

# **Corrosion Control for Metallic Structure Using Cathodic Protection**

**By**

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## **CATHODIC PROTECTION**

### **1.0 Corrosion & Its Electro-Chemical Nature**

All corrosion of steel in soil or water is electro-chemical in its origin and nature. There are certain condition which must be met before a corrosion cell can function. They are:

1. there must be anodes (which are at higher potential) and cathodes (which are at higher potential).
2. There must be an electrical potential can result from a variety of conditions of pipelines.
3. There must be an electrical metallic path connecting the anode and cathode. Normally, this will be the pipe itself.

The anode and the cathode must be immersed in an electrically conductive electrolyte, which is ion meaning that of the water molecule “H<sub>2</sub>O” are broken down into positively charged Hydrogen ions “H” and negatively charged hydroxyl ions “OH”

(The usual soil moisture or water surrounding pipelines normally fulfills these conditions).

Once these condition are met, an electric current will flow an metals will be consumed at the anode. Ref. To fig. (A)

In such cells an electric current flow from the cathodic or higher potential areas, through the steel of the structure or pipeline to the anodic or lower potential areas, and hence bake through the surrounding soil or water to cathodic areas. At the anodes, where the current leaves the steel and enters the soil or water, iron ions pass into the surrounding electrolyte, thus giving rise to corrosion.

The distribution of anodic areas cathodic areas depends upon the physical and metallurgical properties of the steel surface and upon the properties of the surrounding medium.

The amount of metal that will be removed directly proportional to the amount of current flow. One ampere of direct current discharging into the usual soil electrolyte can remove approximately twenty pounds of steel in one year. This is based on the elector-chemical equivalent of the metal involved; other metals than steel will be removed at other rates, some more and some less.

## **2.0 Types of Corrosion Cells**

### **2.1 Dissimilar Metal Corrosion Cells:**

Such a cell can be established whenever different metals are used in pipeline construction provided there is an electrical contact between them and provided they are in contact with common electrolyte (soil or water). Under such conditions, any two dissimilar metals may be expected to have an electrical potential between them. The magnitude of this potential and which of the two metals will be anodic and corroded will normally depend upon the position of the metals in the electromotive force series.

### **2.1 Corrosion Resulting from Dissimilar Soils:**

In much the same manner that corrosion cell can be established with dissimilar metals. A steel pipeline (or structure) passing through dissimilar soils can establish corrosion cells this illustrated by figure "1"

In this figure a pipeline is shown passing through two dissimilar soil areas. As illustrated, the potential of the pipeline metal, to the electrolyte represented by soil "A" is slightly different from the potential of the same metal to the electrolyte represented by soil "B" As was mentioned in discussing the e.m.f. series, the natural of half-cell potential of a metal with respect of its environment can vary with differences in the electrolyte composition. This give rise to the potential difference illustrated and satisfies the conditions necessary to establish a corrosion cell. In the figure, the pipe where in soil "A" is anodic to that in soil "B" and is corroding as indicated by the current discharge.

A specialized case the principal illustrated above involves steel in concrete versus steel in soil. Figure "2" indicates that the portion of steel pipe which is imbedded in concrete will be cathodic with respect to adjacent pipe sections buried in earth. In figure "3" the condition shown results in many small corrosion cells at the pipe surface which are not detectable by potential measurements taken at the surface of the ground as was shown in figure "1"

### **2.3 Differential Aeration Corrosion Cells:**

Another important source of corrosion cell activity is the condition referred to as (differential aeration). Some investigations consider this source as one of the most important reasons for corrosion damage. Assume for the moment that a pipeline is buried in a completely uniform soil but that some areas of the line have a free supply of oxygen (well aerated) whereas other areas are oxygen starved (poorly aerated). Under these conditions, the pipe in well aerated soil will be cathodic and the pipe in poorly aerated soil will be anodic and corroded. A simple condition is shown in figure "4". Another example of a similar nature is a pipeline buried

under a river or stream but in contact with well aerated soil on either side. Corrosion then will be concentrated in the area under the river or system.

