MIE TALK – August 2016

CATHODIC PROTECTION

AND HAZARDOUS AREAS

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ABSTRACT

Corrosion is a major issue in industrial plant processes especially where any part of the structure is submerged in ground or water. The management of corrosion using cathodic protection (CP) has been successfully utilised for many years. CP is typically designed, installed and maintained but in essence it is “left alone” for most of its life. CP is supposed to operate and remain underground and out of the Hazardous Area but this does not always happen and due to its design may create high powered arc i.e. a source of ignition. This document provides some guidance.

EXECUTIVE SUMMARY

This document is not intended to be a detailed cathodic protection (CP) description but rather to provide a basic understanding of CP. The next part is to explain the effect in terms of the use of CP in Hazardous Areas and some controls required pertaining to limiting sources of ignition.

Metal that has been extracted from its primary ore (metal oxides or other free radicals) has a natural tendency to revert to that state under the action of oxygen and water. This action is called corrosion and the most common example is the rusting of steel. Corrosion thus occurs at the anode but not at the cathode (unless the metal of the cathode is attacked by alkali). Figure 1: Corrosion cell / bimetallic corrosion below provides a graphic view of the corrosion process of a metal.

The principle of cathodic protection is in connecting an external anode to the metal to be protected and the passing of an electrical dc current so that all areas of the metal surface become cathodic and therefore do not corrode. The external anode may be a galvanic anode, where the current is a result of the potential difference between the two metals, or it may be an impressed current anode, where the current is impressed from an external dc power source. In electro-chemical terms, the electrical potential between the metal and the electrolyte solution with which it is in contact is made more negative, by the supply of negative charged electrons, to a value at which the corroding (anodic) reactions are stifled and only cathodic reactions can take place.

In the case of Impressed Current Cathodic Protection (ICCP) the power supply may be required to cover large distances and therefore also require large voltages i.e.

50Vdc at high currents of 50Adc. This power may “leak” to the surface pipes and could create sources of ignition in the form of arcs or even hot surfaces in Hazardous Areas. An arc is in essence the creation of “a luminous electrical discharge between two electrodes or other points” and is the same as on an electrical arc welder.

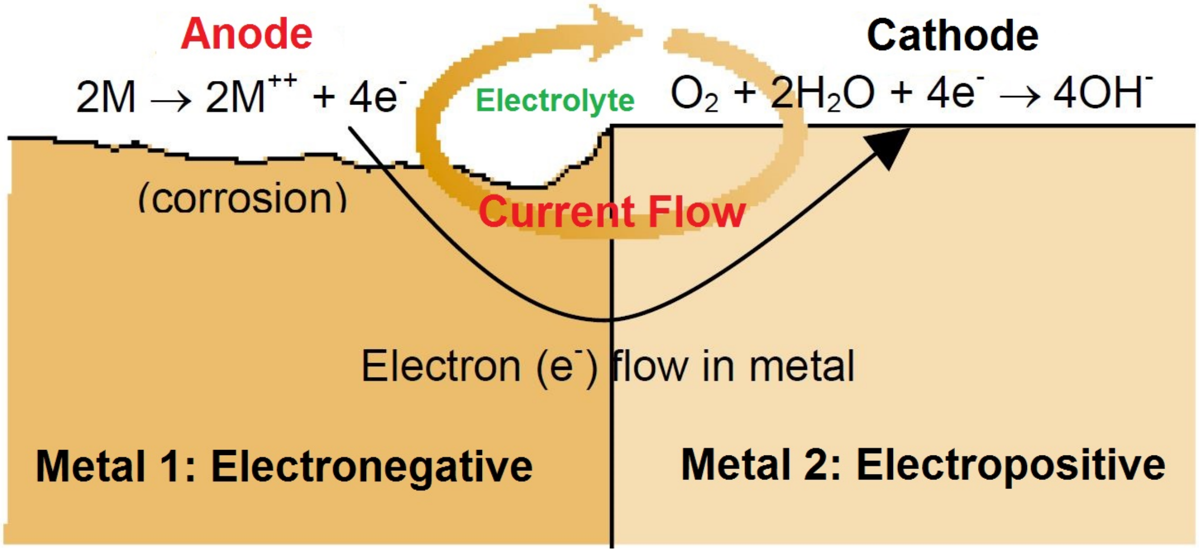

Figure 1: Corrosion cell / bimetallic corrosion

APPLICABLE STANDARDS

The following standards have references to cathodic protection.

Standard	Name
SANS 15589-1	Petroleum and natural gas industries – Cathodic protection of pipeline transportation systems Part 1: On-land pipelines
SANS 15589-2	Petroleum and natural gas industries – Cathodic protection of pipeline transportation systems Part 2: Offshore pipelines
SANS 53509	Cathodic protection measurement techniques
SANS 60146-2	Semiconductor converters Part 2: Self-commutated semiconductor converters including direct d.c. converters
SANS 10199	The design and installation of earth electrodes
SANS 10087-3	The handling, storage, distribution and maintenance of liquefied petroleum gas in domestic, commercial, and industrial installations Part 3: Liquefied petroleum gas installations involving storage vessels of individual water capacity exceeding 500 L
SANS 10089-1	The petroleum industry Part 1: Storage and distribution of petroleum products in above-ground bulk installations
SANS 10089-2	The petroleum industry Part 2: Electrical and other installations in the distribution and marketing sector
SANS 10089-3	The petroleum industry Part 3: The installation, modification, and decommissioning of underground storage tanks, pumps/dispensers and pipework at service stations and consumer installations
SANS 10280	Code of practice. Overhead power lines for conditions prevailing in South Africa
SANS 310	Storage tank facilities for hazardous chemicals — Above-ground storage tank facilities for flammable, combustible and non-flammable chemicals
SANS 60079-14	Explosive atmospheres Part 14: Electrical installations design, selection and erection
SANS 827	The installation of pipes and appliances for use with natural gas
SANS 10086-1	The installation, inspection and maintenance of equipment used in explosive atmospheres Part 1: Installations including surface installations on mines
SANS 10123	Code of practice. The control of undesirable static electricity
SANS 61024-1-2	Protection of structures against lightning. Part 1-2: General principles - Guide B - Design, installation, maintenance and inspection of lightning protection systems
SANS 62561-3	Lightning protection system components (LPSC) Part 3: Requirements for isolating spark gaps (ISG)

1. INTRODUCTION

Cathodic protection (CP) is a method of corrosion control that can be applied to buried and submerged metallic structures.

