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Federal Aviation
Administration

Advisory Circular

Subject: Corrosion Control for Aircraft
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Change:

This advisory circular (AC) is a summary of the current available data regarding identification and treatment of corrosive attack on aircraft structures and engine materials. Corrosion inspection frequency, corrosion identification, and especially corrosion treatment continues to be the responsibility of the operator. These inspections should be accomplished per this AC, the manufacturer's recommendations, or the operator's own maintenance program. The procedures in this AC are an acceptable means, but not the only acceptable means, of corrosion treatment. The information in this AC is applicable to aircraft for which the manufacturer has not published corrosion control information. Where the airframe or engine manufacturer has published a recommended corrosion inspection schedule and treatment program, the applicable program must take precedence over the recommendation of this AC. The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies.

Rick Domingo
Executive Director, Flight Standards Service

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CHAPTER 1. GENERAL

1.1 Purpose of This Advisory Circular (AC). This AC provides guidance to aircraft operators and maintenance, repair, and overhaul (MRO) organizations for the development of a corrosion control program. This AC applies to Title 14 of the Code of Federal Regulations (14 CFR) parts 121, 129, and 135 operators. This AC is a summary of the current available data regarding identification and treatment of corrosive attack on aircraft structures and engine materials. Corrosion inspection frequency, corrosion identification, and especially corrosion treatment continues to be the responsibility of the operator. These inspections should be accomplished per this AC, the manufacturer's recommendations, or the operator's own maintenance program. The procedures in this AC are an acceptable means, but not the only acceptable means, of corrosion treatment. The information in this AC is applicable to aircraft for which the manufacturer has not published corrosion control information. Where the airframe or engine manufacturer has published a recommended corrosion inspection schedule and treatment program, the applicable program must take precedence over the recommendation of this AC. The contents of this document do not have the force and effect of law and are not meant to bind the public in any way, and the document is intended only to provide information to the public regarding existing requirements under the law or agency policies. This AC is intended for use by persons performing maintenance, alteration, or preventive maintenance on aircraft, engines, propellers, or appliances in accordance with 14 CFR part 43.

1.2 Audience. This AC applies to aircraft operators and MRO organizations.

1.3 Where You Can Find This AC. You can find this AC on the Federal Aviation Administration's (FAA) website at https://www.faa.gov/regulations_policies/advisory_circulars and the Dynamic Regulatory System (DRS) at https://drs.faa.gov.

1.4 What This AC Cancels. AC 43-4A, Corrosion Control for Aircraft, dated July 25, 1991, is canceled.

1.5 Related Reading Material.

1.5.1 FAA Documents (current editions). AC 65-15, Airframe and Powerplant Mechanics Airframe Handbook. You can find this AC at https://www.faa.gov/regulations_policies/advisory_circulars.

1.5.2 Other Documents:

- Naval Air Systems Command, NAVAIR 01-1A-509-1, Cleaning and Corrosion Control.
- U.S. Air Force Technical Order TO 1-1-691, Cleaning and Corrosion Prevention and Control, Aerospace and Non-Aerospace Equipment.

1.6 Background. Corrosion is the electrochemical deterioration of a metal because of its chemical reaction with a surrounding environment. While the aerospace industry is continuously developing new and better materials, progress is offset partly by a more aggressive operational environment and by the complexity of the corrosion phenomenon, which can take many different forms. The resistance of aircraft materials to corrosion can drastically change with only a small environmental change.

1.7 Catastrophic Corrosion Events. Corrosion is most often a slow process of material deterioration, taking place over a long period of time. Examples are general corrosion, pitting, stress-corrosion cracking, environmental embrittlement, and corrosion fatigue and exfoliation. Corrosion degradation can occur very quickly, in days or even hours, and with catastrophic results. Corrosion thrives on both the chemical and mechanical aspects of the environment and can cause catastrophic structural failure without warning.

1.8 Corrosion Control Program.

1.8.1 The possibility of an in-flight mishap or excessive down time for structural repairs mandates an active Corrosion Prevention and Control Program (CPCP). The operational environment of the aircraft sets the type and aggressiveness of the program. Aircraft exposed to such environments as salt air, heavy atmospheric industrial pollution, or over-water operations, will need a more stringent CPCP than an aircraft operating in a dry environment.

1.8.2 Operators must follow a constant cycle of cleaning, inspection, operational preservation, and lubrication to prevent corrosion. Prompt detection and removal of corrosion will limit the extent of damage to an aircraft and its components. The basic philosophy of a CPCP should consist of:

1. Personnel adequately trained in recognizing corrosion, including conditions, detection and identification, cleaning, treating, and preservation;
2. Thorough knowledge of corrosion identification techniques;
3. Proper emphasis on the concept of all-hands responsibility for corrosion control;
4. Scheduled corrosion inspections;
5. Aircraft washing at regularly scheduled intervals;
6. Routine cleaning or wipe down of all exposed unpainted surfaces;
7. Keeping drain holes and passages open and functional;
8. Scheduled inspections, removals, and reapplications of preservation compounds;
9. Early detection and repair of damaged protective coatings;
10. Periodic thorough cleaning, lubrication, and preservation;
11. Prompt corrosion treatment after detection;
12. Accurate recordkeeping and reporting of material or design deficiencies; and
13. Use of appropriate materials, equipment, and technical publications.

1.9 AC Feedback Form. For your convenience, the AC Feedback Form is the last page of this AC. Note any deficiencies found, clarifications needed, or suggested improvements regarding the contents of this AC on the Feedback Form.

1.10–1.99. RESERVED.

CHAPTER 2. CORROSION THEORY

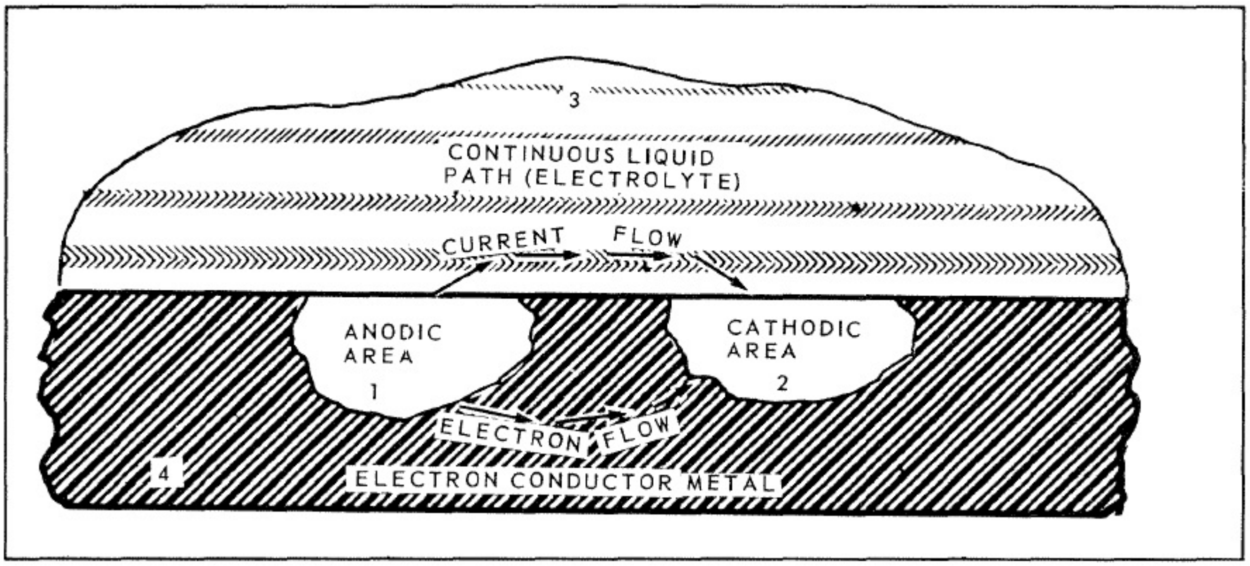
2.1 Introduction. This chapter introduces corrosion theory, causes of corrosion, factors influencing its development, and descriptions of forms of corrosion and common corrosive agents.

2.2 Background.

2.2.1 Corrosion is a natural phenomenon which attacks metal by chemical or electrochemical action and converts it into a metallic compound, such as an oxide, hydroxide, or sulfate. Corrosion is different from erosion, which causes destruction by mechanical action. The corrosion occurs because metals tend to return to their natural state. Noble metals, such as gold and platinum, do not corrode since they are chemically uncombined in their natural state. Four conditions must exist before corrosion can occur (see Figure 2-1, Simplified Corrosion Cell Showing Conditions which Must Exist for Electrochemical Corrosion):

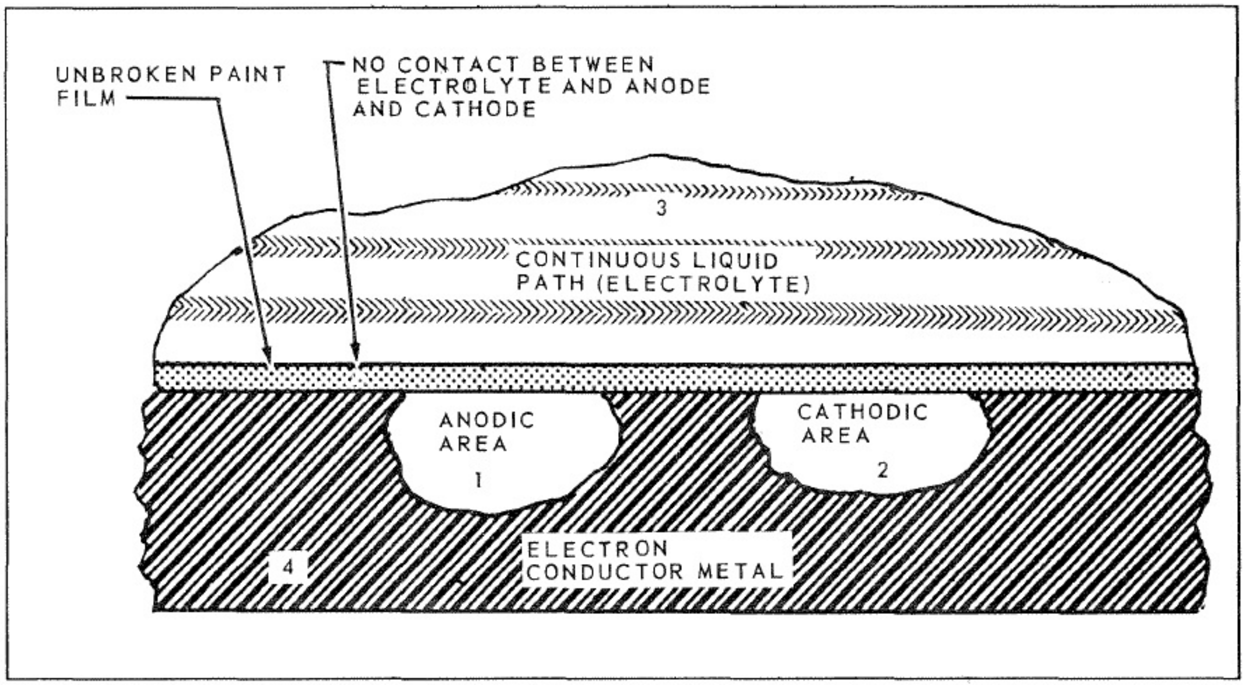
1. Presence of an anode, or a metal that will corrode;
2. Presence of a cathode, a dissimilar conductive material which has less tendency to corrode;
3. Presence of an electrolyte, a conductive liquid; and
4. Electrical contact between the anode and cathode, which is usually by metal-to-metal contact, or through a fastener.

Figure 2-1. Simplified Corrosion Cell Showing Conditions which Must Exist for Electrochemical Corrosion



2.2.2 Elimination of any one of these conditions will stop corrosion. An example would be a paint film on the metal surface (see Figure 2-2, Elimination of Corrosion by Application of an Organic Film to Metal Surface). Metals such as stainless steel and titanium can produce corrosion products so tightly bound to the corroding metal that they form an invisible oxide, or passive, film, preventing further corrosion. When a film of corrosion products is loose and porous, such as those of aluminum and magnesium, an electrolyte can easily penetrate and continue the corrosion process, producing more extensive damage than surface appearance would show.

Figure 2-2. Elimination of Corrosion by Application of an Organic Film to Metal Surface



2.3 Development of Corrosion.

2.3.1 All corrosive attack begins on the surface of the metal, and the corrosion process involves two chemical changes: 1) the metal that is attacked or oxidized undergoes an anodic change, and 2) the corrosive agent is reduced or undergoes a cathodic change. The tendency of most metals to corrode creates one of the major problems in aircraft maintenance, particularly where adverse environmental or weather conditions exist.

2.3.2 Paint coatings can mask initial stages of corrosion. Since corrosion products occupy more volume than the original metal, paint surfaces should be inspected often for such irregularities as blisters, flakes, chips, and lumps.

2.4 Factors Influencing Corrosion.

2.4.1 Some factors which influence metal corrosion and the rate of corrosion are the:

1. Type of metal;
2. Heat treatment and grain direction;
3. Presence of a dissimilar, less corrodible metal (galvanic corrosion);
4. Anode and cathode surface areas (in galvanic corrosion);

5. Temperature;
6. Presence of electrolytes (such as hard water, saltwater, or battery fluids);
7. Availability of oxygen;
8. Presence of different concentrations of the same electrolyte;
9. Presence of biological organisms;
10. Mechanical stress on the corroding metal;
11. Time of exposure to a corrosive environment; and
12. Lavatory fluids with hard water, saltwater, or battery fluids.

2.4.2 Most pure metals are not suitable for aircraft construction and are used to form alloys. Most alloys are made up entirely of small, crystalline regions called grains. Corrosion can occur on the less resistant surfaces of these regions and at boundaries between regions, resulting in the formation of pits and intergranular corrosion. Metals have a wide range of corrosion resistance. The most chemically active metals (which tend to lose electrons easily, such as magnesium and aluminum) corrode easily. The most noble metals (which do not lose electrons easily, such as gold and silver) do not corrode easily.

2.4.3 High-temperature environments accelerate corrosion by increasing chemical reaction rates and moisture content in saturated air.

2.4.4 Electrolytes, or electrically conducting solutions, form when condensation, salt spray, rain, or rinse water accumulate on surfaces. Dirt, salt, acidic gases, and engine exhaust gases can dissolve on wet surfaces, increasing electrolyte conductivity and also the rate of corrosion.

2.4.5 When areas such as between faying surfaces or in deep crevices partially confine an electrolyte on a metal surface, that surface corrodes more rapidly than other metal surfaces outside this area. This area of corrosion is called an oxygen concentration cell. The reduced oxygen content of the confined electrolyte causes adjacent metal to become anodic to other metal surfaces immersed in electrolyte and exposed to air on the same part.

2.4.6 Slimes, molds, fungi, and other living organisms, some of which are microscopic, can grow on damp surfaces. The area where such organisms become established tends to remain damp, increasing the possibility of corrosion.

2.4.7 Manufacturing processes, such as machining, forming, welding, or heat treatment, can leave stresses in aircraft parts. This residual stress can cause cracking in a corrosive environment when the threshold for stress-corrosion is exceeded.

2.4.8 In some cases, corrosion progresses at the same rate no matter how long the metal has been exposed to an environment. In other cases, corrosion can decrease with time because of a barrier formed by corrosion products, or increase with time if a barrier is breaking down.

2.5 Forms of Corrosion. Different types of corrosive attack will vary with the metal concerned, corrosive media location, and the length of time of exposure. For descriptive purposes, the types are listed under what the FAA considers the most commonly accepted titles.

2.5.1 Uniform Etch Corrosion. Uniform etch corrosion results from a direct chemical attack on a metal surface and involves only the metal surface (see Figure 2-3, Uniform Etch Corrosion). On a polished surface, this type of corrosion may first appear as a general dulling of the surface. If the attack continues, the surface becomes rough and possibly frosted in appearance. However, it should be noted that the discoloration or general dulling of metal created by exposure to elevated temperatures is not uniform etch corrosion.

2.5.2 Pitting Corrosion. This is the most common effect of corrosion on aluminum and magnesium alloys, but can occur in other metal alloys (see Figure 2-4, Pitting Corrosion). 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 pits or holes in the surface can be seen. The combination of small active anodes and large passive cathodes causes severe pitting. The principle also applies to metals passivated by chemical treatments or environmental condition.

Figure 2-3. Uniform Etch Corrosion

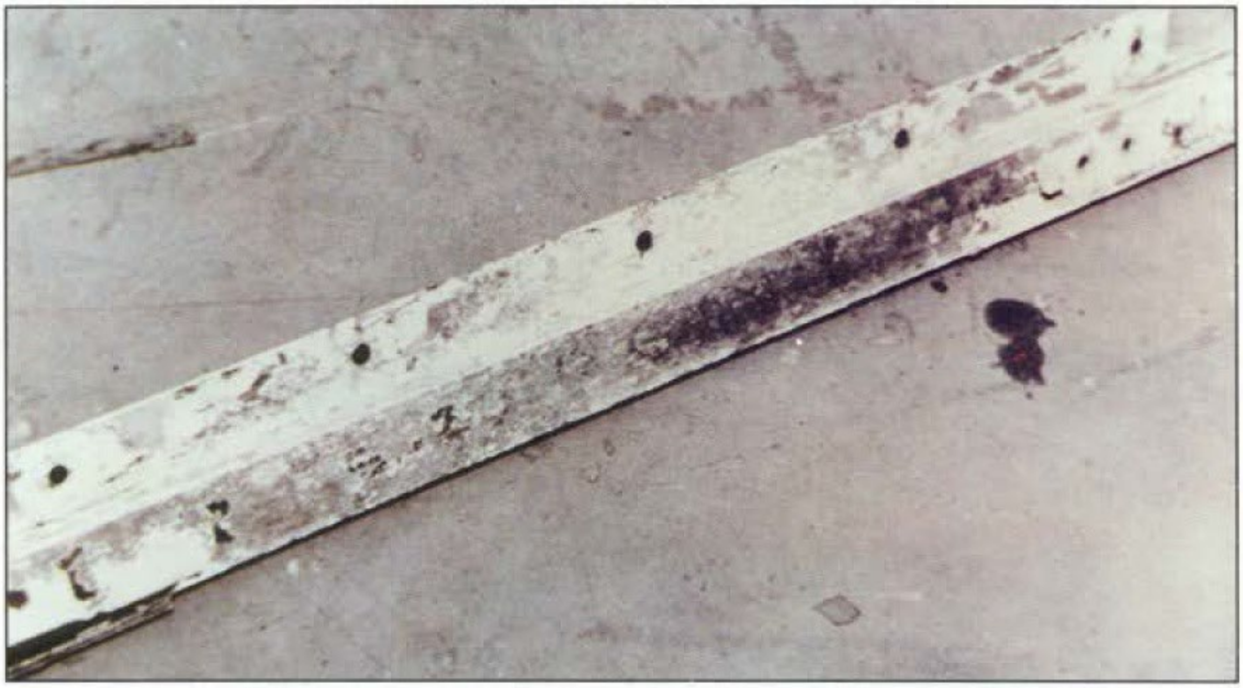
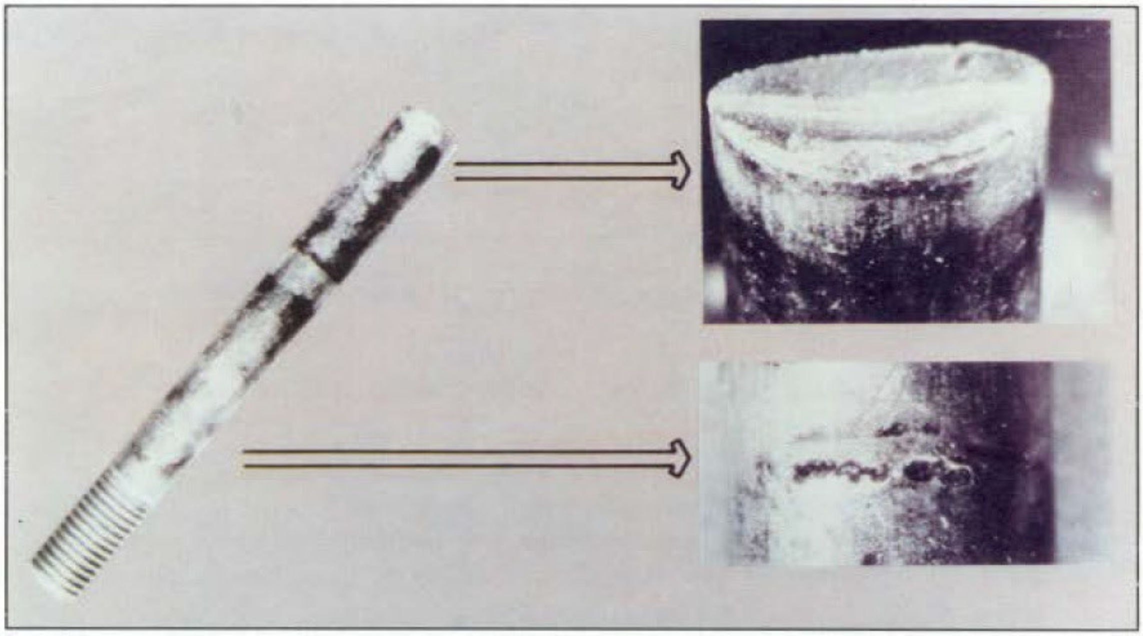
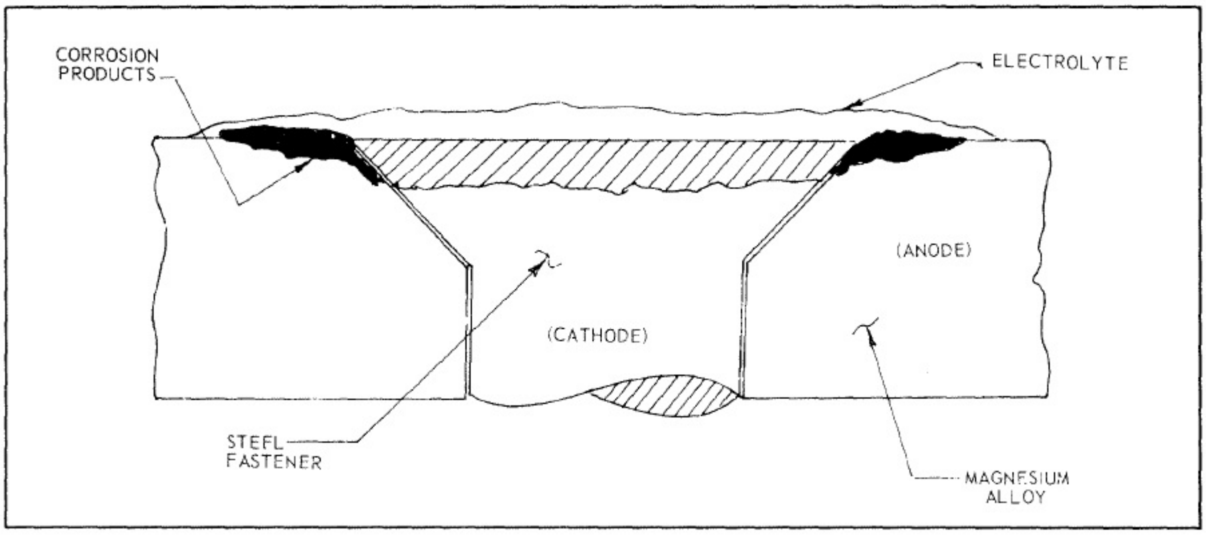


Figure 2-4. Pitting Corrosion



2.5.3 Galvanic Corrosion. This corrosion type occurs when two dissimilar metals make electrical contact in the presence of an electrolyte (see Figure 2-5, Galvanic Corrosion of Magnesium Adjacent to Steel Fastener). The rate of corrosion depends on differences in reaction activity between dissimilar metals. The greater the difference, the faster corrosion occurs. For example, aluminum skin panels and stainless steel doublers, riveted together in an aircraft wing, form a galvanic couple if moisture and contamination are present. The rate of galvanic corrosion also depends on the size of the parts in contact. If the surface area of the corroding metal (the anode) is smaller than the surface area of the less active metal (the cathode), corrosion will be rapid and severe. But if the corroding metal is larger than the less active metal, corrosion will be slow and superficial.

Figure 2-5. Galvanic Corrosion of Magnesium Adjacent to Steel Fastener



2.5.4 Concentration Cell Corrosion or Crevice Corrosion. In this type, corrosion occurs in either a metal-to-metal joint, at the edge of a joint of identical metals, or on a spot on the metal surface covered by a foreign material (see Figure 2-6, Concentration Cell Corrosion). Below is a discussion on the three general types of concentration cell corrosion:

2.5.4.1 **Metal Ion Concentration Cells.** A liquid solution that may consist of water and ions of a metal in contact with water. A high concentration of the metal ions will normally exist under faying surfaces where the solution is stagnant. A low concentration of metal ions will exist adjacent to the crevice created by the faying surface. An electrical potential will exist between the two points of connection, and the area of the metal in contact with the low concentration of metal ions will be anodic and will corrode. The area in contact with the high metal ion concentration will be cathodic and will not show signs of corrosion. Figure 2-6 illustrates metal ion concentration cell corrosion.

2.5.4.2 **Oxygen Concentration Cells.** A solution in contact with a metal surface that normally contains dissolved oxygen. An oxygen cell can develop at any point where oxygen in the air does not diffuse into the solution, and creates a difference in oxygen concentration between two points where the solution and metal meet. Typical locations of oxygen concentration cells are under: 1) either metallic or nonmetallic deposits on the metal surface, 2) faying surfaces such as riveted lap joints, or 3) gaskets, wood, rubber, and other materials in contact with the metal surface. Corrosion will occur at the area of low oxygen concentration (the anode), as Figure 2-6 illustrates. Alloys such as stainless steel, which owe their corrosion resistance to surface passivity, are particularly susceptible to this type of crevice corrosion.

2.5.4.3 **Active-Passive Cells.** Metals which depend on a tightly adhering passive film, like an oxide for corrosion protection such as on corrosion resistant steel (CRES), are prone to rapid corrosive attack by active-passive cells. 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 a dirt particle. Once the passive film is broken, corrosion will attack the active metal beneath the film. An electrical potential will develop between the large area of the cathode, or passive film, and the small area of the anode, or active metal, and rapid pitting of the active metal will result, as shown in Figure 2-6.

2.5.5 Intergranular Corrosion. This corrosion attacks grain boundaries of a metal. Each grain has a clearly defined boundary which differs chemically from the metal within the grain center. The grain boundary and grain center can react with each other as anode and cathode when in contact with an electrolyte. Rapid selective corrosion at the grain boundary can occur and cause delamination (see Figure 2-7, Intergranular Cracking and Corrosion on a Wing Spar Chord). High-strength aluminum alloys, such as schedule 2014 or 7075, are more susceptible to intergranular corrosion if improperly heat-treated then exposed to a corrosive environment.

Figure 2-6. Concentration Cell Corrosion

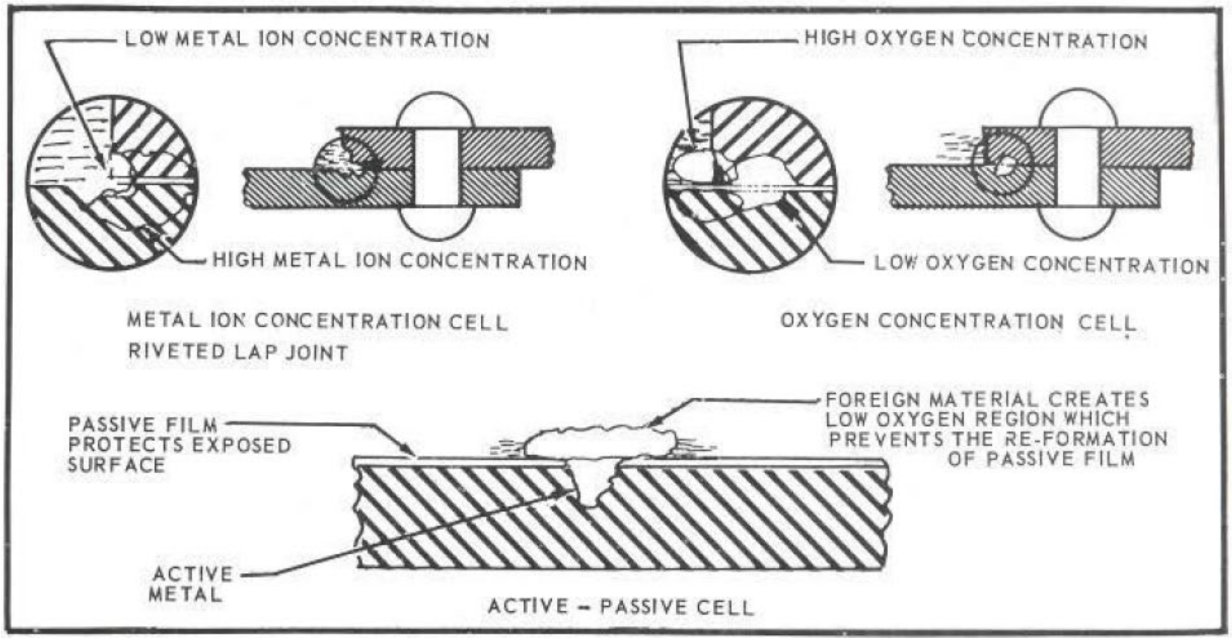
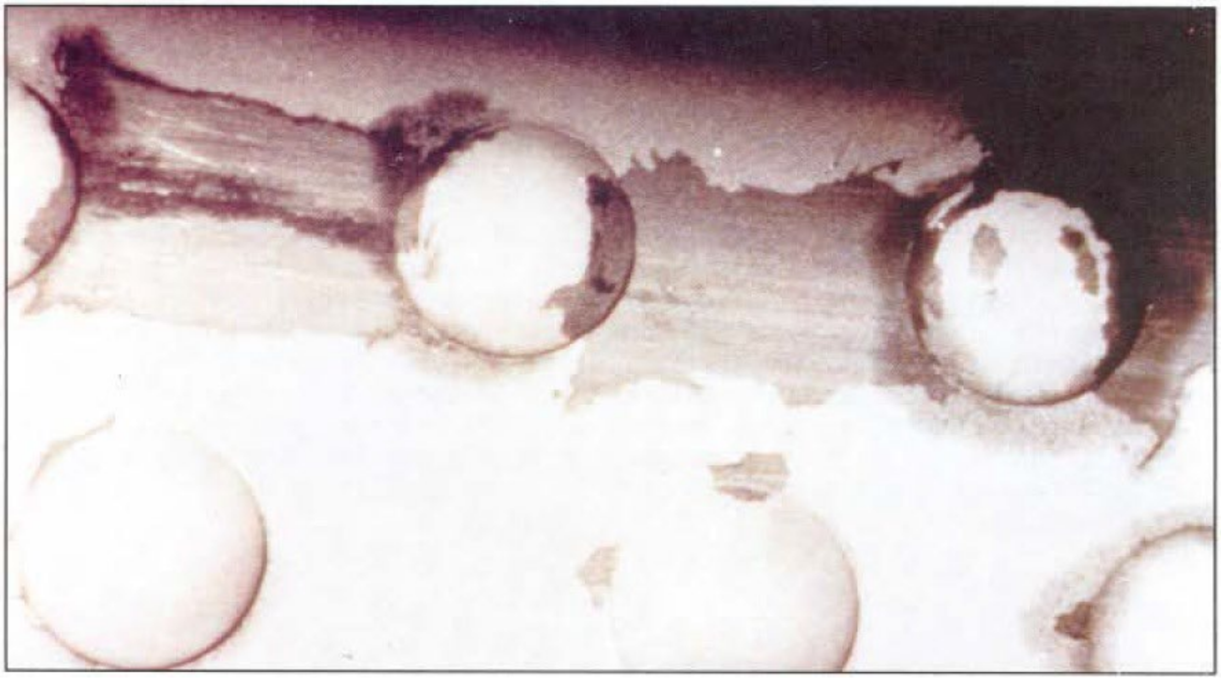


Figure 2-7. Intergranular Cracking and Corrosion on a Wing Spar Chord



2.5.6 Exfoliation Corrosion. Exfoliation is an advanced form of intergranular corrosion where the surface grains of a metal are lifted up by the force of expanding corrosion products occurring at the grain boundaries. The lifting up or swelling is visible evidence of exfoliation corrosion. Exfoliation occurs on extruded, rolled, wrought, and forged high-strength aluminum and magnesium parts. See Figures 2-8, Severe Exfoliation Corrosion of a Seat Track, and 2-9, Severe Exfoliation Corrosion.

