AIRFRAME & POWERPLANT MECHANICS

GENERAL HANDBOOK

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REVISION LOG

1-6	Replaced existing image with standard fire triangle for clarity.
1-6	Added and clarified Class D fires as a standard classification.
1-17	Stated that a fast EGT rise is an indicator of a hot start.
1-18	Modified drawing for improved clarity.
1-26	Added Jet-A to fuel color chart and specified that grade 100/130 is green.
2-5	DMEs, DMRs, etc., are decribed in part 183, not 21.
2-14	Included DAMIs under representative types.
3-4	Added missing dimension lines to Figure 3-2.
3-8	Specified that gear speed is measured in rpm.
3-10	Figure 3-7; Labeled pinion driving gear and spur driven gear.
3-21	Corrected erroneous formula for circumference.
4-17	Added word "Schematics" as alternative term to "Wiring Diagrams"
4-21	Figure 4-24. 5th line corrected to Break (short) type line.
4-25	Inserted wiring diagram from computer testing supplement with explanation as an example of a nomogram.
5-8	A screw is not a "simple machine". It is an application of an inclined plane.
5-12	Figure 5-13; Arrows and labels added to show gear direction.
5-13	Rewrote incorrect paragraph regarding chisels.
5-14	"Something" called stress clarified to "forces" called stress; plus other grammar corrections.
5-17	Corrected erroneous equation in left column.
5-19	Clarified the sun is a source of radiant energy; not a form of energy in itself.
5-21	Most forced air engine cooling comes from the forward movement of the aircraft; not the propeller.
5-23	Numerous typos corrected.
5-30	Corrected erroneous output value in Figure 5-45.
5-32	Fixed erroneous value for speed of sound.
5-36	The effect of humidity, (not just fog), on engine performance is noticeable.
5-46	Figure 5-72; The rear moveable surface on the rudder is called an anti-servo tab, not an anti-balance tab.
6-21	Figure 6-34; Corrected erroneous arm values to conform with text and math.
7-5	Firewalls added as a common application for stainless steel.
7-35	Paragraph added explaining manufacturer's shelf life of packed seals.
7-41	A Jo-Bolt is a blind fastener, not a rivet.
7-42	Specified that hardware substitutions are allowed only with manufacturer's approval.
7-44	Removed rocker box covers as an example for the use of self locking nuts.
7-45/46	"Fiber" locknut inserts are obsolete and have been replaced with "Nylon" inserts. (14 instances)
7-46	Spring nuts are commonly called Tinnerman nuts.
7-46	Elastic stop nuts have limited time use and some shops require discarding after each use.
7-51	Explanation added on drag torque.
7-52	Added that washers may be placed on the nut end of a bolt to realign the cotter pin with the hole.
7-52	Stated need of a bucking bar when setting solid rivets.
7-54	AN470 rivets are typical for interior structures; not MS20430 or MS20442.
7-69	Only older aircraft (35 years +) used rivnuts to attach de-icer boots. Modern aircraft bond them on.
7-75	Left hand turnbuckle barrel ends are identified with a groove. Knurling hasn't been used for 35 years.
7-78	Specified that clip locks are not reusable.
8-14	Figure 8-22; Clarified aluminum alloy described in Figure.
8-16	Added warning about steam cleaning aluminum parts.
9-5	Deleted reference to 35º AC flared fittings which are now obsolete.
9-7	Deleted instruction to anneal metal tubing prior to flaring which is only done in the factory.
9-10	Figure 9-16; Added missing fluid line identifiers and corrected label designation for rocket catalyst.
9-11	Figure 9-19; Filled in missing AN fitting identifications.
9-12	Figure 9-20; Numerous errors and omissions in chart. Replaced with correct data from *AC43.13-1B*.
9-12/13	Flareless fittings are colored green; not blue.
9-16	Deleted incorrect paragraph regarding identifying faults on the flare of a flareless fitting.
9-16	Specified "bullet" method is only practical on soft, thin walled tubing.
9-20	Corrected caption on Figure 9-35 misstating it to be a flexible hose.
9-22	Figure 9-39; The assembly shown is a low pressure hose, not medium.
11-2/3	Replaced term "common" screwdriver as "flat blade" screwdriver.

