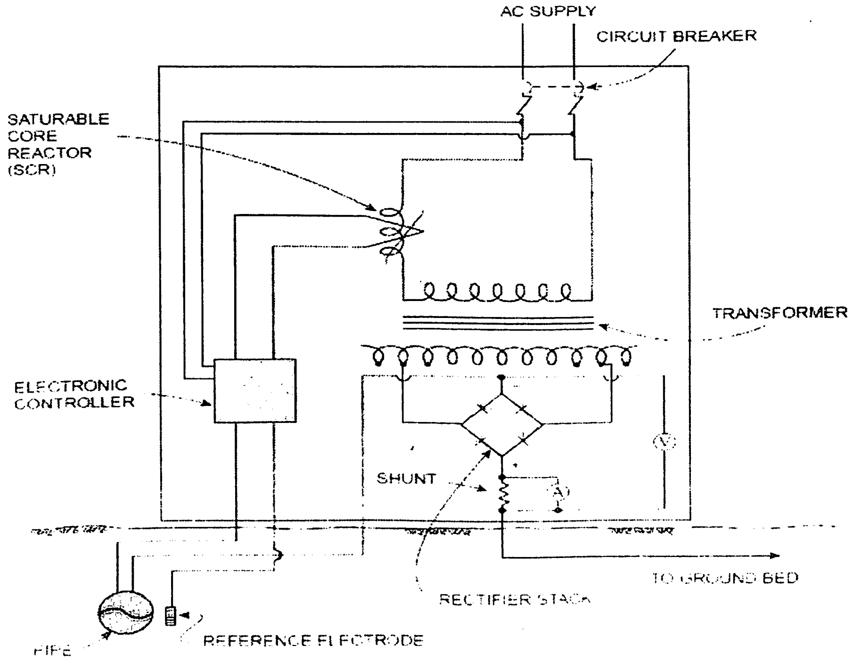


FIGURE 4 IMPRSSED CURRENT CATHODIC PROTECTION SYSTEM

MATERIAL FOR IMPRESSED CURRENT METHOD.

Graphite anodes have largely replaced the previously employed carbon variety, with the crystalline graphite structure obtained b high temperature exposure as part of the manufacturing process that includes extrusion into the desired shape. These Anodes are highly porous, and it is generally desirable to restrict the anode reactions to the outer surface to limit degradation processes. Impregnation of the graphite with wax, oil or resins seals the porous structure as far as possible, thereby reducing consumption rates by up to 50%. Graphite is extremely stable under conditions of chloride evaluation. Oxygen evaluation and the concomitant formation of carbon dioxide gas accelerate the consumption of this anode. Buried graphite anodes are used in different orientations in anode beds that contain carbonaceous backfill. But their operating current densities are restricted to relatively low levels. Graphite is brittle, with a risk of fracture during installation and operation.

PLATINIZED ANODES

They are designed to remain completely passive and utilize a surface coating of platinum on titanium, niobium and tantalum substrates for these purposes. Restricting the use of platinum to thin surface film has important cost advantages for extended life, the thickness of platinum surface layer has to be increased. The inherent corrosion resistance of the substrate materials through the formation of protective passive films, is important in the presence of discontinuities in the platinum surface coating, which invariably arise in practice. The passive film tend to break down at a certain anodic potential which is dependent on the corrosiveness of the operating environment. In chloride environments, tantalum and niobium tend to have higher break down potential than titanium, and the on former materials are thus preferred at high system voltages. These anodes are fabricated in the form of wire, mesh, rods, tubes and strips. They are usually embedded in a ground bed of carbonaceous materials. The carbonaceous back fill provides a high surface area.

Mixed metal anodes

They utilize titanium, niobium etc. as substrate materials. A film of oxides is formed on these substrates, with protective properties similar to the passive film forming on the substrate materials. This important difference is that where as the "natural" passive film is an effective electrical insulator, the mixed metal oxide surface films passes an anodic current. The product forms are similar to those of the platinized anodes. These anodes typically used with carbonaceous backfill. Excessive current densities accelerate the building up of insulating oxides to dangerous levels. Scrap steels and irons represent consumable anode material and have been used in the form of abundant pipes, rail road's or well casings, as well as any other scrap steel beams or tubes. These anodes found applications particularly in the early years of impressed current CP installations. Because the dominant anode reactions are iron dissolution, gas production is restricted at the anode.

These anodes are not prone to failure at a particular level of current density. Limitations again include the buildup of corrosion products that lower the current output.

Advantages:

- Large area can be protected
- Variation in soil resistances can be adjusted with the current density
- Over protection is possible
- Higher flexibility in operation
- No need to replace the anode, replacement needed if a consumable anode is used
- More reliable than when compared to sacrificial anode CP system

DISADVANTAGES

- Higher costs for installation and maintenance
- Needs some skilled labor to perform survey and other maintenance activities
- Needs external power source
- Rectifier needs additional safety monitoring
- Continuous monitoring
- When AC power is turned off pipe is unprotected.
- Safety aspects of negative lead connections.

2.4 CODES AND STANDARDS

The design, selection and installation of equipments and materials shall also conform to the requirements of the relevant applicable standards.

IS 7098	XLPE Insulated cables.
BS: CP:2008	Protection of iron &steel structure from corrosion
BS: 7361	Cathodic protection.
NACE RP-01-69	Recommended practice control of external corrosion on Underground or submerged metallic piping systems.
NACE RP-02-86	Recommended practice-The electrical isolation of cathodically Protected pipelines.

API 651 -- Cathodic Protection of Aboveground Petroleum Storage Tanks

API 653 -- Tank Inspection, Repair, Alteration, and Reconstruction

API 1104 -- Welding of Pipelines and Related Facilities

API 1107 -- Pipeline Maintenance Welding Practices

Standards

DNV RP F106 -- Factory applied external coating of pipeline

DNV RP F113 -- Pipeline Subsea Repair

DNV OS F101 -- Cathodic Protection of Submarine Pipelines by Galvanic Anodes

2.5 SURVEY METHODS

Various testing methods and techniques may be used on underground pipelines during the course of field surveys.

Before any field survey, the corrosion engineer should gather as much information as possible about the pipeline to be studied. This may provide valuable data on corrosion conditions to be expected and should be helpful in planning a survey program that will yield useful data for design purposes.

The following items of information are typical of those which should be accumulated before planning and starting the field survey.

- Pipe material: Steel (including grade of steel), cast iron, wrought iron, or other material of known electrical resistance.
- Is the line bare or coated? If coated, what is the coating material and what coating specifications were used?
- If it is an existing line, is there a leak record? If so, information on the location and date of occurrence of each leak will positively indicate the more serious problem areas.
- Pipe diameter, wall thickness, and weight per foot; data on any changes in these items along the route of the line.
- Location and construction details of all corrosion test points that have been installed along the line. If no test points have been installed for corrosion test purposes, determine locations where contact can be made with the pipeline for test purposes (other than by driving contact bars down to the pipe).

2.5.1 Soil Resistivity Survey

This indication of a tendency for current to flow becomes more important if something is known about the soil resistivity. High-resistivity soils may offer so much resistance to current flow that conditions are not as severe as the plotted potential data might lead one to believe. Conversely, severe potential peaks coupled with a relatively low resistivity environment may mean a truly serious condition. Frequent soil resistivity determinations are important when making a detailed survey on a pipe line. In addition to being a valuable aidwhen interpreting the severity of corrosive areas, a soil resistivity profile is extremely helpful in the later selection of sites for CP installations.

Instruments used for measuring soil resistivity by the four-pin method

The Wenner method requires the use of four metal probes or electrodes, driven into the ground along a straight line, equidistant from each other, An alternating current from the soil resistance meter causes current to flow through the soil, between pins C1 and C2. The voltage or potential is then measured between pins P1 and P2. The meter then registers a resistance reading.

The resistivity values obtained represent the average resistivity of the soil to a depth equal to the pin spacing. Resistance measurements are typically performed to a depth equal to that of the pipeline being evaluated. Typical probe spacing's are in increments of 2.5 ft (76.2 cm).

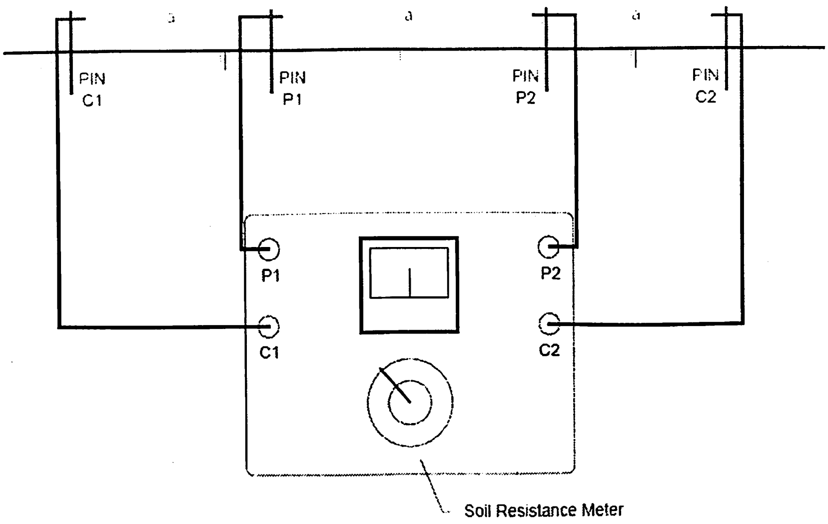


FIGURE 5 FOUR-PIN WENNER METHOD

2.6 Maintenance required for Temporary cathodic protection system

2.6.1 Introduction

The designed and installed cathodic protection system require periodic maintenance. Without a suitable maintenance program, money spent for designing and installing corrosion control can be wasted.

