

CORROSION PRINCIPLES

CORROSION is the disintegration of metal through an unintentional chemical or electro- chemical action, starting at its surface. It is recognized as one of industry's most difficult problems and the resulting losses each year are in the tens of billions of dollars.

Metals are usually extracted from ores through the application of a considerable amount of energy. Certain environments offer opportunities for these metals to combine chemically with elements to form compounds and return to

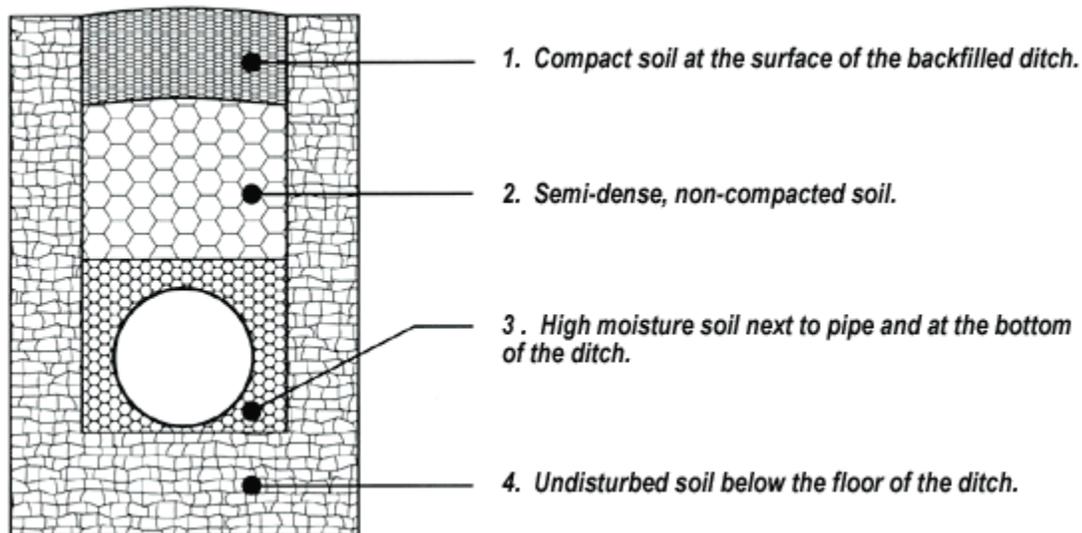
their lower energy levels. In other words, corrosion can be viewed as the tendency of a metal to revert back to its natural and more stable state as an ore.

Corrosion of a buried metal is greatly influenced by the soil in which it is buried. The major soil conditions which affect corrosion and must be considered are type, drainage, resistivity, acidity, and particle size. The ditch backfill environment is a man made disturbance of the natural environment and can adversely affect these soil conditions.

- TYPE** Soil may consist of sand, loam, clay, mulch, or a combination of any or all of these. The most corrosive is mulch; the least, sand.
- DRAINAGE** Soils with the poorest drainage are the most corrosive while well drained soils are the least corrosive. The exception to this is a soil which contains cinders. Cinder fills are well drained but any moisture present makes it a very corrosive environment.
- RESISTIVITY** Low resistivity soils are corrosive and high resistivity soils are the least corrosive, as a rule. However, acidity and oxygen concentration can alter this.
- ACIDITY (PH)** A neutral soil (PH-7.0) is least corrosive. A soil with a PH of 3.0 would be very acidic and corrosive. Alkaline soils (PH above 7.0) contain dissolved salts which can accelerate corrosion. This is especially true in desert soils.
- PARTICLE SIZE** Large soil particles can allow oxygen to penetrate to the buried metal product. If an area with an abundance of oxygen is next to an area of a limited supply of oxygen, a differential aeration corrosion cell is created.

BACKFILL

A backfilled ditch contains four different soil conditions:



The original texture and drainage of a soil can be adversely affected in a backfilled ditch.

