Fundamentals Of Corrosion

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When a football game draws a half-million dollar gate for a two hour show of color and action, we concede that the performance was worth the price of admission. But what about the men in industry who are needlessly paying billions of dollars for a show they can not even see? We are referring to the metal "disease" called corrosion. Many complicated explanations have been written of corrosion; yet, it is simply a transformation of energy. The corrosion process itself is quiet and unheralded, without any noticeable display of heat, light or sound. A major portion of this cost and destructian can be stopped by applying known methods of corrosion control.

It is an odd turn of events when we realize that mankind is responsible for corrosion. This all came about when man devised a method of removing ore from the earth and converting it into a usable metal. We then buried these refined metal structures, bare in the soil. Since most structural materials have been obtained from an ore, they will have a tendency to return to that state when exposed to the elements. The refining operation consumed heat or electrical enregy, and this energy will be emitted when the reversion occurs. Man is now aware of what is occurring and has called on his ingenuity to devise a method by which he can prevent such metal structures from corroding.

Let us now look at the causes of corrosion, and what mankind has done to find a cure for this "disease".

The electrochemical (transformation of energy) action involves metal, chemicals and electric current, which in nature form electrolytic or galvanic cells All such cells have four basic components. The are: (figure 1)

a. The "electrolyte" which is composed of water containing dissolved chemicals, and will conduct an electric current.

b. The "anode" which is a substance capable of conducting electric current, in contact with the electrolyte. When composed of a reactive metal, its surface is corroded by combining with chemicals in the electrolyte.

c. The "cathode" which is a substance also contacting the electrolyte. Its surface is not attacked, but receives protection against corrosion.

d. The "conductor" which externally connects the anode to the cathode to complete the circuit for current flow.

Electrochemical cells fall into three general groups: Electrolytic cells, galvanic cells, and concentration cells.

"Electrolytic" cells consist of the above four components, plus an external source of electrical energy connected in the conductor between anode and cathode, to cause current flow. A good example of this type of cell is the rectifier (figure 2) set-up for cathodic protection of a pipe line. In this instance, a rectifier is connected to the pipe line on one side and a ground bed of carbon or junk iron on the other. The ground bed serves as the anode, and the pipe line as the cathode. The current flows from the rectifier to the anode and from the anode through the soil to the pipe; thus we have a protected pipe line system.

"Galvanic" cells consist of the same four basic components, with dissimilar electrodes immersed in a homogeneous electrolyte (figure 3). The commmon dry cell battery is typical. The metallic anode reverts to a more stable form by combining with chemicals from the electrolyte. This liberates the energy stored in the metal, causing an electric current to flow through the electrolyte from anode to cathode. Current returns through the external metallic circuit connection to the anode. This type of cell is established when zinc, magnesium or similar metal anodes are used to protect iron pipes against corrosion, without an external source of electric power.

Galvanic cells also appear on burial structures, and are usually caused by electric currents resulting from potential differences on the metal surface. The factors responsible for these differences are the heterogeneous structure in the steel. Also, rough surfaces, cuts or scratches caused by pipe tongs, or mill scale, will cause potential differences resulting in localized pitting or corrosion.

A good example of this type of corrosion (figure 4) would be a piece of pipe fitted into a coupling. The bright threaded surfaces exposed will corrode more rapidly than the unbroken pipe surface. Also, where the connection has been made-up by the use of a pipe wrench or tongs, the scarred surface will act as an anode. It is also possible that the coupling has received a different thermal treatment than the rest of the pipe, so that is will act as a cathode.

Thus, galvanic cells consist of two dissimilar metals in the same electrolyte. These metals will always display the same electrical potential between each other. This potential relationship is called the "Electromotive Series."

