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PROTECTING PIPELINES FROM CORROSION USING THE CATHODIC PROTECTION TECHNIQUE

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For
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This report will show how to protect Aramco's pipelines from corrosion. It will first define the term corrosion. Then it will introduce the most used method in Aramco to protect its pipes, which is the cathodic protection. The cathodic protection can be implemented using two systems-the impressed current and galvanic anode systems. The latter system will be discussed in this report.

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1.INTRO2 U1TION

This report will represent the work done in Saudi Oil Company (ARAMCO) in Abqaiq in the Southern Area Pipe Lines Department (SAPD) during the summer training. I was assigned to join the Corrosion Engineering (COE). Under the COE umbrella, I was involved to the Cathodic Protection Engineering division (CP).

2.1ORROSION

2.1 2 efinition

The simplest definition of the corrosion is the deterioration of an object's surface due to the reaction with the surrounding environment.

2.2 1auses Of The 1orrosion Of The Metals

Most of metals are made from natural compounds called ores. These ores contain metals that are combined with oxygen or sulfur. Metals are formed when ores are heated to remove the oxygen or sulfur. Metals store this heat as a chemical potential energy during the refining process. So when metals release that energy, they corrode. Metals corrode at different rates because they store different amount of energy.

3.10THO2 I1 PROTE1TION PRIN1IPLE

3.1 The Principle

Electrochemical reactions cause most of the corrosion in the petroleum industry. These reactions involve the transfer of electrons and ions. That transformation of electrons and ions associated with the creation of an electrical circuit.

3.2 The Electrochemical 1orrosion 1ell

The electrical circuit and its associated chemical reactions are called the electrochemical corrosion cell. For corrosion cell to exist, the following four components must present:

- an anode where corrosion (metal loss) occurs .
- a cathode where electrons are consumed and metal is protected.
- a metal path through which electrons move from the anode to the

cathode.

- an electrolyte path in which ions transfer.

An electrochemical corrosion cell can occur between two metals or on the surface of one metal. When a metal corrodes, metal atoms lose electrons and go into the electrolyte as positively charged metal ions. Figure 1 shows an electrochemical corrosion cell between two dissimilar metals, magnesium and steel. The two dissimilar metals are connected with a copper wire (metal path) and placed in salt water (electrolyte). The magnesium has a more negative potential so it acts as an anode. The steel has a less negative potential than magnesium. It acts as a cathode.

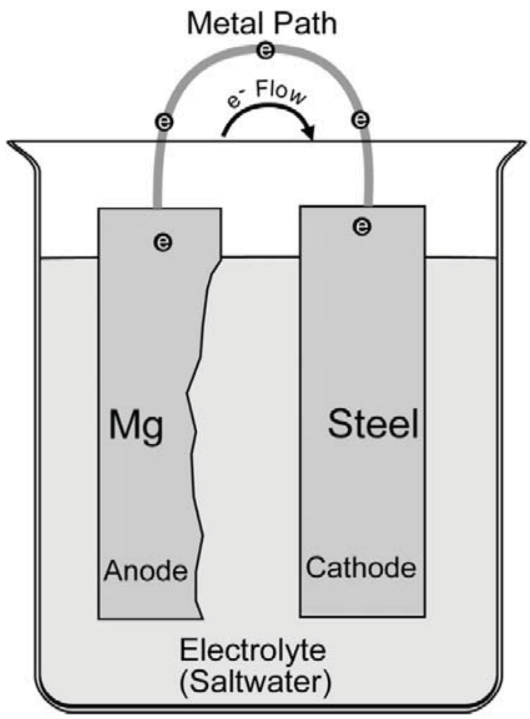


Figure 1: The Electrochemical Corrosion Cell

3.3 Anodic Reaction

Figure 2 is a magnified view of the anodic reaction. When the metal corrodes, metal atoms lose electrons and go into the electrolyte as positively charged metal ions. This is shown in the following equation:

$$Mg \Rightarrow Mg^{2+} + 2e^{-}$$

Magnesium　　Magnesium Ions　　Electrons

The loss of metal into the electrolyte is characteristic of the corrosion at the anode.

