

# Impressed Current Cathodic Protection of Deep Water Structures

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## Abstract

Of all the various anti-corrosion systems used by offshore structures and ship-building industry to reduce the ravages of sea-water corrosion, cathodic protection is one of the most important. Impressed current cathodic protection (ICCP) is the principal means of corrosion control for submerged structures. The developments of offshore energy resources is rapidly moving into water depths greater than 300 metres. However changes in the sea water environment at greater depths have raised the concern that the cathodic protection design approaches for shallow water may not be adequate for deeper water. This paper discusses on environmental factors encountered in deep water and their effect on cathodic protection behaviour of steel. Further, current CP design approaches and deep water CP studies are also discussed. Finally, work being carried out in National Institute of Oceanography (NIO) on ICCP system for deep water structures is briefly described.

## Introduction

Most metals occur in nature in the chemically combined state and the energy must be supplied to win them from the ores. Furthermore once extracted and exposed to natural environments like moist, aerated conditions, these same metals attempt to return to the combined state spontaneously. It is only by the expenditure of the energy that this spontaneous degradation of the metal can be prevented. One means of controlling corrosion is by the use of cathodic protection.

In 1824, Sir Humphery Davy introduced cathodic protection as a means of preventing the rapid decay of copper sheathing of His Majesty's naval

ships that iron or zinc would protect the copper when the two were connected. He thus established the principle of cathodic protection by means of sacrificial anodes.

Today cathodic protection is still the principal means of corrosion control for submerged steel structures. Long lengths of hydrocarbon pipes, large diameter water pipes, offshore structures for petroleum industries, lock gates, harbour piles, births, casing pipes and ships are some of the structures for which cathodic protection has been applied effectively. Figures 1,2 & 3 shows the principle of cathodic protection system for sacrificial anode method, impressed current method and impressed current cathodic protection of ship's hull respectively. Since steel is the major construction material for these facilities, good corrosion control is required for long term protection. Till today, no required for long term protection are available on impressed current cathodic protection in the public domain on the experiences with deep water.

In this paper attempt has been made to summarize cathodic protection systems, effect of deep sea environment on CP design and finally on the proposed work for the cathodic protection of deep sea structures.

## Effect of Various Environmental Parameters on Cathodic Protection

The electrochemical behaviour of the anode and cathode and the quality and solubility of the generated cathode deposit are influenced by a range of factors like calcareous deposit, dissolved oxygen, temperature, salinity, pH, sea currents, pressure and fouling.

Several authors have demonstrated a direct correlation between dissolved oxygen (DO) and corrosion rate in seawater. The cathodic current density required to provide corrosion protection is also proportional to the rate at which DO diffuses to the cathodically protected surface. Since the solubility of oxygen in seawater is a function of temperature and salinity DO also varies considerably with seasons. DO also decreases with ocean depth. Thus theoretically current density requirement for CP could be reduced where DO is lower. However lower current may not be adequate for the development of sufficiently high pH near the protected steel surface to produce precipitation of calcareous deposit. If this were the case very significant reduction in current demand could be anticipated in CP design that results from calcareous deposits.

Ocean temperature decreases with depth. Brown *et al* observed that CP requirement were unaffected by temperature changes within the range of 0 to 80°C. Temperature, however, does have an influence on the seawater resistivity, dissolved oxygen and the calcareous deposit formation. As sea water chemistry is directly related to the effective resistance of CP anodes, it is critical in CP designs. Also, the major effect of salinity on CP is its influence on seawater resistivity.

A small change in pH occurs in depth. Since seawater pH is controlled by the carbon dioxide/carbonate system, the decrease occurs as a result of the change in this equilibrium. Since calcareous deposits are produced as a result of high pH at the steel surface, a lower pH will tend to retard calcareous deposit formation.

In general, sea currents are lower at increased ocean depths. Since the rate of dissolved oxygen transport to a steel surface is diffusion controlled, increased sea current, increases CP current density requirements for bare steel, especially during initial polarization before calcareous deposit or fouling has occurred. Fischer *et al* have shown that once a quality calcareous deposit is formed sea currents within limits do not affect CP requirements.

Pressure is directly proportional to depth. Brown *et al* performed tests that measured current densities required to maintain various protective potentials on steel surface as a function of temperature. Influence of pressure on anodes have been studied. Lead, Silver, and antimony shows reduced efficiency at greater depths. This is due to the formation of protective oxide layer on its surface.