It is normally used in conjunction with coatings and can be considered as a secondary corrosion control technique. The primary corrosion control method on any given structure is normally a coating system which can be between 50 and 99 % efficient depending upon age, type, method of installation, etc. A properly designed and maintained cathodic protection system will take up the remainder resulting in a 100 % efficient corrosion protection system.

Through the application of a cathodic current onto a protected structure, anodic dissolution is minimized. Cathodic protection is often applied to coated structures, with the coating providing the primary form of corrosion protection. The CP current requirements tend to be excessive for uncoated systems.

2. BASIC THEORY

A potential difference (refer to Figure 8: Stability Diagram for Iron) is created that will allow current to flow through the circuit based on the conductive surface area of the protected equipment.

In the case of a coated pipeline, it should be noted that current (using the conventional direction) is flowing to the areas as the coating is defective (refer to Figure 3: Coating Discontinuity).

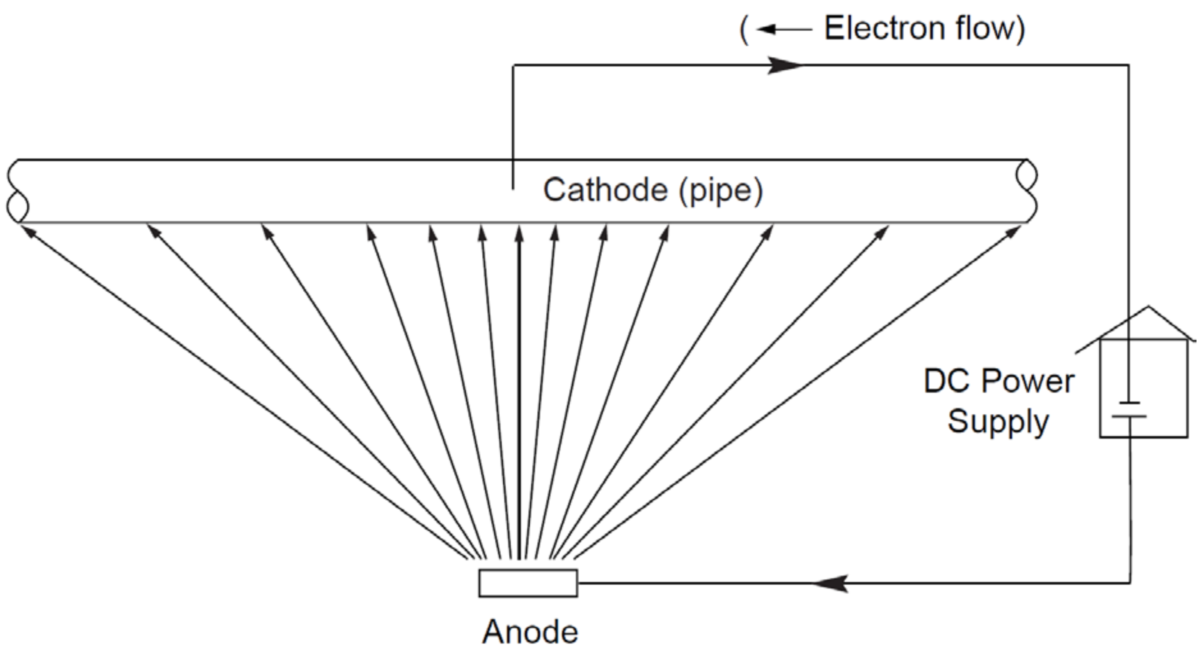

Figure 2: Basic ICCP Diagram

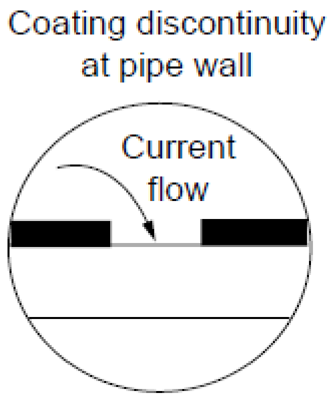

Figure 3: Coating Discontinuity

The current is related to the total surface area that needs to be protected. This comes back to Ohm's law i.e. V = I x R. The voltage is stable and the current is determined by the resistance.

3. CATHODIC PROTECTION SYSTEMS

There are a couple of different Cathodic Protection (CP) Systems.

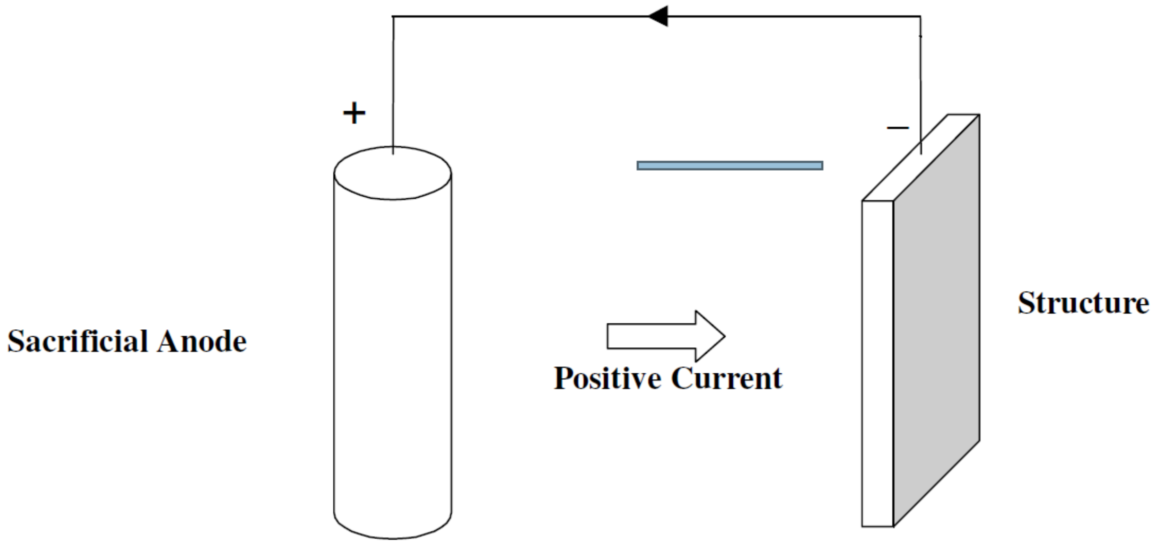

Figure 4: Sacrificial Anode CP Systems (SACP)

Sacrificial anodes are coupled to the structure under protection and conventional current flows from the anode to the structure as long as the anode is more "active" than the structure. As the current flows, all the corrosion occurs on the anode which "sacrifices" itself in order to offer protection from corrosion to the structure.