Electrons that are produced in the anodic reaction flow through the metal path to the cathode. At the cathode, the electrons are used in a chemical reaction.

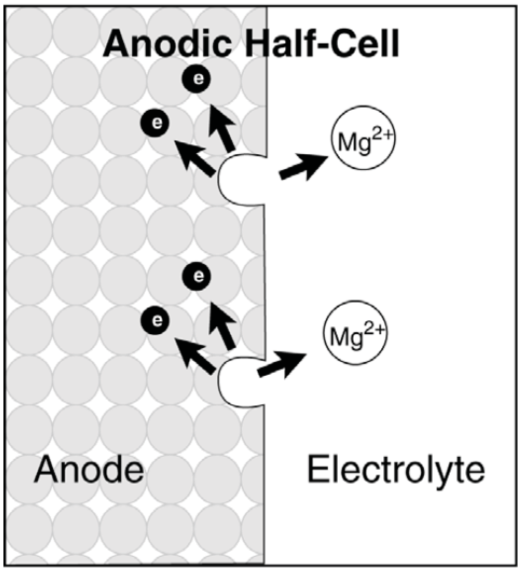


Figure 2: The Anodic Reaction

3.4 Cathodic Reaction

Electrons that are produced in the anodic reaction flow through the metal path to the cathode. At the cathode, the electrons are used in a chemical reaction. Figure 3 shows reactions that occur at the cathode in acid solutions. Hydrogen ions from the acid solution use electrons from the cathode to form hydrogen atoms. Two hydrogen atoms usually combine to form one molecule of hydrogen gas as follows:

$2H^+$ + $2e^-$ ⇒ H_2 (g)⇑

Hydrogen Ions Electrons Hydrogen Gas

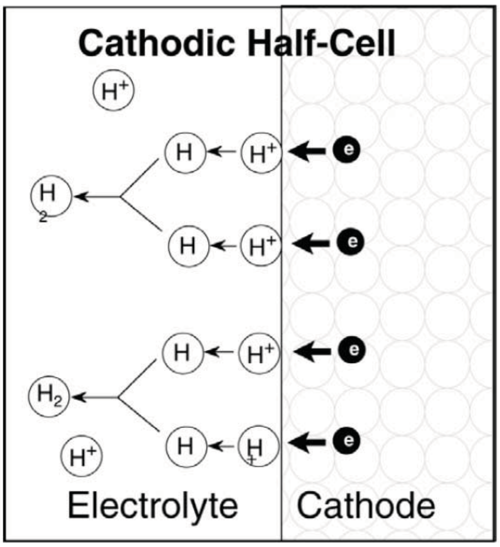


Figure 3: The Cathodic Reaction

Above, I have shown the corrosion cell for two dissimilar metals. Corrosion cell can occur in a surface of one metal. For example, Figure 4 is a magnified view of an iron surface corroding in an acid solution. The anodic reactions at the anodic area generate electrons and release iron cations (Fe^{2+}) into the acid. The electrons travel through the metal to the cathode. At the cathode, the electrons reduce hydrogen ions from the acid solution to hydrogen atoms. Some of these hydrogen atoms combine to form molecular hydrogen and then hydrogen gas. Corrosion only occurs at the anodic areas of the metal surface.

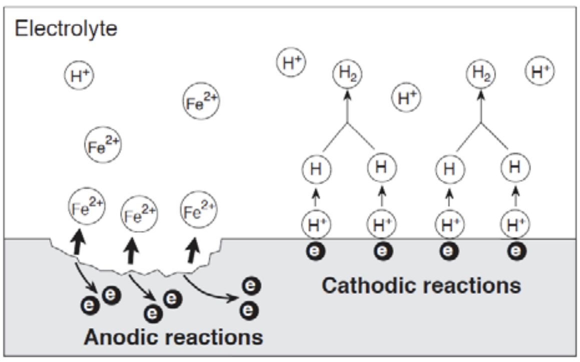


Figure 4: Corrosion of One Metal

As we know, the net flow of electron creates an electric current. So the larger the current is the faster corrosion rate.

