

MODULE 06

FOR B2 CERTIFICATION

MATERIALS AND HARDWARE

Aviation Maintenance Technician Certification Series



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WELCOME

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REVISION LOG

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6.4(B) - TYPES OF CORROSION AND THEIR IDENTIFICATION

Alloy	Type of attack to which alloy is susceptible	Appearance of corrosion product
Magnesium	Highly susceptible to pitting	White, powdery, snow-like mounds and white spots on surface
Low alloy steel (4,000–8,000 series)	Surface oxidation and pitting, surface, and intergranular	Reddish–brown oxide (rust)
Aluminum	Surface pitting, intergranular, exfoliation stress–corrosion and fatigue cracking, and fretting	White–to–grey powder
Titanium	Highly corrosion resistant; extended or repeated contact with chlorinated solvents may result in degradation of the metal's structural properties at high temperature	No visible corrosion products at low temperature. Colored surface oxides develop above 700 °F (370 °C)
Cadmium	Uniform surface corrosion; used as sacrificial plating to protect steel	From white powdery deposit to brown or black mottling of the surface
Stainless steels (300–400 series)	Crevice corrosion; some pitting in marine environments; corrosion cracking; intergranular corrosion (300 series); surface corrosion (400 series)	Rough surface; sometimes a uniform red, brown, stain
Nickel–base (Inconel, Monel)	Generally has good corrosion resistant qualities; susceptible to pitting in sea water	Green powdery deposit
Copper–base Brass, Bronze	Surface and intergranular corrosion	Blue or blue–green powdery deposit
Chromium (Plate)	Pitting (promotes rusting of steel where pits occur in plating)	No visible corrosion products; blistering of plating due to rusting and lifting
Silver	Will tarnish in the presence of sulfur	Brown–to–black film
Gold	Highly corrosion resistant	Deposits cause darkening of reflective surfaces
Tin	Subject to whisker growth	Whisker–like deposit

Figure 4-4. Corrosion of metals.

All corrosive attacks begin on the surface of the metal making the classification of corrosion by physical appearance a convenient means of identification. (*Figure 4-4*)

GENERAL SURFACE CORROSION

General surface corrosion (also referred to as Uniform Etch or Uniform Attack Corrosion) is the most common form of corrosion and results from a direct chemical attack on a metal surface and involves only the metal surface. (*Figure 4-5*)

General surface corrosion usually occurs over a wide area and is more or less equal in dispersion. On a polished surface, this type of corrosion is first seen as a general dulling of the surface, and if allowed to continue, the surface becomes rough and possibly frosted in appearance. The discoloration or general dulling of metal created by exposure to elevated temperatures is not to be considered general surface corrosion.

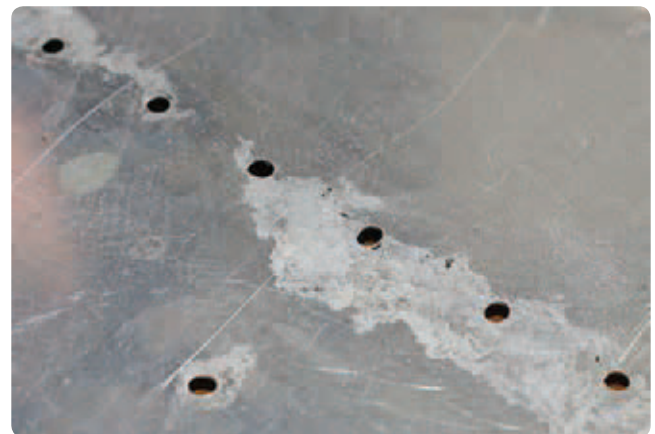


Figure 4-5. Surface corrosion.

Sometimes corrosion spreads under the surface coating and can not be recognized by either the roughening of the surface or a frosted appearance. Instead closer inspection reveals the paint or plating is lifted off the surface in small blisters that result from the pressure of the underlying accumulation of corrosion products.

PITTING CORROSION

Pitting corrosion is one of the most destructive and intense forms of corrosion. It can occur in any metal but is most common on metals that form protective oxide films, such as aluminum and magnesium alloys. It is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is cleaned away, tiny holes or pits can be seen in the surface. (*Figures 4-6*)

These small surface openings may penetrate deeply into structural members and cause damage completely out of proportion to its surface appearance.