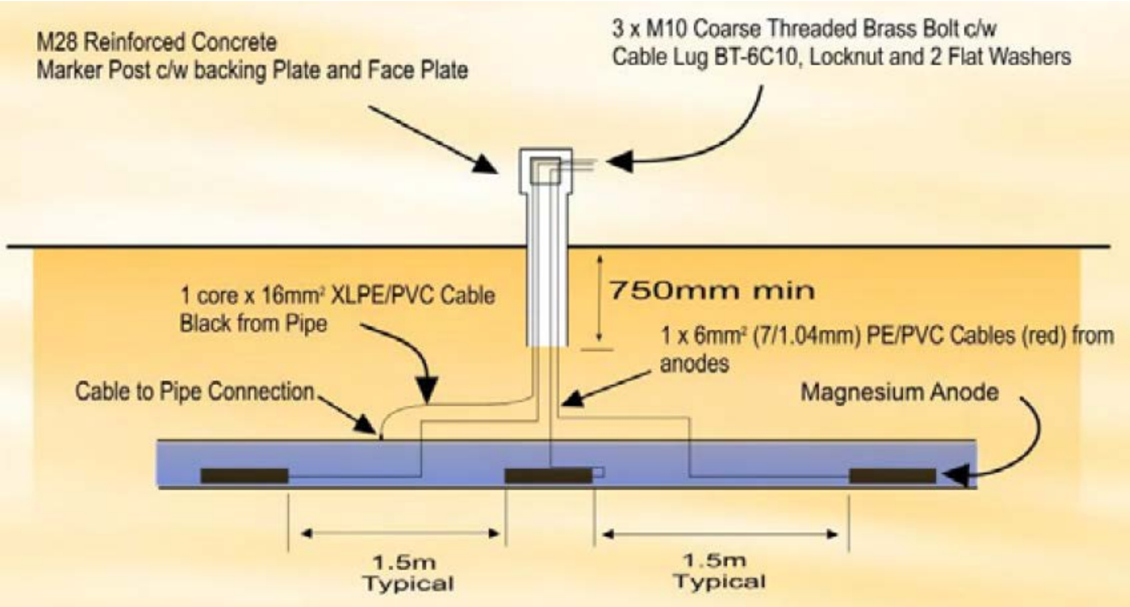

Figure 5: SACP Typical application on a pipeline

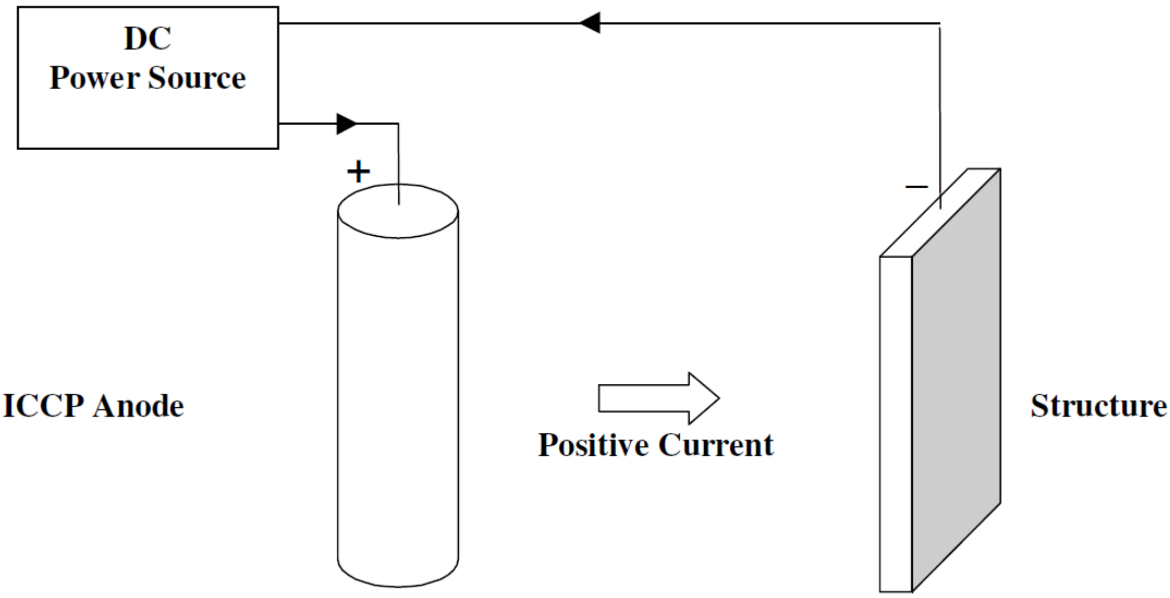

Figure 6: Impressed Current Cathodic Protection (ICCP)

With an impressed current system the current is "impressed" or forced by a power supply. The power source must be able to deliver direct current (DC) and examples are transformer rectifier units, solar generating units or thermo-electric generators.

The anodes are either inert or have low consumption rates and can be surrounded by carbonaceous backfill to increase efficiency and decrease costs. Typical anodes are titanium coated with mixed metal oxide (MMO) or platinum, silicon iron, graphite and magnetite.