4. HOW THE CATHODIC PROTECTION WORKS

As corrosion occurs, the electrons that are released in anodic reactions are consumed in cathodic reactions, see Figure 5. Assume that we supply additional electrons to the metal from an external source; more electrons will be available for cathodic reactions so the cathodic reaction rate and the evolution of hydrogen gas will increase. However, the demand for electrons at the cathode will decrease and the anodic reaction rate will decrease to produce fewer electrons. This is the basic principle of cathodic protection.

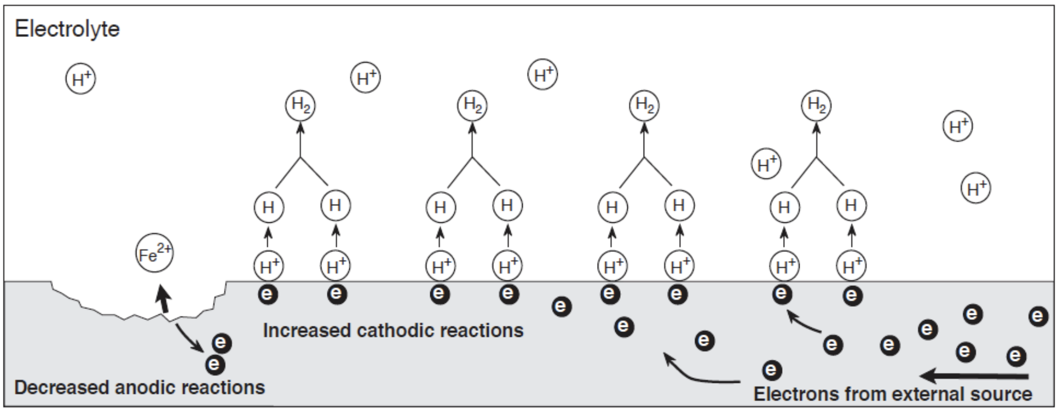


Figure 5: Metal after applying a DC current

The additional electrons are supplies by a direct current. The potential of the cathodic area will be more negative and its value will be close to that of the anodic area. So if enough direct current is applied to the cathode, the potential difference between the anode and the cathode will be small such that the corrosion will cease. To complete the circuit, a lead wire returns current to the current source, Figure 6. It is important to note that CP does not eliminate corrosion. It transfers corrosion from the protected structure to the expendable external current source or **anode**.