2.6.2 Requirement of maintenance program:

The following items should be included, as applicable, in a maintenance program for a Pipeline corrosion control system:

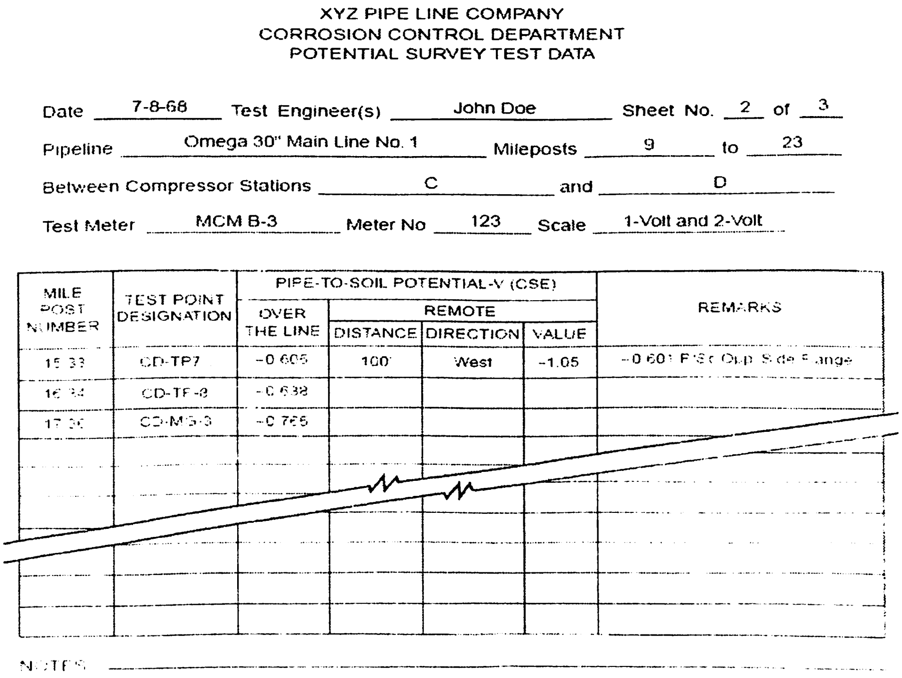
- Periodic surveys to determine the status of CP and related items
- Coating maintenance procedures
- Maintenance procedures for and ground beds in CP installations
- Maintenance procedures for galvanic anode CP installations
- Maintenance procedures for test points
- Maintenance procedures for cased crossings
- Maintenance procedures at foreign line crossings.

2.6:2.1 PERIODIC SURVEYS:

On catholically protected pipelines, the following data should be taken as outlined in NACE INTERNATIONAL RP0169 (latest revision) and code of Federal Regulations-Transportation Section 49, Part 192:

- A potential survey along the protected pipeline. This should include, on a coated Pipeline, potentials to close copper sulfate electrode (CSE) at all test points along the line.
- On coated pipelines, data for calculation of effective coating resistance.
- The current output and resistance of each galvanic anode installation.
- Potentials of the line surveyed and of the foreign line at foreign line crossings. Where Intersystem bonds exist; measure the bond current and direction of flow.
- At cased crossings, the resistance between carrier pipe and casing plus the potential to reference electrode of both pipeline and casing.
- In variable stray current areas, verification that bonds, electrolysis switches or other corrective measures are operating properly and are providing the required degree of protection.
- Verification that insulated joints are effective and that any protective lightning arresters, spark gaps, grounding cells, and polarization cells are performing their function effectively.
- Notes on maintenance requirements on any of the physical features associated with the corrosion control system.

Table 2.3 Form for potential test data



XYZ PIPE LINE COMPANY
CORROSION CONTROL DEPARTMENT
POTENTIAL SURVEY TEST DATA

Date 7-8-68 Test Engineer(s) John Doe Sheet No. 2 of 3

Pipeline Omega 30" Main Line No. 1 Mileposts 9 to 23

Between Compressor Stations C and D

Test Meter MCM B-3 Meter No 123 Scale 1-Volt and 2-Volt

MILE POST NUMBER	TEST POINT DESIGNATION	PIPE-TO-SOIL POTENTIAL-V (CSE)				REMARKS
		OVER THE LINE	REMOTE			
			DISTANCE	DIRECTION	VALUE	
15.33	CD-TP7	−0.605	100'	West	-1.05	−0.601 P/S on Opp. Side Flange
16.34	CD-TP-8	−0.638				
17.36	CD-MG-3	−0.765				

NOTES

2.6.2.2 COATING MAINTENANCE

Although coated pipelines are buried and inaccessible under normal conditions, there are things that can be done to maintain coating systems. During normal operations on most pipeline systems the line will be frequently uncovered for other maintenance work. This work may involve damage to the coating or removal of portions of it. Coating repair or replacement should be of a quality at least as good as the original coating. Maintenance crews should be trained in good coating application procedures, care of materials, and compliance with specifications so that acceptable coating work will result.

Maintaining a performance record of pipeline coatings on the system will help the corrosion engineer to prepare and present recommendations for material to be used on new construction. The general electrical condition in terms of effective resistance can be obtained from the periodic corrosion surveys. In some cases, specific information can be obtained by training all line maintenance crews to report on the coating condition whenever pipe is uncovered. Information desirable in such a report includes date, specific location, coating type and description, manufacturer and grade of material (if known) or other identifying information as available or applicable, temperature at the coating surface in place, general condition of the coating, bond quality, evidence of cold flow, evidence of moisture under the coating, evidence of soil stress effects, presence of pitting **266** Maintenance Procedures at holidays (with data on number of pits, depth range, and range of pit diameters), and data on environmental conditions surrounding the pipe that could have an adverse effect on coating. Accumulation of information by this method allows for a continuous reporting procedure to compare historic data, thereby providing the corrosion engineer with knowledge of how the pipeline's coatings are performing.

Where anomalies are found as part of the ongoing surveys, special dig-ups may be required. These may be caused by conditions where potentials are declining along a specific section of pipeline with no apparent cause. Actual points to be excavated are typically selected on the basis of areas of low potentials, sections with higher than normal current demands, and areas having the more severe holiday indications following holiday detection. Although uncovering a pipeline and replacing a coating is expensive, it may be necessary in some instances. This is typically true where coating deterioration is found to be severe over a short length of pipeline because of unusual environmental conditions. This circumstance may result in loss of protective levels of CP over an area of the pipeline.

Recoating the section usually restores CP to proper levels over the entire line with no significant changes in the CP system current outputs. If a section is recoated, the chances are that the original coating was not a suitable selection for conditions in that area. The material used for recoating should be selected specifically for its ability to stand up under the particular environmental conditions encountered. Another means of reestablishing proper levels of CP in the deficient area(s) is to provide supplemental localized CP. Economic justification for recoating versus simply adding local CP in the affected area should be evaluated for each case.

2.6.2.3 GROUND BED MAINTENANCE

Surface Anodes

Ground bed maintenance will consist of periodic checks to ensure that there has been no disturbance of the earth above the header cable and line of anodes in a conventional (surface) type bed. If any part of the ground bed is subject to washing (by storm water) with exposure of cable, the cable should be covered again for protection. This should be done only after determining that there has been no insulation damage. Washes should be diverted to prevent reexposure of the cable.

If construction activity is noted in the vicinity of the ground bed, the location of the ground bed route should be staked or marked with paint so that inadvertent damage may be avoided. If new construction involves installation of underground structures, tests may be necessary to determine whether or not they will be within the potential gradient field surrounding the ground bed and subject to possible stray current damage.

During routine testing, any significant increases in ground bed resistance (or an open circuit), will prompt additional testing. Measurement techniques will be required to locate cable breaks or anodes that have failed. When an increase in resistance is found, a pipe-cable locator can be used to find the problem. If the locator indicates a continuous cable throughout the ground bed length, one or more anodes may have failed. If there is a header cable break along the line of anodes, the signal will drop to essentially zero in the vicinity of the break.

Where failed anodes are indicated, they may be located by an over-the-line potential profile (made along the line of anodes with the rectifier energized) with the measured potentials being taken between a remote reference electrode and the over-the-line CSE which is moved by two or three foot increments along the line. The potential profile will show positive potential peaks at each working anode. Any areas where peaks in potential are not found represent anodes that are no longer working and require repair or replacement. The number and spacing of anodes installed originally should be known.

GALVANIC ANODE MAINTENANCE

Maintenance of galvanic anode installations is typically performed to determine that anode leads or header cables have not been exposed or damaged by accident, right-of –way washing or construction work. Where such exposure or damage is found, repairs should be scheduled promptly. At installations having test points, maintaining the connection between the lead from the anodes and that from pipeline is critical. Due to the low driving potential available from galvanic anodes, resistance in the connection can cause a marked decrease in current output. Annually, such connections should be cleaned.