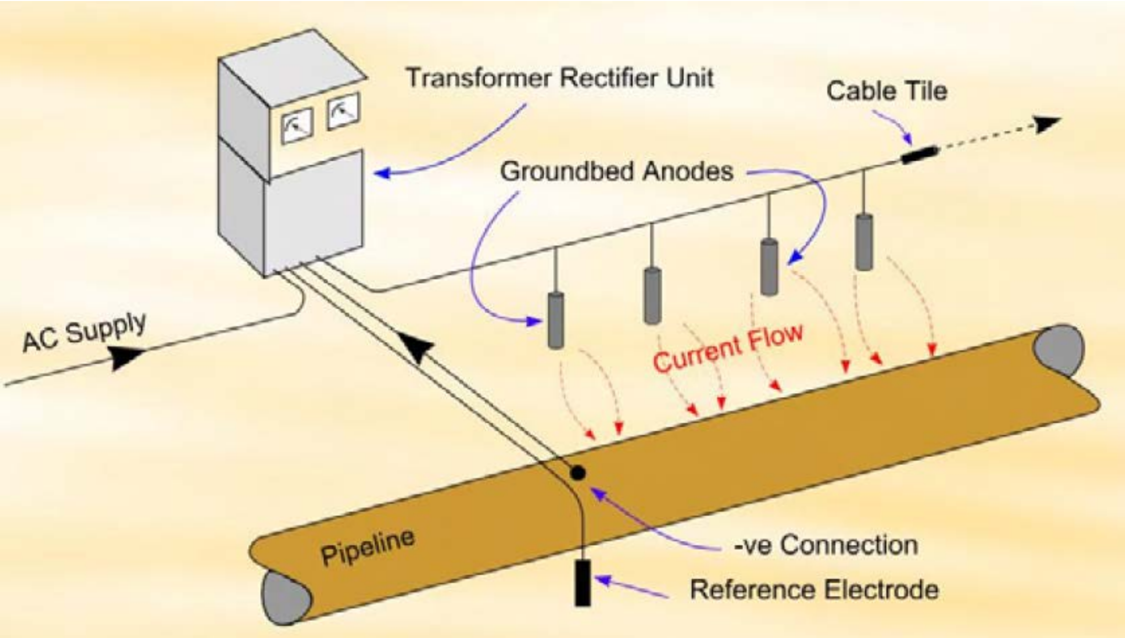

Figure 7: ICCP Typical application on a pipeline

Table 1: Comparison table of the types of CP

SACRIFICIAL ANODES (GALVANIC)	IMPRESSED CURRENT (ICCP)
USES o Generally used for protection of well coated areas where protective current requirements and soil or water resistivities are low. o Where the surface area of a protected structure is relatively small due to economic restrictions. *BENEFITS AND FEATURES* - No independent source of electric power required. - Limited effects on neighbouring structures. - Extremely simple to install. May be directly fixed to the structure. - Simple additions can be made until the desired effect is achieved - Anode connections are also protected. - Self adjusting but the output generally cannot be controlled - Correct material selection ensures no over protection, thus avoiding metal embrittlement and coating damage. - No possibility of plant damage due to incorrect connections i.e. reversed polarity. - Straight forward to install, operate and maintain	*USES* o For structures where protective current requirements and life requirements are high. o Can be used over a wider range of soil and water resistivities. o For protection of large uncoated areas, where relatively few anodes are required. *BENEFITS AND FEATURES* - Requires external power source - Can be applied to a wide range of structures in various states of coating condition. - May be adjusted manually or automatically to cater for changing conditions. - May be remotely adjusted, monitored and connected to Plant Alarm System. - Anodes are very compact, thus drag and water flow restriction are negligible. - Requires a small number of anodes compared to a galvanic system. - Needs careful design and operation to ensure ongoing protection - Can affect other structures if not properly monitored - Installation needs to ensure all connections have a high integrity of insulation and that damage does not occur due to reversed polarity.

4. CATHODIC PROTECTION REQUIREMENTS

Practical protection criteria need to take variations into account. The following are protection criteria that have been proposed for buried steel structures:

- Potential of structure 850 mV w.r.t. saturated Cu/CuSO4 reference electrode (under aerobic conditions)
- Potential of structure 950 mV w.r.t. saturated Cu/CuSO4 reference electrode (under anaerobic conditions where microbial corrosion may be a factor)

The figure below depicts the stability of iron based on the PH of the soil and the potential between the soil and the iron due to the CP system.

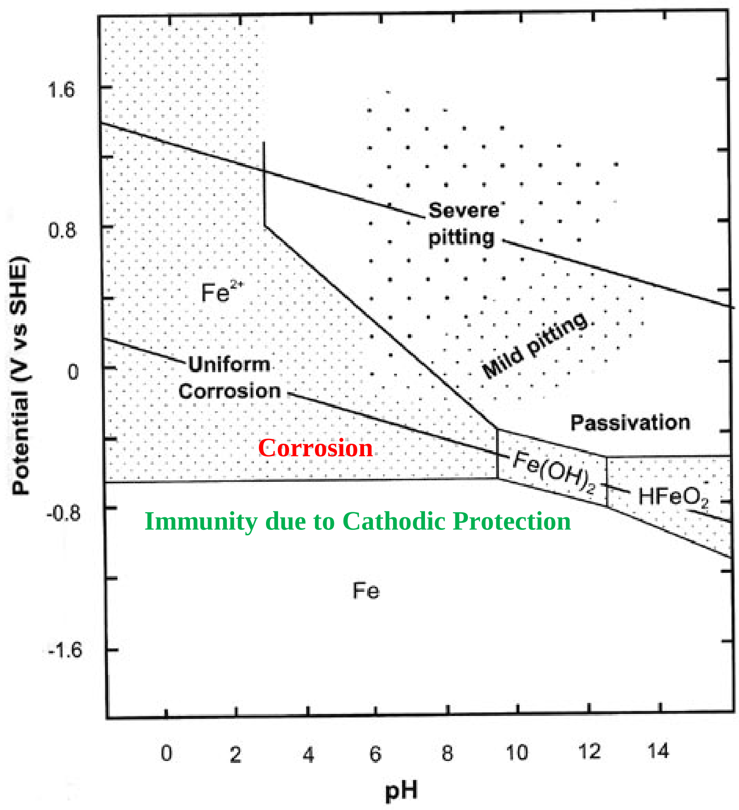

Figure 8: Stability Diagram for Iron

5. ANODES

Different types of anodes are used and the layout of these different anodes may also be different.