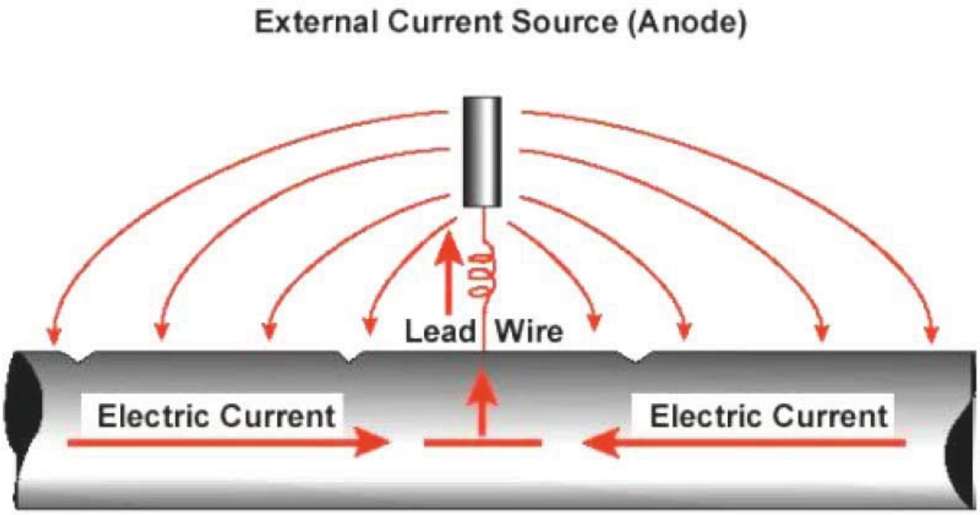


Figure 6: After A cathodic Protection

4.1 Measuring Electrical Potential

When direct current is applied to a metal surface, its potential becomes more negative. This shift in potential can be measured and used as a criterion of cathodic protection. Electrical potentials are always measured with respect to a reference electrode or half-cell. The copper-copper sulfate (Cu-$CuSO_4$) reference electrode is the most common reference electrode used for buried structures in Aramco. Figure 7 is a diagram of a Cu-$CuSO_4$ reference electrode.

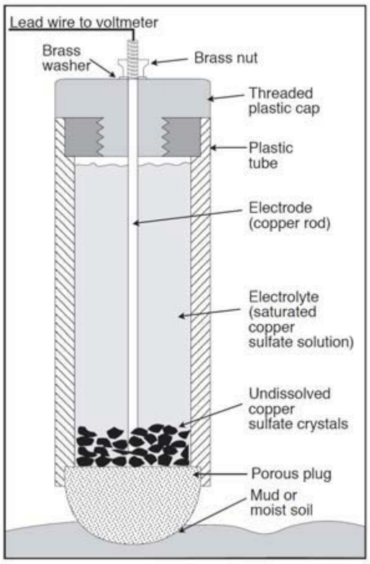
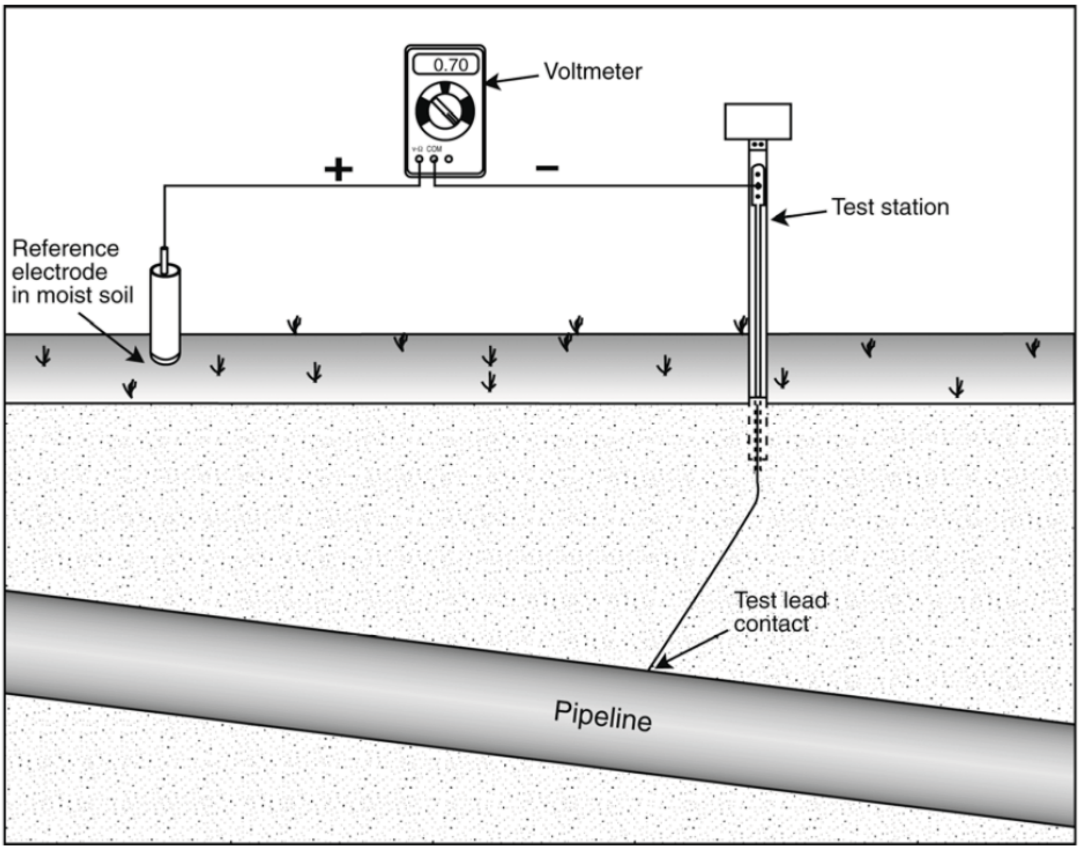


