# Innovative Design For Deep Well Anode Bed
# In High Resistivity Area

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## ABSTRACT

It is challenging to design deep well anode bed lying in the area of high soil resistivity and particularly where cavities and strata defects are restrictive to make a feasible well.
A unique design has been developed using new materials with due validation through innovative tests in house and subsequent practical application in the field. The success of the functioning of deep well has been achieved through holding the backfill with special materials and eliminating the requirement of metal casing.

Key Words : Conductive Liner, Inactive column and water reservoir, Anode support & Backfill Materials

## INTRODUCTION

The standard features of deep well anode bed includes nonmetallic vent pipe, active column consisting of multiple anodes placed between 1.5 to 5m apart approximately, and backfilled with coke breeze (carbon), and an inactive column consisting of nonconductive backfill and sanitary well seal. Other various configurations of making deep well anode beds have been used earlier with limited success, although their use has diminished in recent years. These configurations included carbon steel pipe. Another common deep anode configuration utilizes multiple anodes attached to an individual header cable from each anode.

The central area of Saudi Arabia has generally very high ground resistivity and designing the anode bed in such high resistivity (50,000 ohm-cm to 300,000 ohm-cm) with surface anode bed is very difficult for achieving an optimum functionality. An alternative solution is to have a deep well anode bed with the resistivity study and finding the strata of viable ground resistivity which has been found generally below the depth of 50 meters. The deeper layers have viable resistivity in range of 10,000 ohm-cm to 30,000 ohm-cm but consisting of big cavities and boulders, hence it is very critical to install the conventional deep well anode bed as it faces the migration and shift of carbonaceous backfill inside the pots and cavities. Further deeper strata below 200 m experiences existence of water table where it will prove un-economical to install an active column of the anode bed. Therefore a possibility of forming an active column of anode bed may be sought above the depth of continuous water table and below a depth of high resistivity strata generally found below a depth of 50 m. And with new innovative design with some provision to contain backfill and stop the shift and migration which at the same time provides flexibility so as to not loose contact with surrounding soil.

## 1. CONDUCTIVE LINER

The experience of installation with anode bed using casing pipe was not found practical based on past history of deep well anode beds in the central region of Saudi Arabia. The upper soil layers have cavities and boulders, therefore the inactive column needs to be deeper than approximately 60m. The double casing installation poses considerable problem at these depths. Installations of metal casing as active column have two issues. One - after consumption of casing the coke column may fall down and anodes are hanging in a void thus formed without soil contact due to cavities, pots and boulders. Two – casing pipe adds to the cost of material and installation.

The new solution is stretchable soft conductive liner that forms containment for backfill which is flexible and conductive at the same time. In house research has been conducted for simulating anode bed column using dry sand having resistivity 100,000 ohm-cm.

The research work was performed to establish the conductive liner sock effect on the resistance of the path between the anode surrounded by the carbon backfill contained in the conductive liner sock, and this assembly of anode vent pipe and carbon backfill conductive liner planted in the center of the steel drum with annular space filled with dry sand (Refer Figure -1 for details). The measurement of circuit resistance was performed by applying voltage between anode (TA-4 anode cut-piece) & steel drum using a 50V-50 Amp rectifier and measuring the current through the circuit. Effect of watering, and removal of conductive liner sock was subsequently studied. The results tabulated are in Table - 1:

## 2. INACTIVE COLUMN AND WATER RESERVOIR

Generally it is desirable to prevent (up to the point of elimination) the leakage of anode current up in the inactive column in conventional deep well anode bed. To achieve it, the upper section of the well for deep anode bed should be made of nonconductive materials. Usual choice of materials is PVC casing, sand, gravel, and cement. The use of Sand is not recommended because it trickles easily during installation. Pea gravels backfill above the active column will increase the probability for ground water recharge without trickling. The depth of inactive column is generally related to current distribution requirements. However, long columns of porous backfill can lead to a blending of aquifers with differing water qualities.