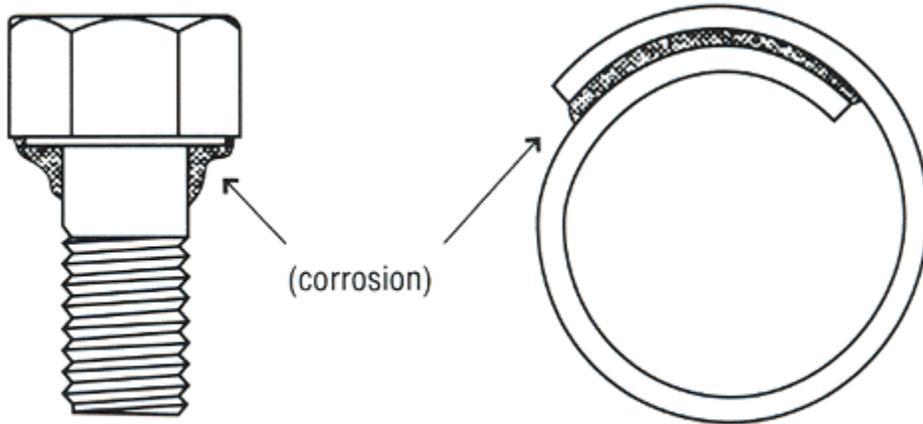
The use of the original soil as backfill can allow organic material from the top to be scattered throughout the ditch contributing to the growth of bacteria.

Cinders, originally from the soil near the top of the ditch, can be buried next to the pipe in the moisture zone in the bottom of the ditch and aid the growth of bacteria.

The semi-dense area above the pipe will allow rapid moisture percolation to the pipe depth and also allow better gas diffusion with the possible establishment of differential aeration cells.

DIFFERENTIAL AERATION AND STAINLESS STEEL

Of the many different types of corrosion, the most common to underground piping systems is concentration cell corrosion. Also called "differential aeration corrosion" and "crevice corrosion", it defines corrosion which has the tendency to build up more rapidly in cracks and crevices or between overlapping layers.



Areas of crevice corrosion caused by differential aeration.

This occurs when one part of a metal is exposed to a different air or oxygen concentration than the other parts.

This causes a difference in potential between differently aerated areas. Areas on a metal surface where the oxygen concentration is low are anodic and corrosion prone.

Stainless steel is susceptible to crevice corrosion depending upon the shape into which it is fabricated and to the degree of crevices or inside corners formed during its fabrication.

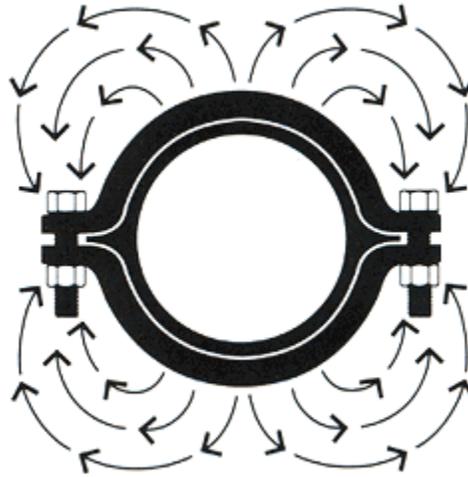
Even though stainless steel is resistant to corrosion due to an oxide coating, any disturbance or damage to this coating exposes the metal underneath.

This exposed area is then vulnerable to corrosive attack. The fabrication process can damage this oxide coating.

MG COUPLING DESIGN

The MG COUPLING was engineered and designed to combat the forces of concentration cell or differential aeration corrosion. Its unique cast iron/stainless steel construction provides a galvanic cell which reverses the current flow and provides full cathodic protection to the bolts and nuts which hold the joint together.

The stainless steel bolts and nuts combined with the cast iron coupling creates a galvanic cell.