Figure 7: Cupper- Cupper Sulfate Structure

4.2 How to measure the potential Difference

Hrl , vh 8 wms . wms . ys q hdwy vh ymh t syhr yndpgriihvhr f h ehy. hhr d trt hprr h drg ymh F, -F, bW4 vhihvhr f h hphfyvsgh. cmh vhihvhr f h hphfyvsgh nwf s r r hfyhg ys ymh t swyn h phdg si d : spyq hyhv. cmh f s q q s r (r hl dyn h) yhvq rr dp si ymh : spyq hyhv nwf s r r hfyhg ys ymh t rt hprr h yhvy wydyns r 5Hrl , vh 8. Rmdg d wyh : nwy dr g Rwd. dr st hvdys v q hdwy vrr l ymh t syhr yndpdr g ny. dwrr ymh wdih vdr l h. c mh wdih vdr l h nwh2t pdrr hg pdyhv.



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4.2.1Test Stations

Ry f s r ydrr wd phdg . nvh5. mf m nw. hpghg ys ymh t rt hprr h. Avdq f s vhu, nvhwt syhr yndpyhvy wydyns r wdy hdf m orps q hyhv q dvohv si d t rt hprr h. Hrl , vh 9 nwd yhvy wydyns r t rf y, vh.

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4.3 Criterion for the Protection

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Wr cq2 ugcf mqi p rug qgi cwmg wlcq -9.2 , roav mqf mecwg cf gt ycwg ecwlrf m surwgewmq. Aqf cq2 ugcf mqi m p rug s rvmmg wlcq -9.2 , roav mqf mecwg 3r qgv wlcwp c2 eruurf g.

t st Prmcol e0Tpf l alUMnl pcUpll i

al gug cug w r w2sgv)v2vvgp v4 r hwlg ecwlrf m surwgewmq. Rqg m ecoogf wlg mp sugvvgf eyuugqwv2vvgp 5: l mg wlg rwlgu rqg m ecoogf wlg i co cqm cqrf g v2vvgp .

Hq Aucp er 5wlg2 yvg wlg mp sugvvgf eyuugqwv2vvgp : mfigo25cqf H ogcuqgf p rug cdr ywmi5vr H: moof m eyvv mwmq wlm ugs ruw Hnqr: wlcwwlg i co cqm cqrf g v2vvgp v cug yvgf mq cr: eyuugqwugt ymgp gqw5: l mg wlg mp sugvvgf eyuugqww2vvgp m yvgf mq l ml eyuugqwugt ymgp gqw

usPE 2 H MN2OO21 0RNN2LP OSOP2I

al g dcvm rsgucwmq rhwlg mp sugvvgf cqrf g m moyvwucwgf mq Friyug 98**s**

The electrical grid supplies high-voltage AC current to a rectifier. The rectifier reduces the voltage and converts the AC current into the DC current. The direct current goes from the positive terminal of the rectifier to a junction box. At the junction box, the current is distributed to an anode bed of impressed current anodes. The anodes drive, or impress, the current into the earth. The current migrates through the earth and protects the structure. The current returns to the negative terminal of the rectifier via a cable, which is connected to the structure (pipelines).