The value of gold has been chosen arbitrarily as zero, and the voltages listed opposite other metals are the

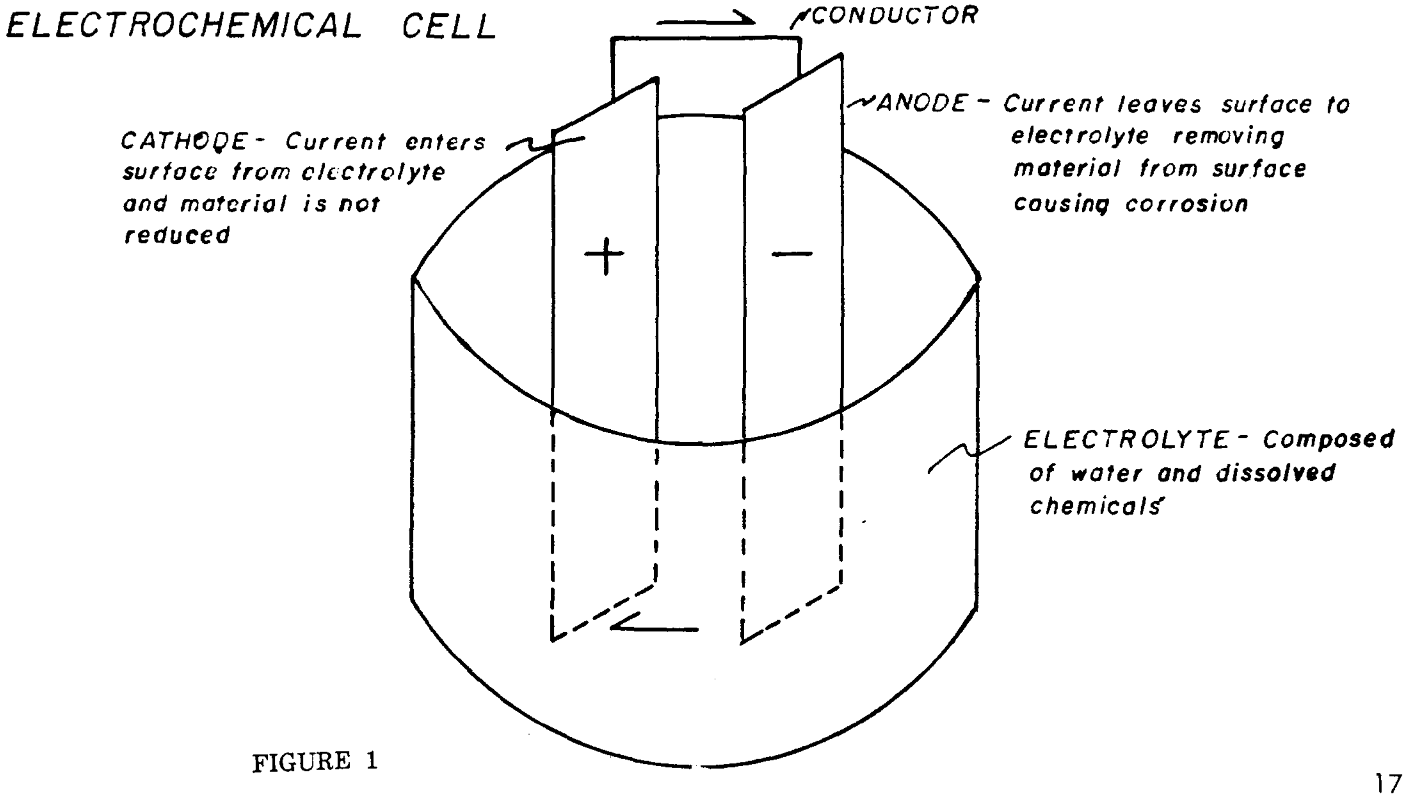

FIGURE 1

CATHODIC PROTECTION RECTIFIER

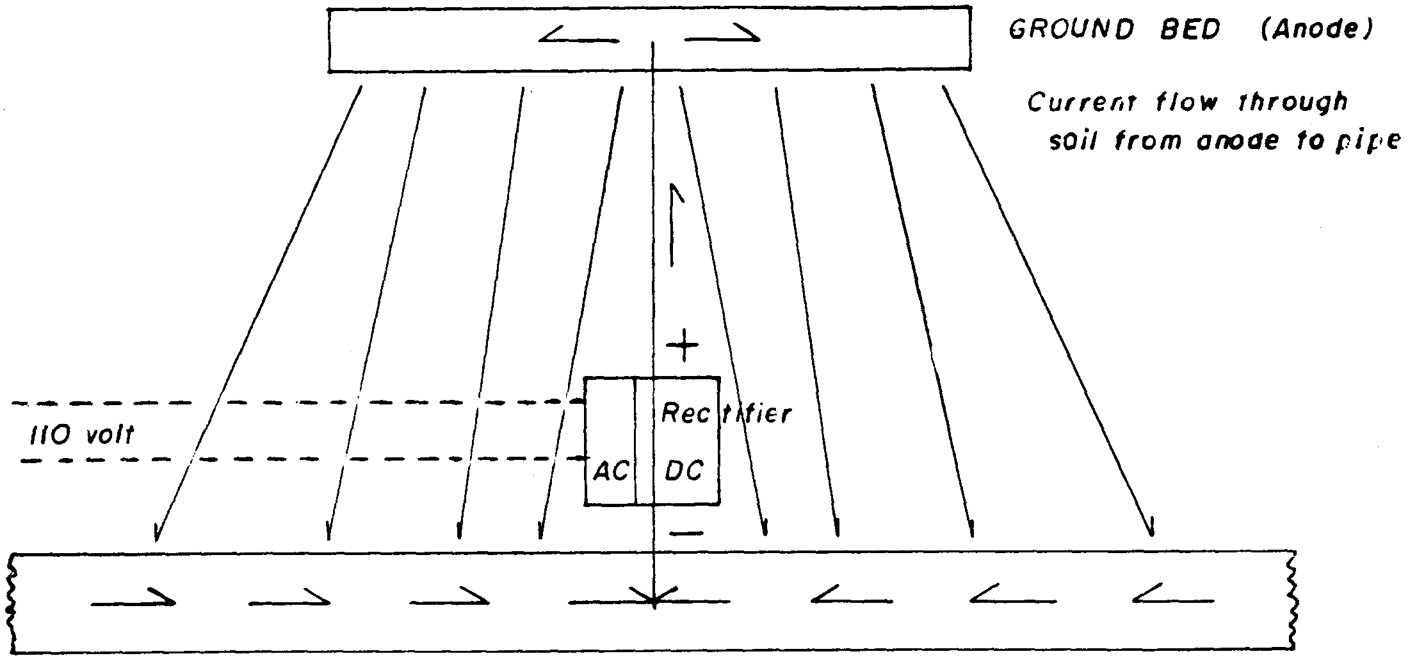

FIGURE 2

potentials which would exist between gold and those baser metals in an electrolytic solution of a salt of the metal. Any metal will oxidize or "corrode" when connected to another metal, above it in this series, when they are immersed in an electrolyte. For example, zinc will corrode if connected to iron and placed in an electrolyte. A potential difference will exist between them equaling 0.32 volts.

"Concentration" cells are similar to galvanic cells except that the anode and cathode consists of the same materials, immersed in a non- homogeneous electrolyte. Differences in the concentration of the dissolved chemicals cause a potential difference, the anode usually occurring in the more concentrated part of the solution. The presence of different dissolved chemicals in different locations in a solution will produce potentials between similar electrodes.

A good example of this type of corrosion is a pipe line buried in a non-homogeneous electrolyte. (figure 6) In this particular case, the pipeline in the anodic clay area is being corroded while the pipe in the cathodic loam area is protected. The current leaves the pipe in the clay area and travels through the soil (electrolyte) entering the pipe again in the loam area. The current then travels through the pipe to the clay area again, and as it leaves, takes particles of iron with it.