5.1 HORIZONTAL ANODE

Horizontal anodes may typically be placed in an anode coke backfilled bed inside a horizontal pit. Refer to Figure 5: SACP Typical application on a pipeline and Figure 7: ICCP Typical application on a pipeline.

5.2 DEEP WELL ANODE

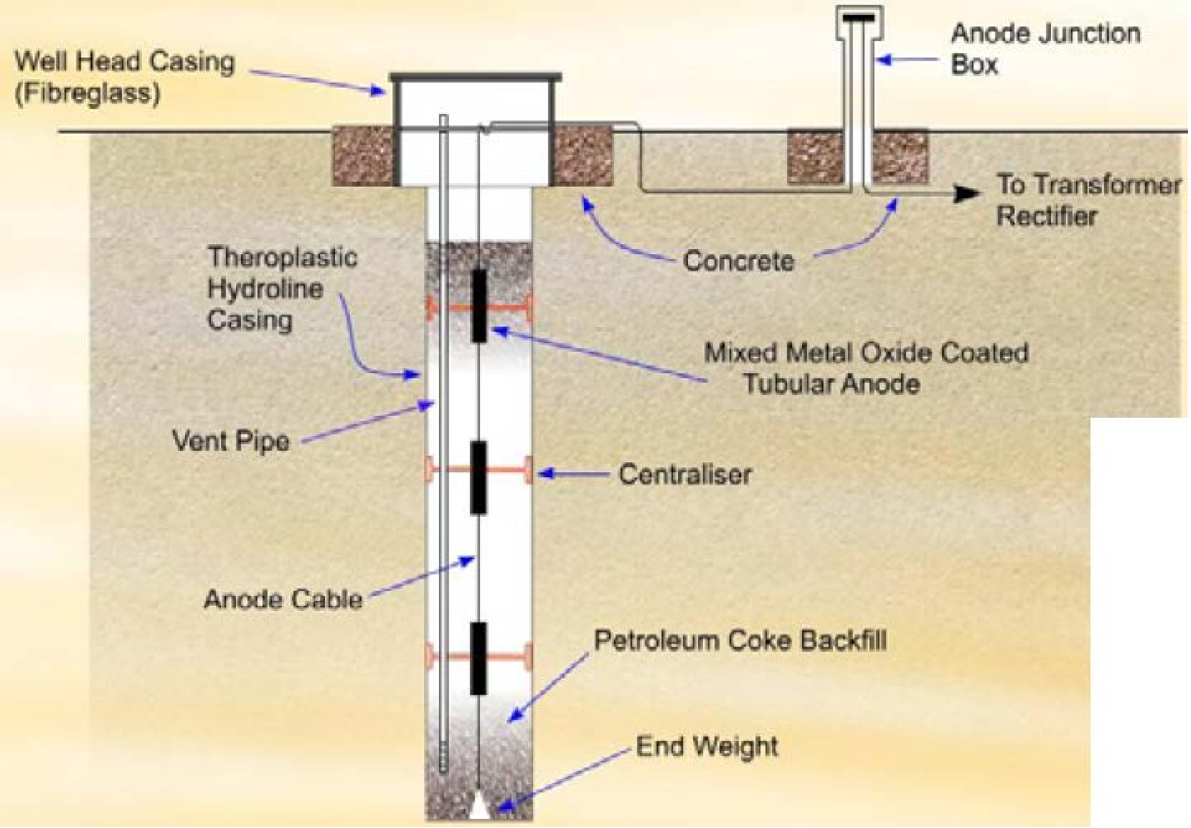

Figure 9: Deep well ground bed

5.3 ANODES BELOW STORAGE TANKS

In the case of large storage tanks the challenge is to get the same level of CP all over the base. Shadowing and earth resistance limits the farthest end of the tank and the case of horizontal anode beds. The Anodes are therefore placed under the tank.

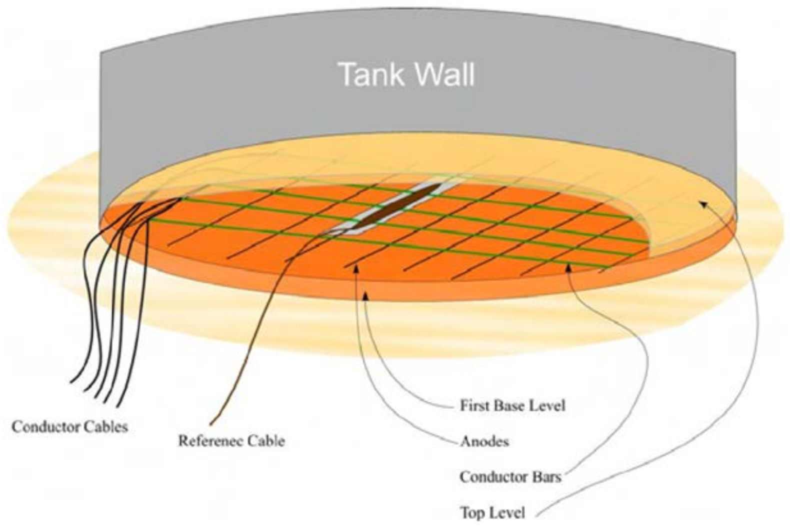

Figure 10: Storage Tank CP

6. ANODE PROXIMITY

The layout of the anodes is critical. If the anode is too close then the current distribution is limited.