I had a site visit to investigate this system. I have seen the step-down transformer, the rectifier and the junction box.

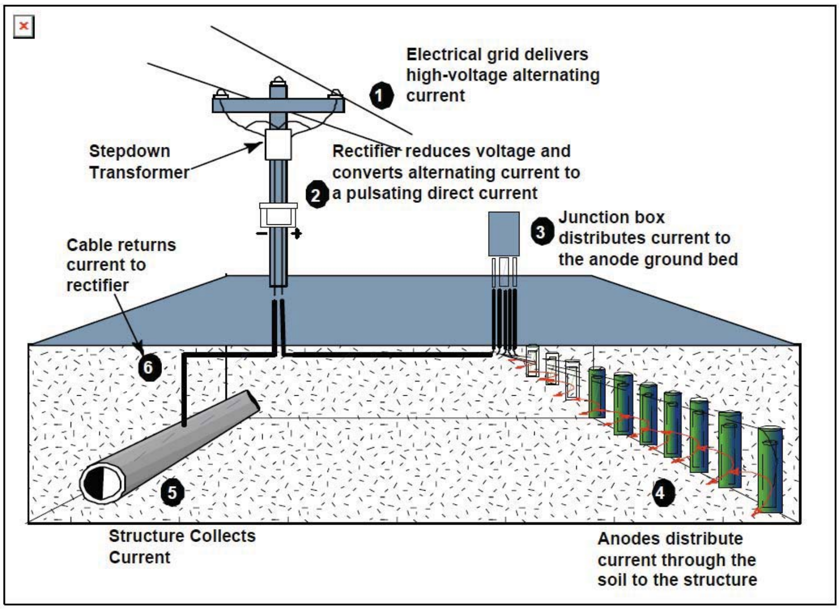

Figure 10: The Impressed Current System

The following information describes the operation of most important impressed current system components.

Rectifiers - Electrical transmission systems supply high-voltage single phase or three-phase alternating current (ac). Rectifiers step down the voltage and convert the alternating current to direct current.

The transformer and rectifier elements generate heat inside a rectifier cabinet. This heat must be dissipated for the rectifier to work properly. Two methods are used to cool rectifiers—air-cooling and oil immersion.

In air-cooled rectifiers, the transformer windings and diode heat sinks are surrounded by ambient air. Heat is removed by natural convection of the surrounding air through holes.

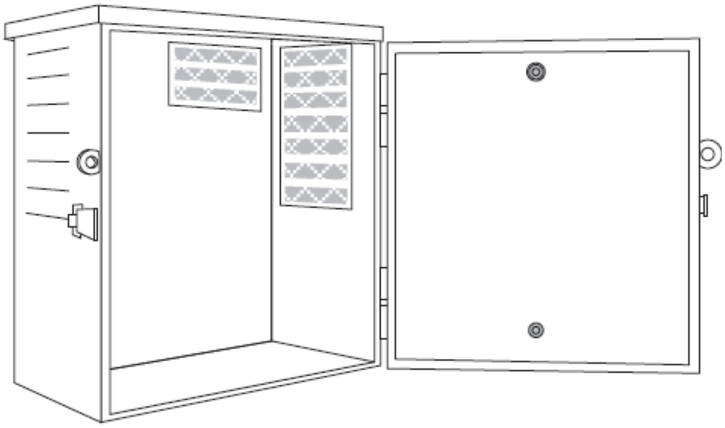

Figure 11: The Air Rectifier Enclosure

Oil-immersed rectifiers are often required for dusty areas. Mineral oil transfers heat from interior elements to the exterior surface of the rectifier.

Figure 12: Oil-Immersed Rectifier

Junction Boxes: A single cable goes from the positive terminal of the dc power source to a junction box as shown in Figure 13. The junction box is connected to the individual anode lead wires. A shunt is inserted in each anode lead wire inside the junction box. We commonly use 0.001-ohm shunts, Figure 13.