CONCENTRATION CELL CORROSION

Concentration cell corrosion, (also known as crevice corrosion) is corrosion of metals in a metal to metal joint, corrosion at the edge of a joint even though the joined metals are identical, or corrosion of a spot on the metal surface covered by a foreign material. Metal ion concentration cells, oxygen concentration cells, and active passive cells are three general types of concentration cell corrosion.

Metal Ion Concentration Cells

The solution may consist of water and ions of the metal which is in contact with water. A high concentration of the metal ions will normally exist under faying surfaces where the solution is stagnant, and a low concentration of metal ions will exist adjacent to the crevice which is created by the faying surface. An electrical potential will exist between the two points. The area of the metal in contact with the low concentration of metal ions will be anodic and corrode, and the area in contact with the high metal ion concentration will be cathodic and not show signs of corrosion. (*Figure 4-7*)

Oxygen Concentration Cells

The solution in contact with the metal surface will normally contain dissolved oxygen. An oxygen cell can develop at any point where the oxygen in the air is not allowed to diffuse into the solution, thereby creating a difference in oxygen concentration between two points. Typical locations of oxygen concentration cells are under gaskets, wood, rubber, and other materials in contact with the metal surface. Corrosion will occur at the area of low oxygen concentration (anode). Alloys such as stainless steel are particularly susceptible to this type of crevice corrosion. (*Figure 4-8*)

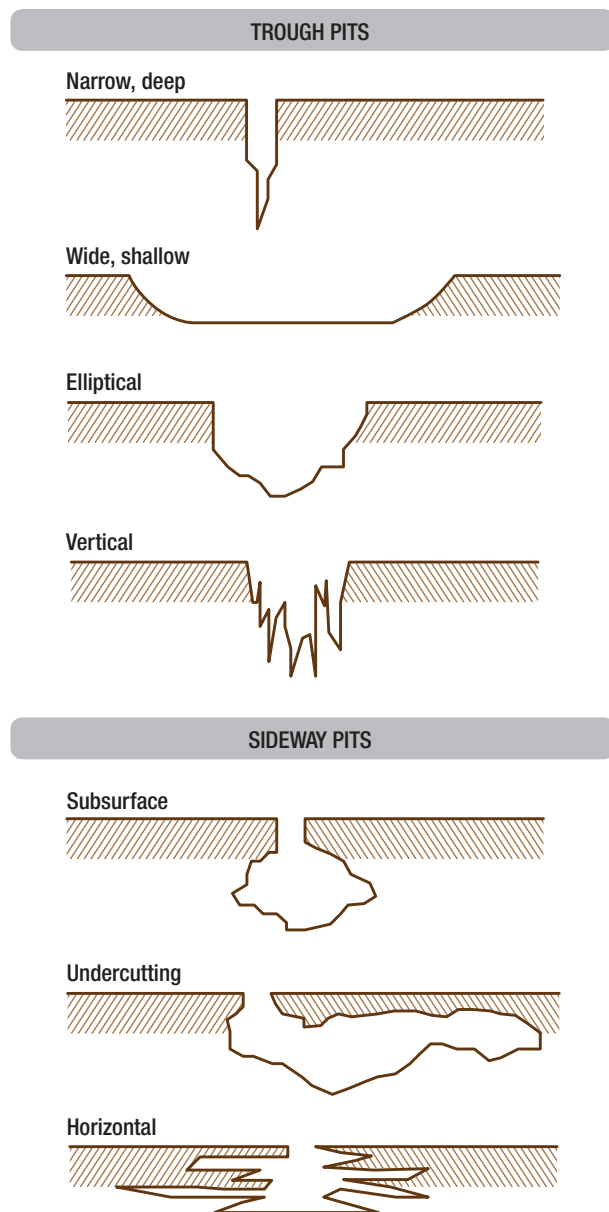
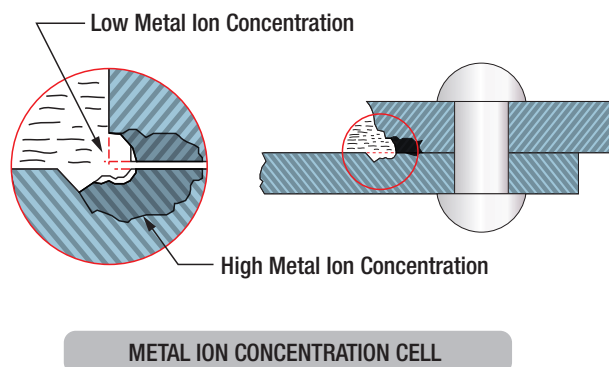


Figure 4-6. Types of pitting corrosion.