Figure 2-8. Severe Exfoliation Corrosion of a Seat Track

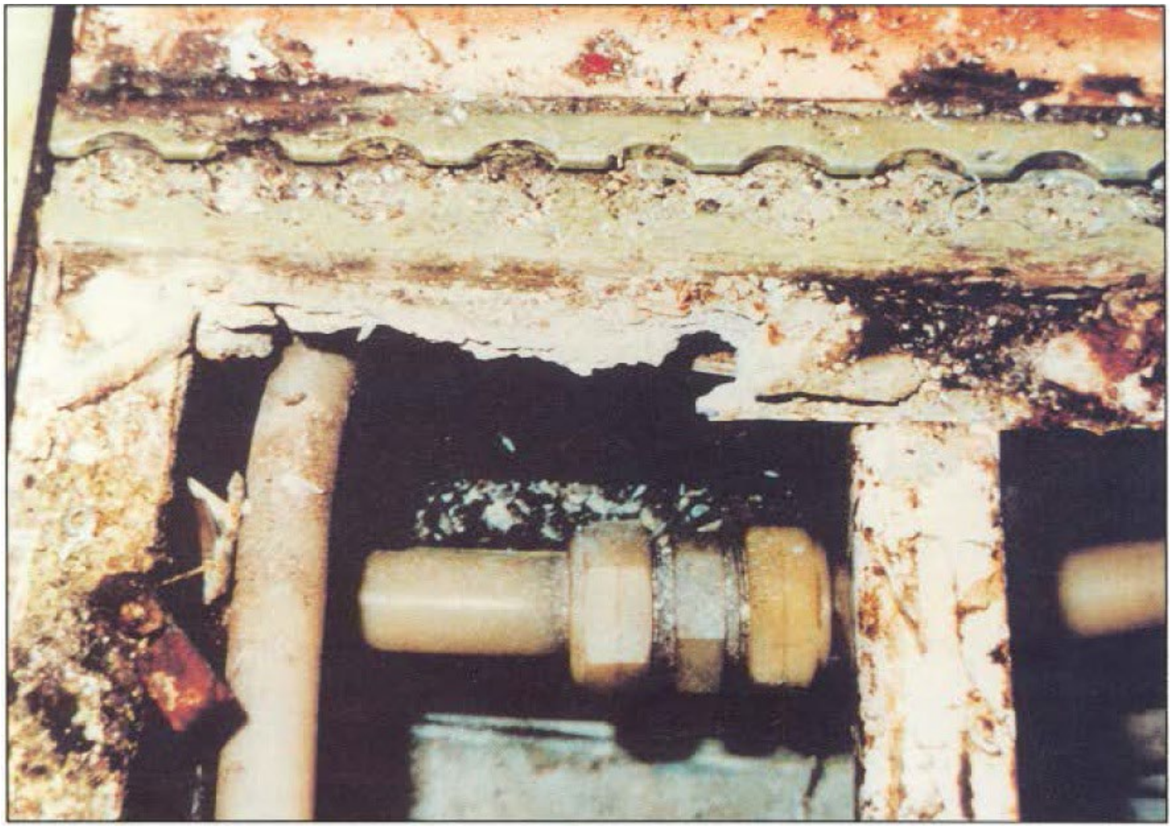
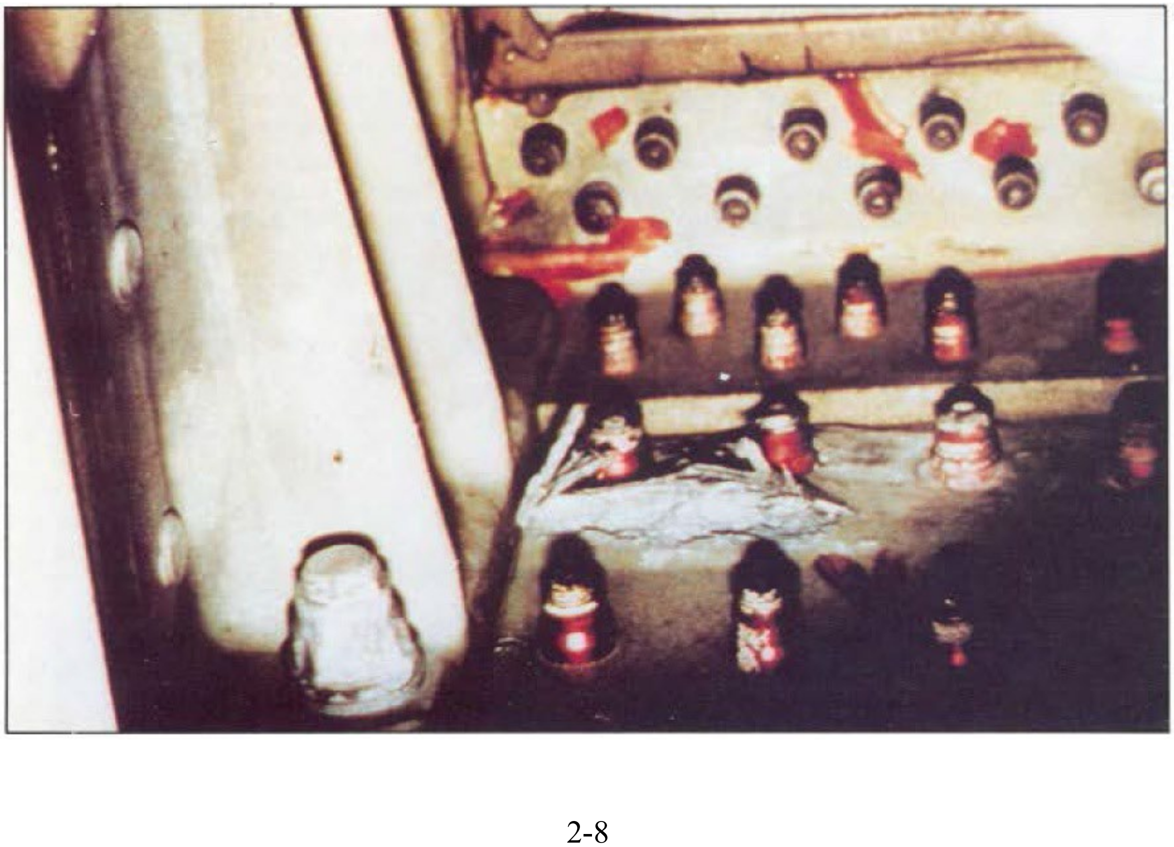


Figure 2-9. Severe Exfoliation Corrosion



2.5.7 Filiform Corrosion. A special form of oxygen concentration cell corrosion or crevice corrosion occurring on metal surfaces with an organic coating system. You can recognize filiform corrosion by a worm-like trace of corrosion products beneath a paint film. Figures 2-10, Filiform Corrosion, and 2-11, Filiform Corrosion Before and After Paint Removal, illustrate this corrosion. Filiform occurs when atmospheric relative humidity is between 78 and 90 percent and the metal surface is slightly acidic. Corrosion starts at breaks in the coating system and moves underneath the coating due to diffusion of water vapor and airborne oxygen through the coating. Filiform corrosion can attack steel and aluminum surfaces. The corrosion can lead to intergranular corrosion, especially around fasteners and at seams, if filiform corrosion is not removed, treat the area, and apply a protective finish. Prevention of filiform corrosion can involve 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 aircraft to remove acidic contaminants, such as airborne pollutants, from the surface.

Figure 2-10. Filiform Corrosion

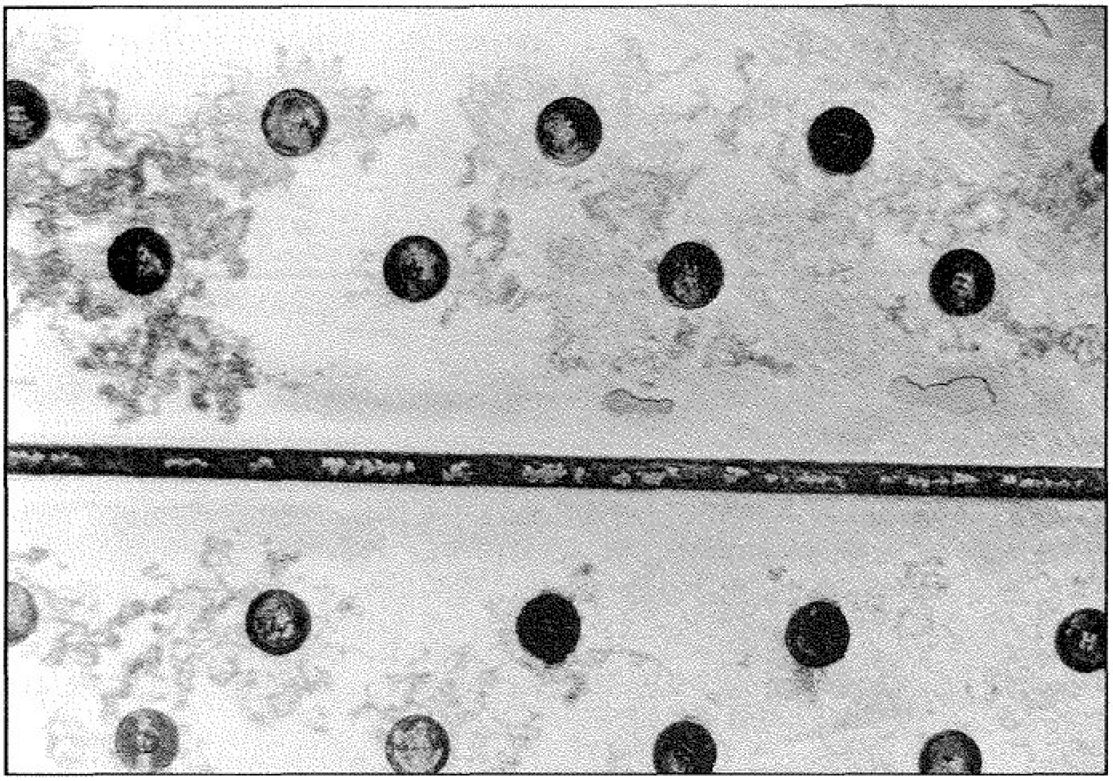
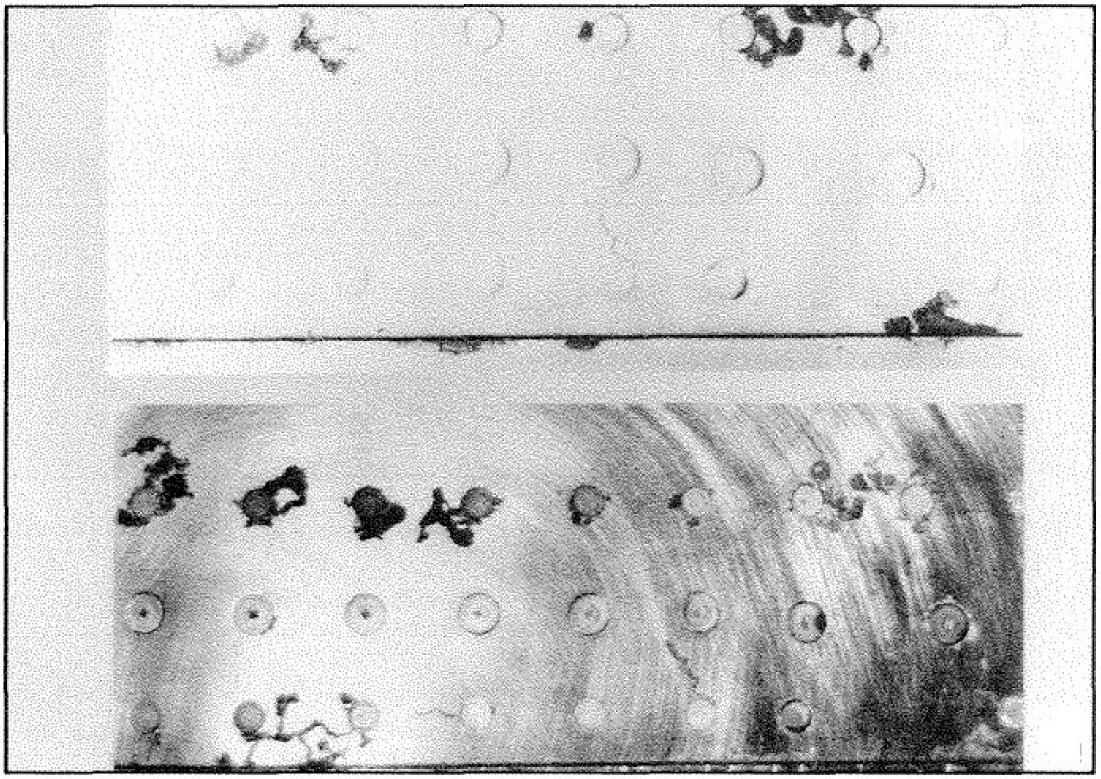


Figure 2-11. Filiform Corrosion Before and After Paint Removal



2.6 Corrosion and Mechanical Factors. Mechanical factors often aggravate corrosive attack by either residual loading inside the part, or by cyclic service loads applied to the part. The extent of the attack can be influenced by environmental conditions, alloy composition, erosion by sand or rain, and mechanical wear. These factors will combine to remove surface protective films and contribute to corrosive attack of underlying metal surfaces. Corrosive attack aided by a mechanical factor usually causes the part to degenerate faster than if it is only corroding. Examples of this kind of alliance between corrosion and mechanical factors are stress-corrosion cracking, corrosion fatigue, and fretting corrosion.

2.6.1 Stress-Corrosion Cracking. Stress-corrosion cracking is an intergranular cracking of a metal caused by combined stress and corrosion, and Figures 2-12 through 2-14 illustrate this. Stress may come from internal or external loading. Causes of internal stresses include nonuniform deformation during cold working, unequal cooling from high temperatures, or internal structural rearrangement involving volume changes. Internal stresses result when a structure is deformed during an assembly operation, such as during pressing in bushings, shrinking a part for press fit, installing interference bolts, or installing rivets. Concealed stress is more critical than design stress because stress-corrosion is difficult to recognize before it has overcome the structure's design safety factor. The level of stress varies from point to point within the metal, and stresses near the yield strength generally promote stress-corrosion cracking. Specific environments which cause stress-corrosion cracking of certain alloys have been identified. Salt solutions and seawater may cause stress-corrosion cracking of high-strength, heat-treated steel and aluminum alloys. Methyl alcohol-hydrochloric acid solutions will cause stress-corrosion cracking of some titanium alloys. Magnesium alloys may stress-corrode in moist air. Stress-corrosion may be reduced by applying protective coatings, using a stress relief heat treatment, applying corrosion inhibitors, or controlling the environment. Shot peening a metal surface creates compressive stresses on the surface which help reduce stress-corrosion cracking and increase the threshold stress level.

Figure 2-12. Stress-Corrosion Cracking of 7079-T6 Fitting

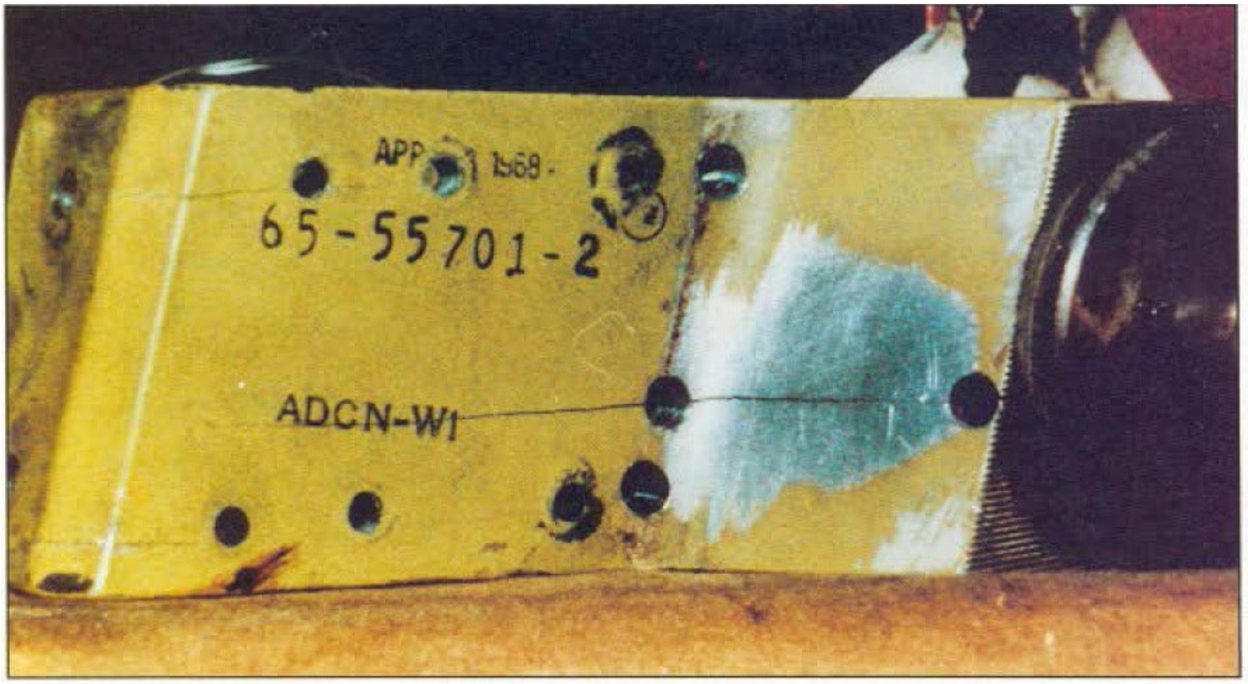


Figure 2-13. Stress-Corrosion Cracking Starting at a Pit in CRES Material

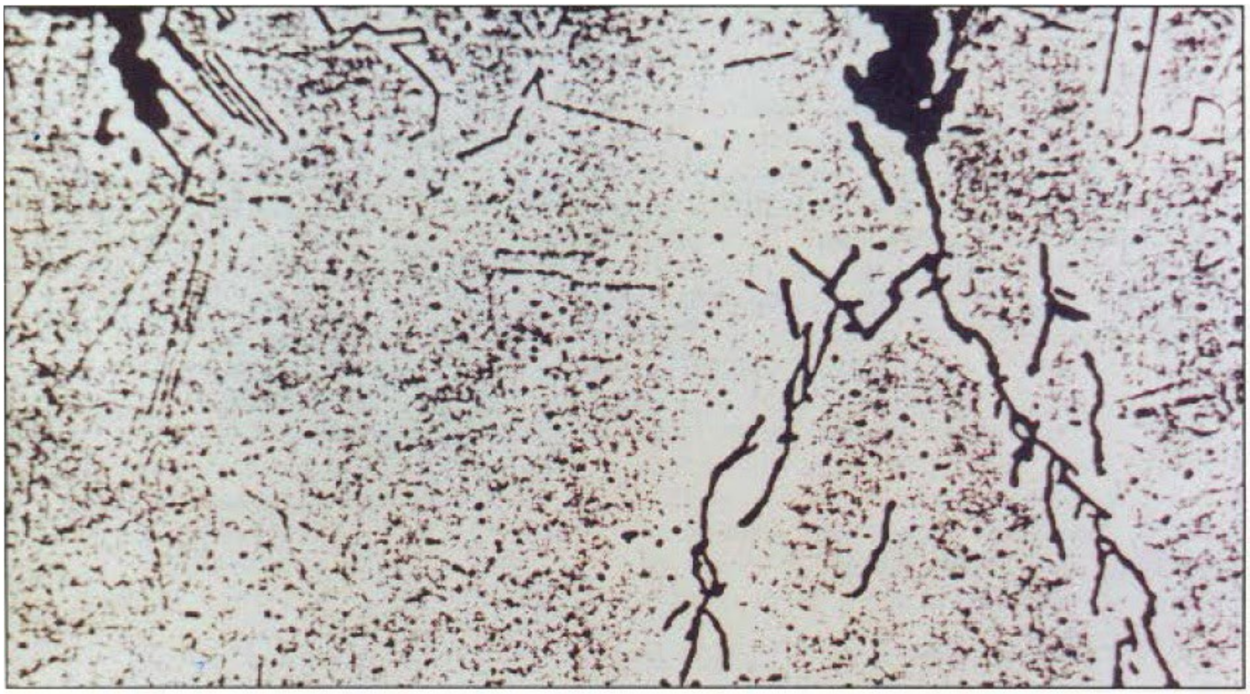
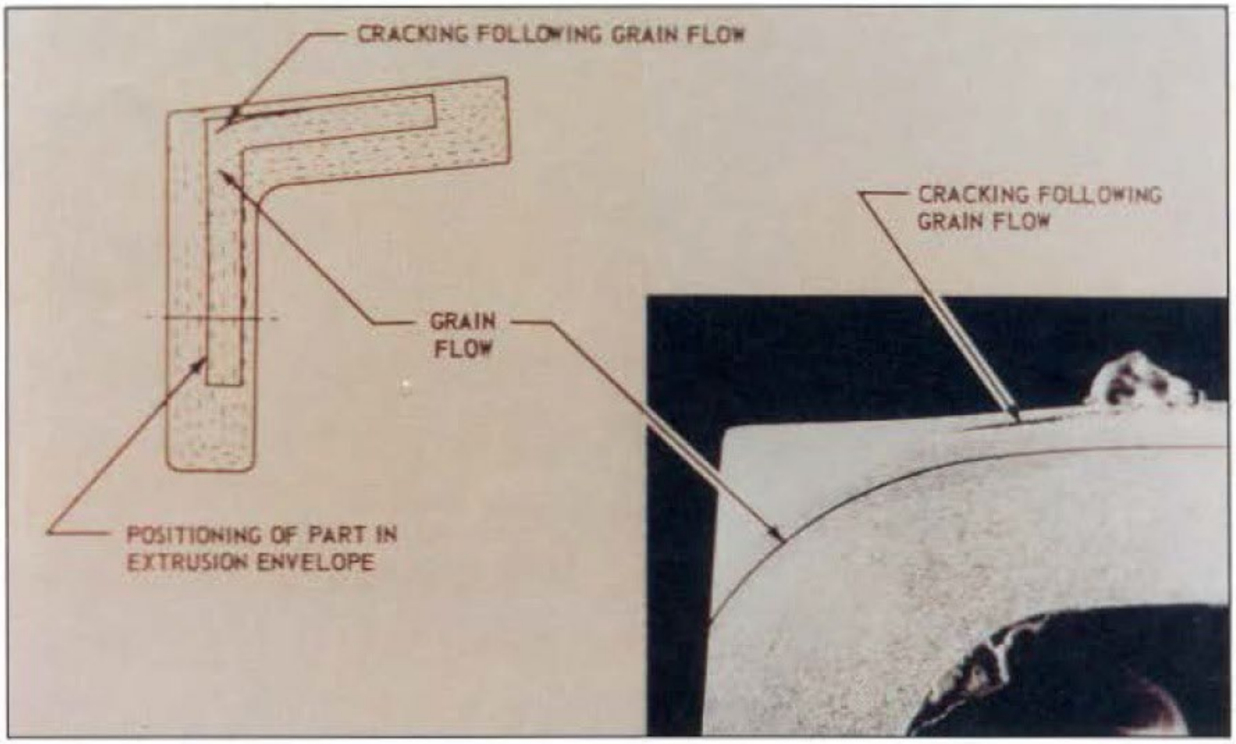


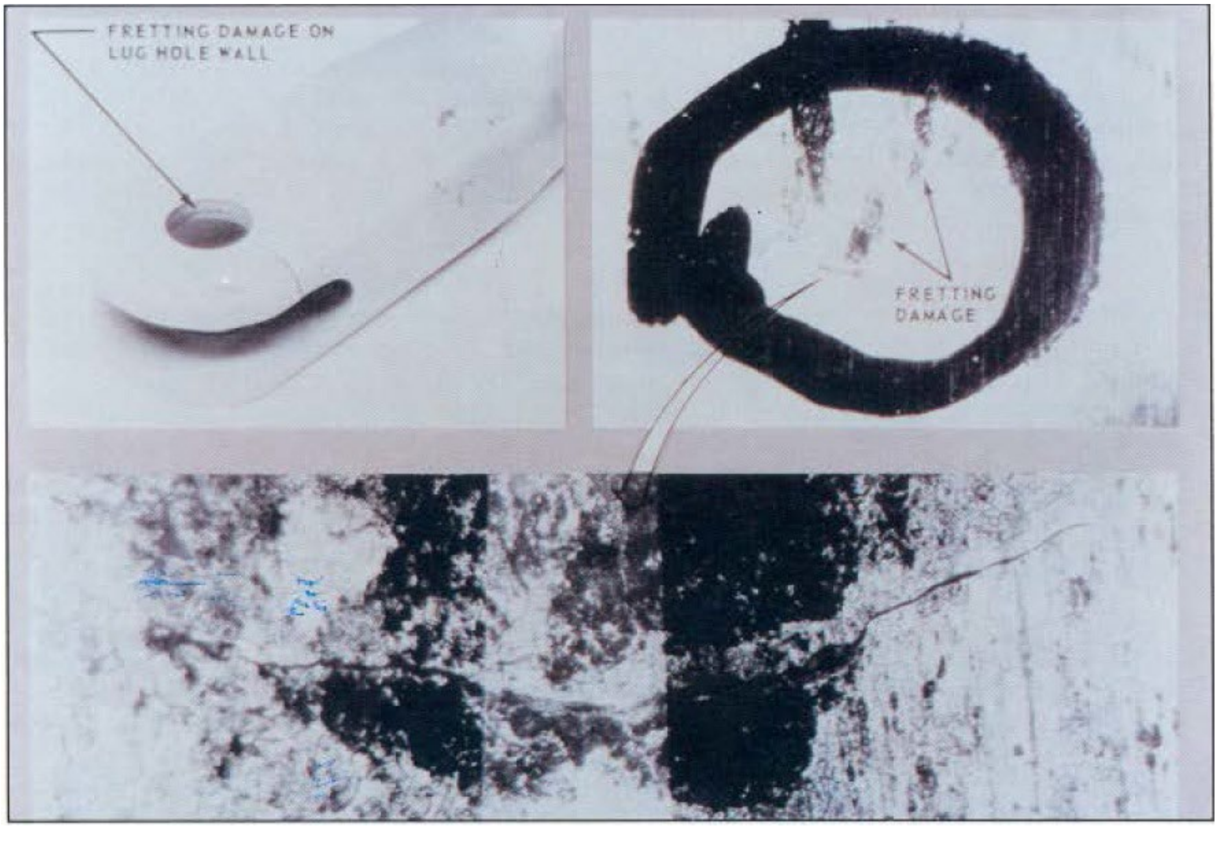
Figure 2-14. Stress-Corrosion Cracking of an Extruded Section



2.6.2 Corrosion Fatigue. Cyclic stress and corrosion combine to form this type of stress in two stages. No metal is immune to cyclic stressing if the metal is in a corrosive environment. However, damage from corrosion fatigue is greater than damage from both cyclic stresses and corrosion. Corrosion fatigue failure occurs in two stages. During the first stage, corrosion and cyclic stress severely damage the metal by pitting and crack formation. Fracture by cyclic stressing will ultimately occur, even if the corrosive environment is completely removed. The second stage is propagation of the crack, often spreading from corrosion pits. Stress concentration effects and the physical properties of the metal primarily control the cracking. Fracture of a metal part by fatigue corrosion generally occurs at a stress level far below the fatigue limit in laboratory air, even though corrosion is relatively minor. For this reason, it is particularly important to protect all parts subject to cyclic stress, even in mildly corrosive environments.

2.6.3 Fretting Corrosion. Damage can occur at the interface of two highly loaded surfaces held immobile against each other. However, vibration may cause the surfaces to rub together resulting in an abrasive wear called fretting. This rubbing action removes any protective film on the metallic surfaces. Continued rubbing of the two surfaces prevents formation of protective oxide film and exposes fresh active metal to the atmosphere. Fretting can cause severe pitting, as shown in Figure 2-15, Fretting Corrosion and Cracking from Cyclic Loading of Lug. Prevention measures include vibration dampening, tightening joints, applying a lubricant, or installing a fretting-resistant material between the two surfaces.

Figure 2-15. Fretting Corrosion and Cracking from Cyclic Loading of Lug



2.6.4 Heat Treatment. Rigidly control heat treatment of airframe materials to maintain corrosion resistance and improve essential mechanical properties. If heat treatment of a clad aluminum alloy is too long or at too high a temperature, this may diffuse the cladding, degrade the cladding’s inherent resistance to corrosion, and reduce its protection of the core aluminum alloy. Aluminum alloys with heavy amounts of copper and zinc are highly vulnerable to intergranular corrosion attack if not quenched rapidly during heat treatment. Stainless steel alloys are susceptible to carbide sensitization when slowly cooled after welding or after high temperature heat treatment. Post-weld heat treatments are normally advisable for reduction of residual stress.