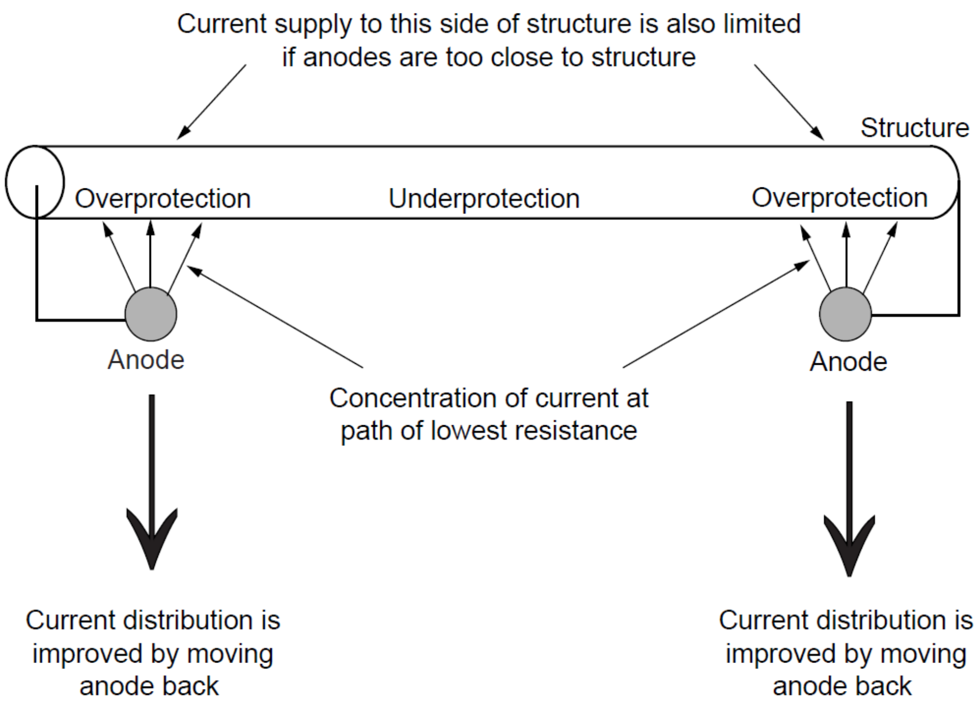

Figure 11: Anode Layout

7. SOIL RESISTIVITY

The resistivity of the soil may be different as the current flows through different layers of soil resulting in different levels of protection. This results in varying potentials on different parts of the pipeline. The same problem as in the section about Anodes below Storage Tanks above.

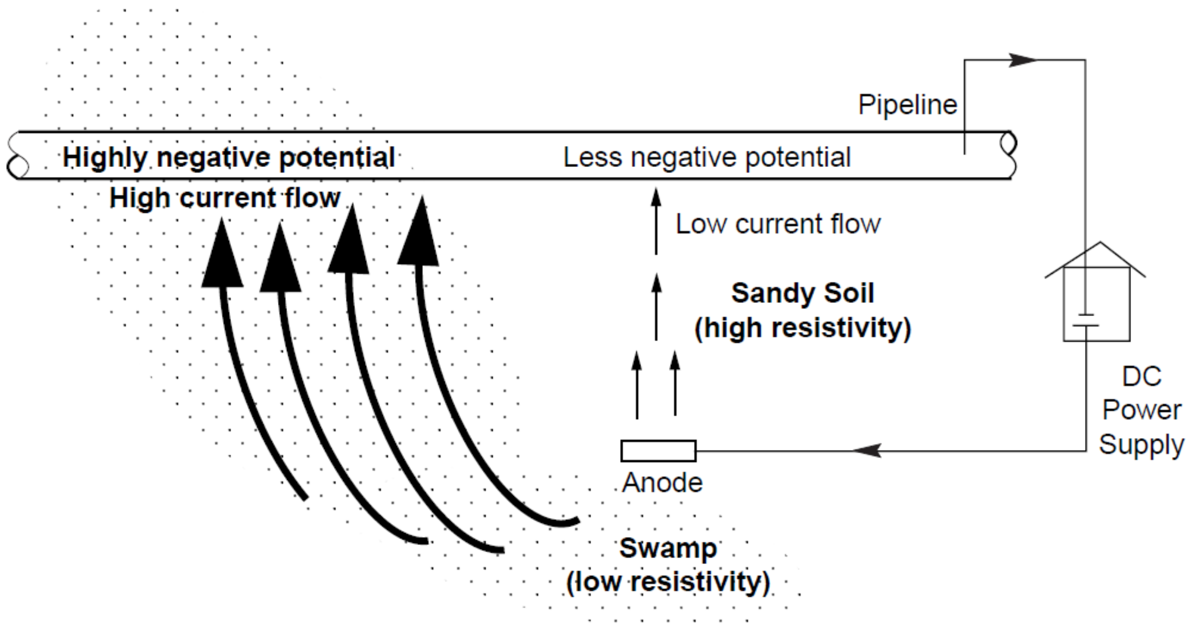

Figure 12: Soil Resistivity

Table 2: Resistivity of Different Soils

Soil Type	Typical Resistance in Ω·cm
Clay (salt water)	< 1 000
Clay (fresh water)	< 2 000
Marsh	1 000 – 3 000
Humus	1 000 – 4 000
Loam	3 000 – 10 000
Sand	> 10 000
Limestone	> 20 000
Gravel	> 40 000

8. STRAY CURRENTS

Stray currents are currents flowing in the electrolyte from external sources, not directly associated with the cathodic protection system.

Any metallic structure, for example, a pipeline, buried in soil represents a low-resistance current path and is therefore fundamentally vulnerable to the effects of stray currents. Stray current tends to enter a buried structure in a certain location and leave it in another. It is where the current leaves the structure that severe corrosion can be expected.

There are a number of sources of undesirable stray currents, including foreign cathodic protection installations; dc transit systems such as electrified railways, subway systems, and streetcars; welding operations; and electrical power transmission systems. Stray currents can be classified into three categories:

- Direct currents: Direct stray currents come from cathodic protection systems, transit systems, and dc high-voltage transmission lines.
- Alternating currents: Alternating stray current effects arise from the proximity of buried structures to high voltage overhead power transmission lines.
- Telluric currents: Telluric stray currents are induced by transient geomagnetic activity.