#### **2.4 New Pipe and Old Pipe:**

A condition very closely related to dissimilar metal corrosion arises when new steel pipe is intermixed with old steel pipe. Figure “5” often has been experienced in distribution piping systems when it has been necessary to replace section of pipe in an older system. The replacement usually is made because of corrosion. The new pipe, exposed to the same corrosion condition, logically would be expected to last as long as the original section, but in fact it usually will be found that (unless this new section of pipe is electrically insulated from the remainder of the system) this new section will fail sooner than expected. This is simply an application of the practical galvanic series table, which shows that potential of bright (new) steel is markedly different from that of old rusted steel. Thus the new steel is anodic and the old steel is cathodic. Although we have illustrated the effect of adding new sections of pipe to old system, a similar corrosion condition can arise if, during work on an existing system, tools cut or scratch the pipe and expose areas of bright steel. These bright spots will be anodic and can result in aggravated corrosion in a low resistivity soil.

#### **2.4 Mill Scale Corrosion:**

Mill scale although not a metal, mill scale on hot rolled steel acts as a dissimilar metal in contact with the pipe steel, pipe steel will be anodic to mill scale. This can result in severe corrosion in a low resistivity environment.

### **3.0 Corrosion Control Methods: (Protection)**

As has been seen, in a corroding structure the corrosion takes place at the place where current migrates into either soil or water. If steps are taken to counteract this current, or in other words, if the corroding currents are neutralized, the corrosion will proportionately be reduced. Also if pipes are made from non-metallic material such as PVC, Fiber Glass, Plain concrete no corrosion will exist.

#### **How Corrosion can be Controlled**

There are three ways to do so:

- 1 – Coating, electroplating and or painting.
- 2 – Applying cathodic protection either by impressed current system or sacrificial anode system.
- 3 – By using 1 and 2

#### **I- Coating**

Normally are intended to form a continuous film of an electrically insulating material over the metallic surface to be protected. The function of such coating is to isolate the metal from direct contact with the surrounding electrolyte and to interpose such a high electrical resistance.

In the anode-cathode circuit so that there will be no significant corrosion current flowing from the anode to the cathode. It is known that a good coating, better than 99 percent of the pipe surface would be completely free corrosion. Also that cathodic protection would be relatively simple because only the minute areas of exposed steel would have to be protected.

Figure "6" used to demonstrate the idea of *cathodic protection*, illustrates the pattern of current flow to be expected with protection being applied to a section of bare pipeline. With a high resistance barrier coating between the pipeline and environment. The picture is quite different as illustrated by figure "8" this figure, current from the *cathodic protection* ground bed is shown flowing to all areas where pipe metal is exposed. In so doing, the original corrosive current discharge from defects in anodic areas is stopped effectively. In addition to the current shown flowing to defects, current is also shown flowing through the coating material itself. No coating material is a perfect insulator and will conduct some current. The amount will depend on the electrical resistivity of the material and its thickness. When one of the high resistivity coating is used, the current passing directly through the coating will be negligible compared to that flowing to coating defects unless the number and size of defect is unusually small.

## **II- Insulated joints**

They are used to break the metallic electrical connection between the anode and cathode and thereby prevent flow of current between the two. This method has limited applications. Insulated joints can, for example, be used at the junction of two dissimilar metals but obviously would not be effective in the control of localized corrosion cells on the surface of the structure.

## **III- Cathodic Protection**

Cathodic Protection is very simply, they use current electrically from an external source to oppose the discharge of corrosion current from anodic areas. When a *cathodic protection* system is installed for maximum effect., current from the surrounding electrolyte and the entire exposed surface became a single cathodic area.

A corrosion control system will usually, although not necessarily, be sound to utilize a combination of the three principal methods mentioned above. In addition, if needed, there may be provisions of a specialized nature where unusual corrosion exist, the use of corrosion control methods will be fully outlined in the following

### **4.0 Cathodic Protection-How it Works:**

Over the years "cathodic protection" has continued to be treated as a somewhat mysterious term by those not fully conversant with this means of corrosion control. Apparently many feel that *cathodic protection* is a complicated procedure. In actuality, the basic idea of *cathodic protection* is very simple.