METAL ION CONCENTRATION CELL

Figure 4-7. Metal ion concentration cell.

Active Passive Cells

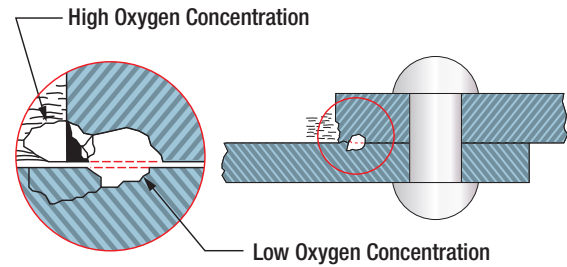
Metals which depend on a tightly adhering passive film, usually an oxide, for corrosion protection are prone to rapid corrosive attack by active passive cells. Active passive cells are often referred to as a type of concentration cell corrosion. However, the active passive cell is actually two forms of corrosion working in conjunction. The corrosive action usually starts as an oxygen concentration cell. As an example, salt deposits on the metal surface in the presence of water containing oxygen can create the oxygen cell. The passive film will be broken beneath the salt crystals. Once the passive film is broken, the active metal beneath the film will be exposed to corrosive attack. (*Figure 4-9*)

Rapid pitting of the active metal will result. This reaction can become locally intense due to several factors. First the reaction is augmented by the affected area, since the proportion of the exposed base metal is small compared to the surrounding nonreactive metal. This effectively concentrates the focal point of the reaction, often resulting in deep pits in a short time and a greater rate of corrosion.

FILIFORM CORROSION

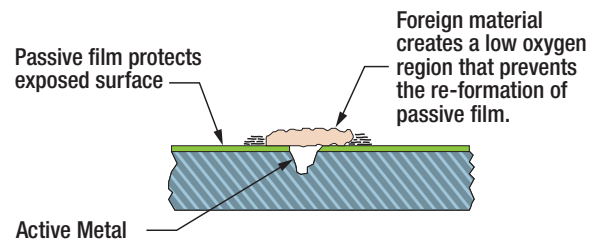
Filiform corrosion is a special form of oxygen concentration cell which occurs on metal surfaces having an organic coating system. It is recognized by its characteristic worm like trace of corrosion products beneath the paint film. (*Figure 4-10*)

Polyurethane finishes are especially susceptible to filiform corrosion. Filiform occurs when the relative humidity of the air is between 78 to 90 percent and the surface is slightly acidic. (*Figure 4-11*) This corrosion usually attacks steel and aluminum surfaces. The traces never cross on steel, but they will on aluminum which makes the damage deeper and more severe for aluminum. If the corrosion is not removed, the area treated, and a protective finish applied; the corrosion can lead to intergranular corrosion, especially around fasteners and seams. Filiform corrosion can be removed using glass bead blasting material with abrasive blasting equipment or sanding. Filiform can be prevented by storing aircraft in an environment with a relative humidity below 70 percent, using coating systems having a low rate of diffusion for oxygen and water vapors, and by washing the aircraft to remove acidic contaminants from the surface.



OXYGEN CONCENTRATION CELL

Figure 4-8. Oxygen concentration cell.



ACTIVE – PASSIVE CELL

Figure 4-9. Active-passive cell.



Figure 4-10. Filiform corrosion.

INTERGRANULAR CORROSION

Intergranular corrosion is an attack on the grain boundaries of a metal. A highly magnified cross section of any commercial alloy shows the granular structure of the metal. It consists of quantities of individual grains, and each of these tiny grains has a clearly defined boundary which chemically differs from the metal within the grain. The grain boundary and the grain center can react with each other as anode and cathode when in contact with an electrolyte. (*Figure 4-12*)

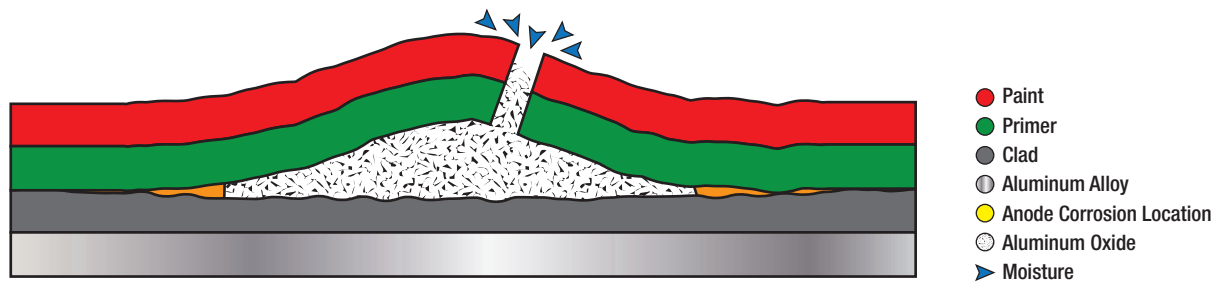


Figure 4-11. Filiform corrosion.