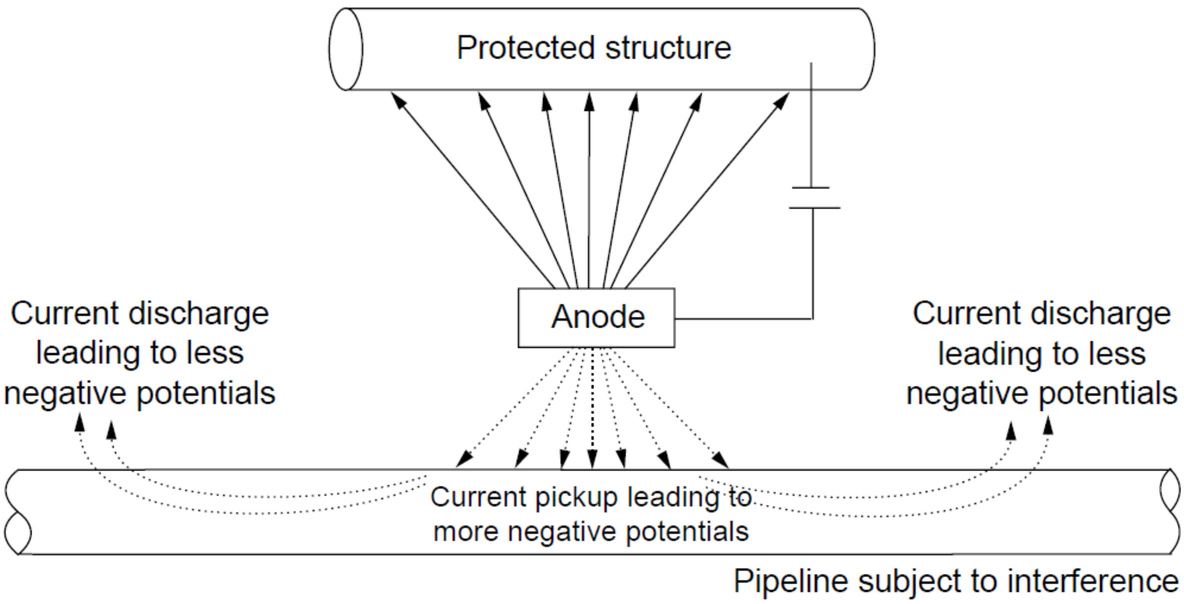

Figure 13: Anodic Interference Example

The bottom structure in Figure 13: Anodic Interference Example above is not supposed to receive protection from the anode as it is protected by another CP system.

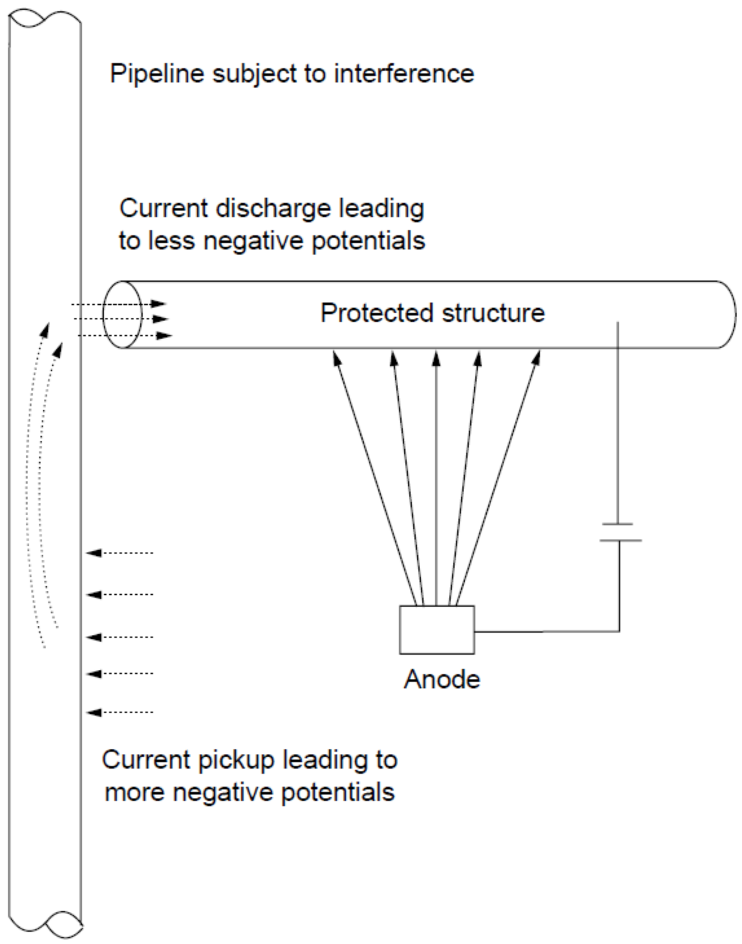

Figure 14: Cathodic interference example

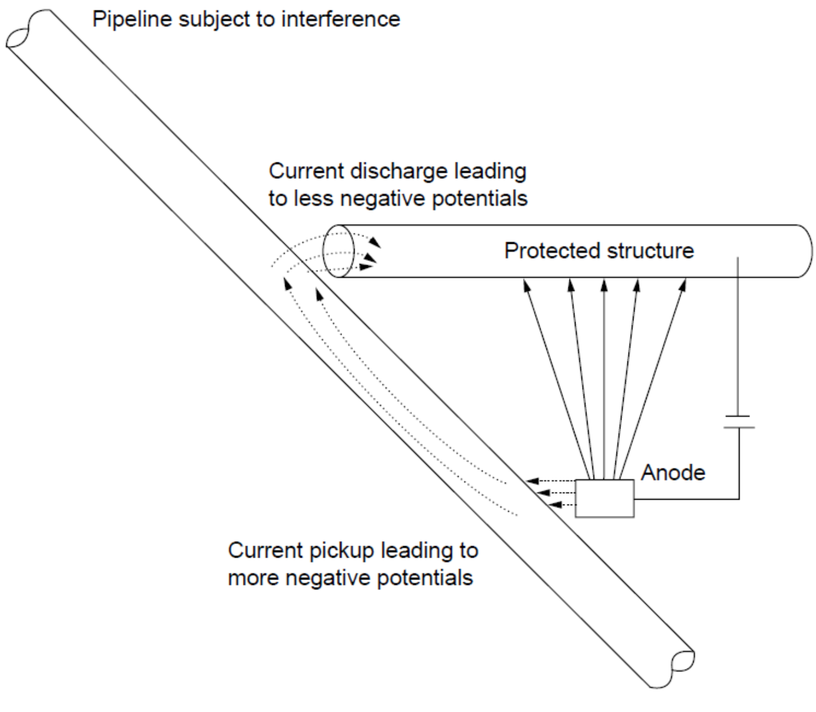

Figure 15: Combined anodic and cathodic interference example

8.1.1 CONTROL OF STRAY CURRENT

Control of stray currents is managed with the following options:

Removal of the stray current source or reduction in its output current

- Use of electrical bonding
- Cathodic shielding
- Use of sacrificial anodes
- Application of coatings to current pickup areas

Some of the methods used by allow CP current to flow through “other” parts of the structure. An example is making use of bonding.