REVISION LOG

11-5	Removed statement: "Allen wrenches are seldom used."
11-8	Added that torque wrenches must be calibrated.
11-8	Stated impact wrenches are rarely used on aircraft.
11-12	Deleted instruction to "tap file on a bench to clean". Use file card. Airplanes do not have benches.
11-19	Corrected erroneous decimal equivalent. "1/8" = .125", not .0125"
11-21	Added decimal equivalents to fractions on ruler.
11-23	Figures 11-35; Replaced poor quality pictures of outside micrometers.
11-25	Figure 11-39; Filled in missing labels depicting vernier and barrel scales.
11-25	To view all scales, the thimble is turned; not the micrometer.
12-2	Aircraft technicians should know about plasma.
12-25	Corrected 4 tolerance specifications in Figure 12-49.
12-38	Values expressed as 200 mA revised to .2 amps for consistency.
12-110	1st paragraph; "emitter and collector" corrected to "emitter and base".
12-111	Figure 12-227; Corrected flow direction on common collector schematic.
12-116	Figure 12-237; Band-pass filter corrected to Band-stop filter.
12-161	Equation for Alternator Frequency corrected.
12-138	Corrected appropriate sand paper type.
14-12/13	Inserted missing headers clarifying discussion of MEDA, SHEL, and Swiss models.

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With the introduction of sealed lead-acid batteries and the use of nickel-cadmium batteries, spilled battery acid is becoming less of a problem. The use of these closed units lessens the hazards of acid spillage and battery fumes.

Many types of fluxes used in brazing, soldering, and welding are corrosive, chemically attacking the metals or alloys that they are used with. Therefore, it is important to remove residual flux from the metal surface immediately after the joining operation. Flux residues are hygroscopic in nature, absorbing moisture, and unless carefully removed, tend to cause severe pitting.

Caustic cleaning solutions in concentrated form are kept tightly capped and as far from aircraft as possible. Some cleaning solutions used in corrosion removal are, in themselves, potentially corrosive agents. Therefore, particular attention must be directed toward their complete removal after use on aircraft. Where entrapment of the cleaning solution is likely to occur, use a noncorrosive cleaning agent, even though it is less efficient.

Electrochemical Attack

Corrosion is a natural occurrence that attacks metal by chemical or electrochemical action, converting it back to a metallic compound. The following four conditions must exist before electrochemical corrosion can occur. *[Figure 8-5]*

1. A metal subject to corrosion (anode)
2. A dissimilar conductive material (cathode) that has less tendency to corrode
3. Presence of a continuous, conductive liquid path (electrolyte)
4. Electrical contact between the anode and the cathode (usually in the form of metal to metal contact, such as rivets, bolts, and corrosion)

Elimination of any one of these conditions stops electrochemical corrosion.

NOTE: Paint can mask the initial stages of corrosion. Since corrosion products occupy more volume than the