2.6.5 Hydrogen Embrittlement.

2.6.5.1 Environmentally induced failures may often be the result of hydrogen damage rather than oxidation. Atomic hydrogen is a cathodic product of many electrochemical reactions, forming during naturally occurring corrosion reactions, as well as during many plating or pickling processes. Whether hydrogen is liberated as a gas or atomic hydrogen is absorbed by the metal depends on the surface chemistry of the metal.

2.6.5.2 Atomic hydrogen, due to its small size and mass, has very high diffusivity in most metals, and penetrates most clean metal surfaces easily and migrates rapidly to favorable sites where it may remain in solution; precipitate as molecular hydrogen to form small pressurized cavities, cracks, or large blisters; or react with the base metal or with alloying elements to form hydrides.

2.6.5.3 The accumulation of hydrogen in high-strength alloys often leads to cracking, which often occurs in statically loaded components several hours or even days after applying a load or after exposure to a hydrogen source. This type of cracking is also called hydrogen stress cracking, hydrogen delayed cracking, or hydrogen-induced cracking. Similar fracture processes can occur in new and unused parts after heat treatments or machining then exposure to a hydrogen source. For this reason, processing must use well-controlled conditions to minimize the amount of hydrogen generated in processes such as pickling or electroplating.

2.7 Common Corrosive Agents. Substances that cause corrosion of metals are called corrosive agents. The most common of these agents are acids, alkalis, and salts. The atmosphere and water, the two most common media for these agents, may act as corrosive agents as well.

2.7.1 Acids. In general, moderately strong acids will severely corrode most airframe alloys. The most destructive of these corrosive agents are sulfuric acid, present in battery acid; halogen acids, such as hydrochloric, hydrofluoric, and hydrobromic acids; nitrous oxide compounds; and organic acids in human and animal wastes.

2.7.2 Alkalis. Although alkalis are generally not as corrosive as acids, alkali solutions aggressively attack aluminum and magnesium alloys unless they contain a corrosion inhibitor. Washing soda; potash, of which wood ashes are an example; and lime, with cement dust as an example, are particularly corrosive to aluminum. However, ammonia, another alkali, is an exception because aluminum alloys are highly resistant to it.

2.7.3 Salts. Most salt solutions are good electrolytes and can promote corrosive attack. Some stainless steel alloys are resistant to salt solutions, but aluminum alloys, magnesium alloys, and other steels are extremely vulnerable. It is harmful to expose airframe materials to salts or salt solutions.

2.7.4 The Atmosphere. Major corrosive agents existing in atmospheric air are oxygen and airborne moisture, both in abundant supply. Corrosion often results from direct action of atmospheric oxygen and moisture on metal, and additional moisture often accelerates corrosive attack, particularly on ferrous alloys. However, the atmosphere in industrial and marine environments may also contain other corrosive gases and contaminants which are unusually corrosive.

2.7.4.1 Industrial atmospheres contain many contaminants, but most common are partially oxidized sulfur compounds. When these sulfur compounds combine with moisture, they form highly corrosive, sulfur-based acids destructive to most metals. At chemical industrial plants, other corrosive atmospheric contaminants may be present in large quantities, but such conditions are usually confined to a specific location.

2.7.4.2 Marine atmospheres contain chlorides such as salt particles or droplets of salt-saturated water. Since salt solutions are electrolytes, they corrosively attack aluminum and magnesium alloys, which are vulnerable to this type of environment.

2.7.5 Water. The corrosiveness of water depends on the dissolved minerals, organic impurities, and dissolved gasses, particularly oxygen, in the water. One characteristic of water which promotes corrosion is conductivity, or the ability to act as an electrolyte and conduct a current. Physical factors, such as water temperature and velocity, also have a direct bearing on corrosiveness.

2.7.5.1 The most corrosive of natural waters, seawater, and fresh waters are those that contain salts. Seawater is extremely corrosive due to the presence of chloride ions, but waters in harbors are often more corrosive because of industrial waste contamination combined with seawater.

2.7.5.2 The corrosive effects of fresh water vary from locality to locality due to the concentration of dissolved impurities in any particular area. Some municipal potable water supplies with chlorine and fluorides added can be quite corrosive. Commercially softened water and industrially polluted rain water are usually very corrosive.

2.8 Microorganisms.

2.8.1 Microbial corrosive attack comes from the actions of bacteria, fungi, or molds. Microorganisms occur nearly everywhere, and bacteria and fungi cause the greatest corrosion problems.

2.8.2 Bacteria may be either aerobic, requiring oxygen to live, or anaerobic, surviving only when free oxygen is not present. Bacteria accelerate corrosion by oxidizing sulfur to produce sulfuric acid. Bacteria living adjacent to metals may promote corrosion by depleting the oxygen supply or releasing metabolic by-products oxidation of inorganic compounds such as iron, sulfur, hydrogen, or carbon monoxide. The resultant chemical reactions cause corrosion.

2.8.3 Fungi are the growths of microorganisms that feed on organic materials. While low humidity does not kill microbes, it slows their growth and may prevent corrosion damage. Ideal growth conditions for most microorganisms are: 1) temperatures between 68 °F and 104 °F, or 20 °C and 40 °C, and 2) relative humidity between 85 percent and 100 percent. Mold, bacteria, or other microbes attack some moisture-proofing coatings, especially if the coated surfaces are contaminated. This is counter to the former belief that operators could prevent fungal attack by either applying moisture-proofing coatings to nutrient materials, or by drying compartment interiors with desiccants. Microbial growth occurs at the interface of water and an aviation fuel, where the fungus feeds only on a fuel. Fungi produce organic acids, alcohols, and esters as a by-product of their growth, and these by-products provide even better growing conditions for the fungus. The fungus typically attaches itself to the bottom of a tank, looks like a brown deposit on the tank coating when the tank is dry, and may start growing again when water and fuel are present.

2.8.4 The spore form of some microorganisms can remain dormant for long periods while dry and can become active when moisture is available. When desiccants become saturated and cannot absorb moisture passing into the affected area, microorganisms can begin to grow. Dirt, dust, and other airborne contaminants are the least recognized contributors to microbial attack. Unnoticed, small amounts of airborne debris may be sufficient to promote fungal growth.

2.8.5 As a rule of thumb, fungi nutrients are only those materials derived from plants or animals. Thus, wool, cotton, rope, feathers, and leather provide sustenance for microbes, while metals and minerals do not. This rule of thumb is mainly still valid, but the increasing complexity of synthetic materials makes it difficult or impossible to determine from the name alone whether a material will support fungus. Many otherwise resistant synthetics are susceptible to fungal attack by chemicals added to change a material’s properties.

2.8.6 Damage resulting from microbial growth can occur when any, or a combination of, three basic mechanisms come into play. First, fungi are damp and have a tendency to hold moisture, which contributes to other forms of corrosion. Second, because fungi are living organisms, they need food to survive. This food is obtained from the material on which the fungi are growing. Third, these microorganisms secrete corrosive fluids that attack many materials, including some that are not fungi nutrient.

2.8.7 Remove microbial growth completely to avoid corrosion. A common practice is to remove microbial growth by hand with a firm, nonmetallic bristle brush and water. Microbial growth removal is easier if the growth is kept wet with water. Microbial growth may also be removed with steam at 100 pounds per square inch (psi) and steam temperatures not exceeding 150 °F, or 66 °C. Protective clothing should be worn when using steam for removing microbial growth.

Note: Steam at 100 psi may damage, lift, or remove some paints or sealants.

2.9 Metallic Mercury Corrosion on Aluminum Alloys. Spilled mercury on aluminum should be cleaned immediately because mercury causes corrosion attack, which is rapid in both pitting and intergranular attack and is very difficult to control. The most devastating effect of mercury spillage on aluminum alloys is the formation of an amalgam which proceeds rapidly along grain boundaries, causing liquid metal embrittlement. If the aluminum alloy part is under tension stress, this embrittlement will result in splitting with an appearance similar to severe exfoliation. X ray inspection may be an effective method of locating the small particles of spilled mercury because the dense mercury will show up readily on the x ray film.

2.10–2.99. RESERVED.

CHAPTER 3. EFFECTS OF CORROSION

3.1 General. Most metals corrode, but corrosion can be minimized by using corrosion-resistant metals and finishes. The principal material in airframe structures is high-strength aluminum alloy sheet coated, or clad, with a pure aluminum coating, called Alclad, which is highly resistant to corrosive attack. However, pitting of the Alclad will occur with an accumulation of airborne salts or industrial pollutants, and an electrolyte, such as moisture. Once the Alclad surface is broken, rapid deterioration of the high-strength aluminum alloy below occurs. Other metals commonly used in airframe structures require special preventive measures to guard against corrosion, such as non-clad, high-strength aluminum alloys, steel, and magnesium alloys.

3.1.1 Aluminum alloys typically have anodize or conversion coatings, which are primed or primed and topcoated. In some later generation aircraft, operators apply an aluminum plating using the ion vapor disposition (IVD) process, then prime and possibly topcoat the surface with paint.

3.1.2 Brass and bronze require cadmium plating, zinc plating, IVD aluminum coating, or a conversion coating. Most stainless steels do not need this protective coating.

3.1.3 Magnesium alloys are highly susceptible to corrosion attack, especially where airborne salts or industrial pollutants are present, and require special chemical and electrochemical treatments and paint finishes.

3.2 Effects of Corrosion on Metals. Below is a list of the characteristics and common properties of corrosion in commonly used aircraft metals:

3.2.1 Magnesium. This is a chemically active metal used in airplane construction, highly susceptible to corrosion, and difficult to protect. When a failure in the protective coating occurs, the coating should be promptly and completely repaired to avoid serious structural damage. Magnesium corrosion is possibly easiest to detect since, even in its early stages, corrosion products occupy several times the volume of the original magnesium metal. The beginning attack appears as a lifting of the paint film and as white spots on the surface which rapidly develop into snow-like mounds or whiskers. Correction of damage involves completely removing corrosion and applying a chemical conversion coat and protective finish. Magnesium always requires protective coatings, and some magnesium parts in current aircraft have been initially protected by proprietary electrolytic processes, such as HAE and DOW 17 coatings. The HAE process can be identified by the brown or mottled gray appearance of the unpainted surface. DOW 17 coatings have a green to grayish-green color. Electrolytic coatings are thicker than those applied by immersion or brushing. Electrolytic finishes cannot be restored in the field. Take care to minimize removal and repair of these coatings.

3.2.2 Steel. Corrosion of steel is easily recognized because the corrosion product is red rust. When iron-based alloys corrode, dark corrosion products usually form first on the surface of the metal. These products are protective, but if moisture is present, this ferrous oxide coating is converted to hydrated ferric oxide, or red rust. This material will promote further attack by absorbing moisture from the air. The most practical means of controlling corrosion of steel is complete removal of corrosion products by mechanical means and by maintaining the protective coating system, usually by a plating, and often combined with a paint system.

Note: Stainless steels generally do not exhibit red rust and should be assessed with the criteria in paragraph 3.2.7.

3.2.3 Aluminum. Aluminum and its alloys exhibit a wide range of corrosive attack, including uniform surface, galvanic, pitting, intergranular, exfoliation, crevice, stress, and fretting corrosion (see paragraphs 2.5 and 2.6). Where airborne salts or industrial pollutants are present, all aluminum alloys require protection. The corrosion product of aluminum is a white-to-gray powdery material which can be removed by mechanical polishing or brushing with materials softer than the metal. General surface attack of aluminum penetrates slowly but is accentuated in the presence of dissolved salts in an electrolyte. Corrosion must be addressed when present, even in small amounts. Some alloys resist general corrosion and instead corrode by pitting or intergranular attack, which can affect the structural strength without appearing widespread. However, at least three forms of attack on aluminum alloys are particularly serious:

1. Penetrating, pit-type corrosion through walls of aluminum tubing.
2. Stress-corrosion cracking of materials under sustained stress and corrosive environment.
3. Intergranular attack characteristic of certain alloys where clearly defined grain boundaries differ chemically from the metal within the grain.

3.2.4 Anodized Aluminum. Some aluminum parts are protected with an anodized coating. Aluminum oxide film on aluminum is naturally protective, and anodizing merely increases the thickness of the oxide film. When this coating is damaged in service, the coating can be partially restored by chemical surface treatment. As only partial restoration is possible, avoid unnecessary destruction of the anodized surface when performing any processing of the surface.

3.2.5 Titanium. Titanium is prone to cause severe corrosion of adjacent parts through galvanic corrosion. Titanium parts may be galvanically isolated from adjacent parts through barrier coatings or films. Frequent inspection for degradation of these barrier films and inspection for corrosion of adjacent parts is recommended. Contact with zinc and cadmium-plated parts can promote cracking of the titanium.

3.2.6 Cadmium and Zinc. Cadmium as a coating protects steel parts and provides a compatible surface when a part contacts other materials. Attack on cadmium is evidenced by a white-to-brown-to-black mottling of the surface. Zinc forms large amounts of white corrosion products. When cadmium and zinc plate show mottling and isolated voids or cracks in the coating, the plating is still performing its protective function. The cadmium plate on iron or steel is still protecting its core until actual iron rust appears.

Note: Any mechanical removal of corrosion products should be limited to metal surfaces from which the cadmium has been depleted.

3.2.7 Stainless Steels. These metals are iron-base alloys containing 12 percent or more chromium and other elements, with both magnetic and nonmagnetic properties. Magnetic steels are identified by numbers in the American Iron and Steel Institute (AISI) 400 series, such as 410 or 430. These steels are less corrosion resistant than the nonmagnetic alloys, which you identify by numbers in the AISI 300 series, such as 304 or 316. The AISI 300-series steels have nickel content ranging from 6 to 22 percent, while 400-series steels have nickel content of only 2 percent. The corrosion resistance of these steels lies in their ability to form a protective oxide film on the surface. This "passive" film can be reinforced by treatment in certain chemical solutions. However, such steels will also pit when exposed to harsh corrosive environments, such as airborne salts and industrial pollutants. Stainless steels are highly susceptible to crevice/concentration cell corrosion and stress-corrosion cracking in moist, salt-laden environments and can cause galvanic corrosion of almost any other metal with which they are in contact if proper techniques of sealing and protective coating are ignored. Precipitation hardening stainless steels such as PH17-4, PH15-5, and PH13-8Mo. are now more widely used as compared to 400 series stainless. Corrosion can be prevented by keeping stainless steel clean.

3.2.8 Nickel and Chromium. These metals are protective coatings and alloying elements with iron in stainless steels. Chromium plating also provides a smooth, wear-resistant surface and reclaims worn parts. A nickel undercoat enhances corrosion resistance in a marine environment. The degree of protection is dependent upon plating thickness. Both metals form continuous oxide coatings that you can polish to a higher luster and still protect not only themselves but any underlying metal. Chromium coatings contain cracks, and corrosion originates in these separations.

3.2.9 Copper and Copper Alloys. These are generally corrosion resistant. However, the effects of minor amounts of corrosion on copper electrical components can appreciably degrade the performance of the components. The product of corrosion on copper is generally a bluish-green coating on the surface of the material. When coupled with most metals used in aircraft construction, copper is the less chemically active metal and greatly accelerates corrosion of other metals.

3.2.10 Silver, Platinum, and Gold. These metals do not corrode in the ordinary sense, although silver tarnishes as a brown-to-black film in the presence of sulfur. Gold tarnish is very thin and shows up as a darkening of reflecting surfaces.

3.2.10.1 When silver is plated over copper, accelerated corrosion of the copper through galvanic action can occur at pinholes or breaks in the silver plating. This corrosion is "red plague," and presents as a brown-red powder deposit on the exposed copper.

3.2.10.2 "Purple plague" is a brittle gold-aluminum compound formed when bonding gold to aluminum. The growth of such a compound can cause failure in microelectronic interconnection bonds.

3.2.11 Tin. This material is common on radio frequency (RF) shields, filters, crystal covers, and automatic switching devices. Tin has the best combination of solderability and corrosion resistance of any metallic coating.

Table 3-1. Corrosion of Metals

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 (4000–8000 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-gray 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, or 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 Alloy	Generally corrosion-resistant; exposure to very high temperatures in air can lead to corrosion product formation on the surface of parts made from nickel; exposure to stagnant seawater can lead to surface pitting due to crevice/concentration cell corrosion	Green powdery deposit on the surface
Nickel-Based (Inconel, Monel)	Generally has good corrosion resistant qualities; susceptible to pitting in sea water	Green powdery deposit
Copper-Based 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

ALLOY	TYPE OF ATTACK TO WHICH ALLOY IS SUSCEPTIBLE	APPEARANCE OF CORROSION PRODUCT
Silver	Will tarnish in the presence of sulfur	Brown-to-black film
Gold	Highly corrosion resistant	Deposits cause darkening of reflective surfaces

3.3–3.99. RESERVED.

CHAPTER 4. CORROSION-PRONE AREAS AND PREVENTIVE MAINTENANCE

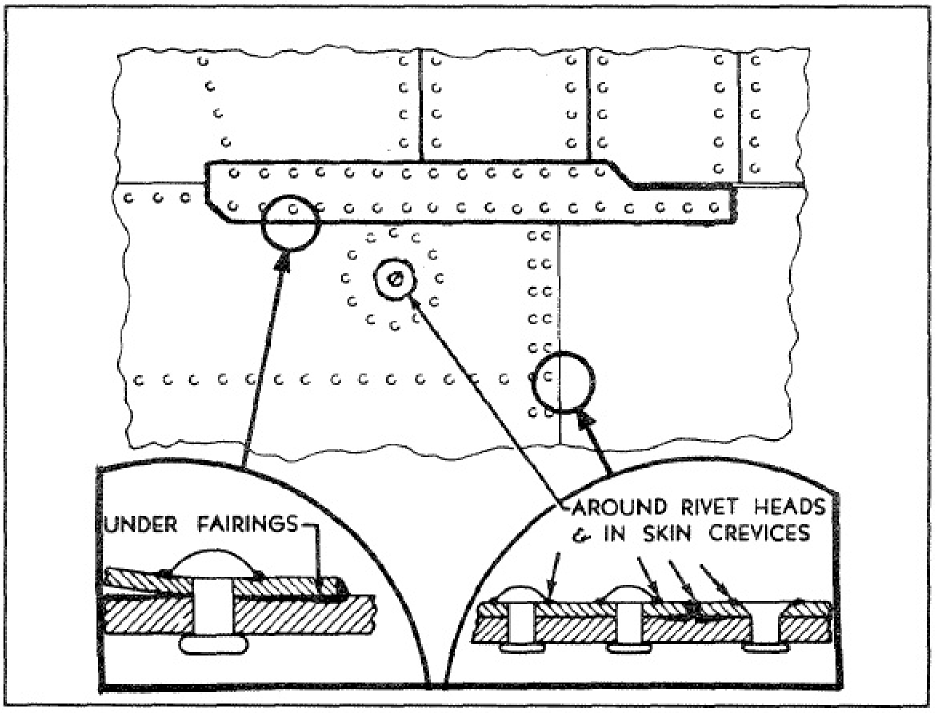
4.1 General. This chapter lists corrosion problem areas common to most aircraft. Be aware to clean, inspect, and treat corrosion-prone areas more frequently. The list is not intended for a specific aircraft, but it can be used to set up a maintenance inspection program. This chapter also includes factors in corrosion control and preventive maintenance.

4.2 Exhaust Trail Areas. Both jet and reciprocating engine exhaust gas deposits are very corrosive. Inspection and maintenance of exhaust trail areas should include attention to areas indicated in Figure 4-1, Exhaust Trail Area Corrosion Control Points, and inspection should include removal of fairings and access plates in the exhaust gas path.

4.2.1 Gaps, seams, hinges, and fairings are areas where exhaust trail deposits may be trapped and normal cleaning methods cannot reach these areas.

4.2.2 Exhaust deposit buildup on the upper and lower wing, aft fuselage, and in the horizontal tail surfaces will be considerably slower and sometimes completely absent on certain aircraft models.

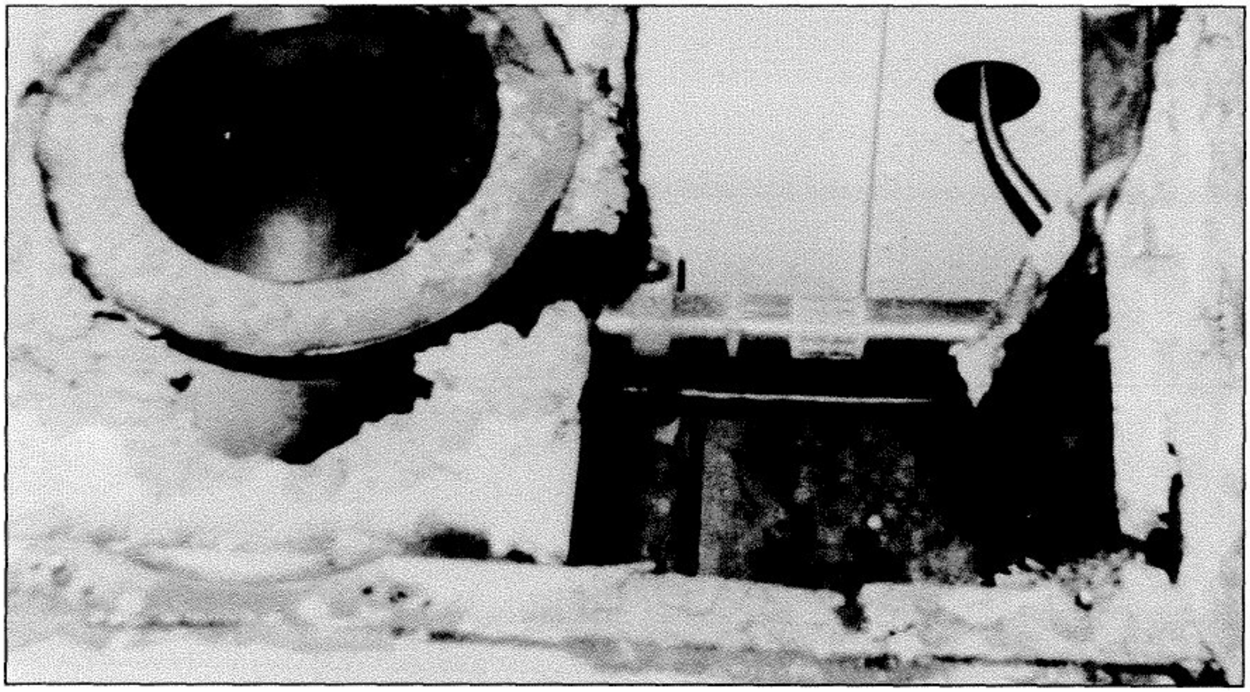
Figure 4-1. Exhaust Trail Area Corrosion Control Points



4.3 Battery Compartments and Battery Vent Openings. In spite of protective paint systems and extensive sealing and venting, battery compartments continue to be corrosion problem areas. Fumes from overheated battery electrolyte are difficult to contain and can spread to internal structures where unprotected surfaces can come under corrosive attack. For lead-acid batteries, frequent cleaning and neutralization of acid deposits with sodium bicarbonate solution will minimize corrosion. If the battery installation includes external vent openings on the aircraft skin, these areas should be included in inspection and maintenance procedures. If aircraft have batteries with electrolytes of either sulfuric acid or potassium hydroxide, electrolyte leakage will cause corrosion. Consult applicable maintenance manuals to determine the battery type installed and recommended maintenance practices. Clean nickel cadmium compartments with ammonia or boric acid solution, dry thoroughly, then paint with an alkali-resistant varnish.

4.4 **Lavatories, Buffets, Galleys, Doorways, and Cockpit Floorboards.** These areas, particularly deck areas behind lavatories, sinks, and ranges, are potential trouble areas where spilled food and waste products may collect. Even though some contaminants are not corrosive, they will attract and retain moisture, and promote corrosive attack. Pay particular attention to bilge areas and aircraft structure located under galleys and lavatories. Clean these areas frequently and maintain protective sealant and paint finishes.

Figure 4-2. Typical Damage to Floor Around Lavatories, Buffets, and Galleys



4.5 **Bilge Areas.** On all aircraft, the bilge area is a common trouble area. The bilge is a natural sump or collection point for waste hydraulic fluids, water, dirt, loose fasteners, drill chips, and other debris. Residual oil quite often masks small quantities of water which settle to the bottom and set up a hidden potential corrosion cell. Except for water displacing corrosion-preventing compounds, keeping bilge areas free of extraneous material, including water and oil, will insure the best protection against corrosion. A good vacuum cleaner and clean wiping cloths are handy tools to clean such areas.

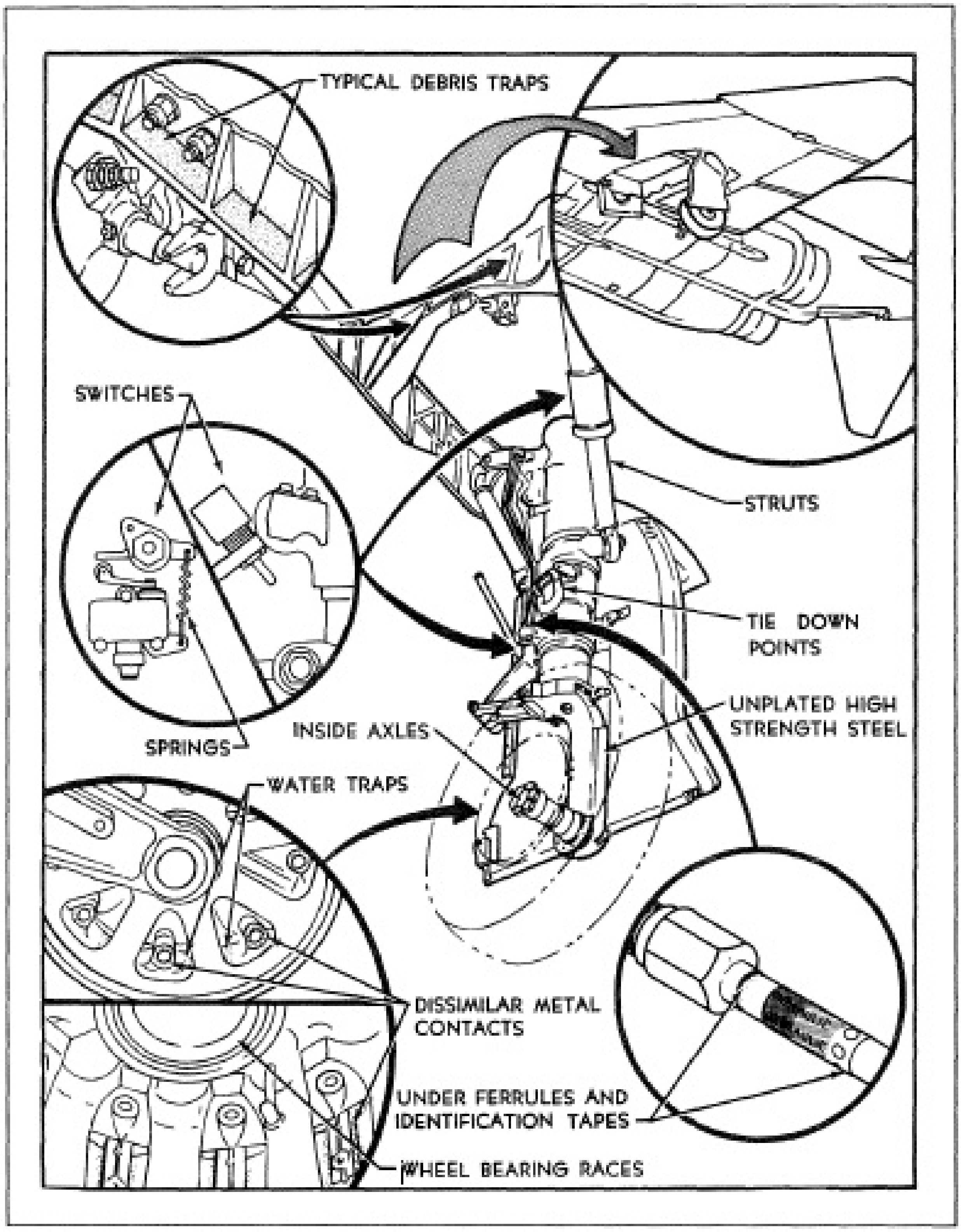
4.6 **Wheel Wells and Landing Gear.** The wheel well area probably receives more punishment than any other area of the aircraft. It is exposed to mud, water, salt, gravel, and other flying debris from runways during flight operations. See Figure 4-3, Landing Gear and Wheel Corrosion Points.

4.6.1 Aircraft wheels and wheel well areas should receive frequent cleaning, lubrication, and paint touch-up. Because of many complicated shapes, assemblies, and fittings in the area, complete coverage with a protective paint film is difficult, and preservative coatings tend to mask trouble rather than prevent it. Do not use preservative coatings on landing gear wheels because of the heat generated from braking.

4.6.2 During inspection of this area, pay particular attention to these trouble areas:

- Aluminum and high-strength steel.
- Exposed surfaces of struts, oleos, arms, links, and attaching hardware, such as bolts or pins.
- Axle interiors.
- Exposed position indicator switches and other electrical equipment.
- Crevices between stiffeners, ribs, and lower skin surfaces, typical water and debris traps.
- Magnesium wheels, particularly around bolt heads, lugs, and wheel web areas.
- Exposed rigid tubing, especially at “B” nuts and ferrules under clamps and tubing identification tapes.