### **4.1 Basic Theory of Cathodic Protection:**

Various conditions were described which result in pipeline corrosion. In each case anodic areas and cathodic areas were present. It was noted that at the anodic areas, where the pipeline corrodes, current was flowing from the pipeline steel to the surrounding electrolyte (soil or water). Likewise, more current was flowing from electrolyte onto the pipe, the pipe surface was cathodic and did not corrode.

In light of the above, it becomes obvious that if every bit of exposed-metal on the surface of a pipeline could be made to collect current, it would not corrode because the entire surface then would be cathodic. This is exactly that cathodic protection does. Direct current is forced to flow from a source external to the pipeline onto all surfaces of the pipeline. When the amount of current flowing is adjusted properly, it will overpower corrosion current discharging from all anodic areas on the pipeline and there will be a net current flow onto the pipe surface at these points. The entire surface then will be cathodic and the protection complete. This concept is illustrated diagrammatically by figure (6).

#### **4.1.1 Cathodic Protection with Galvanic Anodes:**

In *cathodic protection* with Galvanic Anodes, advantage is taken of this effect by purposely establishing a dissimilar metal cell strong enough counteract corrosion cells normally existing on pipelines. This is done using a very strongly anodic metal connected to the pipeline. This metal will corrode and in so doing will discharge current to the pipelines as shown in fig (7). In usual installations, current available from galvanic anodes is limited to relatively small amounts. For this reasons, *cathodic protection* by galvanic anodes normally is used where the current required for protection is small.

The driving voltage existing between pipe steel and galvanic anode metal is limited to low values, so if the anodes are to discharge a useful amount of current, contact resistance between the anodes and earth must be low. This means that, galvanic anodes are used in low resistively soils.

The galvanic anodes are usually made from magnesium or zinc in solid cylindrical form. These anodes are connected with electric insulated wire. Back fill compound must cover the surface of anode with a thick layer to prevent polarization, Fig.(6a).

The size of anode is chosen according to the current consumption and life of system with respect to the electromechanical factor.

#### **4.1.2 Cathodic Protection with Impressed Current:**

in order to be free of the limited driving voltage associated with galvanic anodes, voltage from some outside power source may be “impressed” on the circuit between protected pipeline and ground bed, Fig.(6b). Figure (6) illustrates this situation.

Presently the most common power source are rectifiers. This device simply converts alternating current electric power to low voltage direct current power.

Rectifiers usually are provided with means for varying the DC output ranges from 10 to 100 Volts. Current range not less than 10 Amps.

Although the basic theory of *cathodic protection* is simple – making the entire pipeline a cathodic – the obvious question that arises is, “How do we know when we have attained this condition when working on a buried structure?”

The answer to this is, measurement of potential between the pipeline and earth, these measurements are made at the surface above the buried or submerged line and permit a rapid and reliable determination of the degree of protection attained. Basically, potential criteria are used to evaluate changes in structure potential with respect to the environment which are caused by *cathodic protection* current flowing on the structure from surrounding soil or water.

#### **4.1.3 Limit of Protection:**

the limit of protection measured for any steel structure to soil is 0.85 Volts which respect to Cu/CuSO<sub>4</sub> half cell. Fig (9) represent the potential distribution over the pipeline. The dotted line at 0.85 Volts is the minimum limit of protection. Potential higher than this limit means (protected area) and lower means (unprotected area)

### **5.0 Cathodic Protection Measuring Instruments:**

#### **5.1 Voltmeter:**

This meter usually of the high resistance type “higher than 20.000 Ohms per Volts” to get an accurate measurements. A potentiometer type voltmeters are the best meters for measuring pipe-to-reference electrode “half cell” in high soil resistivity areas.

#### **5.2 Half Cell: “Reference Electrode”**

This device is used most commonly in pipeline corrosion work. It is usually a copper sulfate electrode. The essential parts of the copper sulfate electrode are shown by Fig (10). It is formed from a pure copper rode or plate submersed in a saturated solution or copper sulfate crystals in an insulated container fitted with porous plug “usually wood”. This electrode is connected to the positive terminal of the voltmeter and pushed inside the soil with the porous plug down to act as reference electrode to the soil.