As galvanic anodes approach the end of their useful life, current output will diminish. Replacement of individual anodes or the entire anode ground bed will be required when insufficient current output(s) to maintain protective potentials on the pipeline are identified. Current output can be measured during annual surveys at those installations having test points installed for the purpose. Approximate determination of the useful life of such installations may be predicted from a comparison of the average current output (since installation) with the amount of anode material

If there is a marked decrease in the output of a galvanic anode installation and there is no reason to believe that it is reaching the end of its life, a broken header wire or anode lead may be the cause. If an over-the-line potential profile is made to locate disconnected anodes, the peaks at working anodes will be usually of much less magnitude than those found for impressed current anodes.

2.6.2.4 TEST POINT MAINTENANCE

Test points are the principal means in evaluating the level of CPon most pipeline systems. Post mounted test stations, from time to time, require replacement of box covers or cover retention screws, cover gaskets or terminal nuts or screws within the test box. Occasionally a test station may be broken or missing as the result of accident or vandalism. Pipeline corrosion personnel, when making routine surveys, should carry a complete stock of spare parts and test boxes so that minor maintenance can be implemented at that time. **270** Maintenance Procedures Broken wires at test points can be hard to repair if the break is not near the surface. Where test stations are attached to a cased crossing vent pipe, earth settlement at a deeply buried crossing can create enough tension on the wires to break them. While it is good practice to leave slacked wire in the test box to relieve tension, this is not always sufficient.

Occasionally it is found that test wires were tied around the vent pipe to hold it in place while the crossing excavation was being filled and that this tie-off was not loosened when the test point was set. Soil settlement can pull the wires taut at and below the point where they are tied and either snap them or cut through the wire insulation to short circuit the wires to each other or to the vent pipe. In the case of long buried underground conductors along the current measurement spans, backfill settlement around the pipe may be sufficient to snap the wires if they were not placed properly at the time of installation.

Occasionally, a defective exothermic weld connection between test lead and pipe may separate from the pipe and give an open circuit indication. At locations where the test point is located close to the pipe connections, the excavation required to locate and repair the trouble (unless the line is very deep) is rather simple. If the break is in a long wire span, where to excavate becomes important and requires the use of pipe-cable locator tests to determine the break location.

2.6.2.5 CASED CROSSING MAINTENANCE

Maintaining insulation between carrier pipe and casing is the most important objective at cased crossings. If it is not possible to isolate the casing and the carrier pipe, steps should be taken to eliminate (by methods other than CP) conditions conducive to corrosion on the carrier pipe within the casing.

The status of isolation at cased crossings should be measured at each annual survey. If a shorted condition is found, immediate repair should be scheduled. Before sending a crew to the site, as much information as possible on the probable location of the short circuit should be determined by electrical measurements.

The first thing to check is the test point at the cased crossing. It is not unusual to find that the short circuit is not in the casing itself, but may result from contacts between the test point wires and the casing vent (or the end of the casing) or between the test wires and test point conduit mounted on the casing vent. Locating and clearing such short circuits is discussed in the preceding section. If the short circuit is between the pipe and casing, it should be determined (if casing and test point construction so permit) whether the short is at one of the two ends or is well inside the casing. With a contact at one of the two ends, that end may be uncovered, the end seal removed and the short circuit cleared. This may require jacking the pipe and casing apart and inserting additional insulating spacers. Usually, when the contact is at one end, its location and cause are obvious once uncovered and the end seal is removed. The casing end seal should be replaced after the short circuit is cleared and before backfilling.

CHAPTER-3

OVERVIEW OF CHENNAI-TRICHY-MADURAI PIPELINE

3.1 INTRODUCTION

Indian oil corporation limited looking into the logistic support required for evacuating the CPCL refinery products like petrol, diesel and kerosene, have embarked upon a project to a transport the products to the consumption centres at Trichy, Madurai and salem, by laying pipeline from CPCL refinery at manali. The refined products such as motor sprit (MS), superior kerosene oils (SKO), high speed diesel (HSD) from CPCL tank farm shall be evacuated through the Chennai trichy Madurai pipeline(C TMPL).

chennai-Trichy-Madurai Pipeline

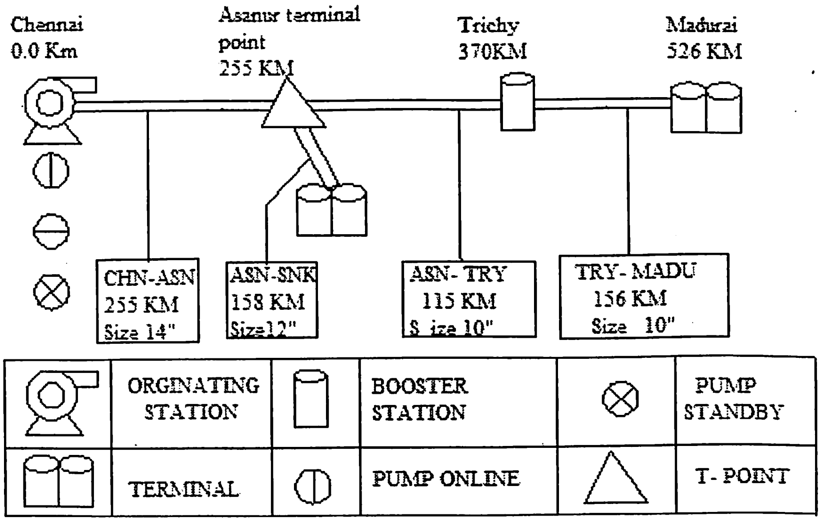


FIGURE 6 PIPELINE DETAILS

- Total length of pipeline 684 km...

3.2 PROJECT DESCRIPTION

CTMPL with a branch line to sankari from Asunur is a 683 km long cross country pipeline is the first of its kind in south India traversing through eleven districts of Tamil Nadu. The pipeline has its.

- Originating pumping station at CHENNAI.
- Terminal point for branch line at ASANUR.
- Tap –off point with delivery station at TRICHY.

- Terminal cum delivery stations at MADURAI & SANKARI

For that above pipeline to designed Temporary cathodic protection system for entire length of pipeline.

3.3 PHILOSOPHY OF TEMPORARY CATHODIC PROTECTION SYSTEM.

- The cathodic protection system shall be a galvanic/ sacrificial anodes system.
- The system shall be designed using pre-packed magnesium anodes.
- The anode shall be installed in a vertical configuration at a depth of 2.5 mtrs from the bottom of the anode.

3.4 ANODE CONSIDERATION:

For Chennai-Trichy-Madurai pipeline the magnesium anode is selected because it has following advantages.

- The magnesium anode are low potential anodes having a close circuit potential of 1.5 volts and thereby having polarized potential of 0.85 volts.
- Very high efficiency = >90%
- No temperature limitations (up to 212° F)

CHAPTER-4

DESIGN PARAMETERS

AND

METHODOLOY FOR

TEMPORARY CATHODIC PROTECTION

4.1 FIELD DATA AND DESIGN ASPECTS OF TEMPORARY CATHODIC PROTECTION SYSTEM.

4.1.1 Cathodic protection of buried structures

Before designing cathodic protection adequate field data must be gathered, analyzed and evaluated.

Field-tests

Nature and conditions of the soil are reflected by field measurements like soil resistivity. To understand the nature of the pipeline, potential measurements, coatings, resistance meaningful design current requirement tests must be conducted.

Soil resistivity

Soil is not an uniform electrolyte. Its resistivity varies from place to place. Marshy soils may have low resistivity where as the resistivity may be several thousand ohms in the case of rocky soils. Corrosivity is always an inverse function of soil resistivity. At low resistant areas, current flow is favored and increases the probability of anodic dissolution. It is quite natural at highly resistant areas corrosion problems will not be severe.

TABLE 4.1 Probability of corrosion activity for steel exposed to soils of varying activity

Resistivity range Ohm. Cm	Corrosion activity
0-1000	Probably severe
1000-10,000	Moderate to severe
10,000 – 1,00,000	Mild if aerated
> 1,00,000	Probably not corrosive

4.2 STRUCTURE TO ELECTROLYTE POTENTIAL

Structure to electrolyte potential surveys are effective in analyzing the corrosion activity of an existing pipeline. High input impedance voltmeters are employed to measure the structure to electrolyte potential measurements. The potential surveys are conducted along the pipelines at incremental distances with reference electrode.

Data must be interpreted incorporating the IR drop values in the measured values, occurring at the point of reference electrode and the underground structure. IR drop is a problem in highly resistant soil and areas covered with concrete. By wetting the soil IR drop can be minimized.

The more negative pipeline potentials corresponds to regions of low electrolyte resistivity for bare and coated structures. The anodic areas corresponding to more negative potential will occur at more negative potentials will occur at river crossing and under areas of clay.

At low resistant areas the large potential difference would correspond to areas of corrosion activity. At high resistive areas this may not be a problem. The potential data must be interpreted in conjunction with soil resistivity data.

More detailed information can be obtained on galvanic attack, stray current corrosion by measuring the potential also along the uncoated pipelines that are lateral to the structure. (e.g. 20 to 50 feet normal to the structure).