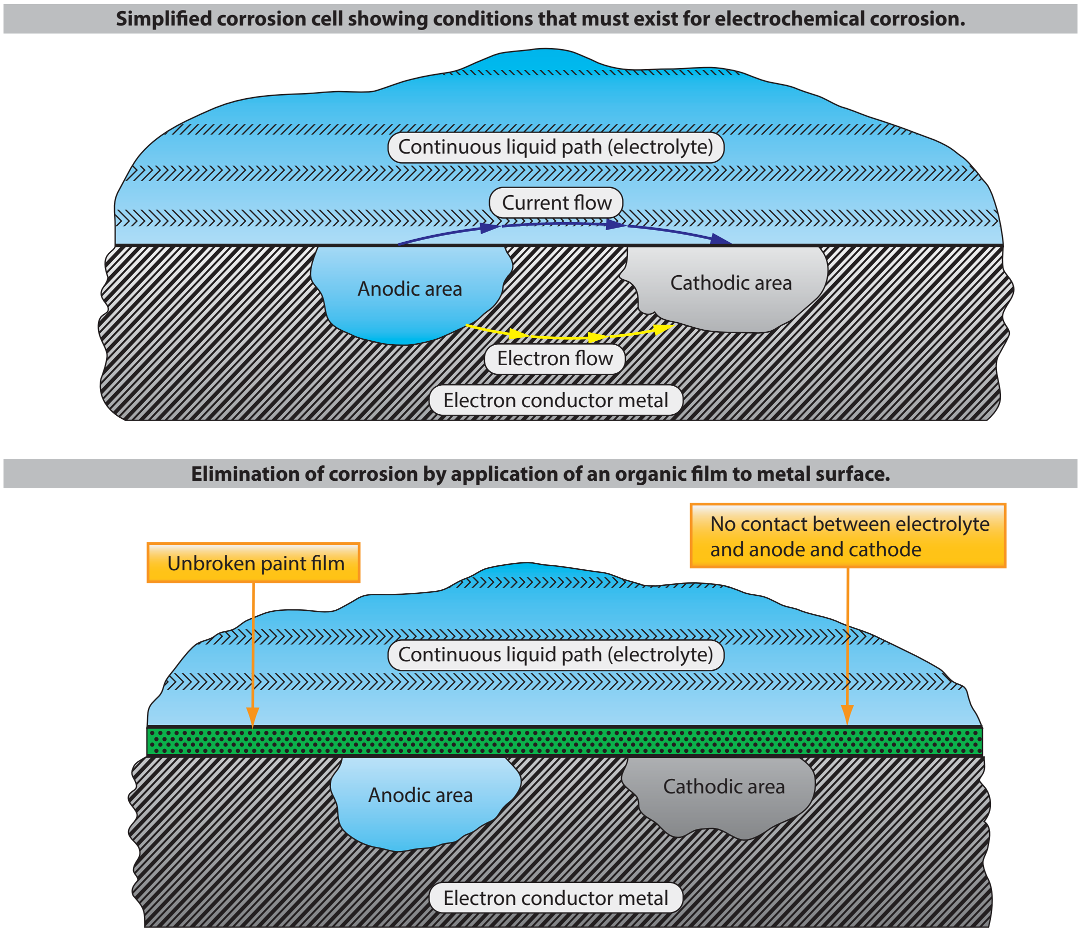

Figure 8-5. *Electrochemical attack.*

original metal, painted surfaces must be inspected often for irregularities, such as blisters, flakes, chips, and lumps.

An electrochemical attack may be likened chemically to the electrolytic reaction that takes place in electroplating, anodizing, or in a dry cell battery. The reaction in this corrosive attack requires a medium, usually water, that is capable of conducting a tiny current of electricity. When a metal comes in contact with a corrosive agent and is also connected by a liquid or gaseous path that electrons flow through, corrosion begins as the metal decays by oxidation. *[Figure 8-5]* During the attack, the quantity of corrosive agent is reduced and, if not renewed or removed, may completely react with the metal becoming neutralized. Different areas of the same metal surface have varying levels of electrical potential and, if connected by a conductor such as salt water, sets up a series of corrosion cells and corrosion will commence.

All metals and alloys are electrically active and have a specific electrical potential in a given chemical environment. This potential is commonly referred to as the metal's "nobility." *[Figure 8-6]* The less noble a metal is, the more easily it can be corroded. The metals chosen for use in aircraft structures are a studied compromise with strength, weight, corrosion resistance, workability, and cost balanced against the structure's needs.

The constituents in an alloy also have specific electrical potentials that are generally different from each other. Exposure of the alloy surface to a conductive, corrosive medium causes the more active metal to become anodic and the less active metal to become cathodic, thereby establishing conditions for corrosion. These are called local cells. The greater the difference in electrical potential between the two metals, the greater the severity of a corrosive attack if the proper conditions are allowed to develop.

The conditions for these corrosion reactions are the presence of a conductive fluid and metals having a difference in potential. If, by regular cleaning and surface refinishing, the medium is removed and the minute electrical circuit eliminated, corrosion cannot occur. This is the basis for effective corrosion control. The electrochemical attack is responsible for most forms of corrosion on aircraft structure and component parts.

Forms of Corrosion

There are many forms of corrosion. The form of corrosion depends on the metal involved, its size and shape, its specific function, atmospheric conditions, and the corrosion producing agents present. Those described in this section are the more common forms found on airframe structures.