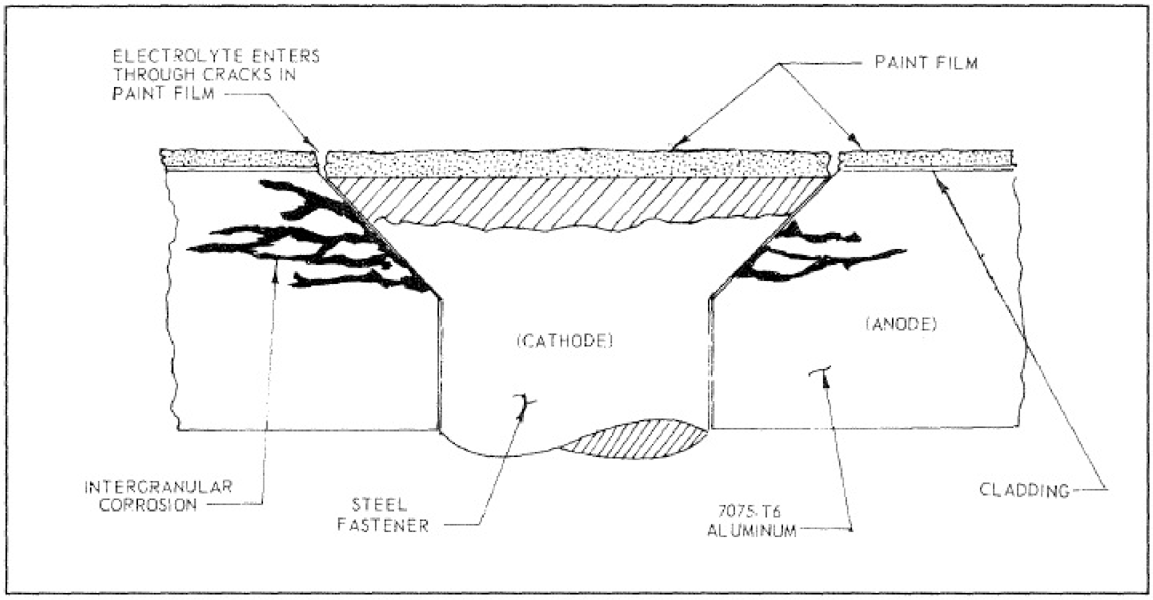
Figure 4-3. Landing Gear and Wheel Corrosion Points



4.7 External Skin Areas. External aircraft surfaces are ordinarily covered with protective finishes, and operators can also apply paint coatings. Affected external aircraft surfaces are readily visible or available for inspection and maintenance. Much emphasis has been given to these areas in the past, and maintenance procedures are well established. Even here, certain configurations or combinations of materials become troublesome and require special attention to avoid serious corrosion difficulties. Some common trouble areas are listed below, other than those attributed to engine exhaust deposits:

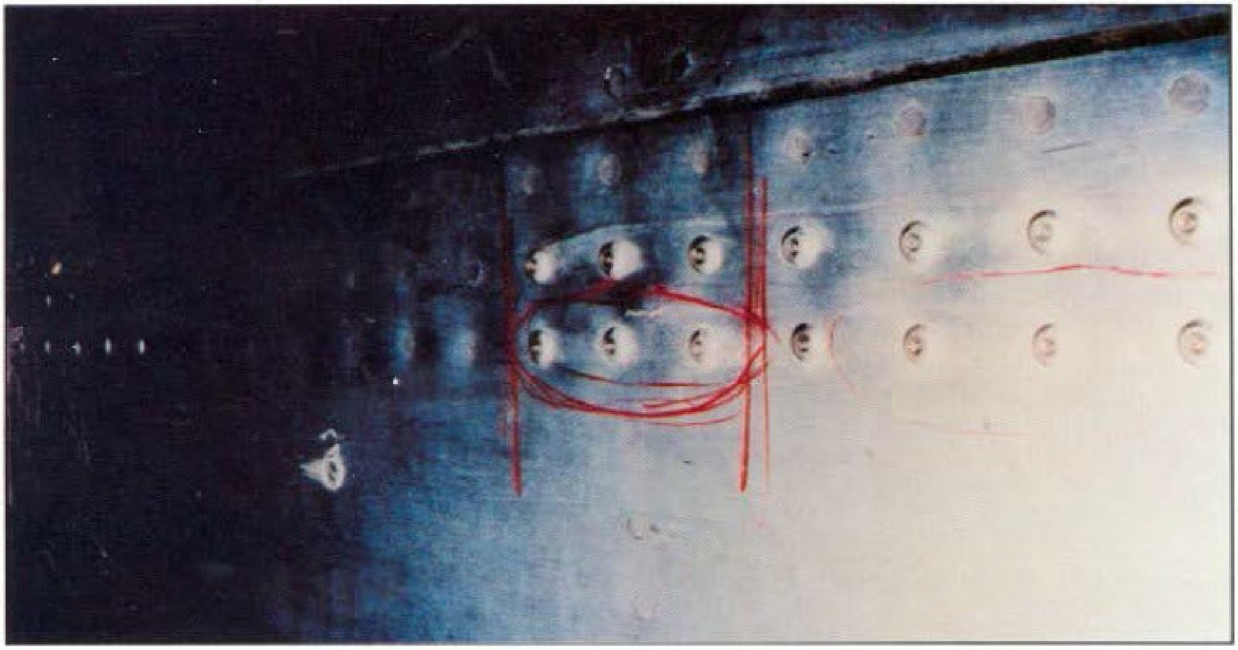
4.7.1 Steel, Titanium, Corrosion Resistant Steel (CRES), and Nickel Alloy Fasteners. Fasteners, and areas around these fasteners, are trouble areas. These areas are subject to high operational loads, moisture intrusion, and dissimilar metal skin corrosion. See Figure 4-4, Intergranular Corrosion of 7075-T6 Aluminum Adjacent to Steel Fastener.

Figure 4-4. Intergranular Corrosion of 7075-T6 Aluminum Adjacent to Steel Fastener



4.7.2 Faying Surfaces and Crevices. Similar to corrosion around fasteners, corrosion in faying surfaces, seams, and joints results from intrusion of moisture and other corrosive agents. The effect of this type of corrosion is usually detectable by bulging of the skin surface.

Figure 4-5. Crack and Skin Bulging Caused by Corrosion



4.7.3 Magnesium Skins. Properly surface-treated, insulated, and painted magnesium skin surfaces give relatively little corrosion-related trouble if the original surface is maintained. However, trimming, drilling, and riveting destroy some of the original surface treatment, which may not be completely restored by touch-up procedures.

4.7.3.1 Some aircraft have steel fasteners installed through a magnesium skin, with only protective finishes under the fastener heads and fillet sealant or tape over the surface for insulation. Paint coatings are inherently thin at abrupt changes in contour, such as at trimmed edges. With magnesium's sensitivity to moisture, these conditions add up to a potential corrosion problem whenever magnesium is used.

4.7.3.2 Corrosion inspections should include all magnesium skin surfaces and magnesium fittings or structural components, with special attention to edges, areas around skin edges and fasteners, and cracked, chipped, or missing paint.

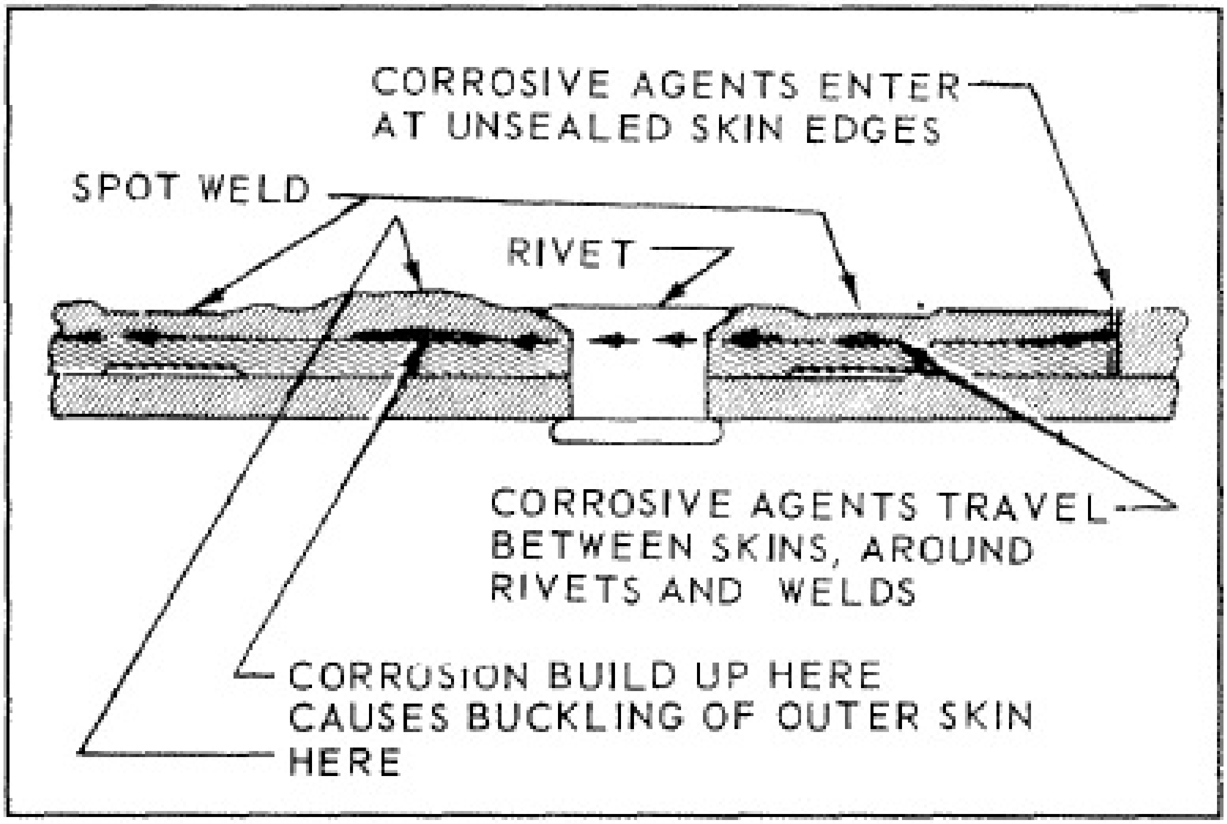
4.7.4 Spot-Welded Skins. Corrosion of this type is chiefly the result of the entrance and entrapment of moisture or other corrosive agents between layers of metal. See Figure 4-6, Spot-Welded Skin Corrosion.

4.7.4.1 Spot-welded assemblies are particularly corrosion prone, and corrosive attack causes skin buckling or spot-weld bulging and fracture. This type of corrosion is evidenced by corrosion products appearing at crevices through which the corrosive agents enter. Some corrosion may originate from fabricating processes, but its progress to the point of skin bulging or spot-weld fracture is the direct result of moisture or other corrosive agents moving through open gaps or seams. Weld-through sealing materials should minimize this problem, but many in-service aircraft have unsealed spot-weld skin.

4.7.4.2 Corrosion may appear at either external or internal faying surfaces, but is usually more prevalent on external areas. More advanced corrosive attack causes skin buckling and eventual spot-weld fracture. Detect skin buckling in this early stage by sighting or feeling along spot-welded seams or by using a straight edge to show variations along the skin.

4.7.4.3 To prevent this condition, keep potential moisture entry points (such as gaps, seams, and holes created by broken welds) filled with a noncorrosive sealant.

Figure 4-6. Spot-Welded Skin Corrosion



4.7.5 Piano-Type Hinges. These are prime spots for corrosion due to dissimilar metal contact between the steel pin and aluminum hinge tangs. These hinges are also natural traps for dirt, salt, and moisture. Hinges tend to corrode and freeze in the closed position between inspections where they are part of access doors or plate assembly and actuated only when opened during an inspection. When the hinge is inspected, lubricate it and work it through several cycles to enhance lubricant penetration. See Figures 4-7, Hinge Corrosion Points, and 4-8, Hinge Failure Caused by Corrosion.

Figure 4-7. Hinge Corrosion Points

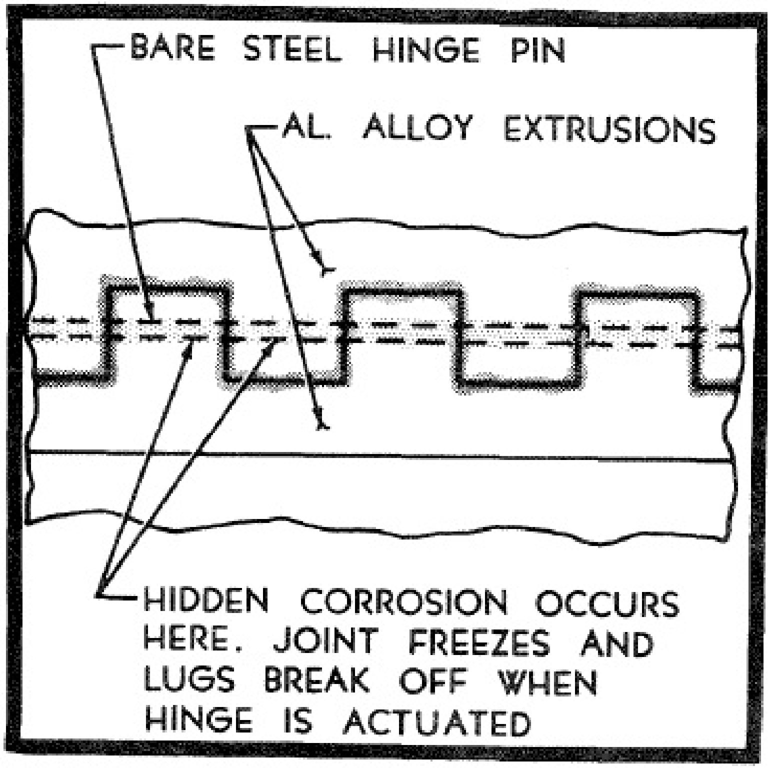
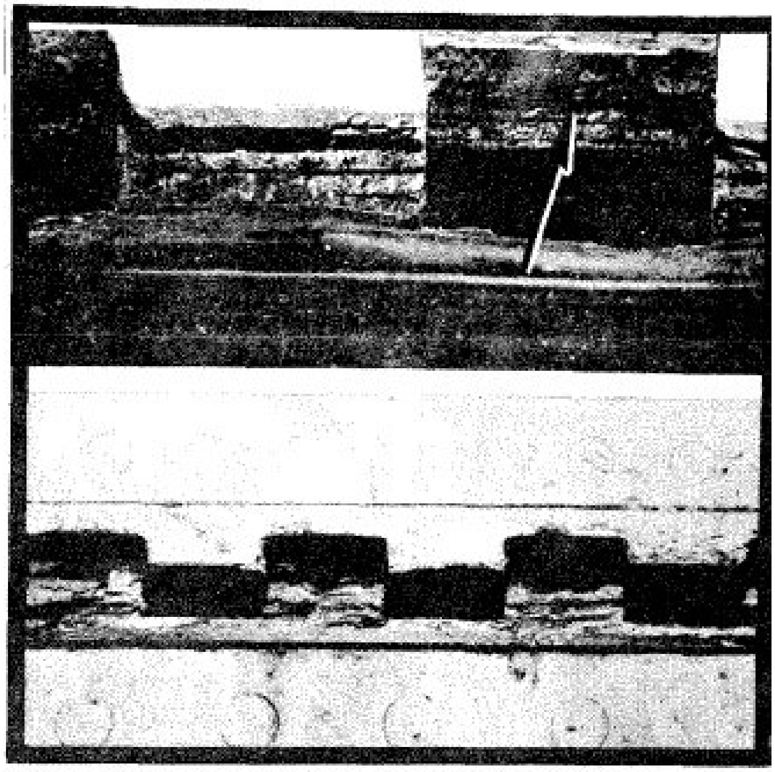


Figure 4-8. Hinge Failure Caused by Corrosion



4.7.6 Heavy or Tapered Aluminum Alloy Skin Surfaces. Heavy or thick sections of most heat-treated aluminum alloys are susceptible to pitting or intergranular corrosion and exfoliation of the metal. When inspecting external skin surfaces, especially around countersunk fastener heads, look for white or gray powder deposits or metal exfoliation. This usually first appears as small, raised areas or bumps under paint film.

4.7.6.1 Treatment of this corrosive attack includes removal of all corrosion products. An example of this product removal is exfoliated metal, which is blended and polished within the limits set by the aircraft manufacturer. If corrosion products remain after reaching limits set by the aircraft manufacturer, contact the aircraft manufacturer for authorized limits. The treatment is not complete until protective surface finishes are fully restored.

4.7.6.2 Protect reworked areas with a chemical conversion coating, sealant primer, and topcoat, if applicable. Watch reworked areas for any indications of renewed corrosive activity.

4.7.7 Organic Composites. Organic composites used in aircraft can cause different corrosion problems than all-metal structures. Composites such as graphite/epoxy act as a very noble, or cathodic, material, creating the electrical potential for galvanic corrosion. The galvanic corrosion potential, coupled with different attachment methods, such as adhesive bonding, stepped structures, or locking mechanical fasteners, leads to multicomponent galvanic couples aggravated by high humidity and saltwater environments. Applying aircraft sealants over dissimilar metal/composite junctions will prevent galvanic corrosion if moisture is completely displaced from the junction. Since moisture displacement is virtually impossible during extended flight operations, the most effective method of eliminating the voltage potential is to provide a nonconductive layer between the composite and dissimilar metal surfaces, such as a fiberglass/epoxy, sealant, or a combination or the two. Application of sealants over dissimilar metal/composite junctions may mask corrosion if the seal is compromised.

4.8 **Water Entrapment Areas.** Corrosion will result from entrapment of moisture. Except for sandwich structures, design specifications usually require that the aircraft have low-point drains in all areas where moisture and other fluids can collect. In many cases, these drains are ineffective either because of location or because they are plugged by sealants, extraneous fasteners, dirt, grease, and debris. Potential entrapment areas are not a problem when properly located drains are functioning and the aircraft has a normal ground attitude and is resting on its landing gear. Plugging a single drain hole or altering the level of the aircraft can result in a corrosion problem if water becomes entrapped in one of these “bathtub” areas, and we recommend a daily inspection of low-point drains.

4.9 **Engine Frontal Areas and Cooling Air Vents.** Constant abrasion by airborne dirt and dust, bits of gravel from runways, and rain all tend to remove protective surfaces from engine frontal areas and cooling air vents. Radiator cooler cores or reciprocating engine cylinder fins, designed for heat dissipation, may not be painted. Engine accessory mounting bases usually have small areas of unpainted magnesium or aluminum on machined mounting surfaces. With moist and salt or industrial pollutant-laden air constantly flowing over these surfaces, they are prime sources of corrosive attack. Inspection of such areas should include all sections in the cooling air path, with special attention to obstructions and crevices where salt deposits may build up during marine operations. See Figures 4-9, Reciprocating Engine Frontal Area Corrosion, and 4-10, Jet Engine Frontal Area Corrosion Points.

Note: When applicable, refer to the engine manufacturer's specific instructions for further guidance.

Figure 4-9. Reciprocating Engine Frontal Area Corrosion

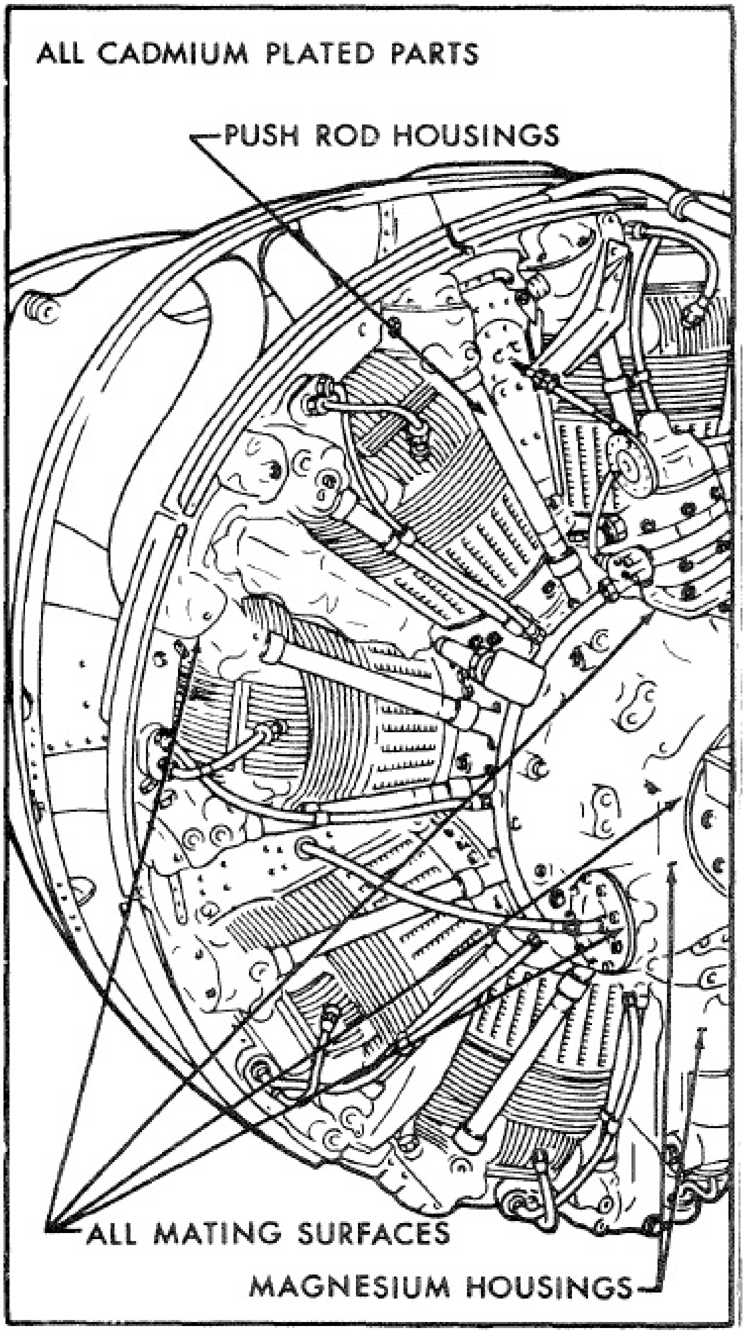
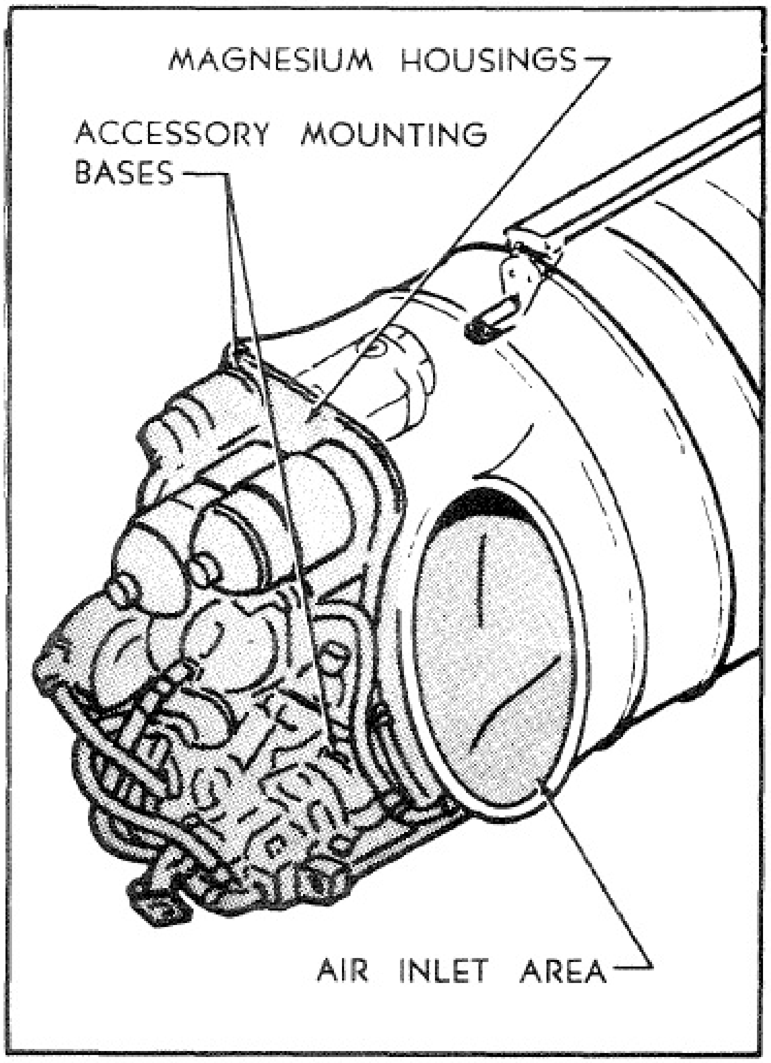


Figure 4-10. Jet Engine Frontal Area Corrosion Points



4.10 Electronic Package Compartments. These areas are cooled by ram air or compressor bleed air and are subject to the same conditions as engine and accessory cooling vents and engine frontal areas. While the degree of exposure is less because of a lower volume of air passing through the compartment and special design features preventing water formation in enclosed spaces, this is still a trouble area needing special attention.

4.10.1 As circuit breakers, contact points, and switches are extremely sensitive to moisture and corrosive attack, inspect for these conditions as thoroughly as the design permits. If design features hinder examination of these items while installed, inspect the items if components are removed for other reasons.

4.10.2 Only qualified personnel familiar with the function of the unit involved should perform or direct the treatment of corrosion in electrical and electronic components, as conventional corrosion treatment may damage some units.

4.10.3 Most corrosion on avionic equipment is similar to basic airframe structure corrosion, but there is a difference: minute amounts of corrosion in avionic equipment can cause serious degradation or complete failure, while similar corrosion on larger structures would go unnoticed.

4.10.4 Smog, smoke, soot, and other airborne contaminants are extremely corrosive to exposed avionic equipment. Many fumes and vapors emitted from factories or industrial complexes are highly acidic and greatly accelerate corrosion. An example is the corrosive effect of ozone, a product of welding machines and large electrical motors. Complete degradation of rubber seals and damage to delicate components have occurred in equipment stored near ozone-producing equipment. Avionic shops and storage areas should have a filtered air conditioning system to help remove ozone from the enclosed shop or storage area.

4.10.5 Another man-made atmosphere is the aircraft environmental control system. These systems direct cooling air to the equipment and may include a filter system that extracts moisture or contaminants from air entering the equipment. Always replace or clean filters, or eliminate leaky environmental seals, to prevent buildup of moisture or contaminants that could cause a corrosive atmosphere inside the equipment.

4.10.6 The control of corrosion in avionic systems is similar to that in airframes, with modifications. Factors affecting corrosion control in avionic equipment include:

- Less durable protection systems;
- Small amounts of corrosion can make equipment inoperative;
- Dissimilar metals are often in electrical contact;
- Stray currents can cause corrosion;
- Active metals and dissimilar metals in contact are often unprotected;
- Closed boxes can produce condensation during normal temperature changes during flight;
- Avionic systems have many areas to trap moisture;
- Hidden corrosion is difficult to detect in many avionic systems;
- Many materials in avionic systems are subject to attack by bacteria and fungi; and
- Organic materials, when overheated or improperly or incompletely cured, can produce vapors corrosive to electronic components and damaging to coatings and insulators.

4.11 **Miscellaneous Trouble Areas.** Additional trouble areas exist, some of which are covered by manufacturer publications. Below is a list of common trouble areas:

4.11.1 Examine and replace all flexible hose assemblies with chafing, weather checking, hardening, discoloration, evidence of fungus, and torn weather protective coatings or sleeves.

4.11.2 Trimmed edges of sandwich panels and drilled holes should have some type of corrosion protection. We recommend a brush treatment with an inhibitor solution or applying a sealant along the edge, or both. With a sealant, fill gaps or cavities where moisture, dirt, or other foreign material can settle. Adjacent structures, not the sandwich, should have sufficient drainage to prevent moisture accumulation. Seal damage or punctures in panels as soon as possible to prevent additional moisture entry, even if permanent repair must be delayed.

4.11.3 Control cables may present a corrosion problem whether of carbon steel or stainless steel construction. Bare spots in the preservative coating are a main contributing factor in cable corrosion. Determine cable condition by cleaning the cable assembly, inspecting for corrosion, and applying an approved preservative if no corrosion is found. If external corrosion is found, relieve tension on the cable and check internal strands for corrosion. Cables with corrosion on internal strands should be replaced. Pay particular attention to sections passing through fairleads, around sheaves, and grooved bell-crank arms. External corrosion should be removed by a clean, dry, coarse rag or fiber brush. After complete corrosion removal, apply a preservative.

4.11.4 Topcoating materials in integral fuel cells, such as Buna-N, polyurethane, or epoxy, repel fuel but can absorb moisture through the topcoating materials and sometimes cause pitting or intergranular corrosion on aircraft structural parts. We have also found that microorganisms which live in water entrained by fuel, particularly jet propellant fuel types, feed on fuel hydrocarbon and hydrocarbon-type elastomeric coating materials. Excreted organic acids and dead microorganisms act as a gelatinous acidified sponge which can deteriorate integral tank coatings and corrode the aircraft structure. Minimize microbial corrosion by preventing as much water contamination of the fuel as possible with well-managed storage facilities, adequate fuel filtration, and drainage of water contamination from integral fuel cells. This drainage keeps the water moving and reduces development of microorganism colonies. Reduce microorganic activity by using a biocide additive such as “Biobor JF” or equivalent. Use manufacturer instructions to determine solution strength and application frequency.

4.11.5 Electrical connectors or components may be potted with a sealing compound for improved reliability, and to prevent moisture entrance into connectors where wires are attached to pins.

4.11.5.1 Use rubber O-rings to keep moisture out of the mating area of pin connections and prevent loss of pressurization in compartments containing bulkhead connectors.

4.11.5.2 Moisture intrusion into electrical connectors can cause corrosion and an electrical failure. Disconnect and disassemble suspected plugs, clean with a solvent, and inspect for corrosion.

4.11.5.3 When electrical components cannot be sealed, these components can have moisture intrusion and internal corrosion.

4.11.6 Severe corrosion damage to rear pressure bulkheads below the floor may occur as a result of contamination by fluids. Inspection for rear bulkhead corrosion may require extensive disassembly of components and fixtures to enable a thorough visual inspection. When inspection access holes are available, inspection by fiber optics is useful. Other nondestructive inspection (NDI) methods, such as x ray, ultrasonic, and eddy current, are also available. However, these inspection techniques require specially trained personnel, NDI comparison standards, and suitable access. Regular inspections of the rear pressure bulkhead, both front and rear faces, below the floor level should prevent serious corrosion buildup between the bulkhead and periphery doubler at the floor level. Such corrosion could weaken the bulkhead skin and lead to sudden cabin pressure loss.