Let is now take a detailed look at what is actually happening to a corroding steel pipe. (figure 7) At the anodic, or pit area, the iron atoms turn into positively charged ions which escape into the wet soil. There, the iron ions react with soil water to form a rust precipitate and positively-charged hydrogen ions. Meanwhile, at the cathodic areas, positively-charged hydrogen ions discharge the current into the pipe, and are converted into unchanged hydrogen atoms which

GALVANIC CELL - BATTERY

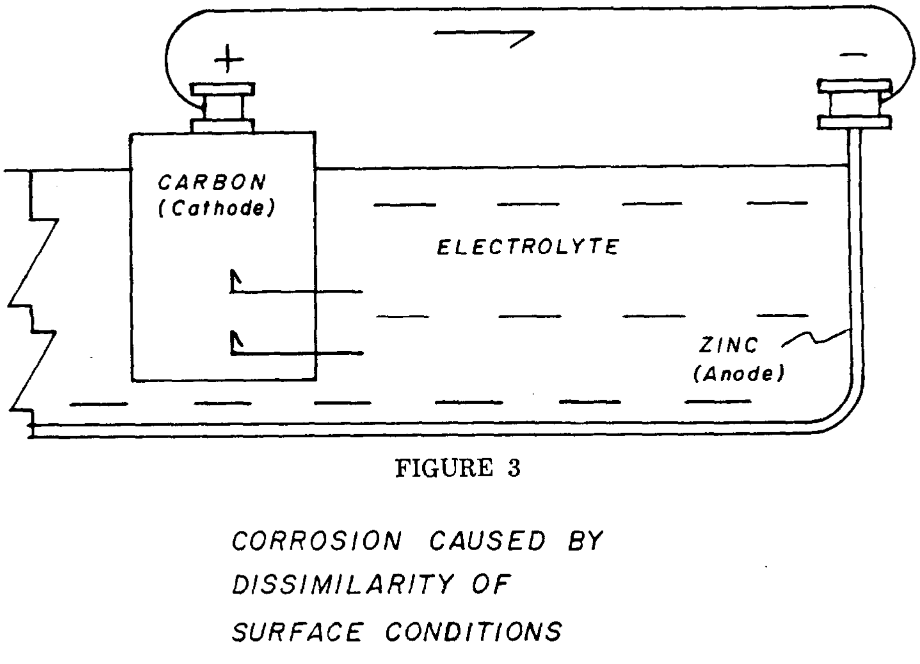

FIGURE 3

CORROSION CAUSED BY DISSIMILARITY OF SURFACE CONDITIONS

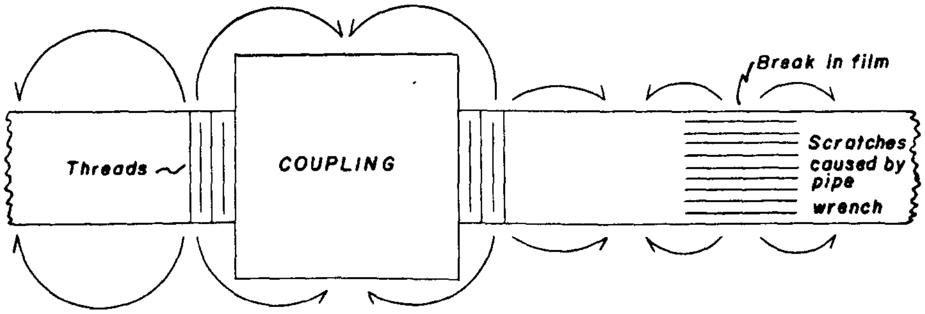

FIGURE 4

form a film on the cathodic surface, protecting it. This is the type of corrosion encountered when the cathode and anode are of the same material in a non-homogeneous electrolyte, and is easily corrected by using a galvanic cell (figure 8). Here magnesium, dissimilar to iron and being lower in the electromotive series, serves as the anode and is sacrificed to give protection to the pipeline. The current will flow from the magnesium anode through the soil (electrolyte) to the pipe, returning from the pipe to the anode by means of the copper wire connection. This type of corrective measure can also be used where the anode and cathode are of dissimilar metals, in a homogeneous electrolyte.

In oil lifting practices, we are primarily interested in the causes of corrosion to the producing oil casing, tubing, rods and pump. This corrosion would fall into two classes: external and internal corrosion.

The external corrosion of oil-well casing has four main causes:

a. Electrolysis—caused by current from surface lines flowing down the casing escaping into the soil at anodic areas.

b. Galvanic action on the casing as it passes through the various formation strata.

c. Action of sulfate-reducing bacteria.

d. Corrosive water.

The first of these can easily be overcome by the use of insulating flanges connecting to all surface lines.