Metal most
likely to corrode
(anodic)

Magnesium
Magnesium alloy
Zinc

Aluminum (1,100)
Cadmium
Aluminum 2,024-T4
Steel or iron
Cast iron
Chromium-iron (active)
Ni-Resist cast iron

Type 304 stainless steel (active)
Type 316 stainless steel (active)

Lead-tin solder
Lead
Tin

Nickel (active)
Inconel nickel-chromium alloy
(active)
Hastelloy alloy C (active)

Brass
Copper
Bronze
Copper-nickel alloy
Monel nickel-copper alloy

Silver solder
Nickel (passive)
Inconel nickel-chromium alloy
(passive)

Chromium-iron (passive)
Type 304 stainless steel (passive)
Type 316 stainless steel (passive)
Hastelloy alloy C (passive)

Silver
Titanium
Graphite
Gold
Platinum

Metal least likely
to corrode
(cathodic)

Figure 8-6. *The galvanic series of metals and alloys.*

Surface Corrosion

General surface corrosion (also referred to as uniform etch or uniform attack corrosion) is the most common form of corrosion. Surface corrosion appears as a general roughening, etching, or pitting of the surface of a metal, frequently accompanied by a powdery deposit of corrosion products. Surface corrosion may be caused by either direct chemical or electrochemical attack. Sometimes corrosion spreads under the surface coating and cannot be recognized by either the roughening of the surface or the powdery deposit. 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. *[Figure 8-7]*

Filiform Corrosion

Filiform corrosion is a special form of oxygen concentration cell that 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 8-8]* Polyurethane finishes are especially susceptible to filiform corrosion. Filiform occurs when the relative humidity of the air is between 78–90 percent, and the surface is slightly acidic. This corrosion usually attacks steel and aluminum surfaces. The traces never cross on steel, but they cross under one another on aluminum, making 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 at seams.

Filiform corrosion can be removed using glass bead blasting material with portable abrasive blasting equipment or sanding. Filiform corrosion 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, such as those created by pollutants in the air.

Figure 8-7. *Surface corrosion.*

Figure 8-8. *Filiform corrosion.*

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. These small surface openings may penetrate deeply into structural members and cause damage completely out of proportion to its surface appearance. *[Figure 8-9]*

Dissimilar Metal Corrosion

Extensive pitting damage may result from contact between dissimilar metal parts in the presence of a conductor. While surface corrosion may or may not be taking place, a galvanic action, not unlike electroplating, occurs at the points or areas of contact where the insulation between the surfaces has broken down or been omitted. This electrochemical attack can be very serious because, in many instances, the action is taking place out of sight, and the only way to detect it prior to structural failure is by disassembly and inspection. *[Figure 8-10]*

The contamination of a metal's surface by mechanical means can also induce dissimilar metal corrosion. The improper use of steel cleaning products, such as steel wool or a steel wire brush on aluminum or magnesium, can force small pieces of steel into the metal being cleaned, causing corrosion and ruining the adjoining surface. Carefully monitor the use of nonwoven abrasive pads, so that pads used on one type of metal are not used again on a different metal surface.

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 that are in contact with water. A high concentration of metal ions normally exists under faying surfaces where the solution is stagnant and a low concentration of metal ions exist adjacent to the crevice, created by the faying surface. *[Figure 8-11]* An electrical potential exists between the two points: the area of the metal in contact with the low concentration of metal ions is anodic and corrodes; the area in contact with the high metal ion concentration is cathodic and does not show signs of corrosion.

Oxygen Concentration Cells

The solution in contact with the metal surface normally contains 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 occurs at the area of low oxygen concentration (anode). Alloys such as stainless steel are particularly susceptible to this type of crevice corrosion. *[Figure 8-12]*