4.11.7 Some older aircraft develop delaminations in cold-bonded joints. Corrosion between the delaminated surfaces stems from moisture intrusion along edges of mating parts or around fasteners securing mating parts together. Localized bulging of a skin or internal structural components, usually around the fasteners, is the first indication of a corrosion problem (see Figure 4-11, Spar Chord Lifting Caused by Corrosion Products). Skin cracks or dished or missing fastener heads may also indicate severe corrosion in bonded joints. Corrosion occurring between skins, doublers, and stringers or frames will produce local bulging or pulled rivets (see Figure 4-12, Skin Bulging Around Fasteners). Corrosion that occurs between the skins and doublers or tear straps away from a backup structure, such as stringer or frame, will not produce local bulging. An external low frequency eddy current inspection should determine the extent of corrosion in the skin. Open lap joints with wedges to determine the full extent of corrosion damage (see Figures 4-13, Opening of a Corroded Lap Joint for Repair, and 4-14, Close-Up View of a Corroded Lap Joint). Internal visual inspection should detect delaminated doublers or tear straps. Apply a penetrating water displacement corrosion inhibitor to faying surfaces after corrosion removal and repair.

4.11.8 Flap and slat recesses and equipment installed in these areas, normally closed, may corrode unnoticed without special inspections.

Figure 4-11. Spar Chord Lifting Caused by Corrosion Products

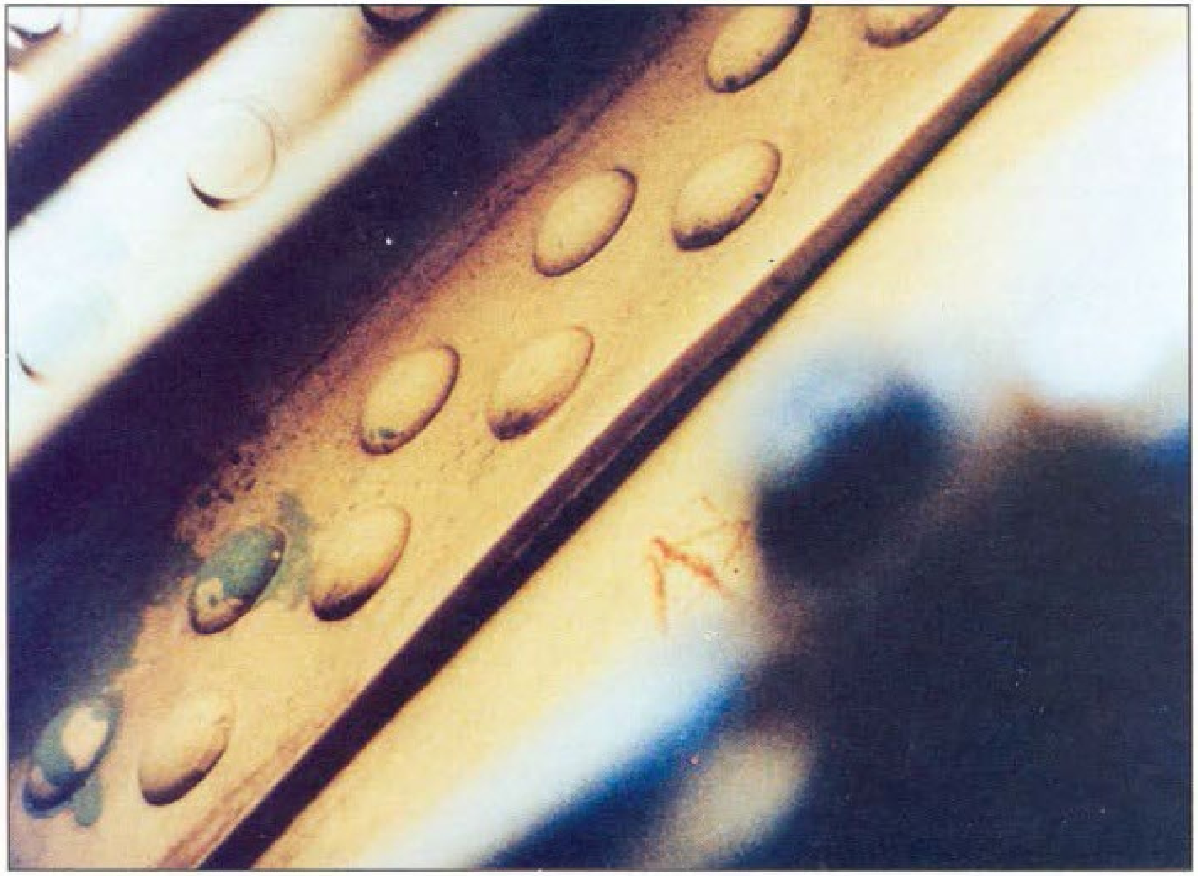


Figure 4-12. Skin Bulging Around Fasteners

Figure 4-13. Opening of a Corroded Lap Joint for Repair

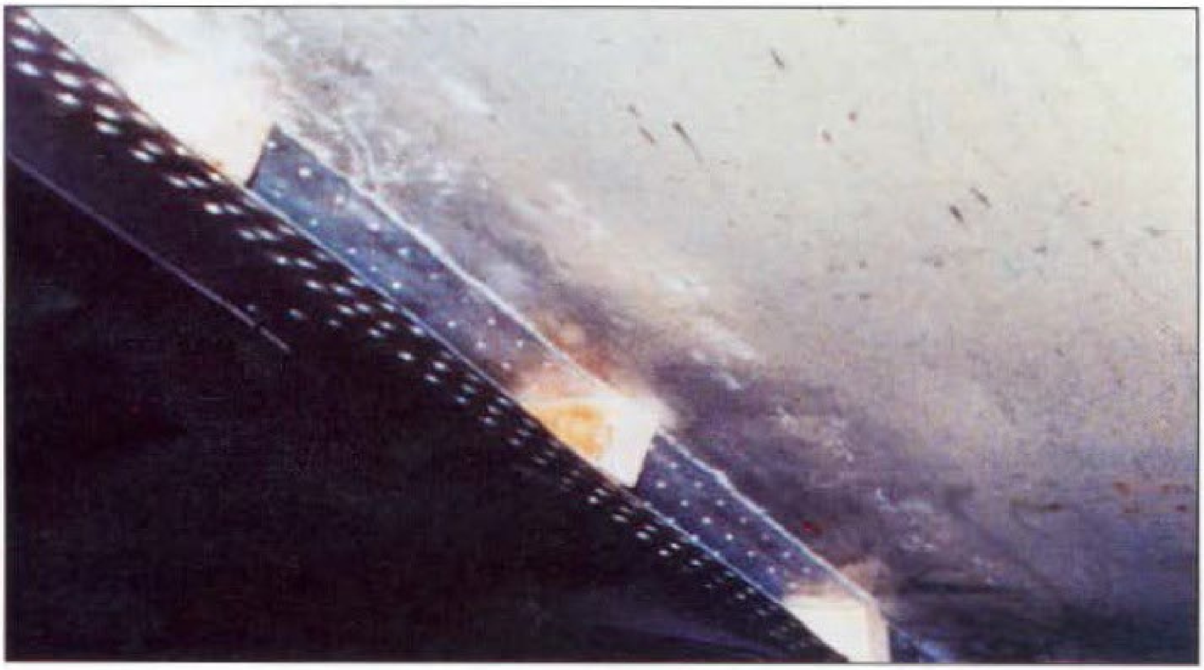
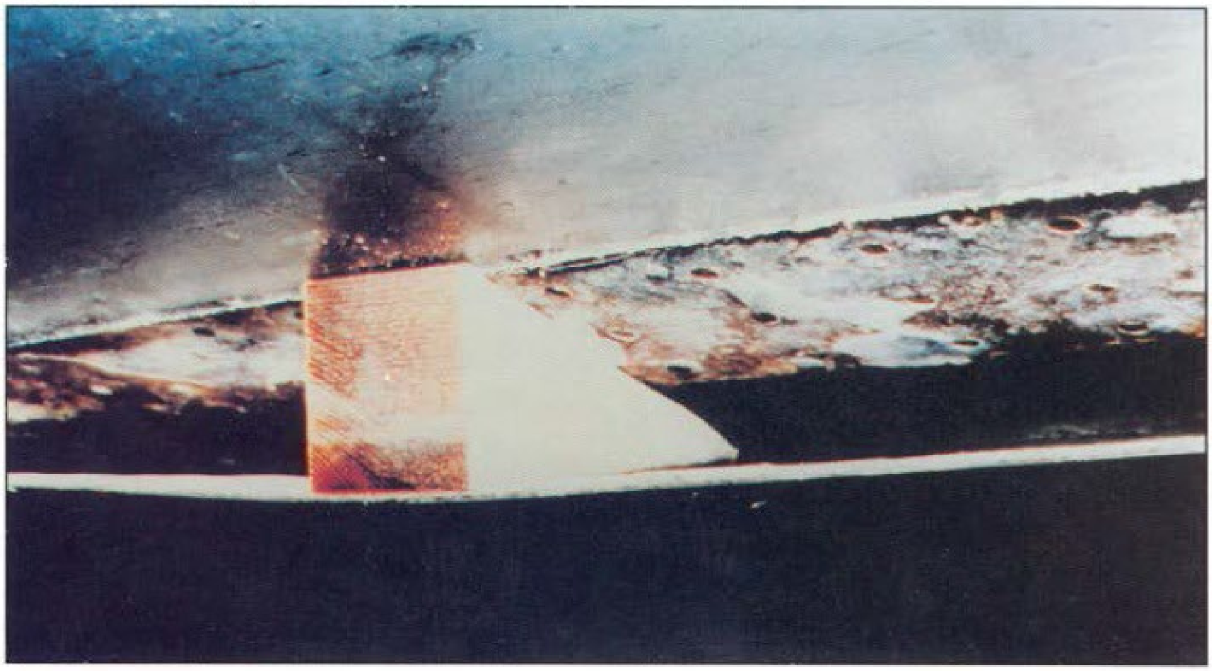


Figure 4-14. Close-Up View of a Corroded Lap Joint



4.12 Factors in Corrosion Control.

4.12.1 Corrosion Factors. The severity, cause, and type of corrosion depend on many factors, including a part's size or thickness, the material, heat treatment of the material, protective finishes, environmental conditions, preventive measures, and design.

4.12.1.1 Thick structural sections are generally more susceptible to corrosive attack because of variations in composition, particularly if sections are heat-treated during fabrication. When large sections are machined or chemically milled after heat treatment, corrosion characteristics of thinner sections may differ from thicker areas. Section size adheres to structural requirements and cannot be changed to control corrosion. From a maintenance standpoint, the correct approach is to recognize the need to ensure the integrity and strength of major structural parts and maintaining permanent protection over such areas at all times.

4.12.1.2 In-service stresses and field repairs may affect rates and types of corrosion. Aircraft structures under high cyclic stresses, such as helicopter main rotors, are particularly subject to stress-corrosion cracking. Areas next to weld-repaired items often have corrosion due to insufficient weld flux removal or buildup of a magnetic field. Closely inspect these areas for signs of corrosion and properly treat when found.

4.12.2 Corrosion Control in Design. Since corrosion is the deterioration of metal resulting from a reaction between a metal and its environment, some form of corrosion control or means to minimize corrosion should become part of an aircraft's design phase before the aircraft enters operational service. The corrosion issues discussed in this AC provide information to reduce the rate of corrosive attack by corrosion control measures introduced early in design.

4.12.2.1 The nature of a 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 environments. The aircraft manufacturer selects material for the aircraft based on material strength, weight, and cost, while corrosion resistance is often a secondary consideration. Corrosion control should be included in an aircraft's preliminary design phase as early as possible.

4.12.2.2 More corrosion-resistant materials in any design normally involves additional weight to achieve the required strength. Weight consideration is a major factor in the construction of airframes, and the primary means of preventing corrosion is through protective coatings and proper maintenance procedures.

4.12.2.3 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; sometimes the corrosion then shifts to another part and increases in severity.

4.12.2.4 Protection against corrosion is minimized if the protected material is intrinsically resistant to corrosion. Aluminum copper alloys (2000 series) are known to have better stress-corrosion resistance and better fatigue strength properties than aluminum zinc alloys (7000 series), so aircraft designers use them more often as the primary structural materials.

4.12.2.5 Galvanic corrosion results from dissimilar metals in contact, and the galvanic series of metals and alloys (see Table 4-1, Galvanic Series of Metals and Alloys) is a factor to consider in aircraft repair. The further apart the potential voltages of the metals listed in Table 4-1 are, the greater the tendency for galvanic corrosion. The metals in Table 4-2, Grouping of Metals and Alloys, have small differences in electrical potential, so 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 potential voltage. The electrode potentials as given in Table 4-1 are valid for pure materials at standard lab conditions. However, in-service conditions are different and potential voltages may shift to either side, positive or negative, as do alloying elements. Although this does not affect the general ranking, it can significantly affect the potential differences relevant for corrosion prevention and, in few cases, this may even invert ranking of two metals.

Table 4-1. Galvanic Series of Metals and Alloys

Electrode Potential of Various Metals and Alloys (a)	
Metal or Alloy (b) PH stainless steels	Potential, volts 0.025 0.1 N calomel scale (c)
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-T6, 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, and T4	-0.68 to -0.70 (d)
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

(a) Data from Alcoa Research Laboratories.

(b) The potential of all tempers is the same unless temper is designated.

(c) Measured in an aqueous solution of 53g of sodium chloride + 3g hydrogen peroxide per liter at 25 degree c.

(d) The potential varies with quenching rate.

Table 4-2. Grouping of Metals and Alloys

GROUP I	Magnesium and Magnesium Alloys.
GROUP II	Aluminum, Aluminum Alloys, Zinc, Cadmium, and Cadmium-Titanium Plate.
GROUP III	Iron, Steels Except Stainless Steels; Lead, Tin, and their Alloys.
GROUP IV	Copper, Brass, Bronze, Copper-Beryllium, Copper-Nickel Chromium, Nickel, Nickel Base Alloys, Cobalt Base Alloys, Carbon Graphite, Stainless Steels, Titanium, and Titanium Alloys.
NOTE:	1. Metals listed in the same group are considered similar to one another. 2. Metals listed in different groups are considered dissimilar to one another.

4.12.3 Protective Finishes. Base material with a protective finish is protected from corrosion and other forms of deterioration. These finishes have two categories: sacrificial and non-sacrificial. Sacrificial coatings include cadmium, zinc, and aluminum. Non-sacrificial coatings include hard plating, such as chromium and nickel, chemical conversion coatings, sealant, primers, and topcoat.

4.12.4 Geographical Location and Environment. This factor concerns systems exposed to marine atmospheres, moisture, acid rain, tropical temperature conditions, industrial chemicals, and soils and dust in the atmosphere. Whenever possible, limit the requirement for operation of aircraft in adverse environments.

4.12.4.1 Moisture is present in the air as a gas, also called water vapor, or as finely divided droplets of liquid, as in mist or fog, and often contains contaminants such as chlorides, sulfates, and nitrates, which increase its corrosive effects. Condensed moisture which evaporates will leave contaminants behind; become trapped in close fitting, wettable joints, such as faying surfaces; and collect along poor bond lines by capillary action.

4.12.4.2 Salt particles, when dissolved in water, form strong electrolytes. Normal sea winds carry dissolved salt which makes coastal environments highly corrosive.

4.12.4.3 Industrial pollutants, such as carbon, nitrates, ozone, sulfur dioxide, and sulfates, contribute to the deterioration of nonmetallic materials and can cause severe corrosion of metals.

4.12.4.4 Warm, moist air normally found in tropical climates accelerates corrosion while cold, dry air normally found in arctic climates reduces corrosion.

4.12.5 Heat Treatment. Proper heat treatment of materials is a vital factor in maximizing resistance to corrosion.

4.13 Preventive Maintenance.

4.13.1 Prevention. Corrosion prevention of aircraft structure depends on a comprehensive corrosion prevention and control plan, implemented from the start of operation of an aircraft, which includes:

4.13.1.1 Adequately trained personnel in:

- Recognition of corrosion-inducing conditions;
- Corrosion identification techniques;
- Corrosion detection, cleaning, and treating; and
- Lubrication and preservation of aircraft structure and components.

4.13.1.2 Scheduled inspection for corrosion.

4.13.1.3 Periodic, thorough cleaning, inspection, lubrication, and preservation. See Figures 4-15 through 4-20. Suggested intervals based on operating environment:

- Mild zones: every 90 calendar-days;
- Moderate zones: every 45 calendar-days; and
- Severe zones: every 15 calendar-days.

4.13.1.4 Prompt corrosion treatment after detection.

4.13.1.5 Accurate recordkeeping and reporting of material or design deficiencies to the manufacturer and the FAA.

4.13.1.6 Use of appropriate materials, equipment, and technical publications.

4.13.1.7 Maintenance of basic finish systems.

4.13.1.8 Keeping drain holes and passages open and functional. Sealants, leveling compounds, miscellaneous debris, or corrosion inhibitors should not block drain paths. See Figure 4-21, Blocked Drain Passages Resulted in Accumulation of Corrosion Contaminates and Moisture.

4.13.1.9 Replacing deteriorated or damaged gaskets and sealants, using noncorrosive type sealants, to avoid water intrusion and entrapment which leads to corrosion.