#### **5.2 Ammeter:**

It is from the conventional type used to measure the current flowing in any part of the *cathodic protection* system.

#### **5.4 Soil Resistivity Meter:**

it is an instrument used to measure the soil resistivity. It usually consists of four electrodes pushed in ground at an equal spacing in line with leads connected to meter. The meter forces current to the ground between the first and the fourth electrode. Measured potential between the second and the third electrode is an indication to the resistivity.

## **5.5 Holiday Detectors:**

This device impresses an electric voltage across the coating. An electrode is passed over the entire coating surface. As the electrode passes over a coating defect, there is an electrical discharge between electrode and pipe as a spark which starts a signaling device. So the defect must be recorded.

## **6.0 Cathodic Protection as an Aid for Preventive Maintenance:**

### **6.1 Pipeline Protection:**

Using any type of the above protection will keep your line free from corrosion i.e. from leaks. Fig (7).

### **6.2 Metal Structure Underground:**

As item 6.1 it will keep your structure as it is without losing any weight of material.

### **6.3 Offshore Structure:**

Sea lines, buoy mooring, offshore drilling, platform, water intakes, screen filters, ...etc. Usually use the two kind of protection discussed before and applied, but the commonly used is the galvanic system using the magnesium or zinc anodes suspended in water as Fig.(11)

### **6.4 Water Tanks:**

The same as item 6.3 but the anode is suspended inside the tank to protect the surface of contact with water preventing formation of corrosion cell figure (12).

### **6.5 Heat Exchangers:**

The same as item 6.4 but the commonly used system is the zinc or magnesium bolted plugs figure (13-b).

### **6.6 Cylinder Head:**

The same as item 6.5 Figure (13-a).

## **7.0 Stray Current:**

Stray current problems on pipelines arising from direct current transit systems and mining operations can be very severe. Solving such problems is more complicated. This is because of the continuously varying nature of exposure as the load on the DC power sources varies. This type of problem is limited to relatively

small areas in Egypt “Cairo, Alexandria”. Electrified railroads operate on DC transit system as shown in figure, are operated normally overhead insulated feeder connected to positive bus of DC substation. The load current (which may be thousands of amperes) is supposed to return to the substation via tracks, which are connected to the negative bus at the substation. A common operating potential for transit system is 600 Volts. Because tracks are laid at the ground level and not insulated completely from earth. Some part of the load current will enter the ground where the tracks are most positive and take an earth back to substation. Pipelines in the area constitute a good return path for a portion of the earth current. Such a pipeline will carry the current to location in the vicinity of the DC substation where it will flow from the pipeline to earth and return to the negative bus of the substation. Severe pipe corrosion will result if corrective measure are not used. Where the pipeline is picking up current it is receiving *cathodic protection*. In severe cases, the pipeline may be many volts negative to adjacent earth in this area and, at the same time, many joints in the pipeline, as shown in the figure, there may be enough driving voltage to force current to bypass the joint and corrode the pipe on the side where the current leaves the pipe. The best solution to this problem is to know the area where the current leave the pipe and connect it with a feeder to the negative bus on the substation. This means that no current will leave passing in the ground “i.e. electrolyte”, no ionization will arise.

The return path of the stray current will not only be a pipeline but also, telephone cable, power cable, bridges, ...etc. Any buried structures will suffer from it.

N.B. One Ampere per year will cause a loss of steel equal to approximately 10

## **8.0 Applying Cathodic Protection**

### **8.1 Where Cathodic Protection can be Applied**

This can be applied on all structures when continuously immersed in water or permanently buried in soil. Oil, gas and water pipes, wharves, jetties, tanks, tankers, steel pilings, ship’s hull, heat exchangers, lead sheathed cables, etc. are but a few cases in steel industry where cathodic protection has been used with large measure of success. Water and gas boards, oil industries, ports and sewage plants are large users of this system.