When two dissimilar metals are in electrical contact with each other and are exposed to a common electrolyte, a cell is formed in which galvanic corrosion occurs at the anode while the cathode metal is protected from attack.

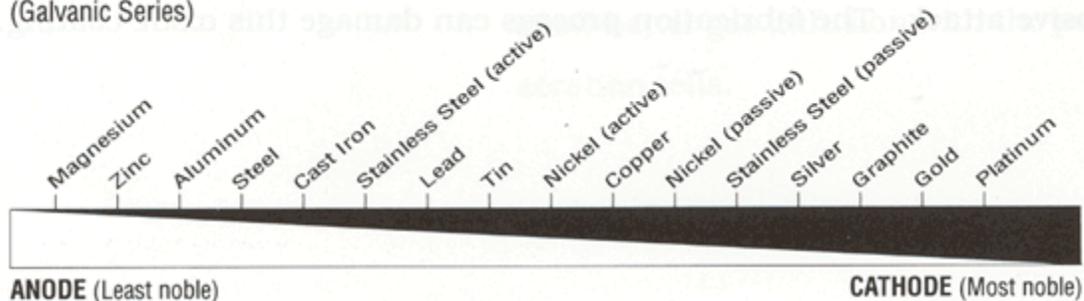
The MG COUPLING forms such a cell in an environment containing a common electrolyte. Tests indicate (see [page 8](#)) that, under such conditions, the stainless steel bolt units are receiving a full level of cathodic protection from the couple with the cast iron clamping members (coupling body).

Since the stainless steel bolting units are lower in the galvanic series, they are cathodic to the cast iron coupling clamping halves which inevitably become anodic and protect the stainless steel bolting units.

Because the cast iron clamping member body and the stainless steel bolting units are relatively close in the galvanic series and more significantly because the cast iron clamping body is decisively large compared to the small cathodic area of the stainless steel bolting members, the current will be small causing no substantial change or damage to the anodic clamping member.

ELECTROMOTIVE SERIES

(Galvanic Series)



The Galvanic Series chart illustrates the position of cast iron to stainless steel. Together they change into a bi-metallic cell providing full cathodic protection.

Testing and Corrosion Study by Harco Corporation Huntington Beach, CA

I. INTRODUCTION

The testing and corrosive study of the MG Coupling was performed in July, August, and September of 1976. The primary purpose of the testing and corrosive study was to determine the effectiveness of the bi-metallic galvanic cell between the stainless nuts and bolts and the cast-iron coupling body.

A. Dissimilar metal/Bi-Metallic Cells:

The simplest cell to visualize is a bi-metallic cell. Such a cell can be established whenever different metals are used as long as there is electrical contact between them provided they are in a common electrolyte (soil or water). Under such conditions, any two dissimilar metals may be expected to have an electrical potential between them. The determining factor of which metal becomes anodic or cathodic depends on its relative position in the electromotive series.

II. TEST PROCEDURES:

A. Test Set Up:

The MG Couplings were tested in a corrosive environment by means of submerging couplings in both fresh and synthetic seawater.

The couplings were disassembled and copper wires were attached to the coupling halves by means of thermite welding and also to the stainless steel bolts units by means of brazing. The coupling halves and bolts units were then placed into their respective bins of fresh and synthetic seawater. Complete coupling units were also put under test in the synthetic seawater bin and in the fresh water bin.

B. Structure-to-Water Potentials:

Each metal has its own potential in the electromotive series. Stainless, which is lower on the series, and cast-iron which is higher create a bi-metallic cell when placed in a common electrolyte. Thus, when they are placed in different resistivity electrolytes, the different effect will be varying potentials.

Structure-to-water potentials were taken and recorded on the stainless steel nuts and bolts. All potentials were obtained using the Miller Multi-Combination Meter Model M3M-A and a copper-copper sulfate half cell as a reference electrode.