4.13.1.10 Minimizing aircraft exposure to adverse environments, such as hangar storage away from salt spray.

Figure 4-15. North America Corrosion Severity Map

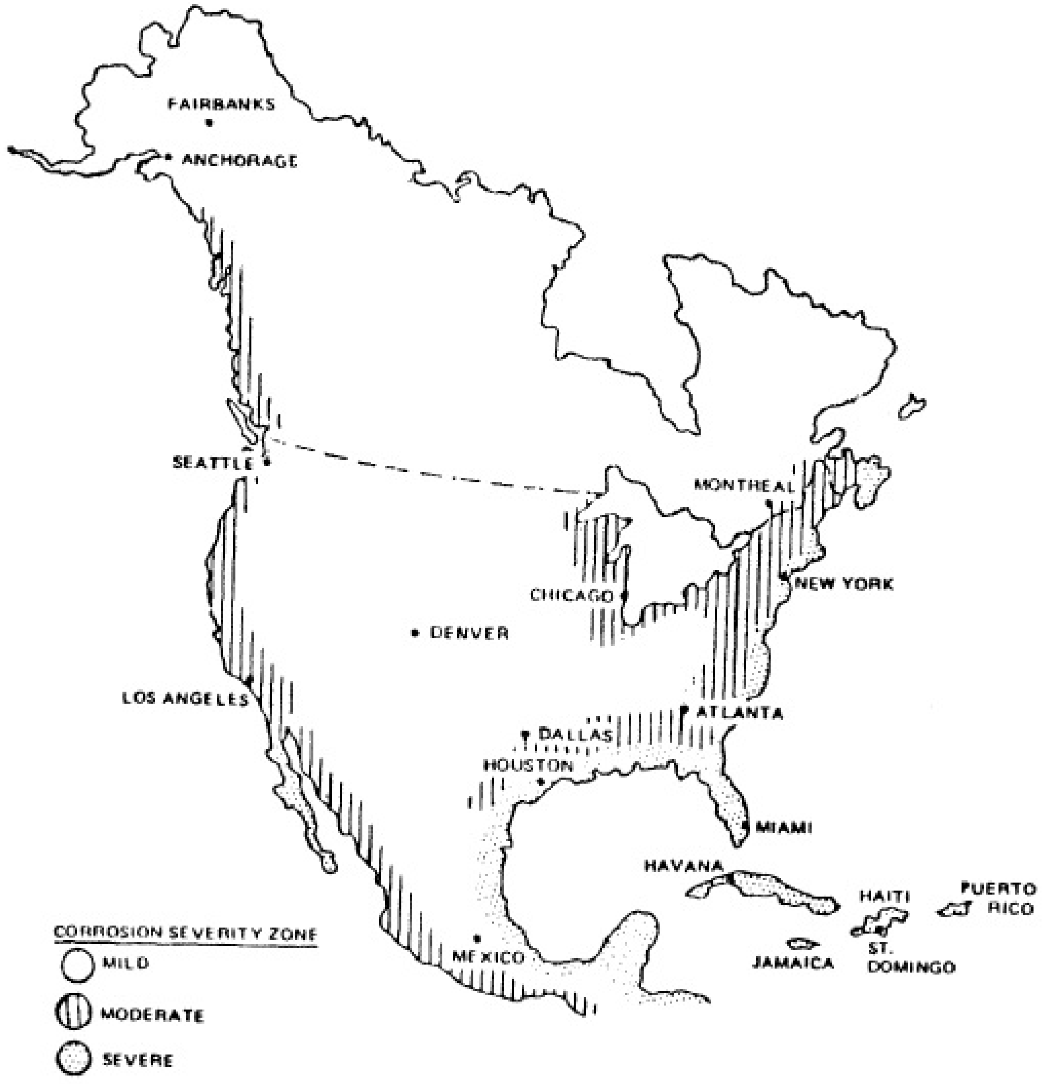


Figure 4-16. South America Corrosion Severity Map

Figure 4-17. Africa Corrosion Severity Map

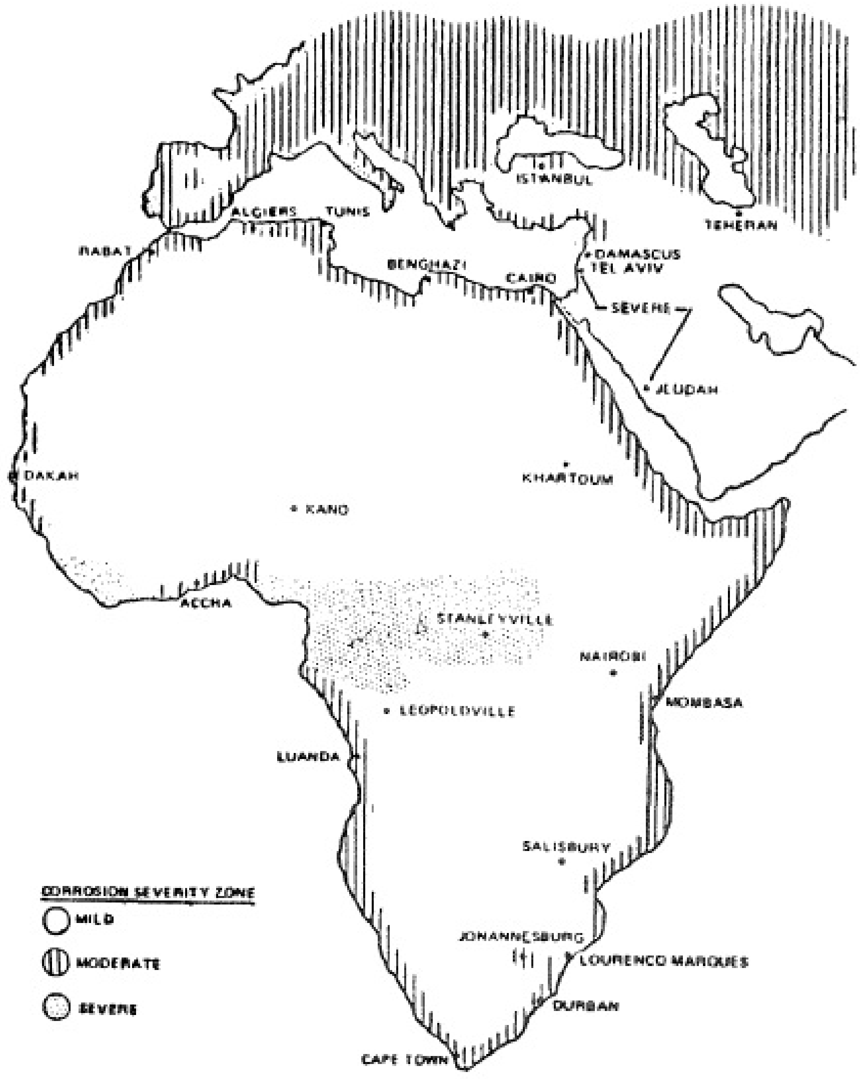


Figure 4-18. South Pacific Corrosion Severity Map

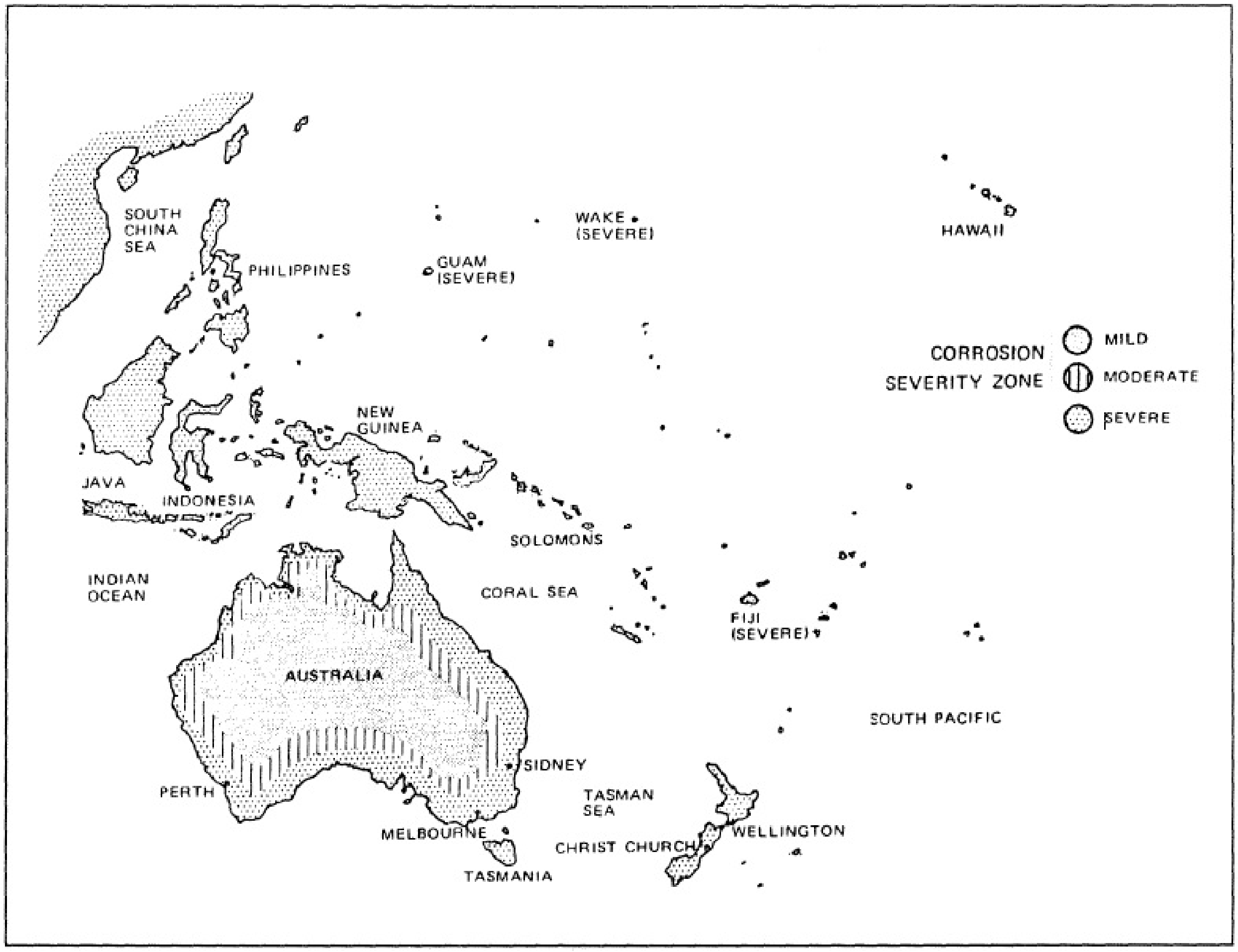


Figure 4-19. Asia Corrosion Severity Map

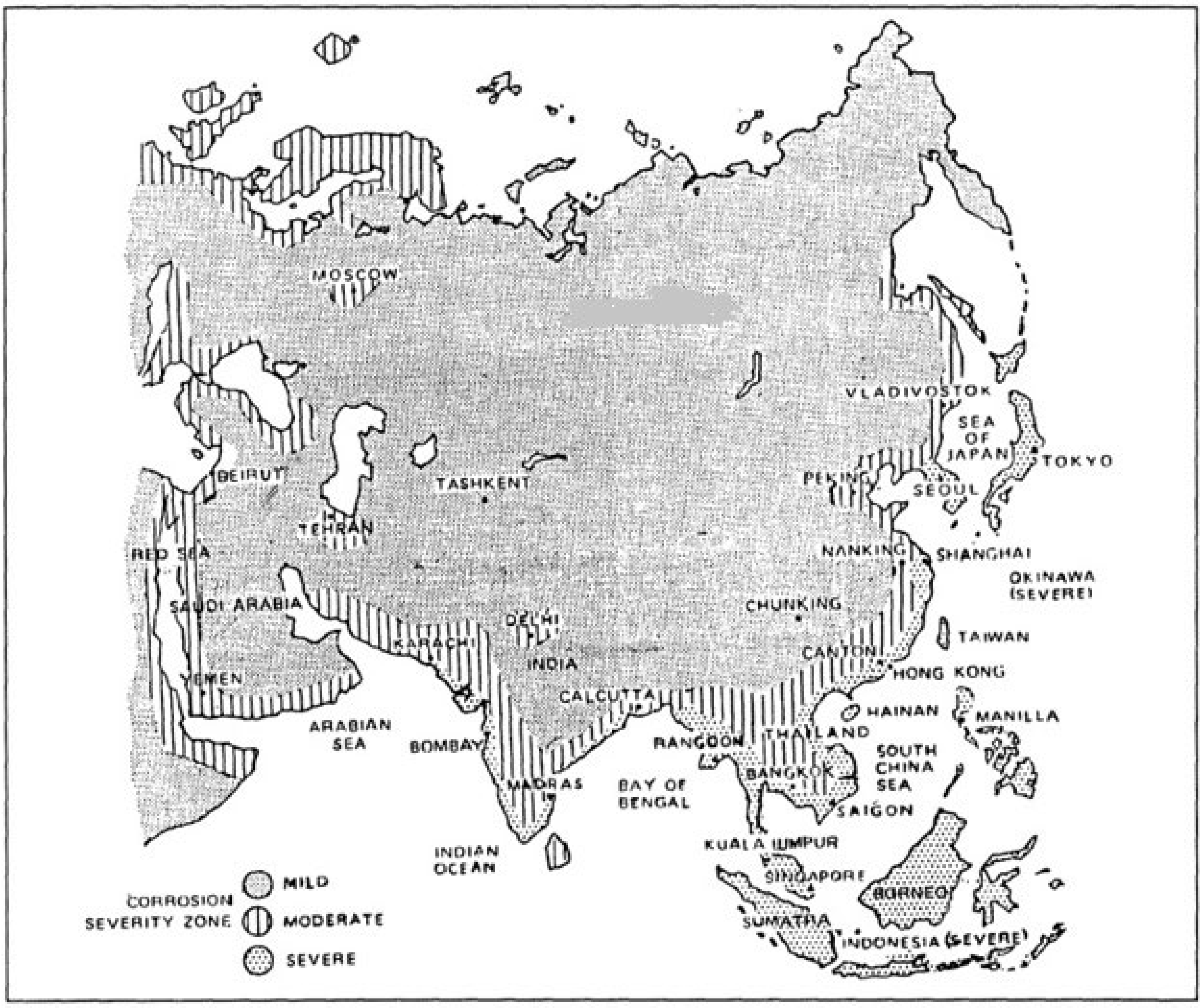


Figure 4-20. Europe and Asia Minor Corrosion Severity Map

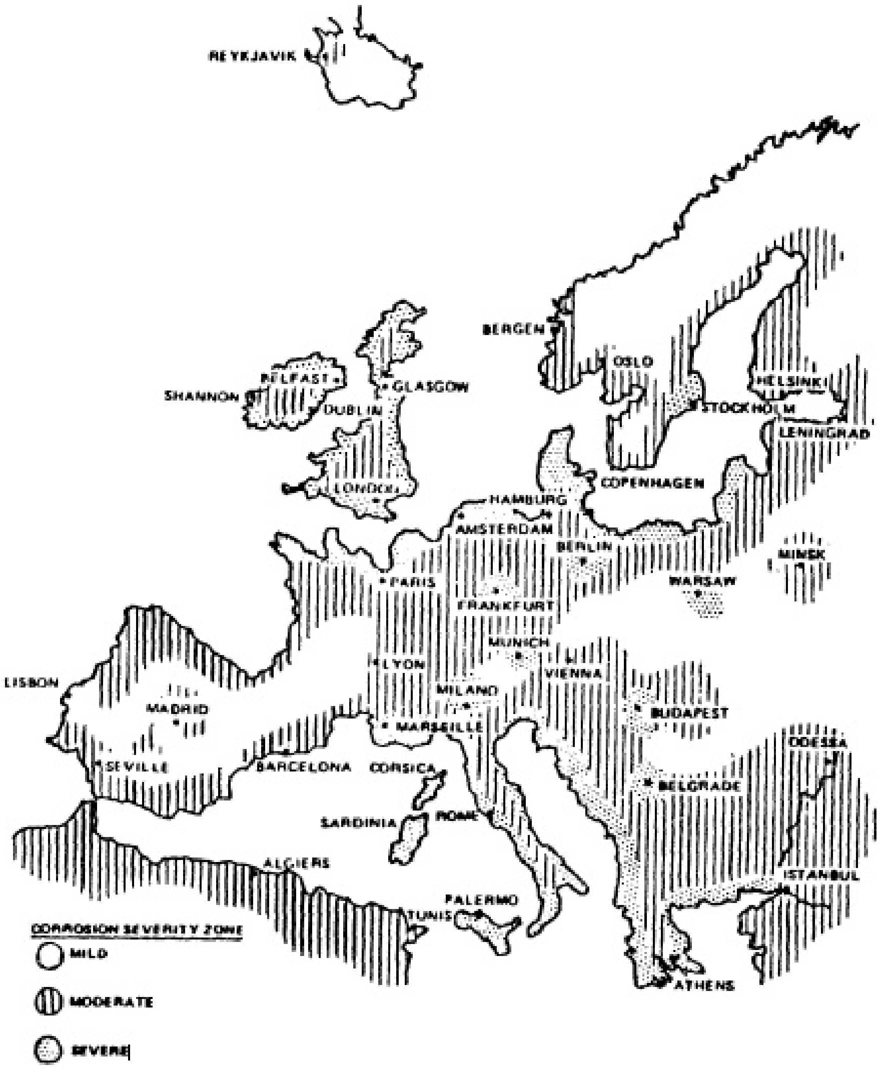
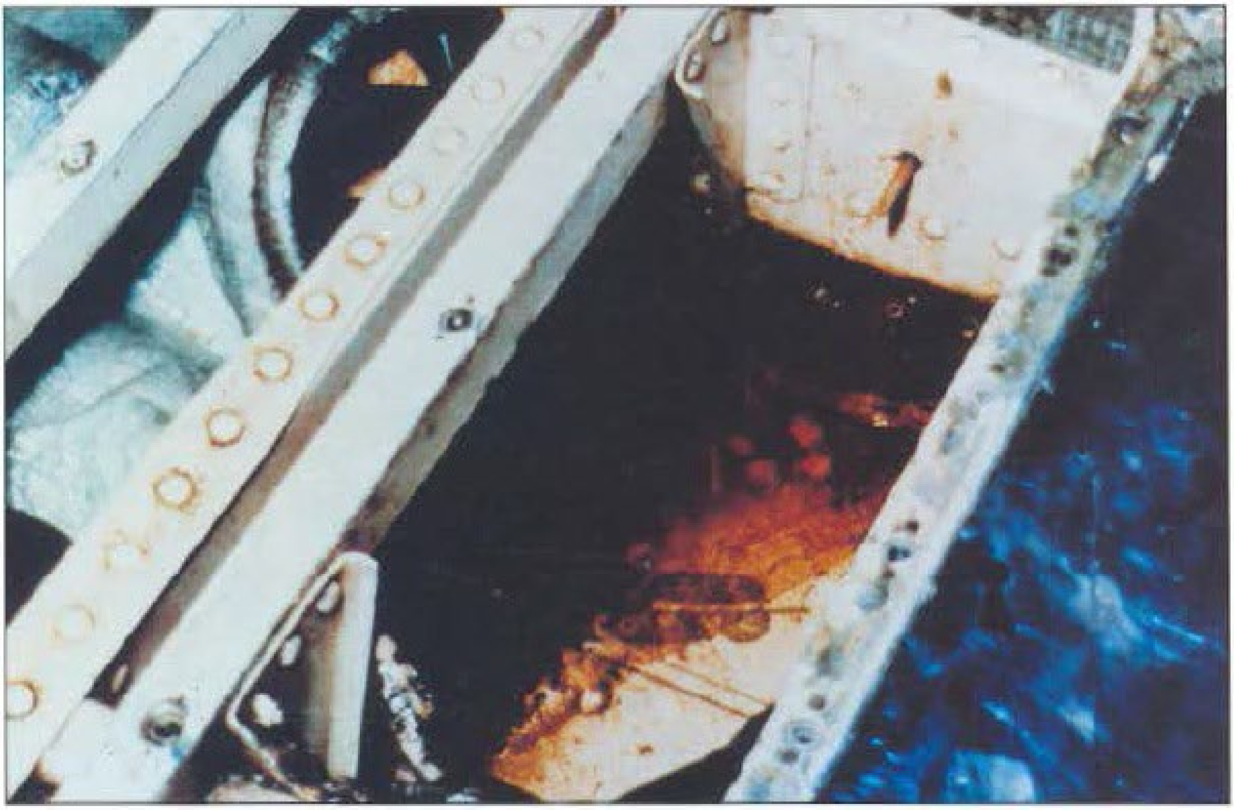


Figure 4-21. Blocked Drain Passages Resulted in Accumulation of Corrosion Contaminates and Moisture



4.13.2 Cleaning Compounds for Metals.

Note: More is not always better, and mixing more cleaning compound increases the pH of a solution, which can do more harm than good. Always mix a cleaning compound using manufacturer recommendations.

4.13.2.1 Cleaning compounds work by dissolving soluble soils, emulsifying oily soils, and suspending solid soils. There are several cleaning compounds, and each cleans a surface using one or more of the below mechanisms.

4.13.2.2 Highly alkaline cleaning compounds (with a pH greater than 10) are not recommended. However, moderately alkaline cleaners (with a pH between 7.5 and 10) conforming to Military Specification (MIL-SPEC) MIL-C-85570, Cleaning Compounds, Aircraft, Exterior, Types I and II, are recommended. Both types contain detergents, foaming agents, and solvents, and work the same as a detergent solution.

4.13.2.3 A high-gloss spot cleaner conforming to MIL-SPEC MIL-C-85570, Type III, is recommended for cleaning exhaust track areas of high-gloss paint systems. This material contains solvents, detergents, and suspended abrasive matter to remove soil by wearing away the surface that holds it.

4.13.2.4 Thixotropic, or viscous, cleaner conforming to MIL-SPEC MIL-C-85570, Type V is recommended for cleaning wheel wells and replacement of some solvent cleaning where water rinsing can be used. This cleaner contains solvents, detergents, and some thickening agents. When applied undiluted to an oily or greasy surface, the cleaner clings long enough to emulsify the soil, usually about 5 to 15 minutes, then can be rinsed away with fresh water.

Note: Solvents for cleaning operations is becoming more and more limited due to environmental regulations. Determine local requirements for waste disposal.

4.13.2.5 Solvent emulsion cleaners conforming to MIL-SPECs MIL-C-43616, Cleaning Compounds, Aircraft Surface, and MIL-C-85704, Cleaning Compound, Turbine Engine Gas Path, become emulsions when diluted. The solvent in the cleaner softens oily soils so that they can be emulsified by the detergent and rinsed away.

4.13.2.6 Detergent solution cleaners conforming to MIL-SPEC MIL-D-16791, Detergents, General Purpose (Liquid, Nonionic), dissolve in water and clean by dissolving soluble salts, emulsifying low-viscosity oils, and suspending easily removed dirt and dust. They are not very effective on grease, but are excellent cleaners for interior lightly soiled areas, plastics, and instrument glass covers.

4.13.2.7 Cleaning solvents dissolve oily and greasy soils so that they can be easily wiped away or absorbed on a cloth. Solvents differ significantly in cleaning ability, toxicity, evaporation rate, effect on paint, and flammability. Cleaning solvents are best for localized spot application only. A dry cleaning solvent conforming to MIL-SPEC MIL-PRF-680, Performance Specification: Degreasing Solvent, Type II, is the most common cleaning solvent used on aircraft, due to its low toxicity, minimal effect on paint, and relative safety. Other solvents, such as alcohols, ketones, chlorinated solvents, and naphtha, are specialized materials and have restricted use. Refer to manufacturer maintenance and cleaning procedures for specific applications.

4.13.2.8 Miscellaneous cleaning agents include:

- Plastic polish, which contains mild abrasive matter to polish out scratches in canopy materials;
- Alkaline chemicals used to neutralize specific acidic soils;
- Sodium bicarbonate for electrolyte spills from sulfuric acid batteries; and
- Monobasic sodium phosphate and boric acid for electrolyte spills from nickel-cadmium batteries.

4.13.2.9 Steam cleaning is not recommended for general use on aircraft. It erodes paint, crazes plastic, debonds adhesives, damages electrical insulation, and drives lubrication out of bearings.

4.13.3 Cleaning Procedures.

4.13.3.1 The following cleaning procedures are recommended:

- Remove/disconnect all electrical power;
- Ground aircraft;
- Aircraft wash personnel should wear protective gear, such as gloves, goggles, or aprons;
- Protect against water/cleaning compound intrusion, such as at closed doors, openings, cover vents, pitot static openings, or cover wheels. Precautions should be taken to ensure these protections are removed after cleaning;
- Accomplish pre-wash lubrication. Lubricate per applicable maintenance manual;
- Mix cleaning solution per manufacturer recommendation;
- Use spray, not a stream, of water during aircraft wash;
- Do not use abrasive cleaning pads; and
- Rinse aircraft with fresh water to remove all cleaning compounds.

4.13.3.2 The following post-cleaning procedures are recommended:

- Remove all covers, plugs, and masking materials;
- Inspect and clear all drain holes;
- Inspect and open all known water trap areas for water accumulation and proper drainage;
- Lubricate aircraft per applicable maintenance manual; and
- Apply operational preservation.

4.13.4 Preservation. The day-to-day application of corrosion preventive compounds protects metal aircraft parts and components. They prevent corrosive materials from contacting and corroding bare metal surfaces. Many of these compounds also displace water and other contaminants from the surfaces. Some also lubricate as well as protect against corrosion. Corrosion preventive compounds vary in appearance and consistency from thick, black types to light oils. Some are water displacing and others are not. Thicker compounds provide the best corrosion protection, are longer lasting, and are more difficult to remove. Thinner materials provide some lubrication and do not crack, chip, or peel, but must be removed and replaced regularly to provide continuing protection.

4.13.5 Surface Treatment.

4.13.5.1 An important step in the corrosion control process is surface treatment of a metal with a prescribed chemical to form a protective film. Chemical surface treatments, properly applied, provide corrosion resistance to the metal and improve the adhesion of subsequently applied paints. These surface treatments, also known as chemical conversion coatings, chromate conversion coatings, chemical films, or pretreatments, are aqueous acid solutions of active, inorganic compounds which convert aluminum or magnesium surfaces to a corrosion-resistant film.

4.13.5.1.1 Aluminum and aluminum alloy chemical conversion materials conform to MIL-SPEC MIL-C-81706, Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys.

4.13.5.1.2 Magnesium alloy chemical conversion materials conform to Aerospace Material Specification (AMS)-M-3171, Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion On.

4.13.5.1.3 Ferrous metals, stainless steel, and titanium treatment, prior to painting, are limited to corrosion removal and cleaning.

4.13.5.2 The surface should be prepared for application of the chemical conversion coatings.

4.13.5.2.1 Feather the edges of paint along the edge of areas that have been chemically stripped prior to pretreatment and repainting to ensure a smooth, overlapping transition between the old and new paint surfaces.

4.13.5.2.2 Clean the area with a fine or very fine clean abrasive mat saturated with water.

4.13.5.2.3 Rinse by flushing with fresh water. Particular attention should be given to fasteners and other areas where residues may become entrapped. At this stage in the cleaning, the surface should be without water beading or incomplete wetting, also called water breaks. A surface showing water breaks is usually contaminated with grease or oil, which will later interfere with conversion coating, sealing, and painting.

4.13.5.2.4 If the surface is not free of water breaks, re-clean the area with a solution of aircraft cleaning compound using an abrasive mat. Rinse thoroughly with water.

4.13.5.3 Chemical conversion coating is applied by brush, sponge stick moistener, or a non-atomizing sprayer to achieve a yellow-to-gold color for aluminum, usually 2 to 4 minutes, or greenish-brown, brassy, or brownish-yellow for magnesium, usually 30 seconds to 2 minutes.

4.13.5.4 Immediately rinse the part thoroughly with fresh water. Do not wipe with a rag or cloth.

4.13.5.5 Allow the chemical conversion coated surface to dry a minimum of 30 minutes and a maximum of 4 hours before painting.

4.13.6 Sealants. Refer to MIL-SPEC MIL-PRF-81733, Sealing and Coating Compound, Corrosion Inhibitive.

4.13.6.1 Sealants are one of the most important tools for corrosion prevention and control. They prevent the intrusion of moisture, salt, dust, and aircraft fluids, which can lead to extensive corrosion. For sealants to be effective, it is critical to choose the correct sealant for a specific area or situation, and that it is applied correctly.

4.13.6.2 Sealants are useful in the following areas:

- Fuel tank;
- Pressure areas;
- Weather sealing;
- Firewalls;
- Electrical;
- Acid-resistant areas;
- Windows;
- High temperature applications; and
- Aerodynamic sealing.

4.13.6.3 There are numerous sealing compounds available with different properties and intended use. Refer to the aircraft manufacturer manual for specific information about selection of the sealing compound and proper application. Observe the warning and cautions of the manufacturer when using sealing compounds. Sealing compounds generally are divided into two major types: those requiring a curing agent and those which cure in air.

4.13.6.3.1 Polysulfide, polythioether, and polyurethane sealing compounds consist of the base, or prepolymer, and the accelerator, or curing agent. When thoroughly mixed, the catalyst cures the base to a rubbery solid. Rates of cure depend on the type of base, catalyst, temperature, and humidity. A full cure may take as long as 7 days.

4.13.6.3.2 Silicone sealing compounds generally consist of one component which cures by reaction with moisture in the air. If silicones are applied too thickly or in such a way as to prevent moisture from entering the material, they may not cure at all. Many silicone sealing compounds also produce acetic acid, which has a vinegar smell, while curing, and can lead to severe corrosion problems. Limit silicone sealing compounds on aircraft to those noncorrosive products conforming to MIL-SPEC MIL-A-46146, Adhesives-Sealants, Silicone, RTV, Noncorrosive (For Use with Sensitive Metals and Equipment).

4.13.6.3.3 Some sealing compounds need a special primer or adhesion promoter before applying the sealant to develop a good adhesive bond with the surface. Use only those primers or adhesion promoters recommended by the product manufacturer.

4.13.6.4 Sealant application procedures:

4.13.6.4.1 Remove corrosion, apply a chemical surface treatment, and prime all surfaces, except internal fuel tank surfaces. If the surfaces have been contaminated following surface treatment, clean the area with cleaning solvent and a clean cloth. Dry the surfaces immediately with a clean cloth. Do not allow solvents to evaporate from the surface.

4.13.6.4.2 Mask off the area being sealed to prevent sealant from contacting adjacent areas during application and post-application smooth-out. Examples of where masking may be beneficial are fillet sealing of exterior surface lap and butt seams.

4.13.6.4.3 When required by the manufacturer, apply a thin coating of an adhesion-promoting solution. Allow to dry by evaporation without touching the area for 30 minutes to 1 hour before applying sealant.

4.13.6.4.4 Spatula type sealants may be applied with a nonmetallic spatula or scraper. Avoid entrapping air. Work sealant into recesses by sliding the edge of the scraper firmly back over the recesses between taped areas next to the sealant application area. Smoothing will be easier if the nonmetallic scraper is first dipped in water.

4.13.6.4.5 If using a brush to apply a sealant, brush it on and smooth until the desired thickness is reached.

4.13.6.4.6 Applying sealant with a caulking gun will not usually require masking and is especially adaptable to filling seams or applying form-in-place gaskets.

4.13.6.4.7 Use a solid, continuous pattern to apply sealant with a spray gun.

4.13.6.4.8 Allow sealant to dry or cure per manufacturer recommendations.

4.13.6.4.9 When required, prime sealant as soon as it no longer feels tacky, then topcoat as necessary.

4.13.6.4.10 Apply faying surface sealant between the contacting surface of two or more parts. Use this sealant for all assembly and, where possible, reassembly. Where at all possible, use it in conjunction with fillet sealing. There are two types of faying surface seal installations, removable and permanent. The removable type is for access doors, removable panels, inspection plates, windows, etc. The sealant is normally applied to the substructure and a parting agent applied on the removable panel during sealant cure. The permanent type is for sealing between parts of a structure that is permanently fastened together with a high-adhesion sealant.

4.13.6.5 Aircraft maintainers commonly use fillet, or seam, seals. Fillet seals cover structural joints or seams along stiffeners, skin butts, walls, spars, and longerons, and seal around fittings and fasteners. Fillet sealant should be used in conjunction with faying surface sealing and in place of it if the assembly sequence restricts the use of faying surface sealing.

4.13.6.6 Injection sealing primarily fills voids created by structural joggles, gaps, and openings. Use only sealants recommended by the aircraft or equipment manufacturer, and inject sealant into the area using a sealant gun. This method produces a continuous seal, normally impossible while fillet sealing. Clean the voids of all dirt, chips, burrs, grease, and oil before injection sealing.

4.13.6.7 The fastener sealing method varies depending on the type of fastener, which is sealed either during or after assembly. To seal a permanent fastener during assembly, apply the sealant to the hole or dip the fastener into the sealant, and install the fastener while the sealant is wet. For removable fasteners, start the fastener in the hole and apply sealant to the lower side of the fastener head or countersink. To seal after assembly, apply the sealant to the fastener head after installation.

4.13.6.8 Seal fuel cells per the aircraft manufacturer's maintenance manual procedures.

4.13.7 Paint Finishes and Touchup Procedures.

4.13.7.1 Paint systems protect exposed surfaces against corrosion and other forms of deterioration. Operational uses for schedule paint schemes include:

- High visibility requirements;
- Identification markings;
- Abrasion protection; and
- Specialty coatings, such as walkway coatings.

4.13.7.2 Aircraft paint systems have a primer coat and topcoat. The primer promotes adhesion and contains corrosion inhibitors, while the topcoat provides durability to the paint system, including weather and chemical resistance, and coloring for operational requirements.

4.13.7.3 Some aircraft surfaces (such as Teflon-filled, rain erosion, or walkways) need specialized coatings because they have service exposure or operational requirements. For these surfaces, refer to the aircraft-specific manufacturer maintenance manuals.

4.13.7.4 The Environmental Protection Agency (EPA), joined by local air pollution control districts, has implemented rules which limit the volatile organic content (VOC), or solvent content, of paints applied to aircraft and ground support equipment. Understand and obey these rules to avoid large fines.

4.13.7.5 Much of a paint finish's effectiveness and adherence to a surface depends on careful preparation of the surface before touchup and repair.

4.13.7.5.1 Aged paint surfaces must be scuff-sanded to ensure adhesion of freshly overcoated, applied paint. In sanding the surface, completely roughen it by hand sanding or with power tools.

4.13.7.5.2 For final preparation, ensure that surfaces are corrosion free, prepared, the surrounding paint feathered, cleaned, and conversion coated. Replace any seam sealants when necessary. Mask areas, as required, to prevent overspray.

4.13.7.6 Spray application for touchup, overcoat and total repaint. Below are preparation tips:

4.13.7.6.1 Thin primers, as required, with a thinner recommended by the paint manufacturer, stir, and apply in even coats. Thickness varies among primers, but generally, the total dry film thickness is 0.6 to 0.9 mils, or 0.0006 to 0.0009 inches. The remaining film thickness should be see-through. Allow the primer to air dry before applying the topcoat; be sure to read the paint manufacturer's recommendations. You should normally apply a topcoat less than 24 hours after primer application.

4.13.7.6.2 Also, treat topcoats with a thinner per the paint manufacturer's recommendations, stir the topcoat, and apply it in even coats. Topcoat thickness varies for each topcoat, but generally, the total dry film thickness is 1.5 to 2.0 mils, or 0.0015 to 0.002 inches. Air dry the topcoat per paint manufacturer's instructions.

- Apply Teflon-filled, or anti-chafe, coatings over a primer per the manufacturer's instructions.
- Apply walkway compounds over a primer, per the manufacturer's instructions.

4.14–4.99. RESERVED.

CHAPTER 5. INSPECTION REQUIREMENTS

5.1 **General.** Corrosion inspections should be a part of daily or preflight maintenance inspections, except for special requirements in trouble areas. Overemphasizing a particular corrosion problem when discovered, and forgetting about corrosion until the next crisis, is an unsafe, costly, and troublesome practice. Inspection for corrosion is a continuing requirement, and requires conducting daily inspections. If a special crew or group handles corrosion control, they should schedule maintenance checks so that these crews can accomplish inspections and rework with access plates removed and components disconnected or out of the way.

5.1.1 Most manufacturer inspection handbooks are complete enough to cover all parts of the aircraft or engine, but no part or area of the aircraft should go unchecked. Use these handbooks as a general guide when inspecting an area for corrosion.

5.1.2 Trouble areas, however, are a different matter. Experience shows that certain combinations of conditions result in corrosion in spite of routine inspection requirements. These trouble areas may be peculiar to particular aircraft models, in conditions similar to most aircraft.

5.1.3 Flight routes and bases of operation will expose some airplanes to more corrosive conditions than others. An aircraft's operational environment may affect the environment's corrosion severity, placing the operational environment in a mild, moderate, or severe category. Figures 4-15 through 4-20 indicate the corrosion severity of operational environments around the world. A particular area may be corrosive because of many factors, including airborne industrial pollutants, chemicals used on runways and taxiways to prevent ice formation, humidity, temperatures, or prevailing winds blowing from a corrosive environment.

5.2 **Frequency of Inspections.** In addition to routine maintenance inspections, observe these special requirements:

- Aircraft operating in a severe environment should be inspected every 15 calendar-days.
- Aircraft operating in a moderate environment should be inspected every 45 calendar-days.
- Aircraft operating in a mild environment should be inspected every 90 calendar-days.
- The aircraft should be washed prior to any inspection for corrosion.
- Crews familiar with corrosion problems and treatment should perform corrosion checks.
- Operators of infrequently flying aircraft should develop a calendar-based corrosion inspection and repair program, rather than basing the program on flight hours. Because of uncertain operating environments, make adjustments to the calendar-time inspection interval after analysis of corrosion inspection findings.

5.3 Recommended Depth of Inspection. Generally speaking, inspection requirements ensure adequate inspection of all compartments and interior aircraft cavities. Adequate maintenance is assured for most operating conditions when such general requirements are observed, along with a periodic check of a list of common trouble areas. To assist in complete coverage, the following summary is included:

5.3.1 Daily and Preflight Inspection. Check engine compartment gaps, seams, and faying surfaces in the exterior skin. Check all areas not requiring removal of fasteners or panels, such as bilge areas, wheel and wheel well areas, battery compartments, fuel cell and cavity drains, engine frontal areas, including intake vents, and engine exhaust areas.

5.3.2 Indepth Inspections. Remove screw-attached panels, access plates, and removable skin sections, as necessary, to thoroughly inspect internal cavities. Remove questionable heavy, internal preservative coatings for at least a spot check of the area underneath the coating. Inspect the aircraft interior in corrosion-prone areas, such as around lavatories, galleys, under floors, or baggage compartments. See Figure 5-1, Corrosion Found After Removing Cargo Door Threshold Covers.

5.3.3 Annual Inspections. Conduct corrosion inspections during annual inspections or other scheduled indepth inspections during which areas of the aircraft not normally accessible will be available for corrosion inspection.

5.3.4 Corrosion Preventive Compounds. Use the Original Equipment Manufacturer (OEM)-recommended corrosion preventive or compounds, such as LPS3, Dinol AV5, equivalent products, or advanced developments of these compounds, to effectively reduce the occurrence of corrosion. Review the results of corrosion inspections to help establish the effectiveness of corrosion preventive compounds and determine the reapplication interval of them.

Figure 5-1. Corrosion Found After Removing Cargo Door Threshold Covers

5.4 Primary Approach. Corrosion detection is primarily detected through corrosion inspections done on a regular schedule. Early detection and treatment reduce costs, out-of-service time, and the possibility of flight or flight-related incidents. All corrosion inspections should start with a thorough cleaning of the area to be inspected. Then, visually inspect the area with a flashlight, inspection mirror, and a 5X to 10X magnifying glass, looking for obvious defects and suspected areas. A detailed inspection follows of damage or suspected areas found during the general inspection. The detailed inspection can be one or more of the following items:

5.4.1 Nondestructive Inspection (NDI).

5.4.1.1 **Visual Inspection.** Visual inspection is the most widely used technique and is an effective method for detection and evaluation of corrosion. Visual inspection employs the eyes to look directly at an aircraft surface, or at a low angle of incidence, to detect corrosion. Using the sense of touch of the hand is also an effective inspection method for the detection of hidden, well-developed corrosion. Other tools such as mirrors, borescopes, optical micrometers, and depth gauges can be used for visual inspections. The following shows the type of corrosion damage detectable during visual inspection: Figures 5-2, Corrosion Under Chipped and Loose Paint on Wing Skin, and 5-3, Corrosion Indicated by Blistering of Paint in Fuel Cell, show chipped, missing, and lifted paint; Figure 5-4, Popped Rivet Heads Resulting from Corrosion Products, shows dished and popped rivets; Figure 5-5, Skin Bulging Around Fasteners Caused by Pressure from Corrosion Products, shows skin bulges or lifted surfaces; Figures 5-6, Corrosion Cracking Between Fasteners on a Wing Spar, and 5-7, Faying Surface Corrosion on Wing Spar Chord with Corrosion Cracking Also Visible, show cracks; and Figures 5-8, Severe Crown Stringer Corrosion, and 5-9, Spar Chord Corrosion, show corrosion products.

5.4.1.1.1 Indications of corrosive attack can take several forms depending on the type of metal and the length of time the corrosion has developed. Corrosion deposits on aluminum and magnesium are generally a white powder, while ferrous metals vary from red to dark reddish-brown stains.

5.4.1.1.2 Sometimes structural members or equipment installations block inspection areas, or for some reason, the areas are awkward to check visually. Ensure adequate access for inspection by removing access panels and adjacent equipment, by cleaning the area as necessary, and by removing loose or cracked sealants and paints. Mirrors, borescopes, and fiber optics are useful in providing the means of observing obscure areas. Figures 5-10 through 5-18 depict some of these conditions.