### **8.2 Is Cathodic Protection Possible for Atmosphere Corrosion**

So that a structure can be protected by this technique, the structure must receive current from the electrolyte or rather its environment. The electrolyte must carry current. In atmosphere, since air is a poor conductor of electricity, prevention of corrosion by this method is not possible.

### **8.3 How long Cathodic Protection will prevent Corrosion**



Protection is achieved if it is continuously and efficiently applied. Cathodic protection must be “ON” all hours of the day and all the year around. Occasional break down of power system is not dangerous if plate thickness is not just absolute minimum as worked out from stress formula. Further, hydrogen film built on cathodic surface takes some time to get destroyed and if the system is again made normal before this film is destroyed, there will be no corrosion even when the system was off.

#### **8.4 Is there any danger to Human, Animal or Vegetation life**

Non has been encountered and no such danger is possible on well designed units.

#### **8.5 The measure of Sufficient Protection**

Bringing the voltage of the structure negative is not enough. If it is not sufficient. Corrosion is not completely stopped, although it is reduced to some extent; if the voltage is swing too much negatively, electrical energy is unduly wasted, and at times we may weaken the metal under pressure and also damage the coating. Usually – 0.85 Volts to –3.0 Volts as measured with a special meter with respect to copper-copper sulphate half cell should be sufficient to prevent corrosion of the structure indefinitely.

#### **8.6 The source of Electrical Energy Utilized for Cathodic Protection**

It must have been observed that current has to be passed on to the structure under protection through the electrolyte such as soil or water. This is usually done at voltages from 6 to 60 volts DC. As current is impressed in the electrolyte from an external source, this system is called “Impressed current system”. D.C. output is obtained from a rectifier connected to the standard A.C. supply obtained from public utilities or as an additional load on the existing system used for motive power. This would restrict installation of Cathodic Protection by this method only near where A.C. supply is available. Sometimes special generators are also installed for the purpose. The other method is called “Sacrificial Anode Method”. Zinc, aluminum and magnesium which are anodic or baser to steel or iron in the electromotive force series are buried in the electrolyte.

These metals establish a galvanic battery, treating the structure as another electrode. By the galvanic current thus setup, these metals get expanded or are sacrificed and hence the term “Sacrificial Anode Method”.

#### **8.7 Which of the above Two Methods is Advantageous**

These cannot be a definite answer to this question. Each structure has its own current requirements, electrolyte resistivity, maintenance

schedule etc. and hence each structure has to be considered individually. This also applies when selecting different metals for sacrificial Anode system. Refer to table- I for comparison.

## **8.8 How does Cathodic Protection Compete economically with other methods of corrosion prevention.**

Galvanizing, anodizing, painting, replacement of steel with better but costlier metals are some of the important methods of corrosion prevention. Each of these has its own individual field and adaptability. Galvanizing, anodizing and painting are extremely useful when structures are small and are in air or accessible for maintenance work. But in the case of structure of large dimensions buried in ground or in water any of the above methods is not practicable or economical. In marine, water, sewage, reinforcement concrete, oil industry, coating with cathodic protection is the only sure way of corrosion prevention besides it is the cheapest. In the case of heat exchangers where accessibility is very little and continuous operation essential, cathodic protection will go a long way to minimize corrosion troubles in pipes. Pipes carrying water, oil and gas at high pressure cannot take any chance with corrosion failures. At high pressures, it is not economical to keep a large factor of safety for plate thickness and minimum reduction due to penetration or pits due corrosion will result in pipe failure. This will bring loss of revenue, increased maintenance cost and plant outages. In such cases, cathodic protection with coating will prove most economical.

For water pipes, it is possible to use plain concrete pipes PVC and fiber glass as an alternative material. Also in dry soil condition and a way from electrical interference and or anaerobic bacteria it is possible to use cast iron pipes.

But for certain diameter and pressure, these pipes cease to be economical and mild steel pipes are the only possible solution.