Fouling obscures steel surfaces exposed to seawater. It can retard DO diffusion to the surface and reduce CP current demand. Fouling can also adhere to sacrificial anodes and affect its performance. With the reduction in fouling at greater depths, whatever benefits are afforded to CP to shallow water will be less in deeper water. Fouling can also influence calcareous deposit formation.

Calcareous deposit formation is considered beneficial, since their presence enhances the effectiveness of the protection system by :

- a. reducing the current demand of the system by increasing the electrical resistance of the current.
- b. assisting the distribution of protection areas progressively.

Calcareous deposit at greater depths can be expected to have inferior protective properties as compared to shallow water conditions.

### **Present State of the Art : Deep Water CP Design**

It is the total impact of all the environmental factors which will determine the efficiency of a given CP system. Thus hydrostatic pressure as a function of various parameters should be studied. From the literature reviewed, effect of deep water CP system is cumulative effect of sea water characteristic that vary with depth and effect of cathodic polarisation and calcareous deposit formation. With increasing interest in deep water production and the uncertainties involved in deep water CP there is considerable activity in developing data needed for

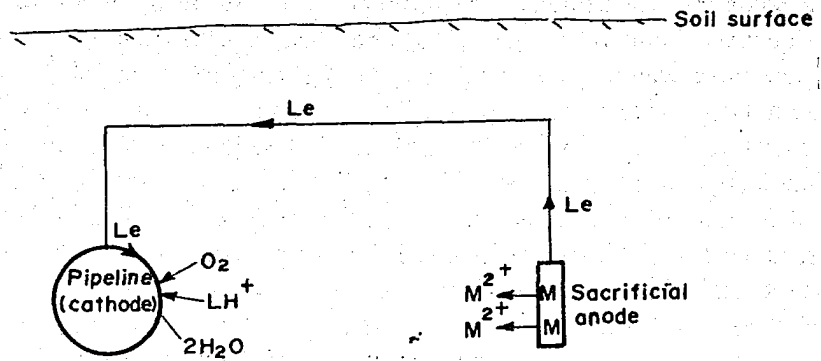


Fig. 1. SHOWS CATHODIC PROTECTION BY SACRIFICIAL ANODE METHOD

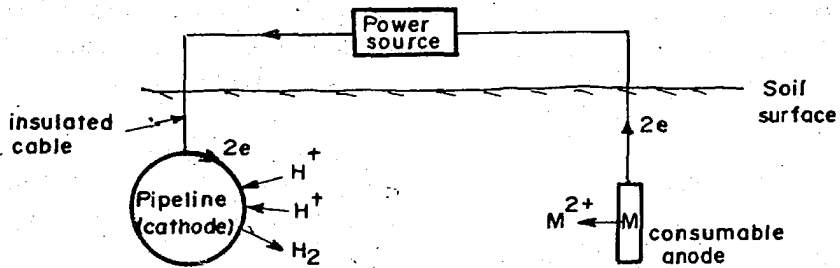


Fig. 2. SHOWS CATHODIC PROTECTION BY IMPRESSED CURRENT METHOD

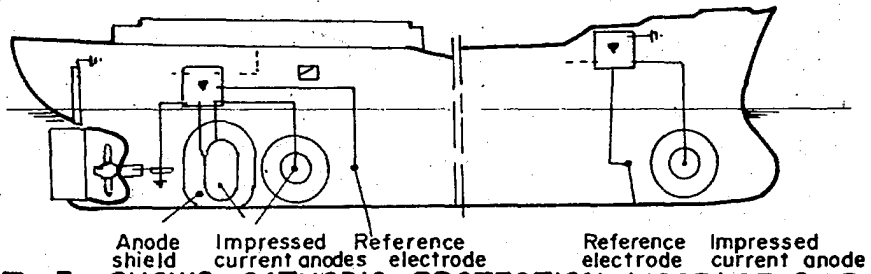


Fig. 3. SHOWS CATHODIC PROTECTION (ICCP) OF SHIP

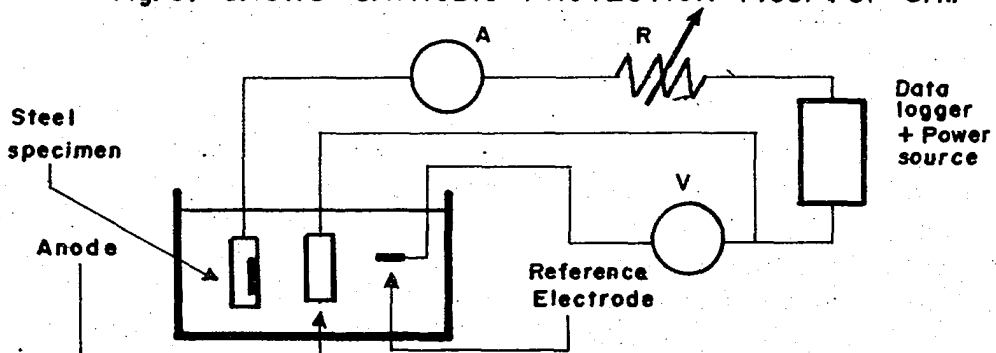


Fig. 4. SHOWS EXPERIMENTAL SET UP FOR ICCP SYSTEM

deep water CP system. Most of the present work is in site specific locations.

### ***Proposed Work***

The general approach is to place electronic logging units at selected water depths and record the current required to maintain a given cathodic potential on a steel coupon or record current potential of a set of mooring systems to be developed in the sea. By incorporating this instrument, additional data on impressed current cathodic protection system can be obtained.

### **Reason for this Study**

The developments of offshore energy resources is rapidly moving into water depths greater than 300 metres. Over 40 years of successful applications of CP have optimised CP systems for water depths less than 300 metres. However changes in the deep water environment at greater depths have raised the concern that CP design approaches adopted for shallow water may not be adequate for deeper waters.

### ***This Proposed Study Aims at***

\* Optimizing the CP system to minimize weight of structure and to maximize reliability and

\* Thorough understanding of sea water chemistry as a function of water depth and its effect on long term cathodic protection.