Figure 5-2. Corrosion Under Chipped and Loose Paint on Wing Skin

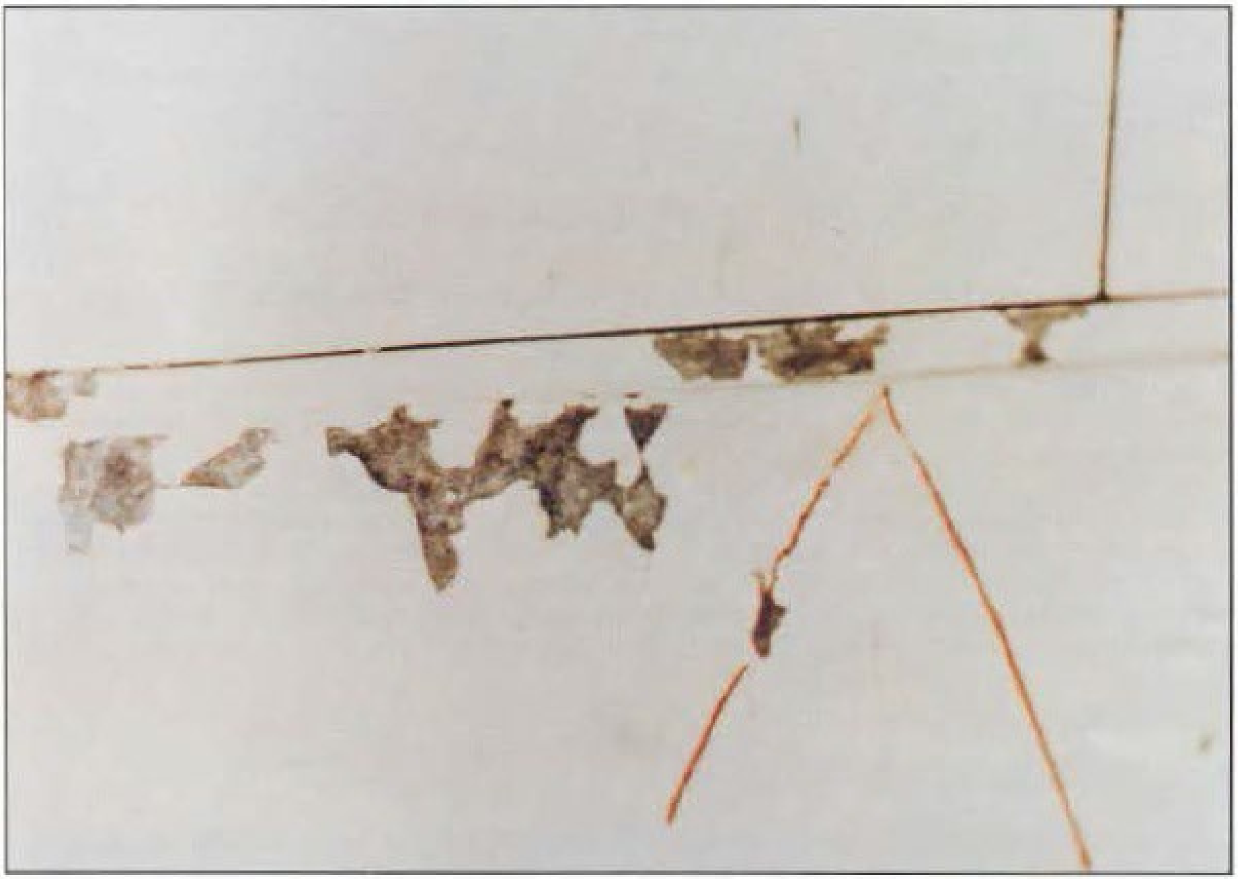


Figure 5-3. Corrosion Indicated by Blistering of Paint in Fuel Cell

Figure 5-4. Popped Rivet Heads Resulting from Corrosion Products

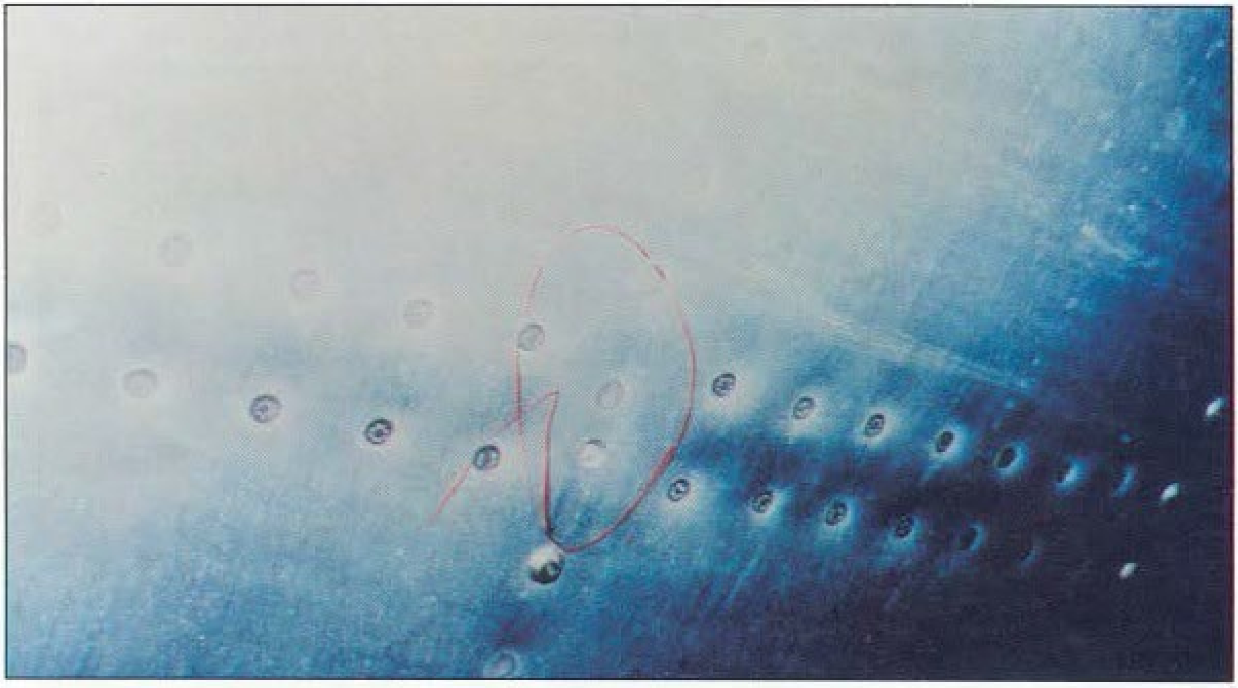


Figure 5-5. Skin Bulging Around Fasteners Caused by Pressure from Corrosion Products

Figure 5-6. Corrosion Cracking Between Fasteners on a Wing Spar

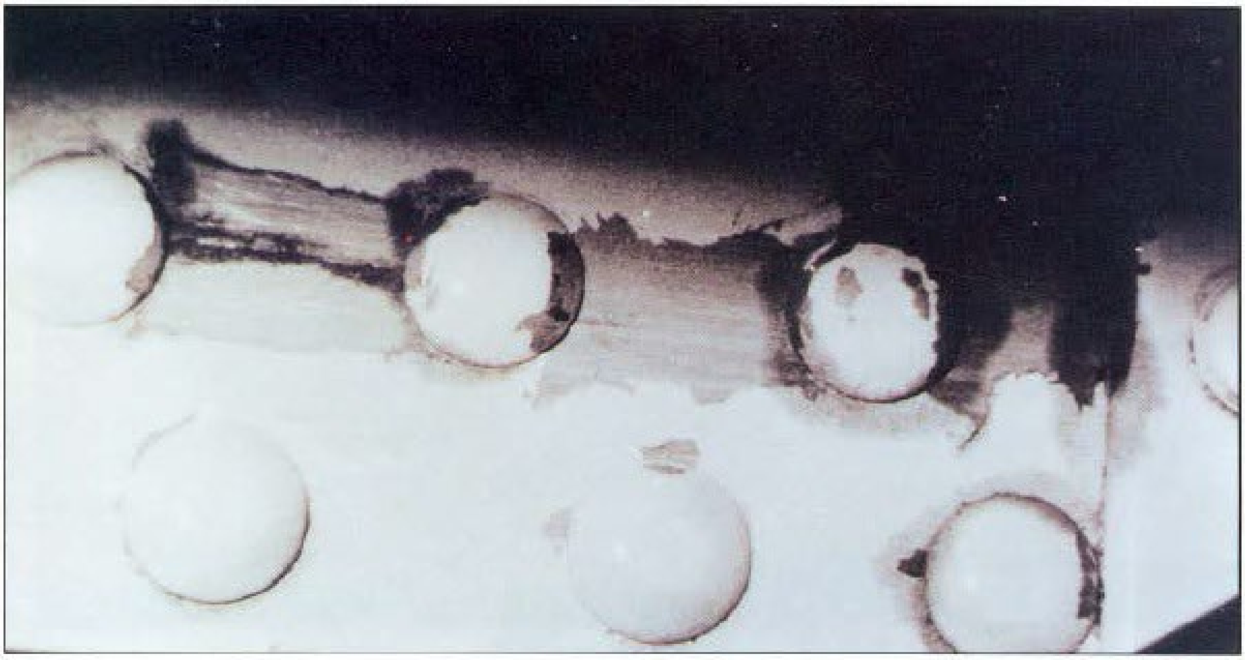


Figure 5-7. Faying Surface Corrosion on Wing Spar Chord with Corrosion Cracking Also Visible

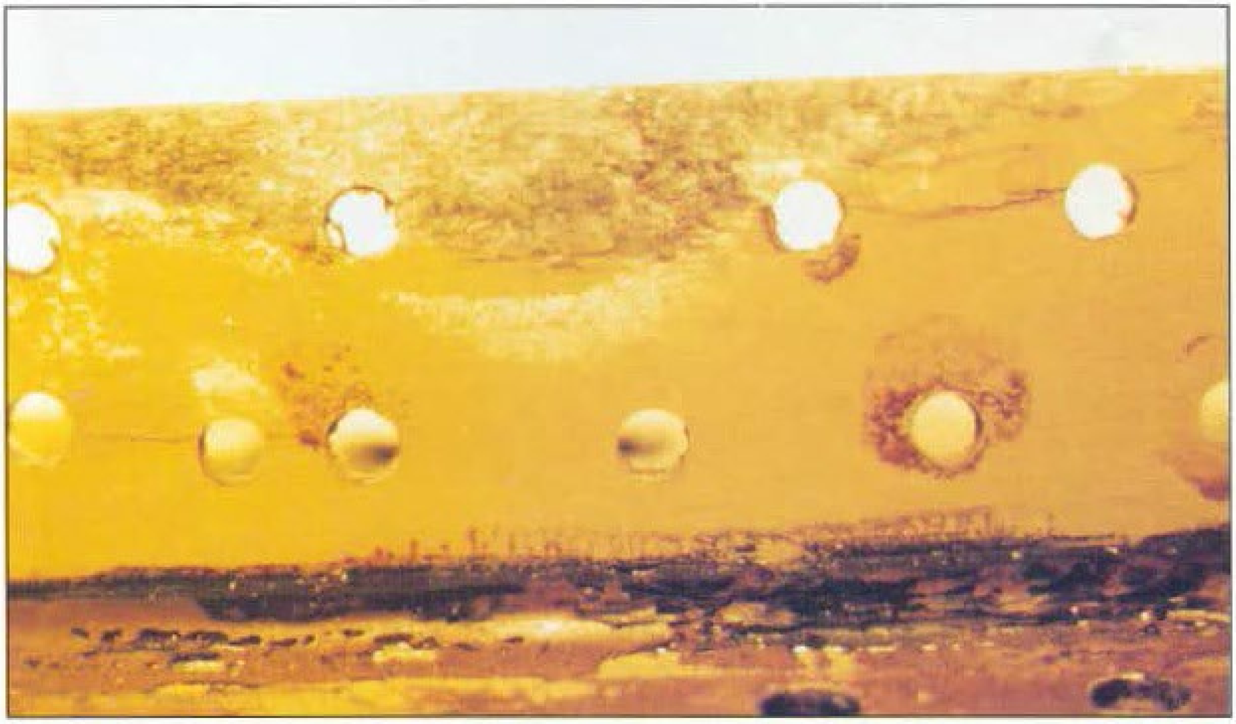


Figure 5-8. Severe Crown Stringer Corrosion

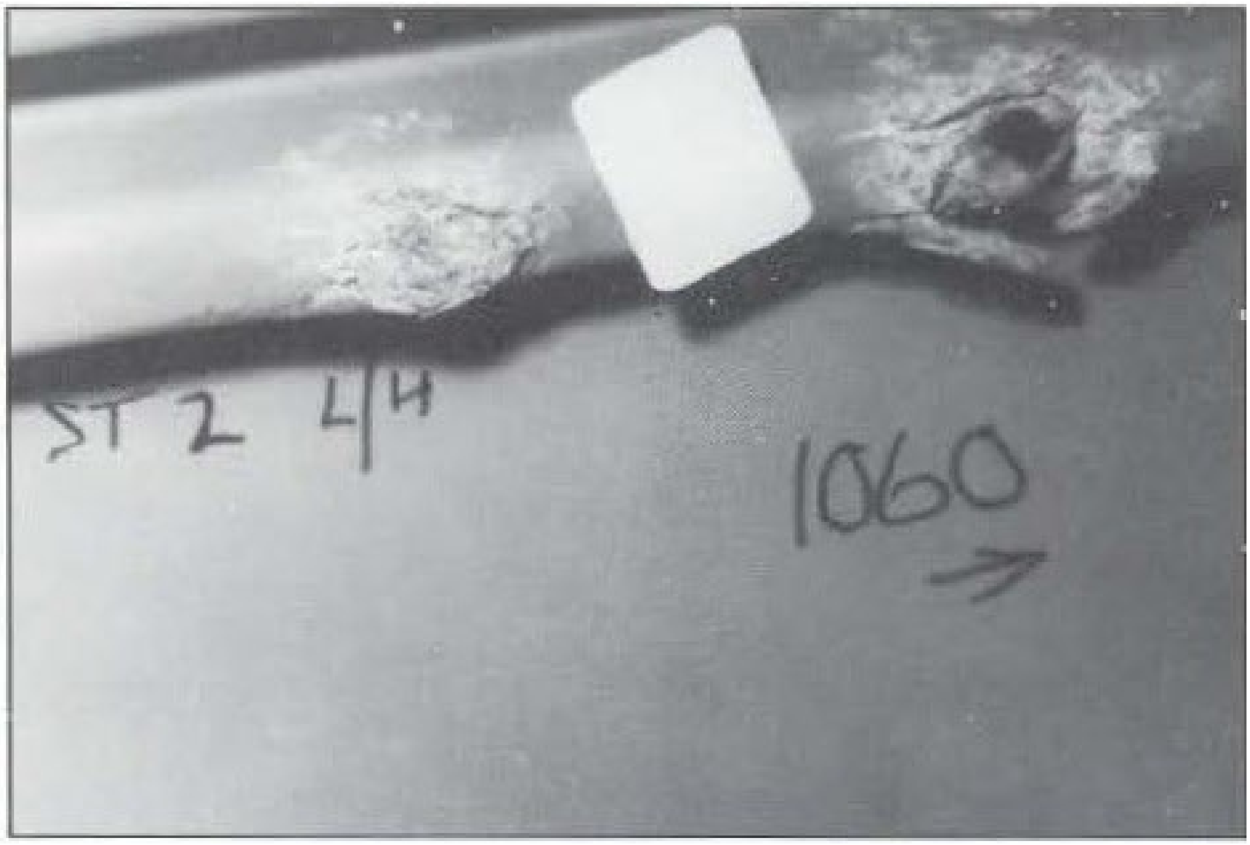


Figure 5-9. Spar Chord Corrosion

Figure 5-10. Removal of Fillet Seal from Internal Edge of Lap Joint Exposed Full Extent of Corrosion

Figure 5-11. Removal of Insulation Blankets Exposed Corrosion

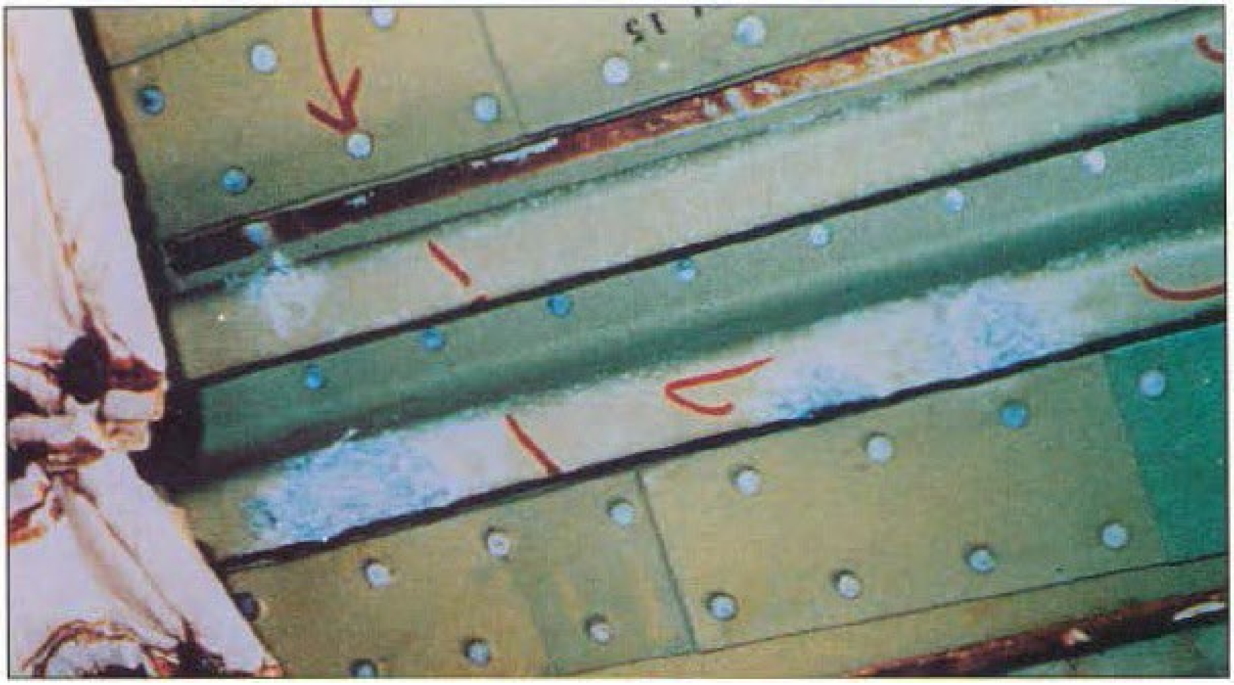


Figure 5-12. Corrosion Developed Under Leveling Compound Installed During Previous Repair of Overwing Exit

Figure 5-13. Corrosion Behind a Structural Component on a Wing Spar

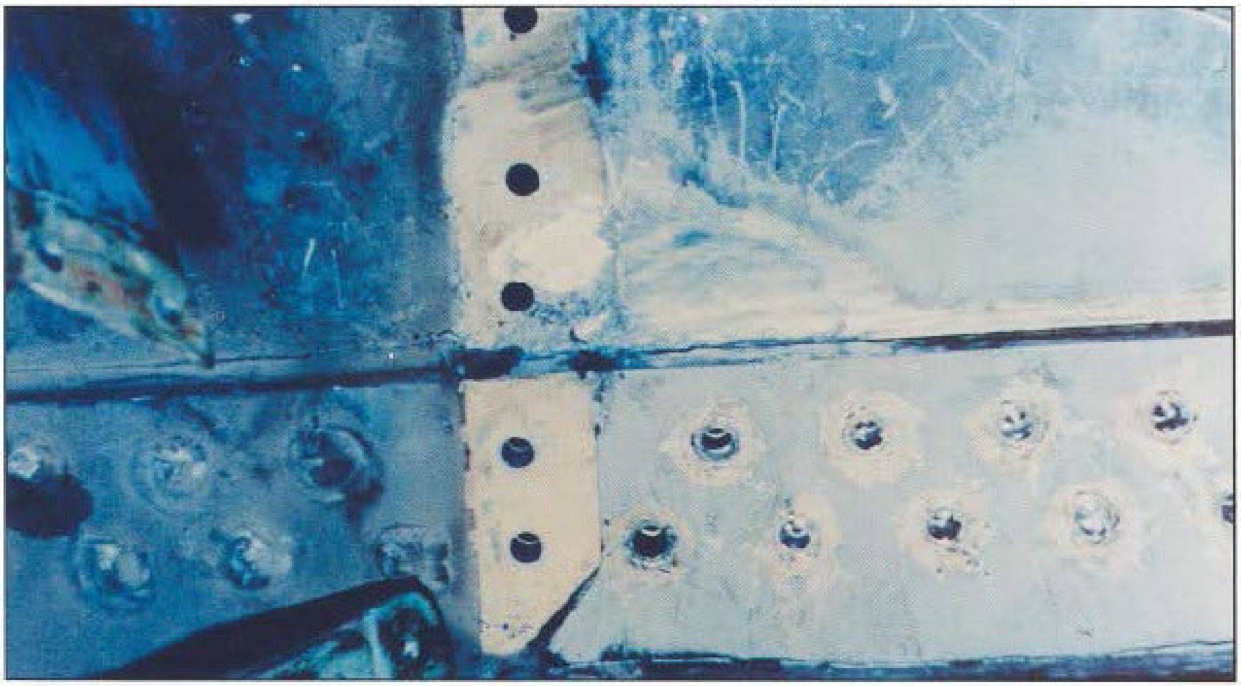


Figure 5-14. Severely Corroded Lap Joint

Figure 5-15. Severely Corroded Lap Joint

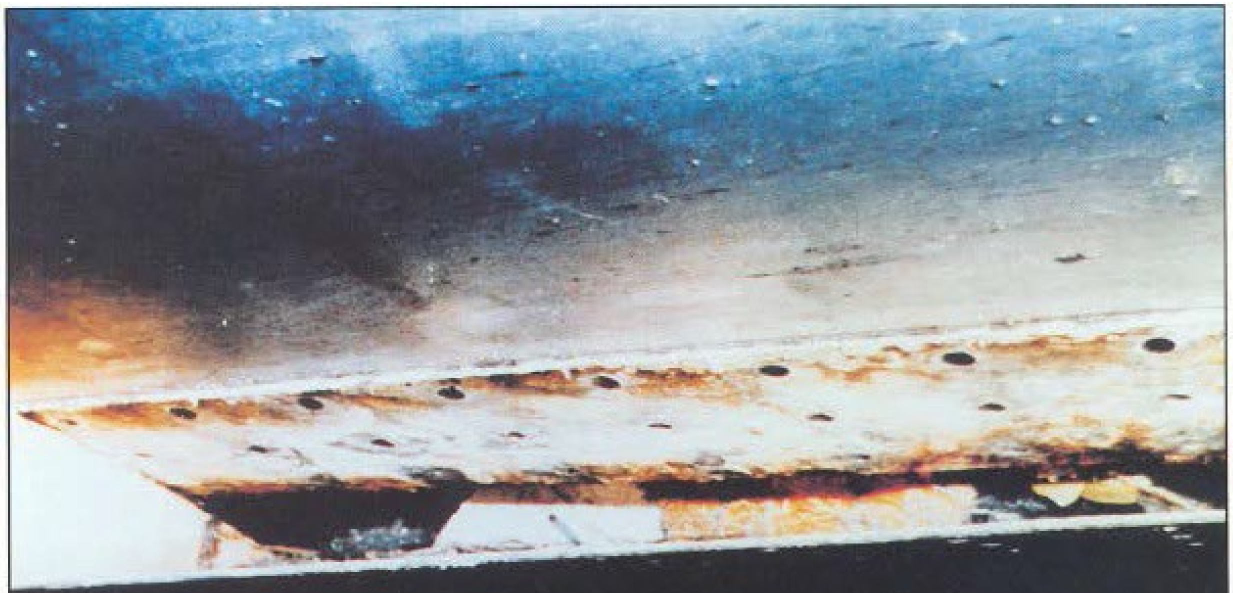


Figure 5-16. Local Paint Removal Required to Expose Full Extent of Corrosion

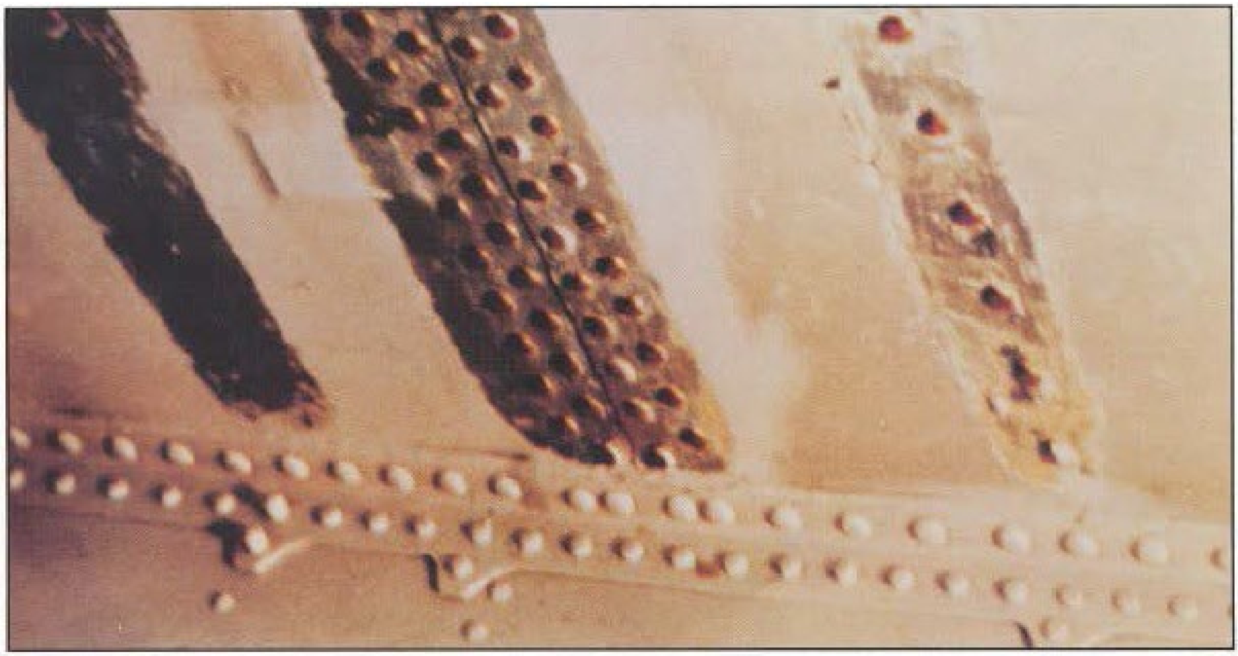


Figure 5-17. Corroded Area After Paint Removal from Wing Skin

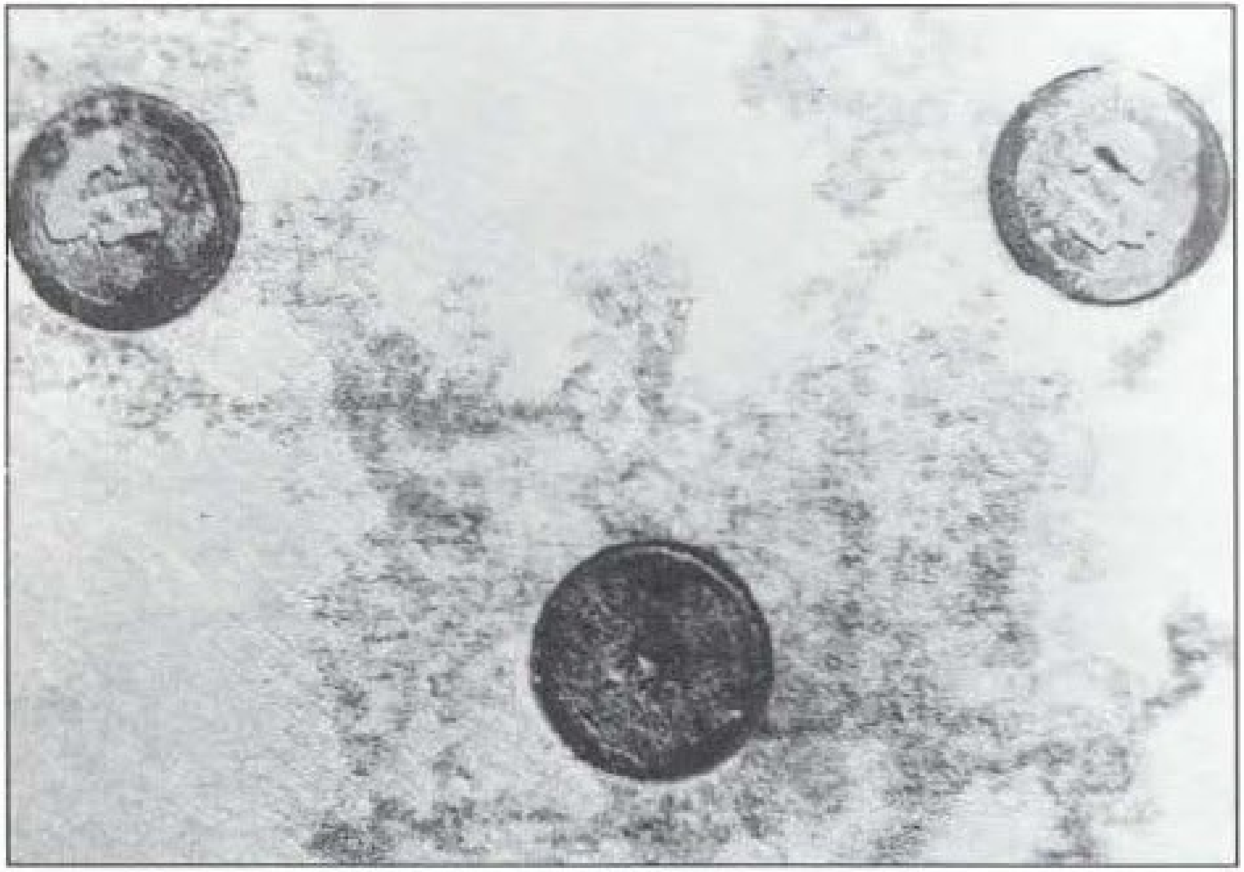
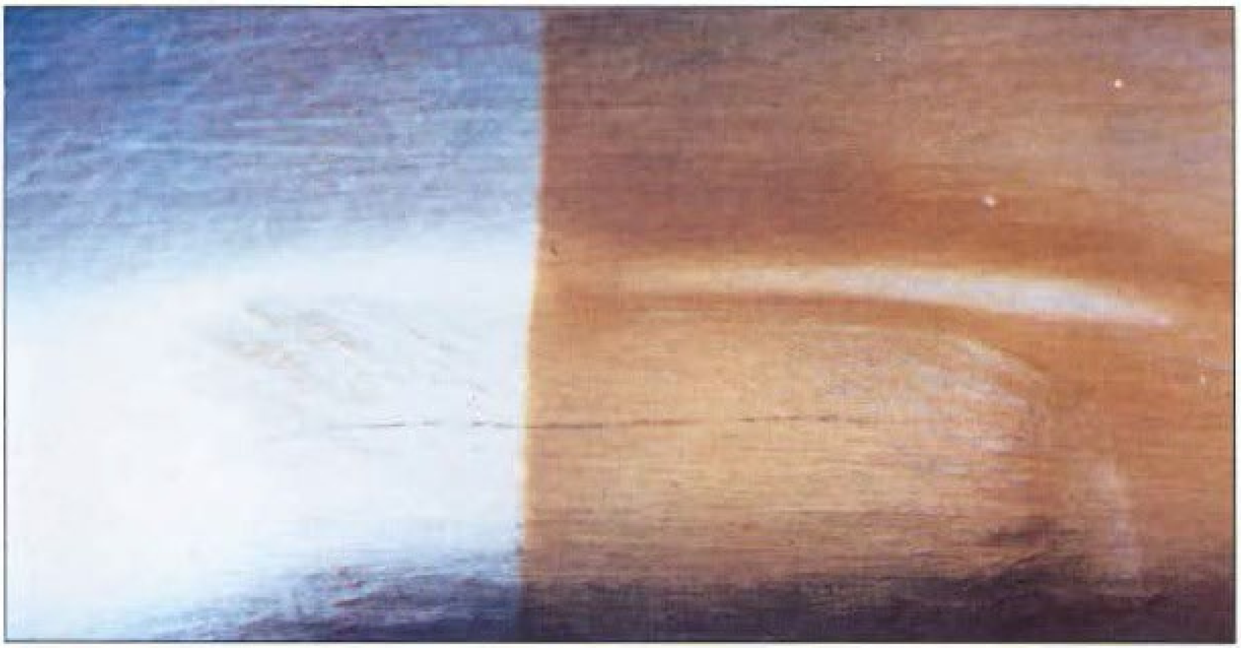


Figure 5-18. Bonderite 1200 Treatment Prior to Painting May Highlight Presence of Remaining Corrosion or Cracks



5.4.1.2 **Other Methods.** There are several NDI methods which may be valuable in detecting corrosion, such as liquid penetrant, magnetic particle, eddy current, x ray, ultrasonic, and acoustical emission. These methods have limitations, and only qualified and certified NDI personnel should perform them. Eddy current, x ray, and ultrasonic inspections require properly calibrated per-use equipment and a reference standard to obtain reliable results.