In general

1. When the lateral potentials are less negative than those measured over the structure anodic areas will occur at locations along the pipelines.
2. When anodic areas coincide with regions of high negative potential normal corrosion activity is probably taking place stray current and galvanic corrosion should not be suspected.
3. When anodic areas coincide with low negative potential corrosion activity is probably caused by stray current or galvanic attack.

General interpretation of pipe to soil potential measurements :

1. Newer pipelines show more negative potential than older pipeline.
2. In acidic soil potentials are more negative than in alkaline soil.
3. Well-coated structures show more negative potentials than uncoated structures.
4. More negative potentials correspond to locations of low resistivity for uncoated structures.

4.3 CRITERIA FOR PROTECTION

The criteria endorsed in corrosion control regulations issued by the office of the pipeline safety United State Department of Transportation.

1. A negative (cathodic) potential at least 0.85V as measured between the structure and saturated copper-copper to sulphate($CU/CUSO_4$)
2. A negative potential shift of at least 300 mV as measured' between the structure and saturated copper-copper to sulphate ($CU/CUSO_4$)
3. A negative polarization potential shift of 100 mV measured between structure and $CU/CUSO_4$ this polarization potential is to be determined by interrupting the polarization decay.

4.4 CATHODIC PROTECTION SYSTEM MONITORING

The best way of monitoring the CP system is to measure and record the pipe to soil potential levels. These PSP values should be measured/read at small intervals and should be recorded and plotted. There will be usually slow cyclic variations with the seasons; irregular variations with soil moisture conditions and perhaps an overall slow decline connected with coating deterioration. A sudden drop is definite indication of some kind of failure and calls for an investigation.

4.5 DESIGN PARAMETERS

The following are design parameters are consider for calculating the temporary cathodic protection system for [chennai-trichy-madurai] pipeline.

4.5.1 Pipeline section:

- Chennai-Asanur

- Asanur-sankari
- Asanur –Trichy
- Trichy - Madurai

TABLE 4.2 DESIGN DATA

Design life	3yrs
Pipeline lengths considered for design	Chennai-Asanur-------14" dia Asanur –sankari------ 12 " dia Asanur –Trichy------ 10 " dia Trichy- Madurai------10 " dia
Type of anode	Magnesium anode
Anode size	80mm(D)*900mm(L)

TABLE 4.3 PIPELINE DETAILS:

Pipeline section	**Dia (mm)**	**Pipeline length(mtrs)**	**Coating**
Chennai-Asanur	356	255000	CTE
Asanur –sankari	304.8	158000	CTE
Asanur –Trichy	254	115000	CTE
Trichy – Madurai	254	156000	CTE

TABLE 4.4 SOIL RESISTIVITY DATA

Length (km)	Soil Resistivity, ρ_s (Ω-cm)
0-75	1000
75-150	1100
150-225	1200
225-305	1500
305-360	1600
360-413	1800
413-453	2000
453-493	2200
493-528	2400
528-578	2500
578-628	2800
628-684	3000

TABLE 4.5 SACRIFICIAL MAGNESIUM ANODES SPECIFICATION

1	Anode type	Magnesium
2	Dimensions	80 mm diameter * 900 mm long
3	Weight	7.6 kgs (min) body wt
4	Composition	
	Zinc	
	Aluminium	2.5 – 3.5 % max
	Manganese	5.3 -6.7 %max
	Copper	0.25 – 0.4% max
	Iron	0.05% max
	Nickel	0.03%max
	Magnesium	0.0 03%max
5	Anode closed circuit potential	(-) 1.55 volts
6	Anode output	1230 Amps hrs/kg

7	Anode utilization factor	0.85
8	Anode tail cable	6 mm^2 XLPE/PVC unarmored single core copper conductor cable
9	Resistance of single core copper conductance single core 6mm^2	0.00195 ohm/ms
10	Pre-package dimensions	1500 mm length x 185 mm dia
11	Back fill material	Gypsum – 75%, Bentonite – 20%, sodium sulphate -05%
12	Wt. of backfilled pre-packaged assembly	40 kgs(approx)

CHAPTER-5

PROJECT WORK CALCULATION

5.1 Formula used

1) Surface Area

$S_a = \pi \times d \times l$

Where:

S_a = Surface area of pipeline m^2

d = Diameter of pipeline m

l = length of pipeline m

2) Protective Current Density

$l_d = 0.288 \times Gc/1000$

where:

G_c = coating conductance

3) Coating Conductance

$G_c = 416000/\rho s$

Where:

Gc = coating conductance

ρ_s = soil resistivity

4) Current requirement.

$$I_t = S_a \times I_d \times \frac{1.3}{1000} \text{ Amps}$$

Where:

I_t = c.p current requirement (Amps)

S_a = surface area of pipeline m^2

I_d = c.p protective current density mA

1.3 = Safety margin.

5) Anode weight requirement

$W = I_t \times C_t \times L / U_f$.

Where:

W = Total anode weight (kg).

I_t = C.P current requirement

C_t = Consumption rate of anode (7.9 kg/ kg Amps-year)

L = Design life (3 Year)

U_f = Anode utilization factor (0.85)

6) Vertical distributed groundbed resistance calculation

R = 0.159ρs/NL $(Ln\,\frac{8L}{D} - 1 + \frac{2L}{S}\,Ln\,(0.656\,N)$

Where:

R = Resistance to earth in ohms of the vertical anodes in parallel

ρ_s = soil resistivity in ohm-m

N = number of anodes in parallel

L = length of prepackaged anode in mtrs

D = diameter of prepackaged anode in m

S = anode spacing in m (3 mtrs)

7) Resistance of the anode to backfill

R_v = 0.159 p / l (Ln (8l/d) - 1)

Where:

R_v = Resistance of vertical anode to backfill in ohms

P = length of bacfill material (0.5 ohms-m)

l = length of anode in m (0.9 m)

d = diameter of anode in m(0.08)

8) Total Cable Resistance.

$R_c = R_a \times L/N$

Where:

R_c = total cable resistance

R_a = cable resistance

L = length of the cable

N = no of anodes

9) Total circuit resistance

$R_T = R + R_v/N + R_c$

Where

R_T = Total Circuit Resistance(ohms)

R =Resistance to electrolyte of ground bed(ohms)

N= Number of anodes in each ground bed

R_C= Cable Resistance

10) Current Output per anode bed

$I = V/R_T$

Where

I= Current output per anode bed(Amps)

V=Driving potential for Mg anodes with line polarized (1.5-(-0.85) = 0.65V

R_T=Total circuit resistance

5.2 DESIGN CALCULATION

Pipeline section- 1 .

- Chennai-Asanur (Dia,0.356m)

Case-1 length taken as 0-75km, Soil resistivity = 1000

1) Surface Area

$S_a = \pi \times d \times l$

$= \pi \times 0.356 \times 75000$

$S_a = 83880.453$ m_2

2) Protective Current Density

$I_d = 0.288 \times Gc/1000$

$Gc = 416000/\ \rho_s$

$= 416000 / 1000$

$= 416$

$I_d = 0.288 \times 416/1000$

$= 0.11908$ mA

3) Current requirement.

$I_t = S_a \times I_d \times \frac{1.3}{1000}$ Amps

$= 83880.453 \ \text{x}\ 0.11908 \ \text{x}\ 1.3/1000$

$= 13.06$ Amps

4) Anode weight requirement

$W = I_t \times C_t \times L/ U_f.$

$= 12.98 \times 7.9 \times 3/0.85$

$= 364.2$kg

5) Number of anode required

$$= \frac{\text{Total weight of anode}}{\text{Weight of single anode}}$$

$= 364.3/7.6$

$= 47.92 \sim 48$

Anode ground bed requirement

3 Anode ground bed is taken.

$= 48/3$

$= 16$

6) Vertical distributed ground bed resistance calculation

$R = 0.159\rho s/NL \; (Ln\,\frac{8L}{D} - 1 + \frac{2L}{S}\,Ln\,(0.656\,N)$

$= 0.159 \times 10/3 \times 1.5$ (In $8 * 1.5/0.185 - 1 + (2*1.5)/3$ In $(0.656*3)$)

$=1.36$ ohms.

7) Resistance of the anode to backfill

$R_v = 0.159\, p / l$ (In $(8l/d)$ - 1)

$= 0.159 \times 0.5/0.9$ (In $(8 \times 0.9/ 0.08)$-1)

$= 0.3091$ohms.

8) Total Cable Resistance.

$R_c = R_a \times L/N$

$= 0.001985 \times 8/3$

$= 0.0052$ ohms.

9) Total circuit resistance

$R_T = R + R_v/N + R_c$

$= 1.36 + (0.3091/3) + 0.0052$
$= 1.468$ ohms.

11) Current Output per anode bed

$I = V/R_T$

$= 0.65/1.468$

$= 0.4426$ Amps.

12) Total Current output per bed

I = current output per anode bed *No. of Anode bed ground requirement

= 0.4426 * 16

= 7.082 Amps.