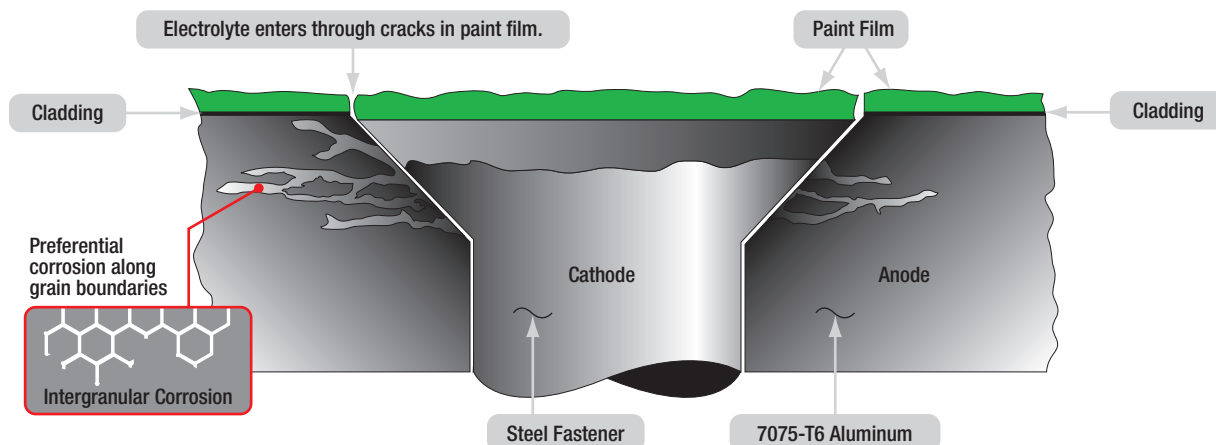


Figure 4-12. Intergranular corrosion of 7075-T6 aluminum adjacent to steel fastener.

Rapid selective corrosion of the grain boundaries can occur. High strength aluminum alloys such as 2014 and 7075 are more susceptible to intergranular corrosion if they have been improperly heat treated and then exposed to a corrosive environment. (*Figure 4-13*)

EXFOLIATION CORROSION

Exfoliation corrosion is an advanced form of intergranular corrosion and shows itself by lifting up the surface grains of a metal by the force of expanding corrosion products occurring at the grain boundaries just

below the surface. (*Figure 4-14*) It is visible evidence of intergranular corrosion and is most often seen on extruded sections where grain thickness are usually less than in rolled forms.

This type of corrosion is difficult to detect in its initial state. Extruded components such as spars can be subject to this type of corrosion. Ultrasonic and eddy current inspection methods are being used to detect early signs of exfoliation with a great deal of success.

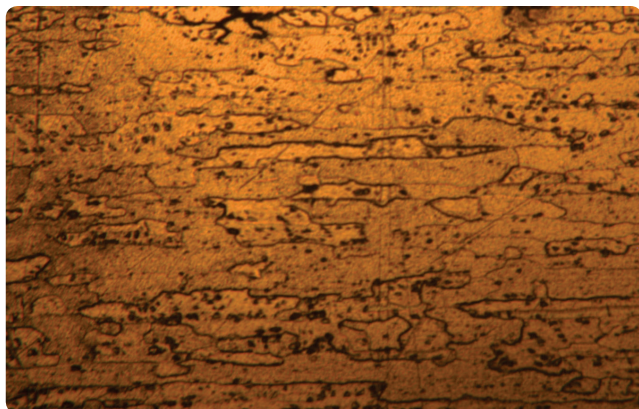


Figure 4-13. Intergranular corrosion present on 6061-T6 aluminum.



Figure 4-14. Exfoliation corrosion.