In the other three cases, it is possible to give protection to the casing by use of cathodic protection (figure 9). Here a galvanic cell is set up, using magnesium as the sacrificial metal anode. The anodes are connected to each other, and tied to the well head by an insulated copper wire. This completes the circuit for the current to travel up the casing (cathode), through the copper wire and back to the anode.

Internal corrosion in oil-wells has been a severe problem to the oil industry, and it has been found that this corrosion stems from the following:

a. Electrolysis.

Stray currents picked up from surface lines.

b. Galvanic cells.

These are caused by marred surfaces, differences in the pipe structure, or from dissimilar metals in the pumping equipment.

c. Concentration cells.

These are formed when water, salts, hydrogen-sulfide, carbon dioxide and other organic acids are produced from the formation. The anode here is usually established in the concentrated portion of the electrolyte or it can be established at the point of contact with the chemical that combines most readily with the electrode material. This type of corrosion causes numerous and severe pits to form on the tubing, rods, casing and pump. The electrolysis can be stopped by the use of insulating flanges. Galvanic cells can be prevented by a careful selection to minimize use of dissimilar materials.

Concentration cells, which are believed to be the greatest cause of in-

ELECTROMOTIVE SERIES

USING GOLD AS REFERENCE

METAL	POTENTIAL TO GOLD
Gold	0.00 volts
Platinum	0.50
Lead	0.56
Copper	1.02
Tin	1.49
Nickel	1.59
Cadmium	1.79
Iron	1.80
Chromium	1.91
Zinc	2.12
Manganese	2.46
Aluminum	3.06
Magnesium	3.76