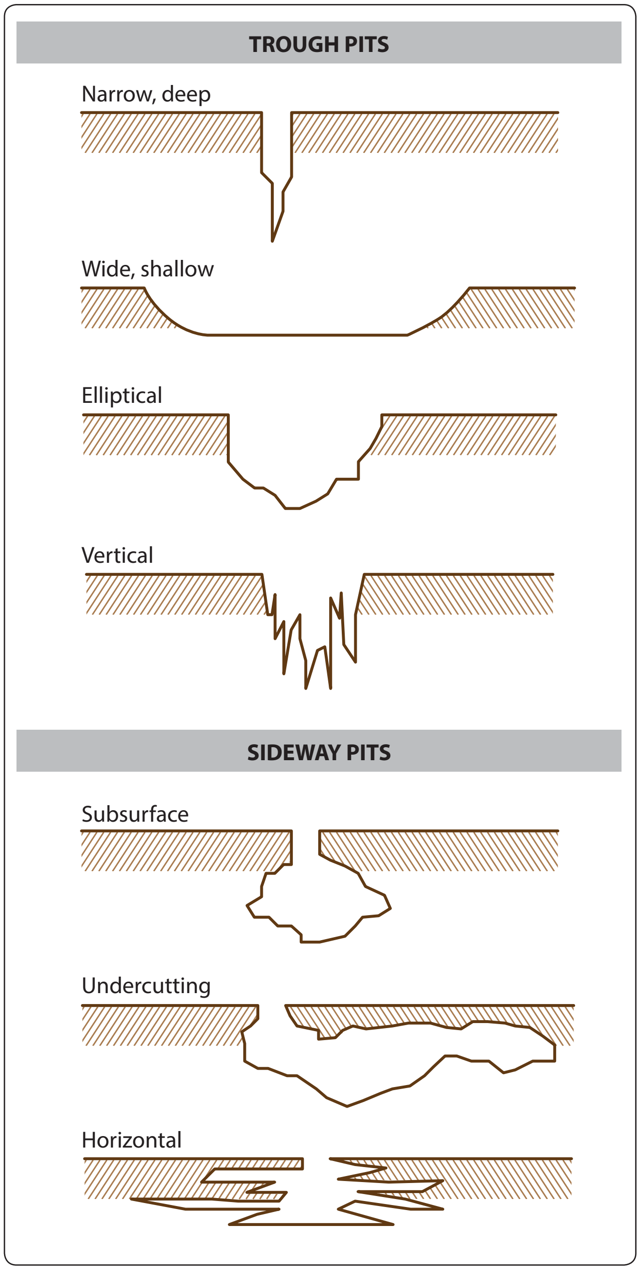

Figure 8-9. *Types of pitting corrosion.*

Figure 8-10. *Dissimilar metal corrosion.*

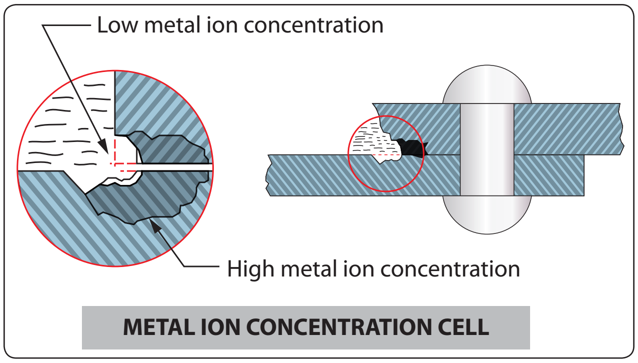

Figure 8-11. *Metal ion concentration cell.*

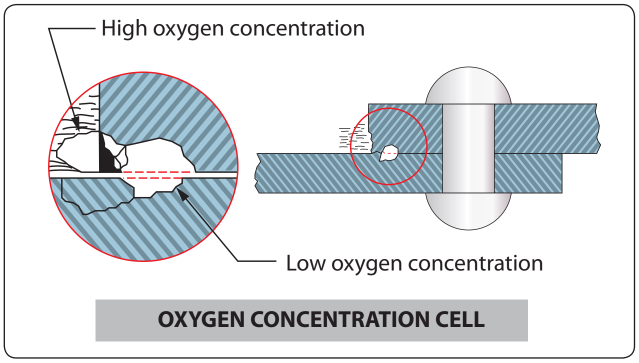

Figure 8-12. *Oxygen concentration cell.*

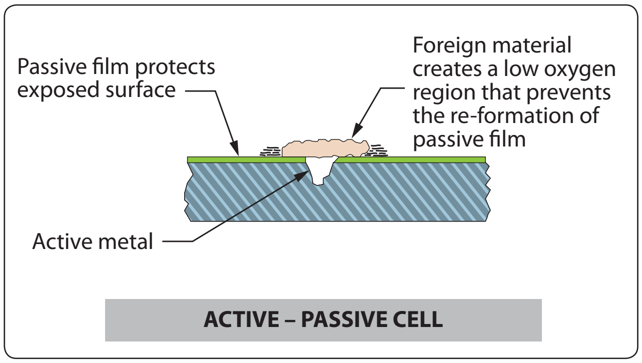

Figure 8-13. *Active-passive cell.*

Active-Passive Cells

Metals that depend on a tightly adhering passive film, usually an oxide for corrosion protection, are prone to rapid corrosive attack by active-passive cells. The corrosive action usually starts as an oxygen concentration cell. The passive film is broken beneath the dirt particle exposing the active metal to corrosive attack. An electrical potential will develop between the large area of the passive film and the small area of the active metal, resulting in rapid pitting. *[Figure 8-13]*