C. Current Output:

There are certain conditions which must be met before a galvanic cell function. These are:

1. An anode and a cathode are required.
2. There must be electrical continuity between the anode and the cathode.
3. An electrical potential difference between the anode and cathode is required.
4. The anode and the cathode must be in a common electrolyte. Once these conditions are met, an electrical current will flow from the anode to the cathode in the electrolyte and thus be measured. Output current of the anodic cast-iron coupling to the cathodic stainless steel nuts and bolt units were obtained at each test coupling set-up by measuring the current output through the ammeter circuit of the M3M-a Multi-Combination Meter.

D. Test Start-Up:

Native potentials were obtained on all stainless steel units. The native potentials ranged from a low of -260mv to a high of -300mv. The purpose of taking the native potentials was to be able to determine the effectiveness of the bi-metallic cell (change in potential) duplicated after the wires of the bolt units and cast-iron coupling halves were connected together. After native potentials were measured and current outputs were taken, the copper wires to the coupling halves and stainless steel bolt units were connected together by means of split bolt connections. Structure-to-water potentials were taken on the stainless steel/cast-iron combination.

III. ANALYSIS AND CONCLUSION:

- A** **Criteria for Cathodic Protection:**
A change of potential in the negative direction of -300mv or more is one criteria for full cathodic protection.
- B** **Structure-to-Water Potentials:**
The structure-to-water potentials after the coupling halves and the bolt units were connected range from a low of -720mv to a high of -810mv. This indicates that a high level of cathodic protection has been achieved on the stainless steel bolt units. The average potential shift of change in the negative direction of stainless steel bolt units was 494mv. This indicates that the stainless steel bolt units are receiving a full level of cathodic protection from the couple with the cast-iron coupling.
- C** **Inspection of Test Samples:**
All test samples were inspected after testing and found to have no visible corrosion attack of the stainless steel bolt units. Through testing and inspection, it has been determine that the MG Coupling, consisting of a cast-iron body and stainless steel bolts, acts as a galvanic corrosion cell. The stainless steel bolt units, being lower in electromotive series, are cathodic to the cast-iron coupling halves making the coupling the anode.
his type cathodic protection is considered sacrificial. The anode (in this case the cast-iron coupling body) protects the stainless steel bolt units. The cast-iron coupling body is acting like the anode in the sacrificial system.
- D** **Conclusion:**
It is concluded that due to the relative size differential and potential difference between the coupling and stainless steel bolt units, that the bolt units will be cathodically protected and the resultant corrosion rate on the coupling should be minimal. It is anticipated that the MG Coupling will have a life expectancy as great or greater than that of a pipe to which it is attached in the small soil environment.

The chart below shows the results of the Harco tests. Below the chart is a graphic illustration of the same test data.

# Structure	Native Potential (mv)	Connected Potential					I(Output) (ma)	Bin#
		7/26	8/02	8/16	8/23	9/28		
1. S/S Bolt to 4" P.C.C.*	-260	-750	-760	-740	-750	-790	.82	1
2. S/S Bolt to 4" B.C.**	-260	-800	-810	-810	-780	-760	.60	1
3. S/S Bolt to 2" P.C.C.*	-300	-750	-720	-750	-750	-790	.82	1
4. S/S Bolt to 2" B.C.**	-290	-750	-760	-780	-780	-760	.70	1
5. S/S Bolt to 4" P.C.C.*	-270	-740	-750	-740	-730	-810	.49	2
6. S/S Bolt to 4" B.C.**	-270	-780	-800	-780	-780	-760	.55	2
7. S/S Bolt to 2" P.C.C.*	-260	-760	-760	-770	-750	-800	.46	2
8. S/S Bolt to 4" B.C.**	-300	-740	-790	-800	-800	-765	.49	2

*Pitch coated coupling halves Bin #1 - Synthetic Seawater (23 Ohm-cm)

**Bare coupling no coating Bin #2 - Fresh Water (1500 Ohm-cm)