GALVANIC CORROSION

Galvanic corrosion occurs when two dissimilar metals make contact in the presence of an electrolyte. (*Figure 4-15*) The rate which corrosion occurs depends on the difference in activities. The greater the difference in activity, the faster the corrosion occurs. The rate of galvanic corrosion also depends on the size of the parts in contact. If the surface area of the corroding metal is smaller than the surface area of the less active metal, corrosion is rapid and severe. When the corroding metal is larger than the less active metal, corrosion is slow and superficial.

STRESS CORROSION CRACKING

This form of corrosion involves a constant or cyclic stress acting in conjunction with a damaging chemical environment. The stress may be caused by internal or external loading. (*Figure 4-16*)

Internal stress may be trapped in a part of structure during manufacturing processes, such as cold working or by unequal cooling from high temperatures. Most manufacturers follow these processes with a stress relief operation. Even so, sometimes stress remains trapped. The stress may be externally introduced in part structure by riveting, welding, bolting, clamping, press fit, etc. If a slight mismatch occurs or a fastener is over torqued, internal stress is present. Internal stress is more important than design stress, because stress corrosion is difficult to recognize before it has overcome the design safety factor. The level of stress varies from point to point within the metal. Stresses near the yield strength are generally necessary to promote stress corrosion cracking. However, failures may occur at lower stresses.



Figure 4-15. Galvanic corrosion.

Specific environments have been identified that cause stress corrosion cracking of certain alloys.

1. Salt solutions and sea water cause stress corrosion cracking of high strength, heat treated steel and aluminum alloys.
2. Methyl alcohol hydrochloric acid solutions cause stress corrosion cracking of some titanium alloys.
3. Magnesium alloys may stress corrode in moist air.

Stress corrosion may be reduced by applying protective coatings, stress relief heat treatments, using corrosion inhibitors, or controlling the environment. Shot peening a metal surface increases resistance to stress corrosion cracking by creating compressive stresses on the surface which should be overcome by applied tensile stress before the surface sees any tension load. Therefore, the threshold stress level is increased.

FATIGUE CORROSION

Fatigue corrosion involves cyclic stress and a corrosive environment. Metals may withstand cyclic stress for an infinite number of cycles so long as the stress is below the endurance limit of the metal. Once the limit has

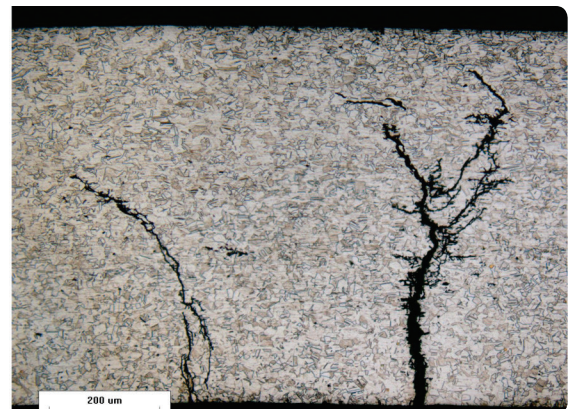


Figure 4-16. Stress corrosion cracking.

been exceeded, the metal will eventually crack and fail from metal fatigue. However, when the part or structure undergoing cyclic stress is also exposed to a corrosive environment, the stress level for failure may be reduced many times. Thus, failure occurs at stress levels that can be dangerously low depending on the number of cycles assigned to the life limited part.

Fatigue corrosion failure occurs in two stages. During the first stage the combined action of corrosion and cyclic stress damages the metal by pitting and crack formations to such a degree that fracture by cyclic stress will occur, even if the corrosive environment is completely removed.

The second stage is essentially a fatigue stage in which failure proceeds by propagation of the crack (often from a corrosion pit or pits). It is controlled primarily by stress concentration effects and the physical properties of the metal. Fracture of a metal part due to fatigue corrosion, generally occurs at a stress level far below the fatigue limit of an uncorroded part, even though the amount of corrosion is relatively small.

FRETTING CORROSION

Fretting corrosion is a particularly damaging form of corrosive attack that occurs when two mating surfaces normally at rest with respect to one another are subject to slight relative motion. It is characterized by pitting of the surfaces and the generation of considerable quantities of finely divided debris. Since the restricted movements of the two surfaces prevent the debris from easily escaping, an extremely localized abrasion occurs. (*Figure 4-17*)



Figure 4-17. Fretting corrosion.

The presence of water vapor greatly increases this type of deterioration. If the contact areas are small and sharp, deep grooves resembling brinell markings or pressure indentations may be worn into the rubbing surface. As a result, this type of corrosion on bearing surfaces has also been called false brinelling.