Intergranular Corrosion

This type of corrosion is an attack along the grain boundaries of an alloy and commonly results from a lack of uniformity in the alloy structure. Aluminum alloys and some stainless steels are particularly susceptible to this form of electrochemical attack. *[Figure 8-14]* The lack of uniformity is caused by changes that occur in the alloy during the heating and cooling process of the material's manufacturing. Intergranular corrosion may exist without visible surface evidence. 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 8-15. *Exfoliation corrosion.*

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 8-15]* It is visible evidence of intergranular corrosion and is most often seen on extruded sections where grain thickness is usually less than in rolled forms. This type of corrosion is difficult to detect in its initial stage. Extruded components, such as spars, can be subject to this type of corrosion. Ultrasonic and eddy current inspection methods are being used with a great deal of success.

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 8-16]* 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

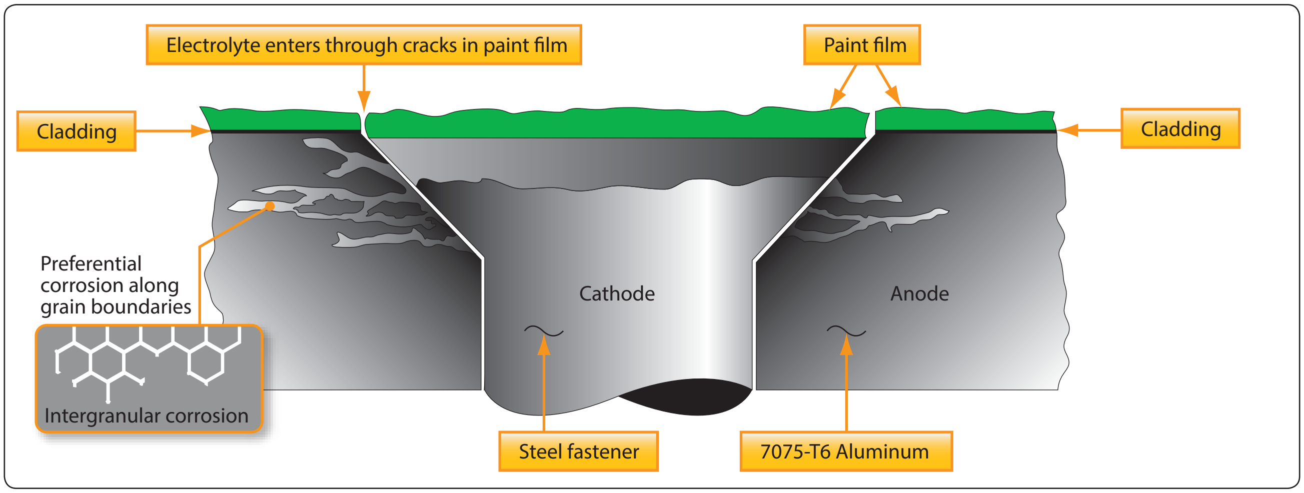

Figure 8-14. *Intergranular corrosion of 7075-T6 aluminum adjacent to steel fastener.*

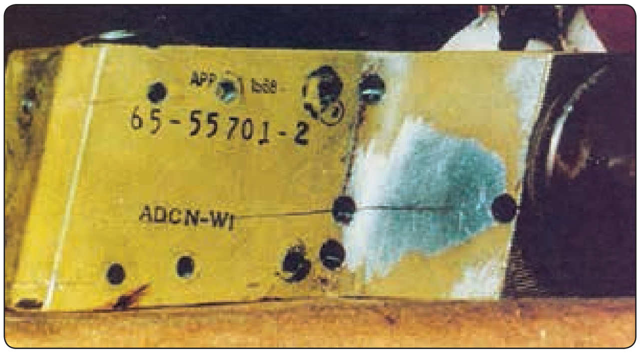

Figure 8-16. *Stress corrosion cracking.*

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.

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.

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 escaping very easily, an extremely localized abrasion occurs. *[Figure 8-17]* 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 in 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 cowling 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.

Figure 8-17. *Fretting corrosion.*

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 been exceeded, the metal eventually cracks and fails 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 occurs, even if the corrosive environment is completely removed. The second stage is essentially a fatigue stage where 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.