Mild steel pipes can also be gunnited by thick layers of concrete. In many cases coating and cathodic protection, depending on various factors is as costly as gunniting or in a few cases will be costlier still. Even if coating and cathodic protection prove 10% to 20% costlier than gunniting, advantages of the former would justify extra cost. Gunniting is efficient when applied in dry and less corrosive soils. But gunniting suffers from cracks and improper bonds due to mechanical vibrations, expansions and improper application. Concrete becomes 10 times more conducting when wet than it is dry and thus in moist and corrosive soils, the cathodic protection would prove to be a better alternative.

With cathodic protection it is possible to adjust current output and voltage as and when required to maintain proper degree of cathodic protection, if coating deteriorates over a period. It is also possible to

check whether the structure is sufficiently protected or not if applied with cathodic protection.

## **8.9 The Cost of Cathodic Protection**

This cost depends on the corrosive conditions of the environment, on the coating and its quality, and in case of the pipelines, on the thickness of the pipe shell. But against this cost, the direct cost of increased maintenance and repairs, increased depreciation, larger capital investment due to higher factor of safety, loss of revenue due to breakdown and wastage, loss of public goodwill, damage suits etc. is to be considered. Extra cost due coating and cathodic protection is more than justified. As a rough measure, this cost comes to 5% to 2% of the cost of the structure depend upon the route of the pipeline.

If the consideration of corrosion is made at the design stage and even if a few percentage of this cost is salvaged, it should prove an asset to the national economy.

## **9.0 Internal Protection:**

### **12.1 Cathodic Protection for Internal Surfaces**

Cathodic protection as explained so far will not protect the internal surface, but if the anodes are mounted inside of the pipes or tanks, it is possible to protect the internal surfaces also. Equipment and material to suit this requirement is available. This is very useful in pipes carrying sea water and sewage.

It is more simpler and economical if the pipe diameter is increased.

### **12.1 Coating's**

The best protection for internals is the use of coating systems.

The 1<sup>st</sup> system is galvanization by hot dip galvanization and still used till now as it is the only solution for small diameter pipes [drinking water and natural gases], it is very costly for larger diameter.

The 2<sup>nd</sup> another famous old system uses cement coating for water and special one for sewage.

The 3<sup>rd</sup> New tecnowlage use polymers, epoxy's and neoprene rubbers.

The 4<sup>th</sup> Polyethylene hoses are also used by pressurizing them inside the pipe and with the addition of epoxy cement in between as a binder.

## 10.0 Coating:

Coatings are applied for two reasons. Coatings are usually derived from epoxy-resins, asphalt or coal tar which have high dielectric strength. When applied uniformly and without flaws. This layer of high resistance material increases the resistance of the corrosion circuit tremendously. For the values of the order of 3 to 4 volts due to galvanic or concentrated cells, encountered in practice, this coating reduces the corrosion current to a minimum. Secondly, a layer of nonporrous-nonhygroscopic materials reduces the possibility of oxygen availability and thereby aids polarization and stifles corrosion.

## 11.0 Coating and Cathodic Protection:

As saying goes, cathodic protection is complimentary and not supplementary to coating. In the case of underground and under marine structures, no corrosion mitigation program can be considered by coating alone. For economical reasons corrosion prevention by cathodic protection alone also cannot be considered. Not that cathodic protection alone cannot be applied but current requirement on a bare or a poorly coated surface is to high that for practical purposes, this coat out weights the saving in coating. It can be safely said that total cost of reasonably good coating along with cathodic protection on a bare metal surface.

This is so far as initial investment is considered. But as the cathodic protection has to be applied continuously the energy bill or the running charges would increase to larger proportion for poorly coated surface.

Even if coating work is carried out under most strict supervision, it is likely that a few pin holes may be left out or perhaps at the time of lowering the pipes or at the time of back filling the earth, the coating may be damaged when this happens, an insignificantly small damaged area becomes anodic to the large areas with coating in good conditions. This sets up accelerated corrosion and as the anodic area from which the metallic ions can migrate into soil or water is extremely small, for can equal weight, the penetration in shall thickness is greater than it would otherwise be. This penetration will in time develop into a leak causing the failure of the pipe or structure. Also coating may be continuously in contact with water and over longer periods coating especially asphalt and gunniting become more conducting. This sets up higher corrosion currents and anodic areas can develop.