The most common example of fretting corrosion is the smoking rivet found on engine cowlings and wing skins. This is one corrosion reaction that is not driven by an electrolyte, and in fact moisture may inhibit the reaction. A smoking rivet is identified by a black ring around the rivet.

CAUSES OF CORROSION

The degree of severity, the cause, and the type of corrosion depend on many factors, including the size or thickness of the part, the material, heat treatment of the material, protective finishes, environmental conditions, preventative measures, and design.

Thick structural sections are generally more susceptible to corrosive attack because of variations in their composition, particularly if the sections are heat treated during fabrication. When large sections are machined or chem-milled after heat treatment, the corrosion characteristics of thinner sections may be different from those of thicker areas. Section size is based on structural requirements and cannot be changed for the purpose of controlling corrosion. From a maintenance standpoint, the correct approach is one of recognizing the need to ensure the integrity and strength of major structural parts and maintaining permanent protection over such areas at all times.

In service stresses and field repairs may affect the rates and types of corrosion. Aircraft structure under high cyclic stresses, such as helicopter main rotors, are particularly subject to stress corrosion cracking. Also areas adjacent to weld repaired items often have corrosion due to insufficient removal of the weld flux, or, for some steels, buildup of a magnetic field. Areas such as these should be closely inspected for signs of corrosion and, when found, proper treatment

Since corrosion is the deterioration of metals resulting from reaction between metals and their environment, some corrosion control or means to minimize corrosion when the aircraft enters operational service should be

introduced during the design phase. The corrosion issues discussed in this sub-module provide information to reduce the rate of corrosive attack by corrosion control measures introduced early in design.

The nature of the material is a fundamental factor in corrosion. High strength, heat treatable aluminum and magnesium alloys are very susceptible to corrosion, while titanium and some stainless steel alloys are less susceptible in atmospheric environment. The aircraft manufacturer selects material for the aircraft based on material strength, weight, and cost, while corrosion resistance is often a secondary consideration. However, corrosion control should be considered as early as possible during the preliminary design phase.

The use of more corrosion resistant materials in any design normally involves additional weight to achieve required strength. Since weight consideration is a major factor in the construction of airframes, the primary means of preventing corrosion is by use of protective coatings and proper maintenance procedures.

The use of corrosion resistant alloys is not a cure all for corrosion prevention. A common mistake is to replace a corroded part with a corrosion resistant alloy only to find that the corrosion has now shifted to another part and increased in severity.

The problem of protection against corrosion is minimized if the material to be protected is intrinsically resistant to corrosion. Aluminum copper alloys are known to have better stress corrosion resistance and better fatigue strength properties than aluminum zinc alloys; therefore, they are often used as the primary structural materials.

Galvanic corrosion is created by dissimilar metals being in contact with each other. The galvanic series of metals and alloys (*Figure 4-18*) is a factor that should be considered in the repair of aircraft. The further apart the metals listed in *Figure 4-18* are, the greater the tendency will be for galvanic corrosion. The metals grouped together in *Figure 4-19* have little differences in electrical potential; thus they are relatively safe to use in contact with one another. However, the coupling of metals from different groups will result in corrosion of the group having a lower number.

ELECTRODE POTENTIAL OF VARIOUS METALS AND ALLOYS	
METAL / ALLOY	POTENTIAL (VOLTS) 0.1 CALOMEL SCALE
Magnesium	-1.73
Zinc	-1.10
7072, Alclad 3003, Alclad 6061, Alclad 7075	-0.96
5056, 7079-T6, 5456, 5083, 214, 218	-0.87
5052, 5652, 5086, 1099	-0.85
3004, B214, 1185, 1060, 1260, 5050	-0.84
1100, 3003, 615, 6053, 6061-T6, 6062-T6, 6063, 6363, Alclad 2014, Alclad 2024	-0.83
Cadmium	-0.82
7075-T6, 356, 360	-0.81
2024-T81, 6061-T4, 6062-T4	-0.80
355-T6	-0.79
2014-T6, 113, 750-T5	-0.78
2014-T4, 2017-T4, 2024-T3, 2024-T4	-0.68 to -0.70
Mild steel	-0.58
Lead	-0.55
Tin	-0.49
Copper	-0.20
Bismuth	-0.18
Stainless Steel (series 300, type 430)	-0.09
Silver	-0.08
Nickel	-0.07
Chromium	-0.49 to +0.018

Figure 4-18. Galvanic series of metals and alloys.