Pipeline section- 1

Chennai-Asanur (Dia,0.356m)

length of pipeline ,l	soil resistivity, ρs ohms cm	surface area **Sa** in m2	coating conductance **Gc**	current densities, **Id** in mA/ sq.m	current requirement, **It** in mA/m2	Anode weight,w in Kg	No of anode	Nearest rounded value
75-150	1100	83880.453	378.1818182	0.1089164	11.8767401	331.151	43.573	44
150-255	1200	117432.6342	346.6666667	0.09984	15.24181646	424.978	55.918	56

No. of ground bed required	vertical Distributed Groundbed Resistance, **R** in ohms	Resistance of anode bed resistance,**Rv** in ohms	Total Cable Resistance, Rc in ohms	Total circuit resistance, RT in ohms	Current Output per anode bed,I in Amps	Total current output/bed I in Amps
14.66666	1.49610389	0.3091499	0.0052	1.60435384	0.40514	5.9421638
18.66666	1.63211333	0.3091499	0.0052	1.74036329	0.37348	6.9717244

Pipeline section- 2

Asanur –sankari (Dia 0.3048m)

Case 2 length taken as 255-305 km, soil resistivity 1500 ohm cm

1) Surface Area

$S_a = \pi \times d \times l$

$= \pi \times 0.3048 \times 50000$

$= 47877.83\ m^2$

2) Protective Current Density

$I_d = 0.288 \times Gc/1000$

$Gc = 416000/\rho_s$

$= 416000/1500$

$= 277.3$

$Id = 0.288 \times 277.3/1000$

$= 0.079872mA.$

3) Current requirement.

$I_t = S_a \times I_d \times \frac{1.3}{1000}$ Amps

$= 47877.83 \text{ x } 0.079872 \text{ x } 1.3/1000$

$I_t = 4.9713276mA/m2.$

4) Anode weight requirement

$W = I_t \times C_t \times L / U_f$.

= 4.9713x 7.9 x 3/0.85

=138.612 kg.

5) Number of anode required

$$= \frac{\text{Total weight of anode}}{\text{Weight of single anode}}$$

= 138.62/7.6
= 18.23~ 19

Anode ground bed requirement

3 Anode ground bed is taken.

= 19/3

= 6.33~7

6) Vertical distributed ground bed resistance calculation

$R = 0.159\rho s/NL\ (ln\ \frac{8L}{D} - 1 + \frac{2L}{S}\ ln\ (0.656\ N)$

= 0.159 x 15/3 x 1.5 (In 8 * 1.5/0.185 - 1 + (2*1.5)/3 In (0.656*3)

=2.040141 ohms.

7) Resistance of the anode to backfill

R_v = 0.159 p / l (In (8l/d) - 1)

= 0.159 x 0.5/0.9 (In (8 x 0.9/ 0.08)-1)

= 0.3091ohms.

8) Total Cable Resistance.

$R_c = R_a \times L/N$

= 0.001985 x 8/3
= 0.0052 ohms.

9) Total circuit resistance

$R_T = R + R_v/N + R_c$
$=2.040141 + (0.3091/3) + 0.0052$
$=2.14839$ ohms.

13) Current Output per anode bed

$I = V/R_T$
$= 0.65/2.14839$
$= 0.302551$ Amps.

14) Total Current output per bed

I = current output per anode bed *No. of Anode bed ground requirement
= 0.302551 * 7

= 1.91616 Amps.

Pipeline section- 2

Asanur –sankari (Dia 0.3048m)

length of pipelinel	soil resistivity, ρs ohms cm	surface area **Sa** in m2	coating conductance **Gc**	current densities, **Id** in mA/ sq.m	current requirement, **It** in mA/m2	Anode weight **w** in Kg	No of anode	Nearest rounded value
305-360	1600	47877.83	260	0.0748	4.66061	129.94	17.099	18
360-413	1800	50750.50	231.1111	0.0665	4.39133	122.44	16.111	17

No. of ground bed required	Vertical Distributed Ground bed Resistance, **R** in ohms	Resistance of anode bed resistance. **Rv** in ohms	Total Cable Resistance.Rc in ohms	Total circuit resistance. RT in ohms	Current Output per anode bed, I in Amps	Total current output/bed I in Amps
6	2.17615111	0.3091499	0.0052	2.28440106	0.28453	1.70723086
5.666666	2.44817	0.3091499	0.0052	2.55641995	0.25426	1.440817

Pipeline section- 3

Asanur –Trichy (Diameter 0.254) (length of pipeline 115km)

Case 3 length taken as (413-453), soil resistivity 2000 ohm cm.

1) Surface Area

$S_a = \pi \times d \times l$

$= \pi \times 0.254 \times 40000$

$= 31918.55\ m^2$

2) Protective Current Density

$I_d = 0.288 \times Gc/2000$

$Gc = 416000/\ \rho_s$

$= 416000/2000$

$= 208$

$Id = 0.288 \times 208/1000$

$= 0.059904mA.$

3) Current requirement.

$I_t = S_a \times I_d \times \frac{1.3}{1000}$ Amps

$= 31918.55 \times 0.059904 \times 1.3/1000$

$I_t = 2.48566 mA/m2.$

4) Anode weight requirement

$W = I_t \times C_t \times L/\ U_f.$

$= 2.48566 \times 7.9 \times 3/0.85$

$= 69.306$ kg.

5) Number of anode required

$$= \frac{\text{Total weight of anode}}{\text{Weight of single anode}}$$

= 69.306/7.6

= 9.119~ 10

Anode ground bed requirement

3 Anode ground bed is taken.

= 10/3

= 3.33~4

6) Vertical distributed ground bed resistance calculation

$$R = 0.159\rho s/NL\ (\ln \frac{8L}{D} - 1 + \frac{2L}{S} \ln (0.656N)$$

= 0.159 x 20/3 x 1.5 (In 8 * 1.5/0.185 - 1 + (2*1.5)/3 In (0.656*3)

= 2.720188 ohms.

7) Resistance of the anode to backfill

R_v = 0.159 p / l (In (8l/d) - 1)

= 0.159 x 0.5/0.9 (In (8 x 0.9/ 0.08)-1)

= 0.3091ohms.

8) Total Cable Resistance.

$R_c = R_a \times L/N$

= 0.001985 x 8/3

= 0.0052 ohms.

9) Total circuit resistance

$R_T = R + R_v/N + R_c$

= 2.720188 + (0.3091/3) + 0.0052

= 2.82843 ohms.

10) Current Output per anode bed

$I = V/R_T$

= 0.65/2.82843

= 0.22980 Amps.

11) Total Current output per bed

I = current output per anode bed *No. of Anode bed ground requirement

= 0.22980 * 4

= 0.766029 Amps.

length of pipeline,l	soil resistivity, ρs ohms cm	surface area Sa in m2	coating conductance **Gc**	current densities, **Id** in mA/ sq.m	current requirement, **It** in mA/m2	Anode weight,**w** in Kg	No of anode	Nearest rounded value
453-493	2200	31918.5544	189.0909091	0.0544582	2.259694371	63.0056	8.2902	9
493-528	2400	27928.7351	173.3333333	0.04992	1.812463193	50.5357	6.6494	7

No, of ground bed required	vertical Distributed Groundbed Resistance, **R** in ohms	Resistance of anode bed resistance,**Rv** in ohms	Total Cable Resistance,**Rc** in ohms	Total circuit resistance,**RT** in ohms	Current Output per anode bed,**I** in Amps	Total current output/bed **I** in Amps
3	2.9922077	0.3091499	0.0052	3.10045773	0.20964	0.62893939
2.3333333	3.2642266	0.3091499	0.0052	3.37247662	0.19273	0.44971896

Pipeline section- 4

Trichy- Madurai (Diameter 0.254) (length of pipeline 156km)

Case 4 length taken as (528-578), soil resistivity 2500 ohm cm.

1) Surface Area

$S_a = \pi \times d \times l$

$= \pi \times 0.254 \times 50000$

$= 39898.193\ m^2$

2) Protective Current Density

$I_d = 0.288 \times Gc/1000$

$Gc = 416000/\rho_s$

$= 416000/2500$

$= 166.4$

$Id = 0.288 \times 166.4/1000$

$= 0.047923$ mA.

3) Current requirement.

$I_t = S_a \times I_d \times \frac{1.3}{1000}$ Amps

$= 39898.193 \times 0.047923 \times 1.3/1000$

$I_t = 2.485663$mA/m2.

4) Anode weight requirement

$W = I_t \times C_t \times L/ U_f.$

$= 2.48566 \times 7.9 \times 3/0.85$

$=69.306$ kg.

5) Number of anode required

$$= \frac{\text{Total weight of anode}}{\text{Weight of single anode}}$$

$= 69.306/7.6$

$= 9.119\sim 10$

Anode ground bed requirement

3 Anode ground bed is taken.

$= 10/3$

$= 3.33\sim 4$

6) Vertical distributed ground bed resistance calculation

$$R = 0.159\rho s/NL\,(ln\,\frac{8L}{D} - 1 + \frac{2L}{S}\,ln\,(0.656\,N)$$

$= 0.159 \times 25/3 \times 1.5$ (In 8 * 1.5/0.185 - 1 + (2*1.5)/3 In (0.656*3)

$= 3.400236114$ ohms.

7) Resistance of the anode to backfill

R_v = 0.159 p / l (In (8l/d) - 1)

= 0.159 x 0.5/0.9 (In (8 x 0.9/ 0.08)-1)

= 0.3091ohms.

8) Total Cable Resistance.

$R_c = R_a \times L/N$

= 0.001985 x 8/3

= 0.0052 ohms.