Since steel is the major construction material for these facilities, good corrosion control is required for long term protection. Till today, no detailed reports or publications are available in the public domain on the experiences with deep water.

### ***Developing Data Base for Deep Water CP System***

The general approach is to place electronic logging units at selected water depths and record

the current required to maintain a given cathodic potential on a steel coupon or record current potential of a selected steel and anode couple with time. This requires set of mooring systems be developed for long durations in the sea. By incorporating this unit onto these mooring time-series data on impressed current cathodic protection (ICCP) system can be collected.

### ***Preliminary Studies: Laboratory Set-Up***

To monitor the current density requirements, steel specimens (12 nos) specially mounted on epoxy resin are to be polished by 600 grit emery paper (0.25  $\mu\text{m}$ ). Then these specimens are to be connected and equally spaced around the circumference of a test cell containing 2 litres of electrolyte (sea water). A platinum piece will be used as central electrode and the potential will be controlled with reference to a miniature silver/silver chloride electrode (SSC) (fig.4).

To provide a constant potential of -850mv an electronic unit is being designed and developed. This unit will adjust the impressed current density according to fluctuations due to various factors like calcareous deposit, barnacle formation and other effects.

Electrolytic cell, Ag/AgCl reference electrode, calomel electrode, steel specimens, electrical wire leads are available. Electronic unit for impressing current and for recording current is being developed with existing facility.

### ***Field Studies***

NIO has instrumented mooring deployed in the sea. Steel coupons can be prepared and exposed alongwith other mooring system being deployed under various programmes. Upon studying the current/potential conditions, water proof self-recording electronic logging unit with battery for impressing current will be developed. This can be developed with the available materials in the Institute.

## Conclusion

1. The effect of deep water cathodic protection is simply a cumulative result of seawater characteristics that vary with depth and effect of cathodic polarisation and calcareous deposit formation. Calcareous deposit and dissolved oxygen are the most important characteristics.

2. Simply impressed current cathodic protection system has been tested and functioning satisfactorily. The complexity of the chemical equilibrium and competing chemical and electrochemical reactions involved with cathodic protection and calcareous deposit should be studied under laboratory simulated deep water conditions for which the facility is not available in this country.

3. For effective CP design, hybrid CP system which is the combination of simpler sacrificial anode and efficient impressed current system should be studied in detail.

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