FIGURE 5

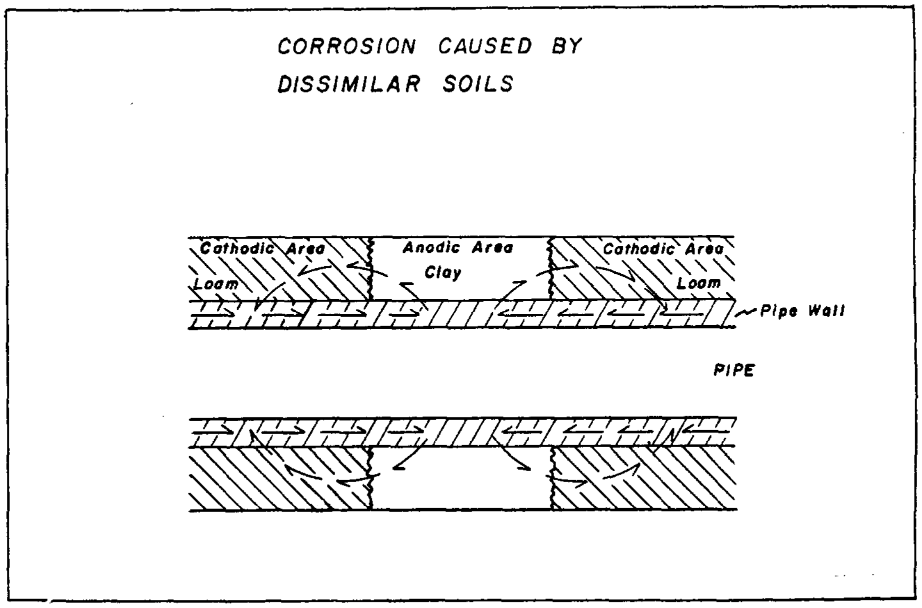

FIGURE 6

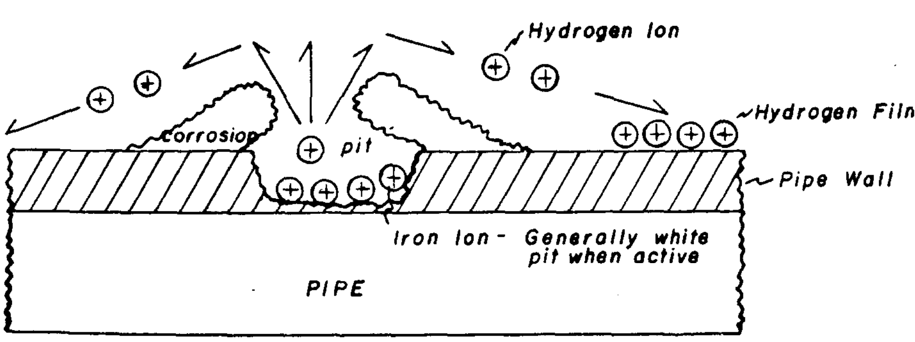

FIGURE 7

ternal corrosion, have been successfully combatted by the use of suitable corrosion inhibitors. These chemicals are injected down the annular space, and form a thin film on the exposed metal parts. They also cause the metal parts to become oil-wet, thus protecting the metal from contact with the corrosive fluids in the well.

In closing, I would again like to call your attention to the three basic causes of corrosion cells (electrolytic, galvanic and concentration), and how easily these can be overcome by diverting their corrosive action by the use of sacrificial anodes or insulating materials.

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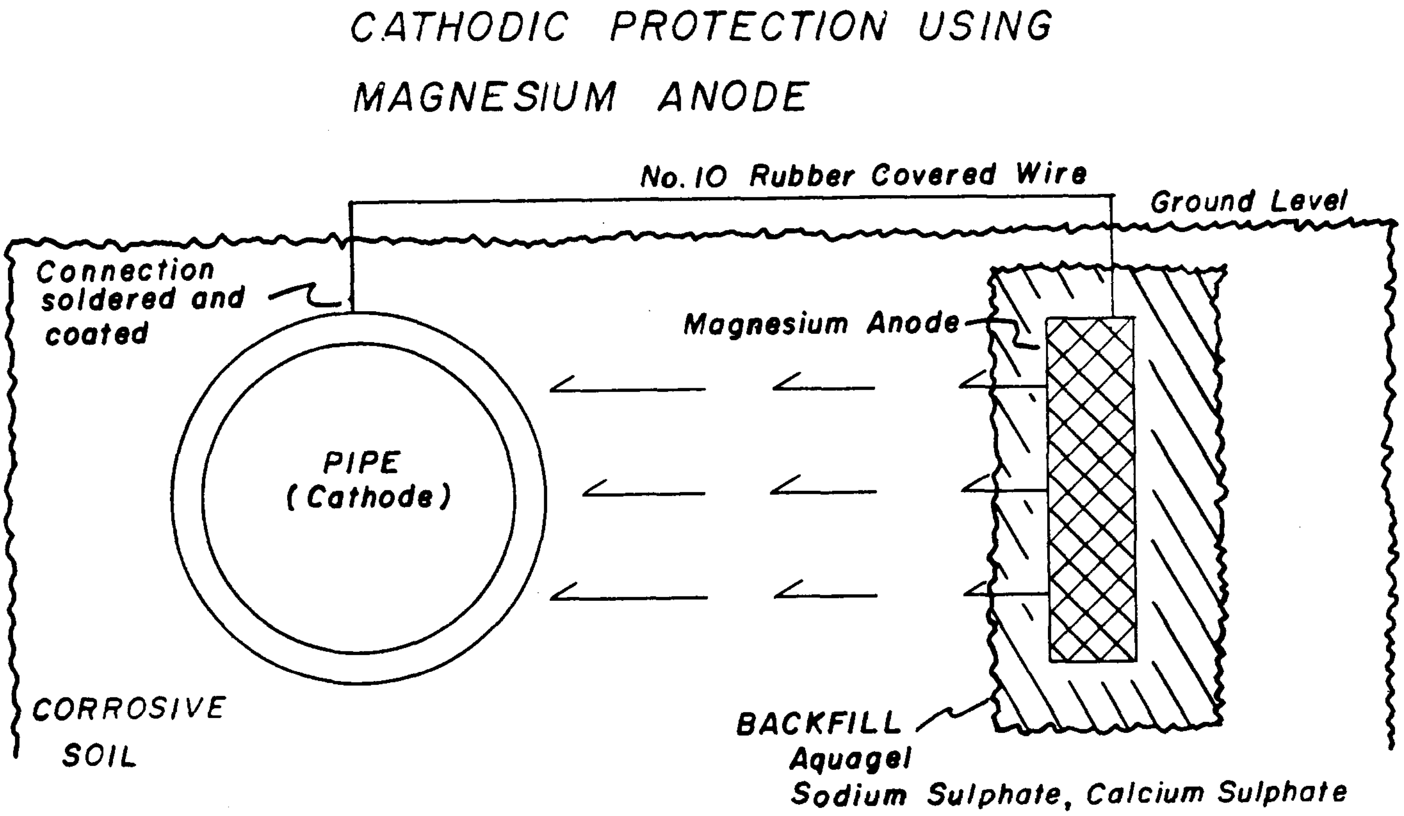