Shunts: Shunt resistors allow the current output of system to be measured without disturbing the system.

The current that flows through a shunt produces a voltage drop, which can be measured with a multi meter. If the resistance of the shunt is known, the current output can be calculated through the use of Ohm's Law, I = E/R. For example, if a voltage drop of 3.20 millivolts is measured across a 0.001-ohm shunt, the amount of current flowing through the shunt is .002 millivolts/0.001 ohm, or 2 amperes.

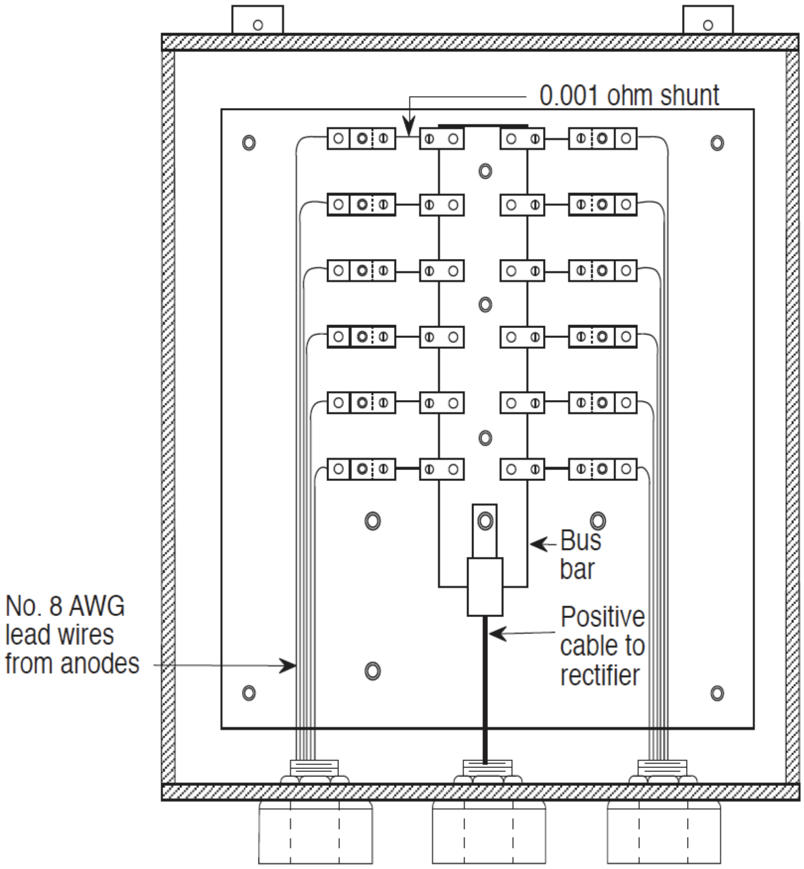

Figure 13: Junction Box Structure

6. CONCLUSION

In this summer training, I have learned new concepts that have not been studied in the university. That's the great thing of the summer training.

The corrosion was introduced to me as a new subject. I have learned its basics and its causes. The main causes of the corrosion is the releasing of the oxygen and sulfur during the refining process of metals.

The main concept that was presented to me in the training is how to protect pipelines from corrosion.

The cathodic protection (CP) is the main way used in Aramco to protect the pipelines. I have been shown the principle of the CP. The principle is to add an external current source to the cathode to supply more electrons to the cathode to decrease the demand of the electrons coming from the anode to slow down the corrosion.

I have also discovered the two systems for the CP-the impressed and the anodic systems. The latter was used in low current requirement while the first was used in a high-demand current.

In this training, the most work was reading about the corrosion and the cathodic protection, because I was in the engineering unit. I had some site visits with some CP technicians to see and understand how the cathodic protection works in practice. I saw test stations, junction boxes, and rectifiers cooled with oil.