9) Total circuit resistance

$R_T = R + R_v/N + R_c$

= 3.400236114 + (0.3091/3) + 0.0052

= 3.50848607 ohms.

10) Current Output per anode bed

$I = V/R_T$

= 0.65/3.50848607

= 0.18526506 Amps.

11) Total Current output per bed

I = current output per anode bed *No. of, Anode bed ground requirement

= 0.18526506 * 4

= 0.46555676 Amps.

length of pipeline,l	soil resistivity, ρs ohms cm	surface area Sa in m2	coating conductance **Gc**	current densities. **Id** in mA/ sq.m	current requirement. **It** in mA/m2	Anode weight,w in Kg	No of anode	Nearest rounded value
578-628	2800	39898.193	148.571428	0.0427886	2.21934268	61.880	8.142	9
628-684	3000	44685.976	138.666666	0.039936	2.31995288	64.685	8.511	9

No, of ground bed required	vertical Distributed Ground bed Resistance, **R** in ohms	Resistance of anode bed resistance,**R v** in ohms	Total Cable Resistance,**Rc** in ohms	Total circuit resistance, **RT** in ohms	Current Output per anode bed, **I** in Amps	Total current output/bed **I** in Amps
3	3.80826445	0.3091499	0.0052	3.9165144	0.165964	0.4978917
3	4.08028334	0.3091499	0.0052	4.18853329	0.155186	0.46555676

CHAPTER-6

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Based on the above computation, the following results are tabulated below.

Summary of anode requirements

length of section Km	surface area Sa in m2	soil resistivity. ρs ohms cm	coating conductance Gc	current densities, Id in mA/ sq.m	current requirement, It in mA/m2	Anode weight,w in Kg	No of anode	Nearest rounded value
0-75	83880.453	1000	416	0.119808	13.06441411	364.2666051	47.929816	48
75-150	83880.453	1100	378.181818	0.108916364	11.8767401	331.1514592	43.572560	44
150-255	117432.6342	1200	346.666666	0.09984	15.24181646	424.9777059	55.918119	56
255-305	47877.8316	1500	277.333333	0.079872	4.971327615	138.6123112	18.238461	19
305-360	47877.8316	1600	260	0.07488	4.660619639	129.9490417	17.098558	18
360-413	50750.5015	1800	231.111111	0.06656	4.391339393	122.4408749	16.110641	17
413-453	31918.5544	2000	208	0.059904	2.485663808	69.30615558	9.1192309	10
453-493	31918.5544	2200	189.090909	0.054458182	2.259694371	63.00559598	8.2902099	9
493-528	27928.7351	2400	173.333333	0.04992	1.812463193	50.53573844	6.6494392	7
528-578	39898.193	2500	166.4	0.0479232	2.485663808	69.30615558	9.1192309	10
578-628	39898.193	2800	148.571428	0.042788571	2.219342685	61.88049605	8.1421705	9
628-684	44685.97616	3000	138.666666	0.039936	2.319952887	64.68574521	8.5112822	9

Spacing of ground beds:

Each ground bed has a pre packed anode set consisting of 3 single anodes.

Section Number	Length in **Km**	cumulative distance in **km**	No of anode required	No of ground bed required	Spacing between each ground bed in **km**
1	0-75	75	48	16	4.6875
2	75-150	75	44	14.6666	5.113659608
3	150-255	105	56	18.66666	5.625002009
4	255-305	50	19	6.3333	7.894778394
5	305-360	50	18	6	8.333333333
6	360-413	53	17	5.6666	9.353051212
7	413-453	40	10	3.3333	12.00012
8	453-493	40	9	3	13.33333333
9	493-528	35	7	2.3333	15.00021429
10	528-578	50	10	3.3333	15.00015
11	578-628	50	9	3	16.66666667
12	628-684	56	9	3	18.66666667

From the calculations we can find that the soil resistivity plays a vital role in the determination of the corrosion current. When the resistivity is too high the chances of corrosion in the material are low i.e. rocky soil and if the resistivity is too low i.e. in the range of 50-500 ohm-cm, the potential for corrosion is very high. This occurs in the marshy terrain and clayey soil.

The variation of soil resistivity along the length is shown in the figure 7 below. Its varies along the length of the pipeline and is independent of the pipeline parameters.

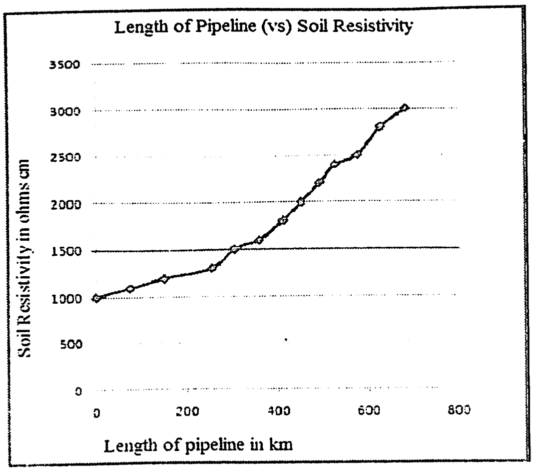


Figure 7 length of pipeline vs soil resistivity

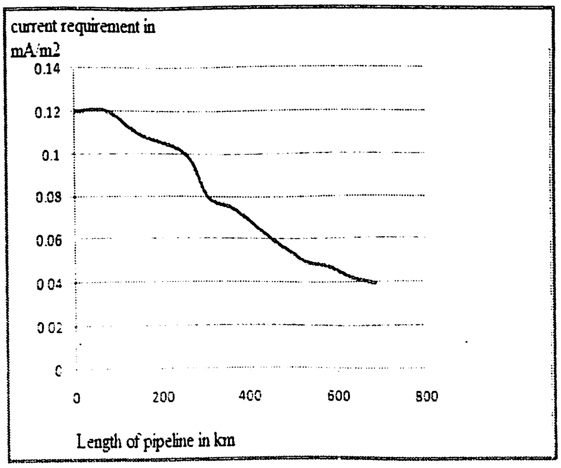


Figure 8 current requirement vs length of pipeline

Soil resistivity initially at 1000 ohms cm and it increases upto 3000. This vary along the length of pipeline.

The figure 8 shows the current requirement and length of pipeline shown below. It is evident that increasing the soil resistivity the current requirement will decreases.

Soil resistivity data is helpful in finding the following Cathodic protection parameters.

- Coating conductance.
- Current requirement
- Anode requirement
- Anode weight
- Vertical distributed ground bed
- Total cable resistance
- Total cable resistance
- Number of anode
- Number of ground bed required
- Current output per anode bed

The figure 9 shows the variation of anode required along with length of pipeline.

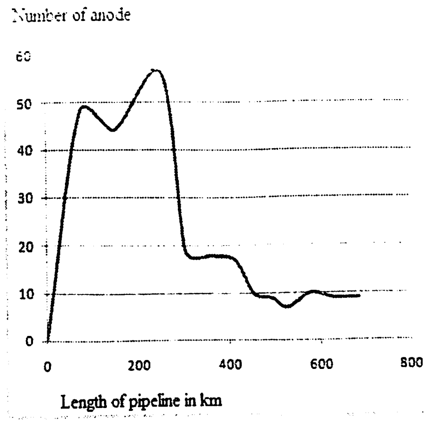


Figure 9 No of anode vs length of pipeline

Anode required varies with the length of pipeline and depends on soil resistivity and other parameter mentioned. If the length is high the anode requirement is more for the section. If the distance is less the anode requirement is high in number.

If the soil resistivity is high for a particular section of length, the anode requirement is less.

CONCLUSION

- Thus for the Chennai-Trichy- Madurai pipeline the following are concluded.
- Anode weight and the current requirement is found using the soil resistivity data.
- The total anode weight requirement for entire 684km of pipeline is 1890.118kg. So the calculated anode weight is sufficient enough to protect the pipeline.
- Number of anode bed requirement has been found. So we are supposed to provide 82 ground beds in total for the entire section of 684 km to protect the pipeline from corrosion during the construction phase.
- Then current outputs for those anode beds have been found. The total current output required for 684 km of pipeline is 28.4865 Amps.
- These data will be necessary to protect the pipeline from corrosion activity.
- This system is applicable only before commissioning of the pipeline

SCOPE OF WORK

- The current work involves the basic calculations in arriving at the current requirement to protect the line from corrosion.
- Even though soil resistivity data are provided. A thorough soil chemical analysis has to be made before preparing the ground bed and the necessary arrangements.
- The sizing of the anode has to be done based on the industry specific availability and is not covered in this current work
- This design is in compliance with ASME and NACE standards. Other European and Canadian standards may have a different approach in designing the TCP.

REFERENCES

[1] Operational and maintenance of Cathodic Protection Systems by U.S ARMY CORPS Engineers.

[2] Handbook of Corrosion Engineers by Pierre R.Roberge, 3rd Edition

[3] Control of Pipeline Corrosion by Peabody 2nd Edition

[4] www.NACE.com

[5] Corrosion Science and Technology by David Talbott & James Talbott

[6] Cathodic Protection System Application and Maintenance Guide by Electric Power Research Institute, Final Report, December 2005

[7] Pipeline Corrosion and Cathodic Protection by Parker Marshall E, 3rd Edition

[8] Cathodic protection of above storage tanks –API 651, 2nd Edition

[9] Cathodic protection design of subsea pipeline-DNV-Recommended procedure -b401

[10] MATCOR Technical Bulletin- New Above Ground Storage Tank Construction FINAL

[11] C.F. Schrieber, J.T. Reding, Field testing a new aluminum anode:Al–Hg–Zn galvanic anode for seawater applications, Mater. Prot. 6 (1967) 33–36.