When cathodic protection is applied the current required depends on this damaged or badly coated surface only and not on the total buried surface of the structure.

To illustrate this point, in one case 45 amps were required to protect equivalent of 6 miles of poorly coated pipe where-as in anther case only 2 amps could protect as many as 75 miles of well coated pipe.

## 12.0 Quality Assurance and Control:

Successful corrosion control system is the result of the following:

- 1- Excellent survey work.
- 2- Excellent design and engineering work.

- 3- Excellent selection of suitable system and materials.
- 4- Excellent inspection for all material used.
- 5- Excellent periodic measurement's
- 6- Excellent periodic maintenance.
- 7- Know how.

## 12.1 Survey Work

Before any system of cathodic protection can be designed, a few data are necessary. These data pertain to the conditions existing on each location. At representative sites would indicate corrosively of the soil. There is no exact dividing line to indicate aggressiveness of the soil, but the soil resistivity gives fair measure of the corrosiveness in the manner indicated below:-

### 12.1.1 Soil resistivity survey: Soil resistivity

Soil resistivity in Ohm-cms	Degree of corrosively				
	Low	Normal	Over normal	High	Very high
	10,000 and above	2,000 to 10,000	1,000 to 2,000	500 to 1,000	500 and less

If any structure is yet at a design stage, this survey helps in determining the quality of the coating. If the soil is of low corrosively, an average coating can be specified and in more corrosive soil coating with very rigid specification and of higher standards is essential. The economy is obvious. Another advantage of the initial soil resistivity survey is that when alternative sites or pipeline routes are available, the one with higher resistivity or lower corrosively can be selected with reduction in the cost of coating.

On structure already existing, this survey is not of much economical advantages, but the knowledge of corrosively of soil aids in assessing the current requirement for cathodic protection. during this survey, sites for ground bed with least resistivity will require least capital investment on cathodic protection.

## 12.2 Design and Engineering Work

It is very simple to use the cathodic protection theory, but it must be taken into consideration that C/P is a very powerful corrosion cell can damage the protected structure.

The goal of eng.& design is to achieve protection between two levels.

- a- Min<sup>m</sup> protection level -0.85 volt.
- b- Max<sup>m</sup> potential level for used coating ofcores the less equipment used and the simplest construction effort is the major goal.

Documentation such as calculations papers, data sheets, drawing, pre-commissioning and commissioning test sheets are the basic foundation if executed and prepared well.

### 12.3 Selection of suitable C/P system

According to the statements before there are two systems for c/p sacrificial and impressed system.

Referring to comparison table No.II it is logical steps for selection. Good selection will be the most economical one.

### 12.4 Inspection

#### 12.4.1 C/P Inspection

(I) Materials :

□ **Anode's**

- Deeply inspected for the detection Cracks, loose cable tail sealing, cut or crack in cable tail, weight of anode labeling and metallurgical content.

□ **Cables**

- Check continuity and ohmic resistance.  
- Check double insulation if scratch, cut or crack.

□ **Back filling**

Content and size graduation

□ **Transformer rectifier**

Check for

- Winding to ground insulation.  
- Winding to shells insulation.  
- Over loading with 25 % for one hour

...etc.

- Temperature rise.  
- Level of oil if oil cooled.  
- Thickness of paint.  
- Sealing of tank and or door.  
- Sealing of tank and or door.

Glands, Earth lug ...etc. and so on for each piece of equipment according to data sheets, DWG'S and compliance with international standard's such as BS, NACE ...etc.

#### (II) Construction and Installation:

□ **Ground Bed**

- Check the location to be in the lowest soil resistivity in the area.  
- Check that perpendicular distance between pipeline and GB is between 75 ÷ 150 m. Check

the dimension of GB ditch and anode spacing, to be according to BWG. Be sure that the cook back fill is compacted before laying anodes and covered tamped according to DWG.