Therefore in the high resistivity areas the deep well resistance is very likely to increase with the passage of time. To mitigate it, the new design utilizes non-active column as a reservoir to hold water and to slowly supply it to active column to keep the active column irrigated to maintain low resistance. The long inactive column having an approximate length of 60m and 10 inch Dia. (Approx. volume of 3 $m^3$), can store up to 3,000 liter of water. This makes a watering system that allows slow supply of water to active column for maintaining the resistance of deep anode bed in high resistivity area up to three months (Approximately). It has been already validated through field experience.

### 3. ANODE SUPPORT, VENT AND CENTERING DEVICES

Anode support structure is a necessity to reduce strain on lead wires of individual anodes; therefore a novel method of supporting it along with the watering vented pipe has been assembled with successful outcome. The installation procedure takes care of anodes being kept centralized until backfilling is completed with the coke breeze that surrounds each anode. The installation procedure ensures the prevention against damage to anode wires during installation and allow anode movement in the well without snagging on down hole formations or other anode assemblies. As most of the electro chemical reactions occurring at deep well, anode bed system produces a lot of gases. The use of a 2" perforated PVC pipe can alleviate by venting out the trapped gases, provide anode support, and act as a means of a watering system. The assembly of the lowest end has been provided with a centralizing dead weight that keeps anode assembly always in the center of the borehole.

### 4. BACKFILL MATERIALS

Carbon is used as a backfill material around impressed current anodes for underground CP applications. The carbon backfill accomplishes three major goals:

- ✓ Reduce the resistivity of the environment surrounding the anode to increase the amount of current the anode can discharge.
- ✓ Extend the anode surface area, thus increasing the amount of current the anode can discharge; and
- ✓ Reduce consumption of the anode since the carbon becomes the part of the anode consumed before the anode itself.

The impressed current anodes have the oxidation reactions that would occur on the periphery of the carbon backfill rather than at the anode surface. Further exploring the contact interface between the primary cathodic protection anode and the carbon backfill, we realize that this view is too simplistic since there are two possible conduction paths present at the anode interface. First, there is the electronic path from the anode surface through the particles of carbon backfill; however, there is also an ionic conduction path from the anode surface into the water molecules trapped in the tiny spaces formed between the irrigated carbon particles.

If current transfers from the anode surface through the carbon particles, no electrochemical reaction will occur at the anode surface. However, if current leaves the anode surface through the intra-particle water, an electrochemical reaction must occur to allow the charge transportation to change from electronic to ionic. In the case of electronic transfer of current through the carbon, the periphery of the carbon backfill becomes the reaction surface. In the case of ionic transfer into the water found in pores, the reaction surface is the anode surface itself. Since the carbon backfill surface is much larger than the anode surface, the current density at the backfill to soil surface should be much smaller. Therefore, the opportunity for polarization is reduced significantly at anode surface.

Since the two paths for current discharge from the anode surface are in parallel, some charge must flow through each path. If the ionic discharge is minimized, the anode life is increased, and the electrochemical reactions occur primarily at the periphery of the backfill reducing the possibility of anode operational problems. Therefore, the ratio of the resistances of each path, one through the pore water and one through the carbon backfill, is the determining factor in improving anode life and long-term system operation. The resistivities of the water and the carbon backfill control the resistance through each path. Since the water resistivity is generally outside of our control, minimizing the carbon backfill resistivity becomes a critical controlling factor. The in-situ bulk resistivity of the carbon is the important factor.

Finally, in the application of carbon backfills it is important to ensure that the carbon surrounding the anode surface is as clean as possible. Any soil or mud contaminating the anode surface or carbon particles will hinder electronic current transfer. In addition, the installer should completely surround the anode with carbon on all sides to minimize the possibility of ionic current transfer from the anode surface.

Carbon backfill used for new innovated deep well anode bed is calcined petroleum.

## 5. ANODES

Tubular High Silicon Chromium Cast Iron Anodes with PVDF insulated leads centrally connected to the anode body to minimizes end effect. The anode leads are impervious to the evolved chlorine gas with PVDF end caps at top end to achieve the same effect.

Refer Figure -2 for typical deep well anode installation in high resistivity area.

## 6. CONCLUSION

In the art of making deep anode beds for cathodic protection the new design was verified with encouraging results to the solution of high resistivity problem and defective (pots & cavities) soil strata as found in central region of Saudi Arabia.  Conductive liner can provide economic viable solution in place of the metallic casings. This innovation idea can also maintain the conductivity of the medium through regular irrigation during the dry season.