FIGURE 8

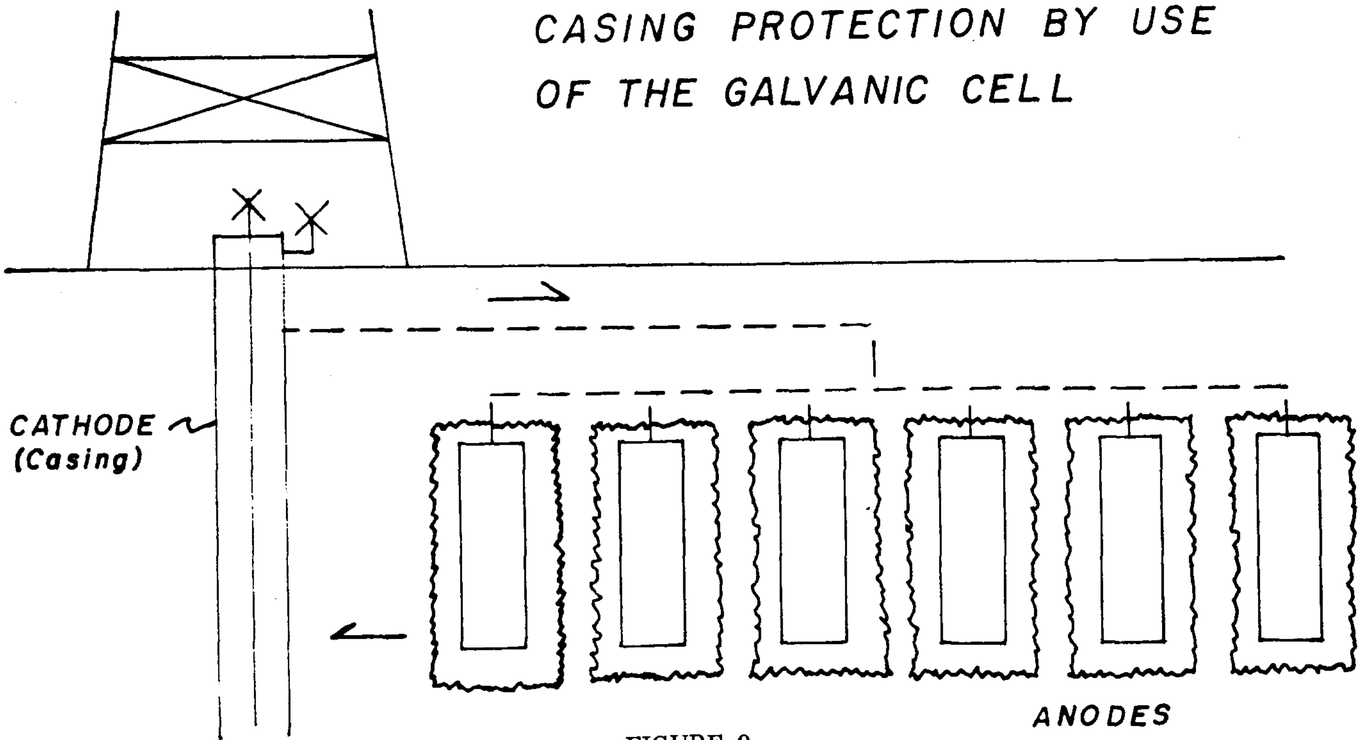

FIGURE 9