- Carefully lay cable tail above the ditch as well as the positive hydrant cable and splice to DWG'S.
- Fill the ditch above cook with 20 to 40 cm of soil and water it. Complete back filling.
- Measure GB resistance to earth and check design figgers. (Resistance to be less and or equal to design)
- Check the GB Marker and locate on as built DWG.

□ **Cables**

- Cable trench with 80 cm deep will be suitable for all c/p cables.
- Check the sand cover around cable.
- Check the armour bricks and or warning tape dimensions.
- Cable markers to be installed at start, end and bend of cable trench and locate on the as built DWG'S.

□ **Transformer rectifier Units**

- Check concrete base before putting T/R on for anchor bolt dimension.
- Check earthing network resistance before and after connection to earthing.
- Check tightness of cable glands after passing the cable.
- Check level of oil and silica gel breather.
- Check the power supply voltage with respect to T/R nameplate.
- Reduce controllers potentiometer's and or step selector to min out put before powering T/R.
- Adjust zero error for all indicators.
- Check tightness of output cables with terminal block as well as surge arrstor.
- Power T/R and look for power signal lamp.
- No reading in ammeter.
- $\approx 00.2$  V change in voltmeter which is the galvanic differential potential.
- Raise output step by step to reach protection level and record.

**N.B.**

- 1- The same for any other equipment according to design and engineering requirements.
- 2- Above mentioned are sample of the work to be done.

### 12.5 Periodic Measurements & Maintenance

Engineering document present the periodic measurement schedules and their period. This must be followed. Periodic report contains all measured values, locaton, data, time as well as the inspector name. These reports will be fed to the engineering office for check and or analyze any deviation and give order with the corrective actions. Maintenance procedure to be followed strictly against maintenance work order's arcaiving all measured and work-order's data give a very good help for forecasting and analyzing system performance.

### 13.0 Source of Corrosion:

- 1- Different metals (fittings, valves, ...etc.)
- 2- Welded pieces (weld defect) prefabricated.
- 3- Concrete imbedded parts.
- 4- Old installation with new installations.
- 5- Coating defect.
- 6- Non continuity of pipeline [built by section pipes]
- 7- Aggressive environmental condition.

**N.B.**

All above seven points works internally and externally, which can be eliminated by the use of cathodic protection.

- 8- Sedimentation's of solids or gell formations internally.
- 9- Vapor locks trapped on siphons.

**N.B.**

- The above two points works internally only.
- These points must be treated one by one after a deep study and the use of reasonable curing system such as:-

- Periodic cleaning internally for sedimentation.
- Venting systems for vapor locks.
- Injection of chemical to reduce aggressiveness of electrolyte.
- Cathodic protection if it possible.

**Table 3. Comparison of sacrificial and impressed current systems**

	<b>Sacrificial</b>	<b>Impressed current</b>
<b>Power source Installation</b>	Self-contained straightforward, welded or bolted connections to structure; connections are cathodically protected in service. Cannot be wrongly	External supply necessary relatively complicated. Structural penetrations required isolation of anodes from structure essential. May



	connected.	be inadvertently connected in the wrong direction.
<b>Control</b>	Not possible from initial design, but changes in number and size of anodes can be made in service.	Controllable Control usually automatic.
<b>Anodes</b>	Relatively heavy and many in number. Wide range of size available. Bulk of anode material may restrict water flow and introduce turbulence and drag penalties.	Usually lighter and few in number. Anodes may be designed to have minimum effect on water flow.
<b>Damage</b>	Anodes are robust and no very susceptible to mechanical damage. Where a system comprises a large number of anodes, the loss of a few anodes, the loss of a few anodes has little overall effect on the system.	Anodes light in construction and therefore less resistant to mechanical damage. Loss of anodes can be more critical to the effectiveness of a system.
<b>Maintenance</b>	Renewals necessary at regular intervals. Interim maintenance not required.	Equipment designed for long life out regular checks required on electrical equipment in service. Where renewals are required. Continual power required.
<b>Cost</b>	Initial cost dependent upon design life but relatively low. Periodic renewals necessary and cumulative costs high. Cost of electrical power higher than from external source.	Initial cost high but in service cost generally low.