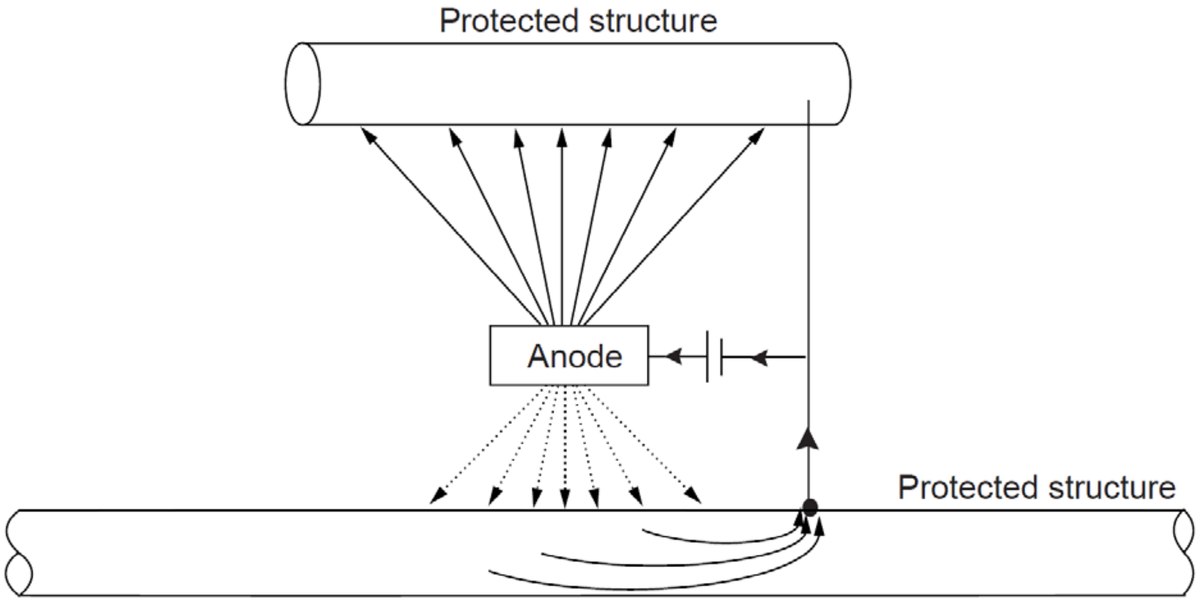

Figure 16: Drainage bond to mitigate stray current

9. EXPLOSION PROTECTION

So what has all this to do with explosion protection you may ask?

9.1 ARCS OR HOT SURFACES

Any source of ignition must be addressed by making use of Explosion Protected Equipment. There are however a number of cases where a source of ignition may be created by the working of the CP system.

9.2 CURRENT IN PIPES

Pipes etc. is not explosion protected but is transporting the flammable product. In general the subsurface pipes are protected by CP. In some cases this CP current “escapes” through for example pipe clamps fitted below the isolation flange or pipes earthed at the wrong point etc.

A good example of the danger is the splitting or opening of an aboveground pipeline by splitting the two flanges. The scenario may be described as follows. I pipeline is used to transport fuel and needs to be changed or repaired. The product is drained and the line is flushed. There however remains fuel vapours in the line. The maintenance personnel do not expect any CP currents to flow in the above surface pipes or the person may be working on an underground pipe to repair a leak.

An ICCP system may have an open circuit voltage of 50 Volts DC and a 50 Amp current capability. The electrical conditions are more than enough to draw and maintain an arc. The mechanical person removes the bolts and pulls apart the flanges. A high energy arc is created between the flanges that may ignite the escaping vapour and could flash back into the pipe. If the ignition flashes back into the pipe you have confinement of the fire that could create a high pressure wave front at the opening between the flanges. This pressure front could create physical damage. The flame front could create fire damage.

The solution is to shut down and isolate all CP systems in the area. Alternatively the flanges may be shorted out and kept at the same potential by the shorting cable.

9.3 MOTOR AND PUMP BEARINGS

In the case where pumps and pipes are connected to storage tanks a number of design principles are to be followed.

When using a local CP system the tank is connected to the local CP system and isolation flanges are used to disconnect the CP system from the plant earth and also to disconnect the anode (the tank) from the rest of the plant pipes.

The isolation flange is placed between the tank and the pump intake. If this isolation flange is not replaced correctly a DC current flows from the CP system to the tank through the flange to the pump. The pump is connected to the motor through the coupling and the motor is earthed to the plant or substation earth. The DC current from the CP therefore flows through the bearings of the pump or motor to earth depending on the lowest resistance path. The bearings on the motor may then create arcs and even a hot surface. The bearings are destroyed by the arcs and will only last a short period. The current depends on the rating of the Transformer Rectifier Unit (TRU) and the constraints in the circuit. The circuit may therefore carry 50 Ampere and it is possible to weld metal to metal at this current.

The type of current may be identified by using a full frequency range current measuring instrument in the form of a clamp meter. The meter should be able to measure ampere in direct current in this case. The current will most probably be flowing in the motor or pump earthing cables.

9.4 INSTRUMENTATION EARTHING

In some cases the tank earthing for large storage tanks is exclusively for the specific tank i.e. the tank has its own earthing pegs or the bottom of the tank is taken as earthed. An instrument (level measurement) is for example connected to the tank. Due to the zone 0 inside the tank this will typically be an intrinsic safe installation. The SANS 60079 standards define earthing and bonding.

If an armoured cable is for example used in the instrument installation then the armouring of the cable may be bonding the tank earth (this is also the cathode of the tank CP system) with the plant earth. There is then a real possibility of large DC currents flowing into the instrument earthing system creating another possible source of ignition.