[12] D.S. Kier, M.J. Pryor, P.R. Sperry, Galvanic corrosion characteristics of aluminum alloyed with group IV metals, J. Electrochem. Soc. 114 (1977) 777–782.

[13] M.C. Reboul, M.C. Delatte, Activation mechanism for sacrificial Al–Zn–Hg anodes, Mater. Perform. 19 (1980) 35–41.

[14] A.G. Kulkarni, I. Gurrappa, J.A. Karnik, Bismuth activated aluminium alloy anodes, Bull. Electrochem. 7 (1991) 549–553.

[15] National Association of Corrosion Engineers Int. – Standard recommended practice for control of external corrosion on underground or submerged piping systems, RP0169-96, September; 1996.

ANNEXURE -A

PROCEDURE

FOR

MAGNESIUM ANODE INSTALLATION

INTRODUCTION

This procedure covers installation of the pre packaged magnesium anode assemblies.

Responsibility

It is the responsibility of the contractor's engineer to ensure that the anodes, cables and the associated test station are correctly installed. Responsibility shall also cover the proper super vision in excavation, backfilling and concreting work as required.

Detailed procedure

The anodes shall be suitably located as enumerated in the design package to provide the adequate levels of corrosion protection.

The installation procedure is as follows:

- The magnesium anode ground bed shall be located at least 3 meters away from the pipeline.
- The magnesium anode shall be installed in vertical configuration perpendicular to the pipeline.
- The anode shall be installed in suitable diameter augured hole of 2.5 meters depth.
- The center to center spacing between consecutive anode shall be 3 meters.

The pre packed anodes shall be lowered inside the augured hole and the balance space around the anodes shall be filed with native soil. The anode shall be installed such that the top of the anode is at least 1.8 meters below the ground level. After installing the anode the soil surrounding the anode shall be compacted. While lowering, the anode should not be suspended or lowered by its lead wire. In dry location a minimum 20 liter of water shall be poured directly on the anode. The anode installation shall be checked by measuring the potential of the pipeline against a standard copper-copper sulphate reference cell before and after the connection of anodes.

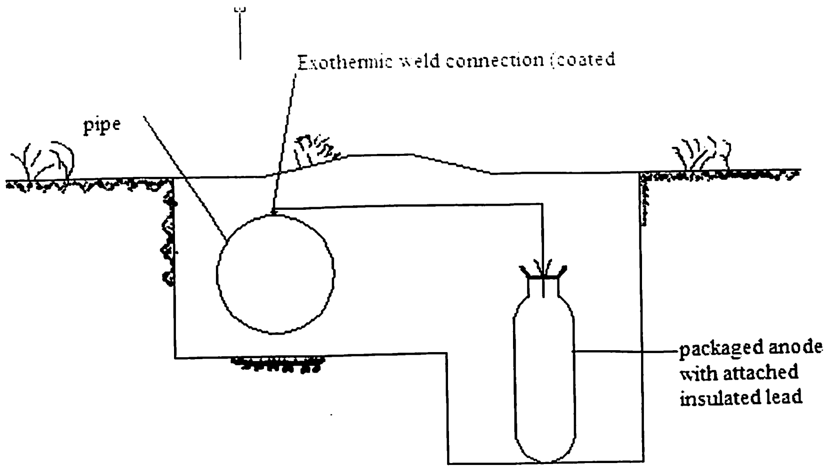


Figure 10 Single package anode installation

Backfill

Anode shall be packaged in a cotton bag and shall be surrounded by a low resistivity rapid wetting chemical backfill of the following composition.

Gypsum : 75%
Bentonite : 20%
Sodium sulphate : 5%\
Approximately . Resistivity in Ohm.cm: 50

Procedure for Test station installation

Test station

Test station shall be provided along the pipeline ROW for monitoring the performance of the cathodic protection systems at intervals not exceeding 1000 meters.

In addition to above, test station shall also be provided at the following locations.

a. At both side of major water, road and rail and all cased crossings.
b. At all insulating joints
c. At crossings of AC/DC electric traction systems.
d. At HT over headed line crossings and selected locations where HT overhead line is in the vicinity of the pipeline.

e. Drastic changes in soil resistivity.
f. At connection of sacrificial anodes, grounding cell an polarization cell as required.
g. At measuring point for pipeline current.
h. In the vicinity of DC network or grounding system where interference problems are suspected.
i. At valve locations.
j. At crossings/ parallel running of other pipelines/ structures
k. Within the battery limit of the plant as required.

Test station for bonding shall be provided with shunt and resistor as a mean to monitor and control current between the pipeline and foreign pipeline or structures that exists in the ROW or in the vicinity.

The test station with the galvanic anode shall have provisions for link insertion to limit the anode current output.

All the test stations shall have weather proof enclosure, having degree of protection IP55 with hinged lockable shutter. Enclosure shall be made of sheet steel of at least 3mm thickness and shall be suitable for M.S post mounting. The test station shall be suitable for total life of permanent CP system.

The test station shall be installed with the front of the test station facing the pipeline. The name plate of the test station shall in minimum carry following information.

- Chainage in Km.
- Test station connection scheme type.
- Pipe no.
- Cad weld location.
- Identification no.

Terminal blocks and different schemes of wiring as required shall be provided in the test station as per the test station connection scheme sketch.

The types shown are not necessarily representative of any particular standard but are intended to represent the variety that may be encountered. A color code is shown to illustrate a system whereby leads may be identified. Whatever color code is adopted should be made standard throughout your pipeline system.

- The two-wire potential test point is the one used most frequently. Two wires make it possible to check pipe-to-earth potential with one while test current is being applied to the line (if desired) using the other.

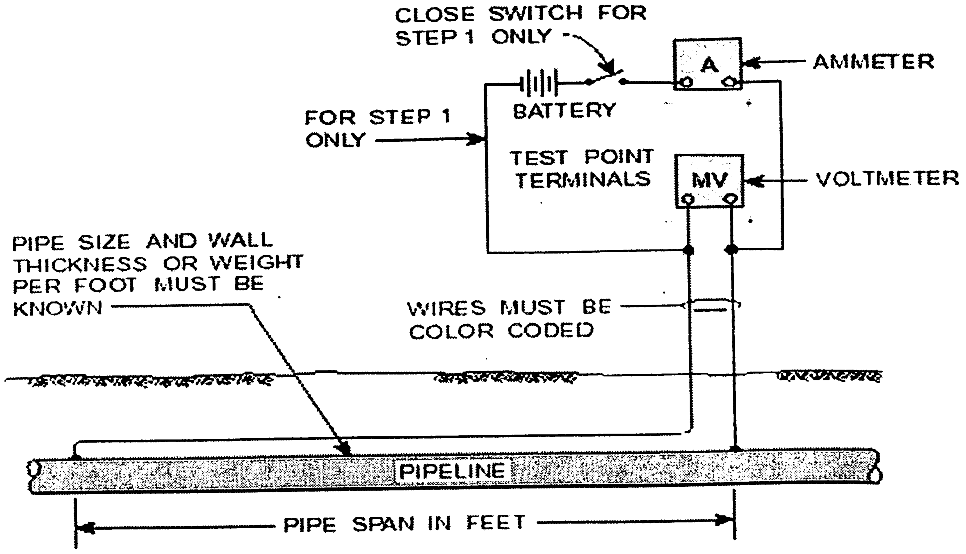


Figure 11 Two wire potential test point

- The four-wire insulated joint test point permits measuring pipe-to-earth potentials on each side of an insulated joint. The second pair of heavier gauge wires are available for inserting a resistance or solid bond across the insulated joint if necessary.
  The four-wire calibrated line current test point permits accurate measurement of pipeline current flow.
- The six-wire combination insulated joint and line current test point is useful, particularly at terminal insulated flanges, because it permits positive measurement of current

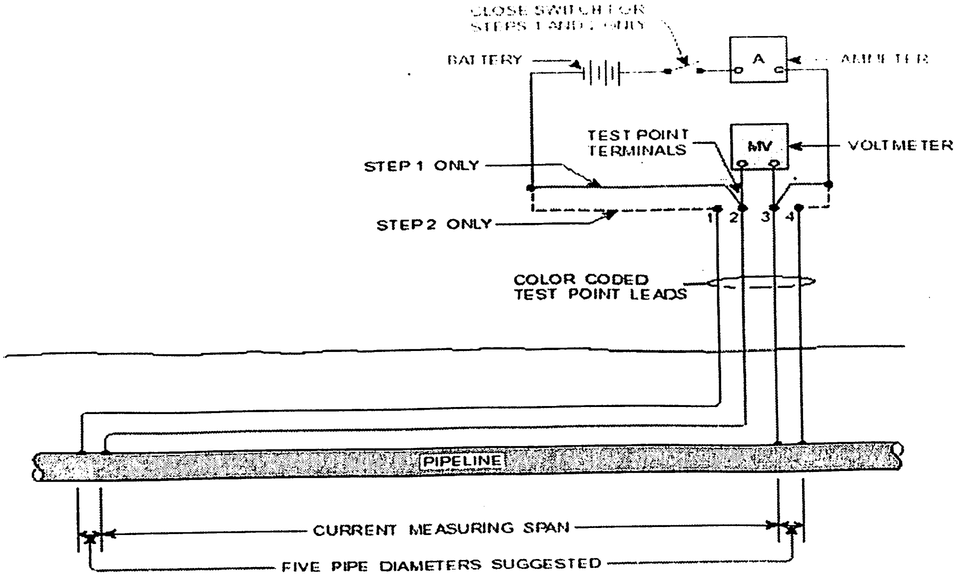


FIGURE 12 Four wire insulated joint test point

Procedure for a test stations:

- Fabricate the reinforcement using M.S rods of 6mm dia. As per drawing.
- Excavate 1m x 1m x 1m where the foundation is to cast.
- Take M.S shuttering and place it in right position.
- Fill annular space with Reinforced Concrete Cement. The mixture shall be constantly Rammed for proper compaction.
- Remove the shuttering after 24 hours.
- The foundation shall be cured by proper curing.
- Place the TLP boxes on the studs of the bend cast in concrete foundation and tighten the bolts.
- The bolts shall then be distorted by hitting with a heavy hammer to make the installation vandal proof and also to ensure that the installation become theft proof.

Cable Laying

- All cables shall be laid in accordance with approved layout drawing. There shall be no joints in a single run of cable.
- The cables shall be laid at a depth of 1.2 m in sand bed or soft earth with a layer of 75mm of sand or soft soil.

- All underground cables shall be enclosed by G.I pipe of appropriate size while passing through road/rail crossings.
- Cables shall be neatly arranged in trenches in such a manner that crisscrossing is avoided and final take off to equipment is facilitated.

Procedure for Thermit cad weld connection

Cad welding of cable to pipe shall be carried out in the following steps

Cable preparation.

- 25mm of protective sheathing and insulation shall be removed from the cable end (or a length appropriate for the size of mould)
- The bare conducter shall be clean, bright and dry. Corroded conducters shall be dried with a clean dry cloth, ensuring that the cable insulation and sheathing are not damaged.

Surface preparation:

The cable connection to pipe shall be at least 150mm from any field joint coating. Where are two more cables to pipe connection are required at one location of pipe, cable to pipe connection shall be at least 150mm apart.

The protective coating and any mastic, adhesive or primer shall be removed from the top of the pipe to provide an exposed steel surface area suitable for the cable connection purposes as follows.

- Measure and mark the area of coating removed (remove 50mm x 50mm square of the pipeline coating.)
- Remove the coating gently, using a sharp knife or sharp chisel and light hammer. The chisel shall be used at an angle not vertically.
- Use a flat rough file to remove the coating residue.
- Take care to ensure that the surrounding coating are not damaged.
- Clean the exposed surface to ensure free from oil and grease by using dry cloth.
- The resulting surface shall be clean, bright and slightly rough.

Cable connection

- Cad weld charges shall not be greater 15 gms. And cables conductor cores shall not be larger than 16 sqmm.
- For conductor of 6 sqmm or less it will be necessary to install a copper sleeve of appropriate size over the bare end of the conductor and crimp into place before making the cad weld.

The cable connection process shall be carried out as follows.

- Position the conductor over the centre of the cleaned pipe surface area.
- Locate the mould over the conductor so that the conductor can be seen through the hole in the bottom of the mould.
- Place metal disc over the hole.
- Open charges cartridge and pour the powder into the mould. Tap the side of the cartridge to ensure that all the powder is emptied from the container. Continue to shake and tab the cartridge to ensure placement of the ignition powder on top of the charge power.
- Close the mould and ignite the ignition powder with a flint ignitor.
- Open the mould and remove after (approx) 10 sec minimum.
- Remove slag from mould before making next connection.

Test after cad welding:

The following test shall be carried out before repairing the coating of the finished cable connection.

- Remove flux and any other debris using hand or power wire brush.
- Visually examine the cad weld, checking that the entire conductor is incorporated in the weld metal.
- Check the mechanical integrity of the weld by use of a light hammer (0.5 kg) striking the weld firmly but gently as close to the steel pipe surface as possible in the direction parallel to the pipe surface.
- Check the continuity of the bare cable conductor to the pipe using a resistance meter (multimeter) with a scale which can be read to less than one ohm. A value of less than 0.75 ohms is acceptable.

Coating repair:

- Coating repair shall be carried out as follows.
- Place a PVC cap / PVC funnel around the cable to pipe connection area such that about 5mm wide CTE coating remains inside the PVC cap.
- Seal the exposed area by pouring mixture of epoxy and hardner in the PVC cap / Funnel so as achieve electrical insulation and bonding.
- Allow epoxy hardner solution to solidify and check the coating with holiday detection.
- For charged pipeline pin brazing shall be used.

Procedure for installation of corrosion coupon.

Scope:

To install corrosion coupon to facilitate measurement of 'OFF' potential and thereby assessing IR drop in the PSP measurement.

Installation and fabrication of coupon.

- Coupons of size 4" x 2" shall be cut from a coated pipe. The cut out coupon shall be grinded on all its edges to strip the loose metal, one face of the copper which corresponds to the internal surface of the pipe will not be having any coating. This face of the coupon shall be cleaned properly and there an area of around 4mm dia shall be covered with an adhesive tape. The coupon lead wire shall be firmly riveted / soldered and shall be sealed with epoxy encapsulation.

- The coupon then shall be dipped in hot coal tar enamel liquid. After the coating is cured the adhesive tape shall be removed so as to provide above spot simulating the holiday. While positioning the coupon burid at pipeline depth this surface of the coupon where in holiday is simulated shall be positioned facing back to the pipeline. These coupons are required to be installed at each TLP along the entire pipeline.

ANNEXURE-B

FIELD TESTING

AND

COMMISSIONING

INTRODUCTION

The commissioning procedure conforms to company specification Standard specification for temporary C.P system for pipelines. The specification lay down the general specification for cathodic protection system testing and surface the checks and tests which we shall be required to carry out to ensure that the cathodic protection system is correctly installed.

Intent

The intent of the document is to provide a framework for performing pre-commissioning checks on the equipments and materials, and finally a scheme of energizing and commissioning the installed cathodic protection system.

Instruments:

We shall provide all necessary instruments, equipments and labor to perform all the required checks and test. For this purposes the following instruments, amongst others, shall be deployed at site.

- Copper / copper sulphate reference half cell.
- High impedance L.C.D digital multimeter.
- Electricians tool kit.
- Cable testing megger.

Electrical facilities:

Before the electrical facilities are placed in operation, suitable tests to establish that all equipment, devices, wiring and connection have been properly installed and connected and are in good working condition for intended operation.

Checking and inspection of equipment and installation:

Equipment:

- A visual inspection of equipment/ facility shall be carried out to detect any mechanical damage and for comparison and verification of dimensions and finish with drawing and specification.
- Detailed physical inspection shall also involved components and accessories

Installation:

As apart of the visual exercise, installation as they exist on completion shall be examined as follows.

Correctness of locations:

This shall be verified in respect of all important equipment namely,

- Anodes ground bed locations.
- Cable routes.
- Test station locations.

Correctness of civil/ mechanical installation:

This shall involve checking the completeness of civil and mechanical aspects and correctness of alignment. Compliance with approved construction drawings and detailed notes appearing therein shall be verified.

Equipment test:

Cables:

- Verify the cable insulation with a 500v megger.
- Check the correctness of termination and lug fixing.
- Check the proper mark of cables and verify their compliance with design data.
- Check the conductor size and characteristic of cables to verify their compliance with design data.
- Check the continuity of each cables.

Anode ground bed:

Location of anodes shall be identified and ascertained with the help of the termination in test stations.

Commissioning procedure / operating tests:

Natural potential measurement:

The natural pipe-to-soil potential shall be measured before energizing C.P system using portable copper-copper sulphate half cell as reference and a portable high impedance corrosion voltmeter/ potentiometer. The corrosion voltmeter shall be connected through test station. The reference cell shall be placed on the ground right over the structure in wetted soil. All result shall be recorded on the test report.

Format for recording commissioning observations

- The closed circuit potential of magnesium anodes shall be recorded. (It should be approximately 1.55 volts).
- The anodes shall connected to the pipeline through the test station.
- The pipe to soil potentials (PSP) is measured after allowing a time of 72 hours for the pipe to polarize and shall be recorded in a tabular form in the following proposed format.

Sr.No	Test Point	Chain age	P.S.P mv		Remarks
			Natural	Protected	

If the current output of the anodes at any of the insulation is found to be more than the design current of anode, then additional anodes shall be provided to achieve desired level of protection at designed current outputs.

The above procedure shall be carried out for all the galvanic anode ground beds as well as for the anodes installed for the casing pipe protection.

As-built documentation

- After completion of the testing and commissioning, we shall prepare as built documentation for the complete CP system.
- The report to be furnished by us shall include.
- Test report on testing and commissioning.
- All structure-to-soil potential readings obtained during the course of survey.
- As built data and documentation giving precise dimensions and construction details of all installation work.