This also has lead to a conclusion that representative research work performed in-vitro got further validation with the good performance of the deep well which was under observation.

## 7. ACKNOWLEDGMENTS

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## 8. REFERENCES

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Figure -1 Factory Test for Validation

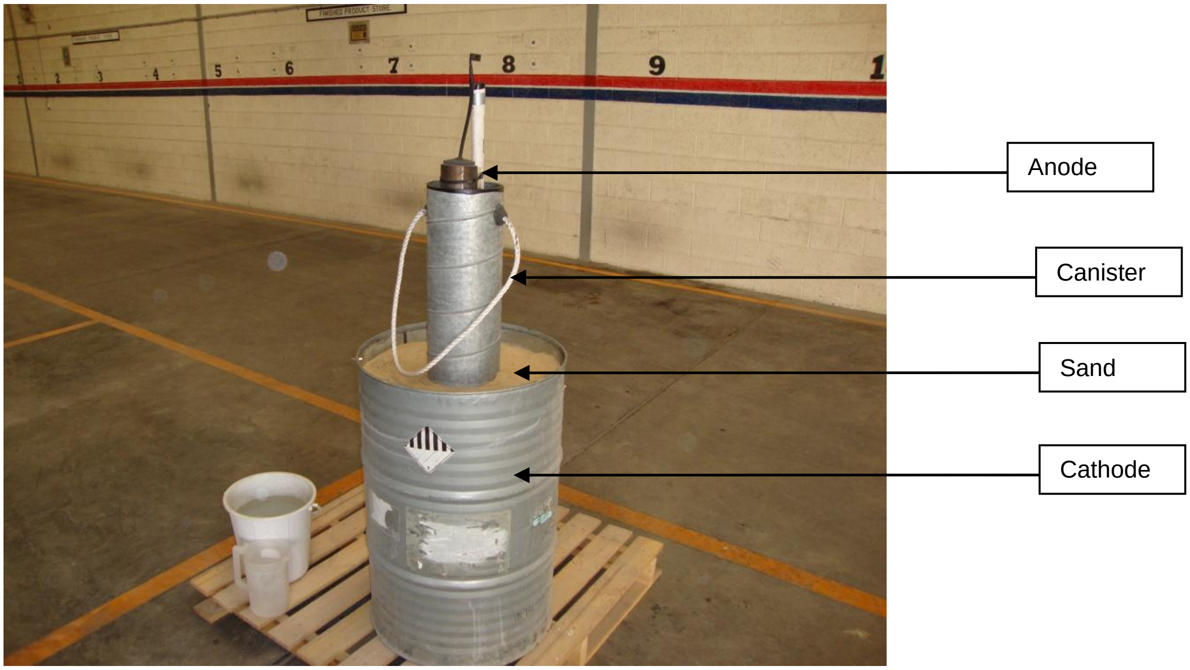


Table -1 Factory Test Results

| Sl.# | ASSEMBLY | HYDRATION STATUS | VOLT APPLIED Volts | CURRENT mA | RESISTANCE OHMS ( of what ?) | REMARKS |
|---|---|---|---|---|---|---|
| 1 | Anode +vent pipe+ coke breeze+ conductive liner sock +dry sand | Dry | 59.60 | 440 | 136.00 | |
| 2 | Anode +vent pipe+ coke breeze+ conductive liner sock +dry sand | Water added | 58.50 | 1657 | 35.30 | Watering was performed through vent pipe (~ 5 ltrs) |
| 3 | Anode +vent pipe+ coke breeze+ steel canister+ dry sand | Dry | 60.62 | 323 | 187.68 | With another collection of dryer sand and conductive liner sock replaced by steel canister. |
| 4 | Anode +vent pipe+ coke breeze+ dry sand (with canister removed | Dry | 60.00 | 288 | 208.33 | |
| 5 | Anode +vent pipe+ coke breeze+ dry sand (with hydration) | Wet | 58.30 | 1510 | 38.60 | Quantity of water added around 6 ltrs. |

Figure – 2 Typical Deep Well Anode Installation in High Resistivity Area