5.4.1.2.1 Liquid Dye Penetrant. Inspect large stress-corrosion or corrosion fatigue cracks on nonporous ferrous or nonferrous metals using this process. The dye will enter cracks, fissures, or other small openings by capillary action when applied to a clean metallic surface. After absorption by any surface discontinuities, remove excess dye and apply a developer substance to the surface. A developer acts like a blotter and draws the dye from the cracks or fissures back to the surface of the part, giving visible indication of faults on the surface. The magnitude of the fault is indicated by the quantity and rate of dye on the surface after developer application.

5.4.1.2.2 Magnetic Particle Inspection. Use this inspection method to detect cracks or flaws on or near the surface of ferromagnetic metals, or metals attracted by magnetism. A portion of the metal is magnetized and coated with finely divided magnetic particles, either in liquid suspension or dry. Surface faults will create discontinuities in the magnetic field and cause the particles to congregate on or above these imperfections, pinpointing their location.

5.4.1.2.3 Eddy Current Inspection. This method detects thinning due to corrosion and cracks in multi-layered structures. Low-frequency eddy current testing can, to some degree, detect or estimate corrosion on the hidden side of aircraft skins because it can measure an uncorroded material's thickness when used with a reference standard. Low-frequency eddy current testing can estimate corrosion in the underlying structure because the currents will penetrate through into the second layer of material with sufficient sensitivity for approximate results. High-frequency eddy current testing is most appropriate for detection of cracks which penetrate the surface of the structure on which test personnel place an eddy current probe, including flat surfaces and holes.

5.4.1.2.4 X Ray Inspection. Because it is difficult to obtain the sensitivity required to detect minor or moderate corrosion, x ray inspection has somewhat limited use for detecting corrosion. Briefly, this method passes high-energy x rays through a material; a special film on the opposite side of the material registers the passage of the x rays. Areas of high density display as underexposed areas, while areas of 1ow density show up as overexposed areas. Moderate to severe corrosion or cracks using x ray inspection can be detected. However, this method, like other NDI methods, requires a qualified and certified operator to obtain reliable results.

5.4.1.2.5 Ultrasonic Inspection. Ultrasonic testing provides a sensitive detection capability for corrosion damage when access is available to a surface with a continuous bulk of material exposed to the corrosion. Personnel commonly use ultrasonic inspection to detect exfoliation, stress-corrosion cracks, and general material thinning. However, ultrasonic digital thickness gauges are not reliable for determining moderate or severe damage prior to removing corrosion. Trained personnel should conduct the examination to derive useful information from indicating devices.

5.4.1.2.6 Acoustic Emission Testing. This method uses heat-generated emissions to detect corrosion and moisture in adhesive-bonded metal honeycomb structures. Acoustic emission testing can detect corrosion initiation as well as advanced corrosion.

5.5–5.99. RESERVED.

CHAPTER 6. CORROSION REMOVAL TECHNIQUES

SECTION 1. SAFETY PROCEDURES

6.1 General. The following general safety precautions contain guidelines for handling materials with hazardous physical properties and emergency procedures for immediate treatment of personnel who have inadvertently come into contact with a harmful material. Materials with hazardous physical properties are referenced to pertinent safety precautions and emergency safety procedures. All personnel responsible for using or handling hazardous materials should be thoroughly familiar with the information in the following paragraphs.

6.1.1 Safety Precautions. When required to use or handle solvents, special cleaners, paint strippers, strong alkalis or acids, etchants, corrosion removers containing acids, or surface activation material, such as Bonderite 1200, observe the following safety precautions:

1. Avoid prolonged breathing of solvent or acid vapors. Solvents and acids should not be used in confined spaces without adequate ventilation or approved respiratory protection;
2. Never add water to acid. Always add acid to water;
3. Mix all chemicals per manufacturer instructions;
4. Clean water for emergency use should be available in the immediate work area before starting work;
5. Avoid prolonged or repeated contact of solvents, cleaners, etchants, acid, or conversion coating material, such as a Bonderite solution, with skin. Wear rubber or plastic gloves when using solvents, cleaners, paint strippers, etchants, or conversion coating materials. Wear goggles or plastic face shields and suitable protective clothing when cleaning, stripping, etching, or conversion coating overhead surfaces;
6. When mixing alkalis with water or other substances, use containers made to withstand chemical heat generated by this process;
7. Wash any paint stripper, etchant, or conversion coating material immediately from body, skin, or clothing;
8. Promptly flush out materials splashed in eyes with water, and get medical aid for injured persons;
9. Do not eat or keep food in areas where the food may absorb poisons. Always wash hands before eating or smoking;
10. Verify that areas are clear and remain clear of all potential ignition sources within 50 feet of any cleaning or treating operations where materials with a flash point of 140 °F or below are in use;
11. Suitable fire extinguishing equipment should be available to the cleaning/treating area;

12. Where any flammable materials are in use, equipment should be effectively grounded;
13. If materials such as acid, alkali, paint remover, or conversion coatings are spilled on equipment or tools, treat immediately by rinsing with clean water if possible, or neutralizing acids with baking soda and alkalis with a 5 percent solution of acetic acid in water;
14. Do not use solvents with a flash point below 100 °F, such as methyl ethyl ketone (MEK) and acetone, in confined locations;
15. Clean all equipment after work is complete;
16. Implement all company safety precautions;
17. Check local environmental regulations for restrictions on the use of solvents, primers, and topcoats; and
18. Dispose of waste material per local environmental requirements.

6.1.2 Emergency Safety Procedures.

Note: Personnel should be thoroughly familiar with the following emergency safety procedures before using any materials referenced to an emergency safety procedure paragraph.

6.1.2.1 If exposed to physical contact with any of the following materials:

Methyl alcohol	Xylene
Methyl ethyl ketone	Petroleum naphtha
Methyl isobutyl ketone	Chromates
Toluene	Dichromate
Trichloroethylene	Acetates
Epoxy resin	Cyclohexanone
Methylene chloride	Cellosolve
Brush Bonderite	Carbon tetrachloride

6.1.2.2 Treat as follows:

- If splashed into eyes, do not rub.
- Flush eyes immediately with water for at least 15 minutes. Lift upper and lower eyelids frequently to ensure complete washing.
- If splashed on clothing or large areas of the body, immediately remove contaminated clothing and wash body with plenty of soap and water. Also wash clothing before wearing again.

- If splashed onto an easily accessible part of the body, immediately wash with soap and water.
- If suffering a headache or other obvious symptoms resulting from overexposure, move to fresh air immediately.
- If vapors are inhaled and breathing has slowed down or stopped, remove person from exposure and start cardiopulmonary resuscitation (CPR)/Automated External Defibrillator (AED) procedures at once. Call local emergency services and continue this treatment until emergency services arrives.

6.1.2.3 If exposed to physical contact with any of the following materials:

- Hydrofluoric acid.
- Nitric acid.
- Phosphoric acid.
- Phenol.
- Cresols.
- Tricresyl phosphate.

6.1.2.4 Treat as follows:

1. If splashed into eyes, quickly wipe eyelids with a soft cleaning tissue and immediately flush eyes with a gentle stream from a drinking fountain, cup, or other convenient water outlet while holding lids open. Call local emergency services and continue this treatment until emergency services arrives.
2. If splashed onto an easily accessible part of the body, immediately drench affected area with water until ambulance arrives.
3. If splashed onto clothing or large area of the body, immediately drench body and remove clothing while drenching until ambulance arrives.
4. If taken internally, begin the following treatment immediately:
   - If the person is conscious, cause vomiting by placing finger in back of the person's throat. Encourage the person to drink large quantities of water and repeatedly wash out the mouth.
   - If the person is unconscious, do not give any liquid. Start CPR/AED procedures at once. Continue until an emergency service arrives. Use the procedure above if the person regains consciousness before emergency services arrives, use the procedure above for a conscious person.

6.2 General Corrosion Control Work Procedures. The effectiveness of corrosion control depends on following basic work procedures. We recommend the following common work practices:

6.2.1 If rework procedures or materials are unknown, contact the aircraft manufacturer or authorized representative before proceeding.

6.2.2 The work areas, equipment, and components should be clean and free of chips, grit, dirt, and foreign materials.

6.2.3 Do not mark on any metal surface with a graphite pencil or any type of sharp, pointed instrument. Use temporary markings (markings soluble in water or methyl chloroform) for metal layout work or marking on the aircraft to indicate corroded areas.

6.2.4 Do not use graphite as a lubricant for any component. Graphite is cathodic to all structural metals and will generate galvanic corrosion in the presence of moisture, especially if applied in dry form.

6.2.5 Inspect footwear and clothing for metal chips, slivers, rivet cuttings, dirt, or sand, and remove all such material before walking or working on metal surfaces such as wings, stabilizers, or fuel tanks.

6.2.6 Do not abrade or scratch any surface unless following an authorized procedure. If surfaces are accidentally scratched, assess the scratch and take action to remove the scratch and treat the area, if necessary.

6.2.7 Do not polish coated metal surfaces for aesthetic purposes. Buffing removes a protective coating, and a brightly polished surface is normally not as corrosion resistant as an unpolished surface, unless it is protected by a coating such as wax or paint. A bare skin sheet polished to a mirror finish is more resistant than a bare, mill-finished sheet when both are given regular maintenance.

6.2.8 Protect surrounding areas when welding, grinding, or drilling, to prevent contaminating the areas with residue from these operations. In those areas where protective covering cannot be used, remove the residue by cleaning.

6.2.9 Replace severely corroded screws, bolts, and washers.

6.2.10 When a protective coating, such as cadmium plating, is damaged, immediately apply an appropriate protective finish to prevent additional corrosion damage.

6.3–6.9. RESERVED.

SECTION 2. CORROSION REMOVAL TECHNIQUES

6.10 General. When active corrosion is visually apparent, it is a good idea to start a positive inspection and rework program to prevent further deterioration of the structure. The following methods of assessing corrosion damage and procedures for rework of corroded areas are recommended during cleanup programs. In general, any rework would involve cleaning and stripping all finish from the corroded area, removing corrosion products, and restoring a surface protective film.

6.10.1 Repair of corrosion damage includes removal of all corrosion and corrosion products. When the corrosion damage exceeds damage limits set by the aircraft manufacturer in the Structural Repair Manual (SRM), the affected part must either be replaced or an FAA-approved engineering authorization must be obtained for continued service for that part.

6.10.2 For corrosion damage on large structural parts in excess of that allowed in the SRM and where replacement is not practical, contact the aircraft manufacturer for rework limits and procedures.

6.11 Standard Methods. Several standard methods are available for corrosion removal, mechanical and chemical methods being normally used. Mechanical methods include: 1) hand sanding using an abrasive mat, abrasive paper, or aluminum oxide impregnated materials, or 2) powered mechanical sanding, grinding, and buffing using an abrasive mat, grinding wheels, sanding discs, and abrasive rubber mats. However, the method used depends upon the metal and the degree of corrosion. Outlined in the following paragraphs is the removal method to use on each metal for each schedule degree of corrosion.

6.12 Preparations for Rework. All corrosion products should be removed completely when corroded structures are reworked. The corroding process will continue even though the affected surface is refinished. Before starting rework of corroded areas, carry out the following:

1. Position airplane in wash rack or provide washing apparatus for rapid rinsing of all surfaces.
2. Connect a static ground line to the airplane.
3. Prepare the aircraft for safe ground maintenance:
    - Remove aircraft batteries, liquid oxygen (LOX) containers (if installed), and external hydraulic and electric power.
    - Install all applicable safety pins, flags, and jury struts.
4. Protect pitot-static ports, louvers, air scoops, engine opening, wheels, tires, magnesium skin panels, and airplane interior from moisture and chemical brightening agents.
5. Protect surfaces adjacent to rework areas from chemical paint strippers, corrosion removal agents, and surface treatment materials.

6.13 Paint Removal. Refer to the Original Equipment Manufacturer (OEM) maintenance manuals for specific guidelines.

6.13.1 For small areas of metallic surfaces, remove paint by hand using a medium grade abrasive mat. For larger areas, chemical paint removal is the preferred method.

6.13.2 Phenolic and non-phenolic chemical paint removers containing methylene chloride are recommended for paint stripping on metallic surfaces only. Do not use chemical paint strippers containing acid because the strippers will cause hydrogen embrittlement on high-strength steel and some stainless steels. The following procedure is recommended when using chemical paint remover:

1. Mask acrylic windows and canopies, plastic parts, rubber hoses, exposed wiring, composite surfaces, wheels and tires, and other areas where paint remover residue cannot be removed and refinishing cannot be accomplished;
2. Remove any sealants by cutting away excess sealant with a sharp plastic scraper;
3. Apply a thick, continuous coating of paint remover to cover the painted surface;
4. Leave the paint remover on the surface for enough time to wrinkle and completely lift the paint. Reapply paint remover as necessary in areas where paint remains tight or where the material has dried. Micarta scrapers, abrasive pads, or fiber brushes can be used to assist in removing persistent paint;
5. Remove loosened paint and residual paint remover by washing and scrubbing the surface with fresh water and a stiff nylon bristle brush or an abrasive pad; and
6. After thorough rinsing, remove masking materials and thoroughly clean the area with a solution of aircraft cleaning compound to remove paint remover residues.

6.13.3 For composite surfaces, paint removal should be done by mechanical removal techniques (scuff sanding) only. Composite surfaces include fiberglass, Kevlar, carbon, and graphite. Due to irregularities in composite surfaces, such as a fiber weave, a paint system cannot be completely removed without damaging surface fibers.

6.13.4 Paint can be mechanically removed by hand or with fine or very fine abrasive mats or flap brushes on power tools. If using power tools, be careful to prevent removal of the base material.

6.14 Special Techniques. In special instances, a schedule or specific method to remove corrosion may be needed. Depending upon rework criteria, corrosion in a hole may be removed by enlarging the hole. Abrasive blasting may remove corrosion from steel fasteners, side skins, or irregularly shaped parts or surfaces. Whenever such special cases occur, observe the specified method for corrosion removal.

6.15 Fairing or Blending Reworked Areas. Fair or blend with a surrounding surface all depressions resulting from corrosion rework. Fairing can be accomplished as follows:

6.15.1 Remove rough edges and all corrosion from damaged areas. All dish-outs should be elliptically shaped with the major axis running spanwise on wings and horizontal stabilizers, longitudinally on fuselages, and vertically on vertical stabilizers. Select the proper abrasive for fairing operations from Table 6-1, Abrasives for Corrosion Removal.

6.15.2 Rework depressions by forming smoothly-blended dish-outs, using a length-to-depth ratio of 20:1 (see Figures 6-1, Blendout of Corrosion as Single Depression Width, and 6-2, Typical Example of Acceptable Cleanup of Corrosion Pits). In areas having closely-spaced multiple pits, remove intervening material to minimize surface irregularity or waviness (see Figures 6-3, Blendout of Multiple Pits in Corroded Area, and 6-4, Profile of Reworked Corroded Areas in Regions of Limited Access). Remove steel nutplates and steel fasteners before blending corrosion out of aluminum structure. Steel or copper particles embedded in aluminum can become a point of future corrosion (see Figure 6-5, Steel Particles from Fasteners or Nutplates May Cause Future Corrosion Problems in Aluminum Structure). Remove all corrosion products during blending to prevent reoccurrence of corrosion (see Figures 6-6, Incomplete Removal of Corrosion Products Resulted in Reoccurrence of Corrosion, and 6-7, Incomplete Removal of Corrosion Products Resulted in Reoccurrence of Corrosion).

6.15.3 In critical and highly stressed areas, pits may remain after removal of corrosion products by any method. These pits should be blended out to prevent stress risers, which may cause stress-corrosion cracking. But if the pits are on noncritical structures, use of abrasive blasting is not required to blend out the pits, since this results in unnecessary metal removal.

Table 6-1. Abrasives for Corrosion Removal

Metals or Materials to be Processed	Restrictions	Operation	Abrasive Paper or Cloth			Abrasive Fabric or Pad	Aluminum	Stainless Steel	Pumice 350 Mesh or Finer	Abrasive Wheel
			Aluminum Oxide	Silicon Carbide	Garnet					
Ferrous Alloys	Does Not Apply to Steel Heat Treated to Strengths to 220,000 psi and Above	Corrosion Removal or Fairing	150 Grit or Finer	180 Grit or Finer		Fine to Ultrafine	X	X	X	X
		Finishing	400 Grit				X	X	X	
Aluminum Alloys Except Clad Aluminum	Do Not Use Silicon Carbide Abrasive	Corrosion Removal or Fairing	150 Grit or Finer		7/0 Grit or Finer	Very Fine and Ultrafine	X		X	X
		Finishing	400 Grit				X		X	
Clad Aluminum	Sanding Limited to the Removal of Minor Scratches	Corrosion Removal or Fairing	240 Grit or Finer		7/0 Grit or Finer	Very Fine and Ultrafine			X	X
		Finishing	400 Grit						X	
Magnesium Alloys		Corrosion Removal or Fairing	240 Grit or Finer			Very Fine and Ultrafine	X		X	X
		Finishing	400 Grit				X		X	
Titanium		Cleaning and Finishing	150 Grit or Finer	180 Grit or Finer				X	X	X

Figure 6-1. Blendout of Corrosion as Single Depression Width

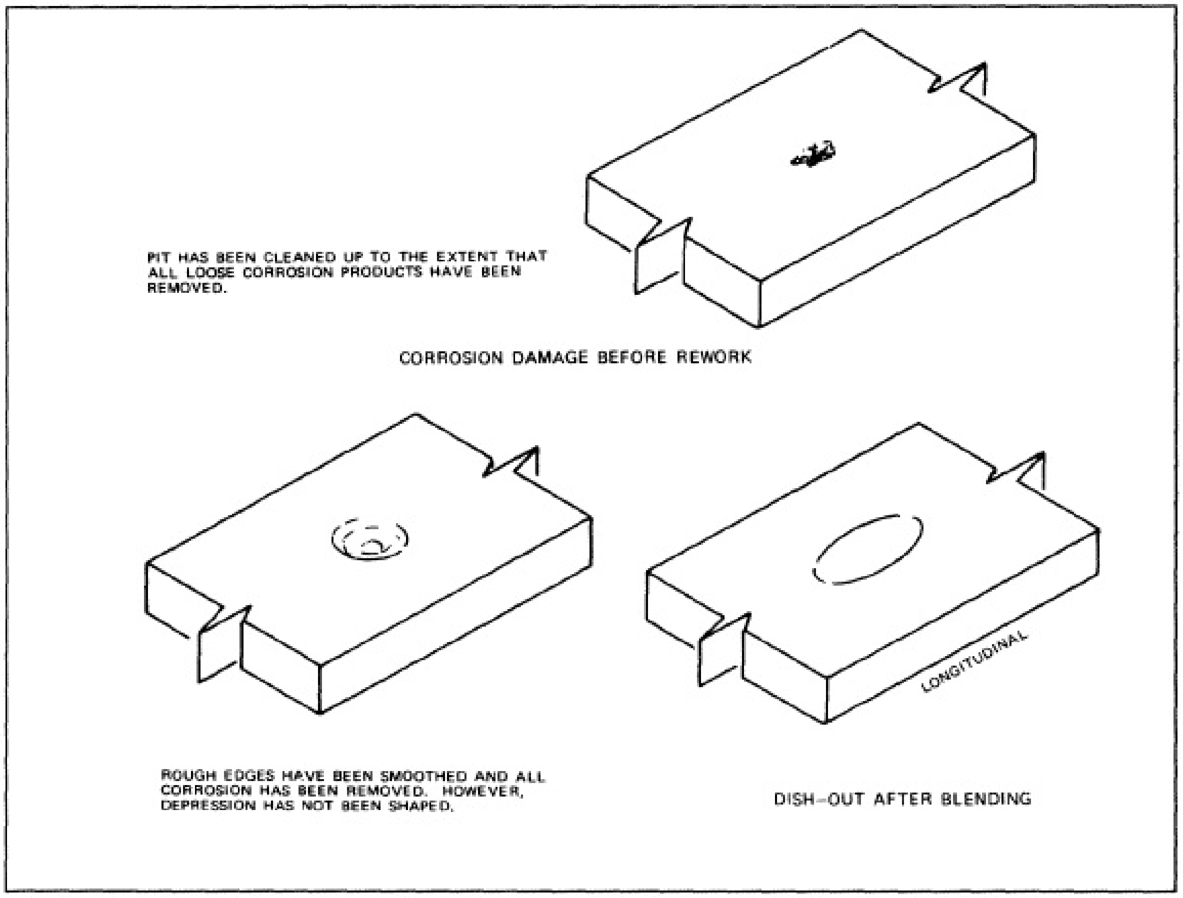


Figure 6-2. Typical Example of Acceptable Cleanup of Corrosion Pits

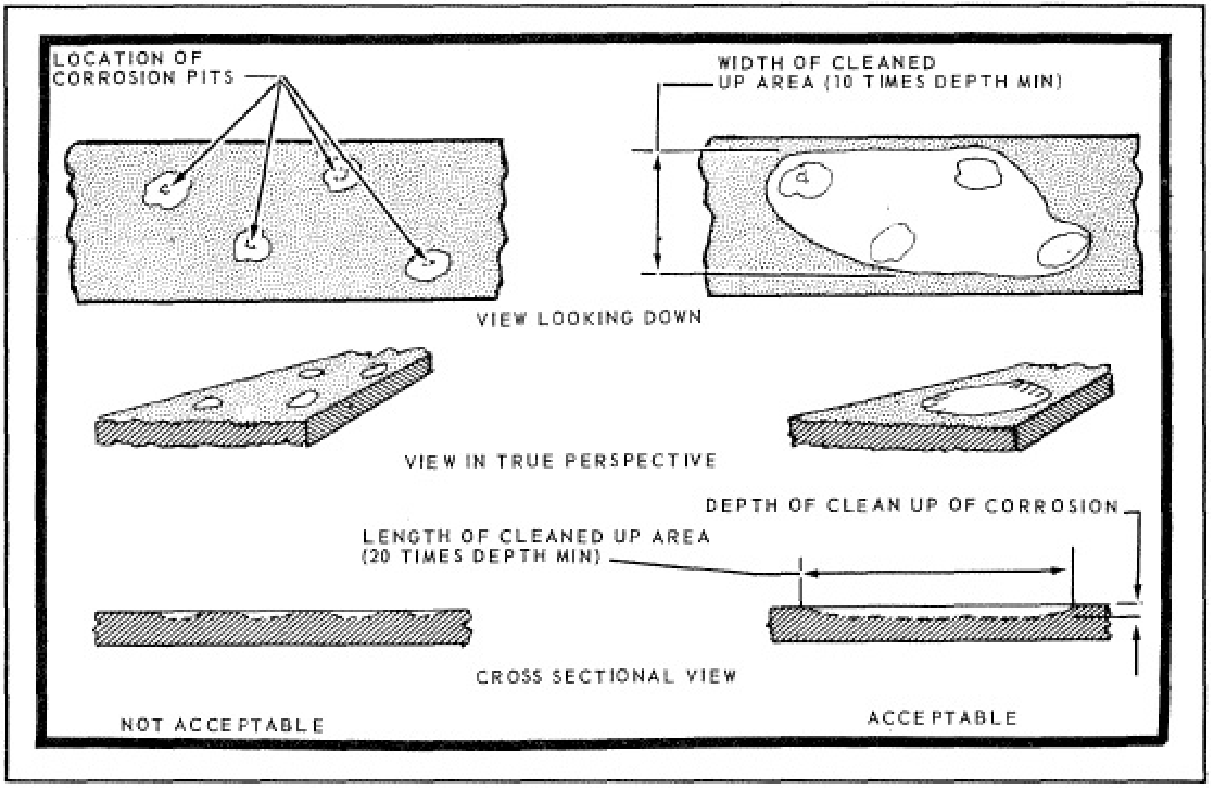


Figure 6-3. Blendout of Multiple Pits in Corroded Area

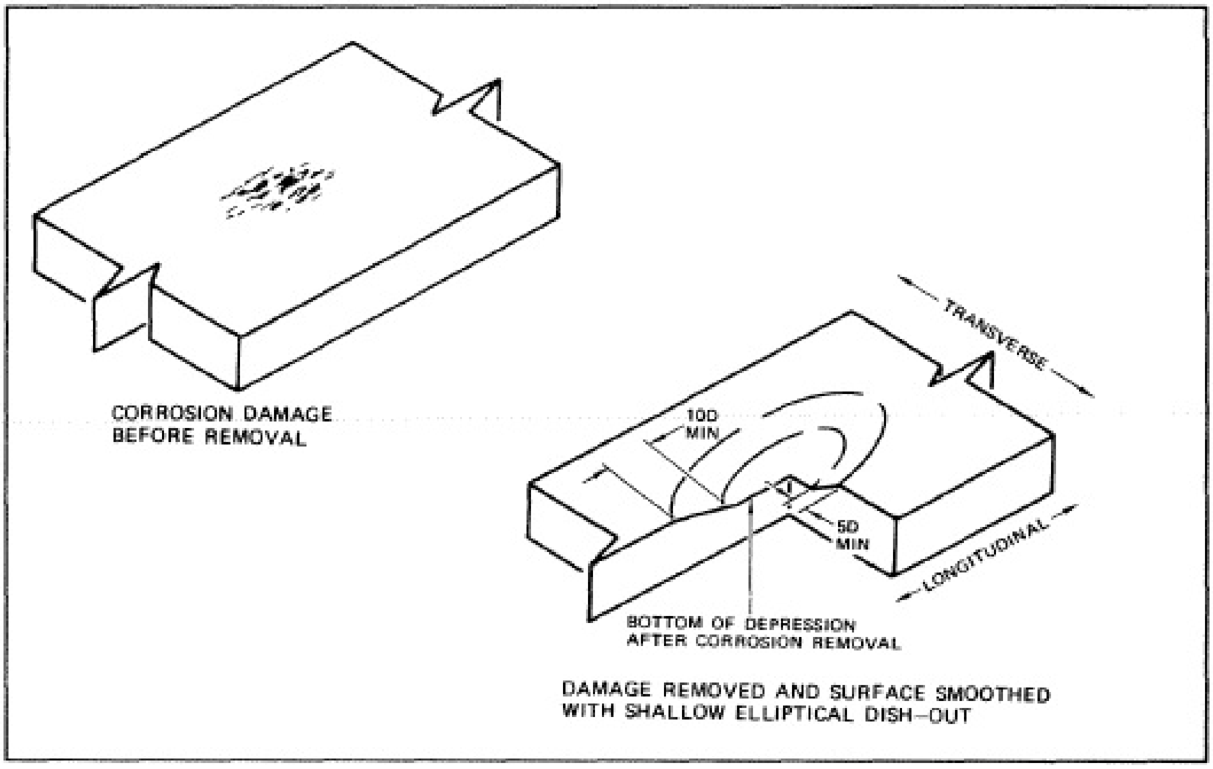


Figure 6-4. Profile of Reworked Corroded Areas in Regions of Limited Access

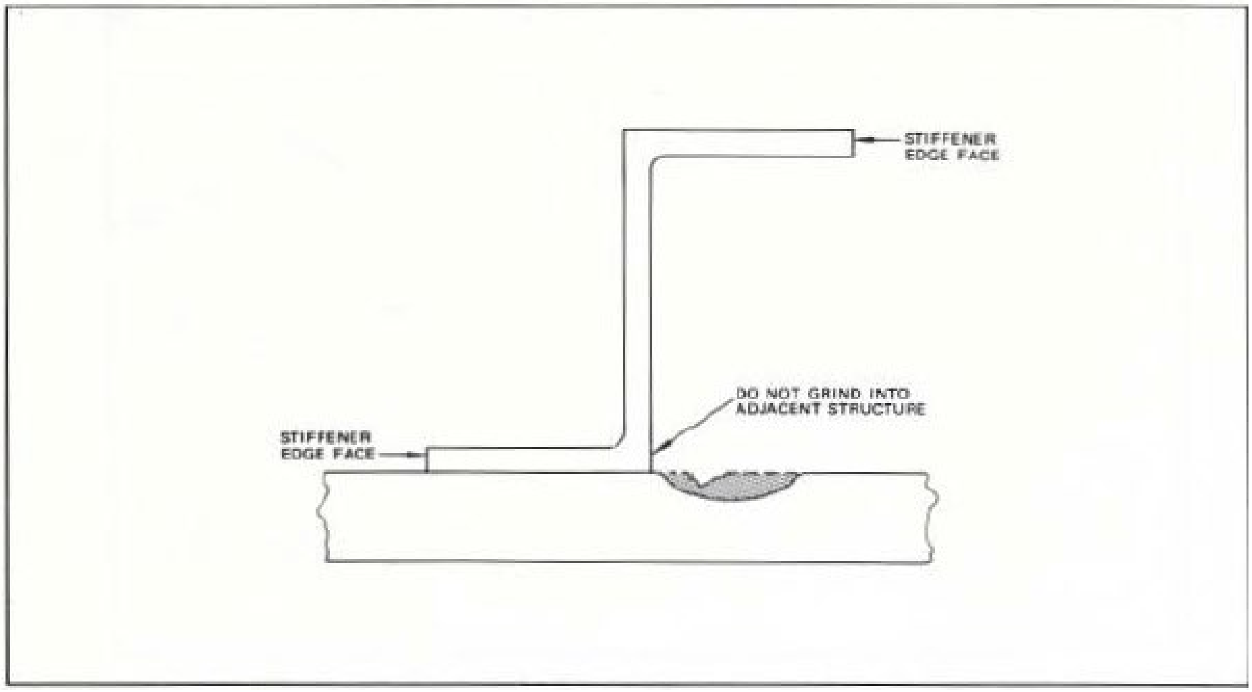


Figure 6-5. Steel Particles from Fasteners or Nutplates May Cause Future Corrosion Problems in Aluminum Structure

Figure 6-6. Incomplete Removal of Corrosion Products Resulted in Reoccurrence of Corrosion

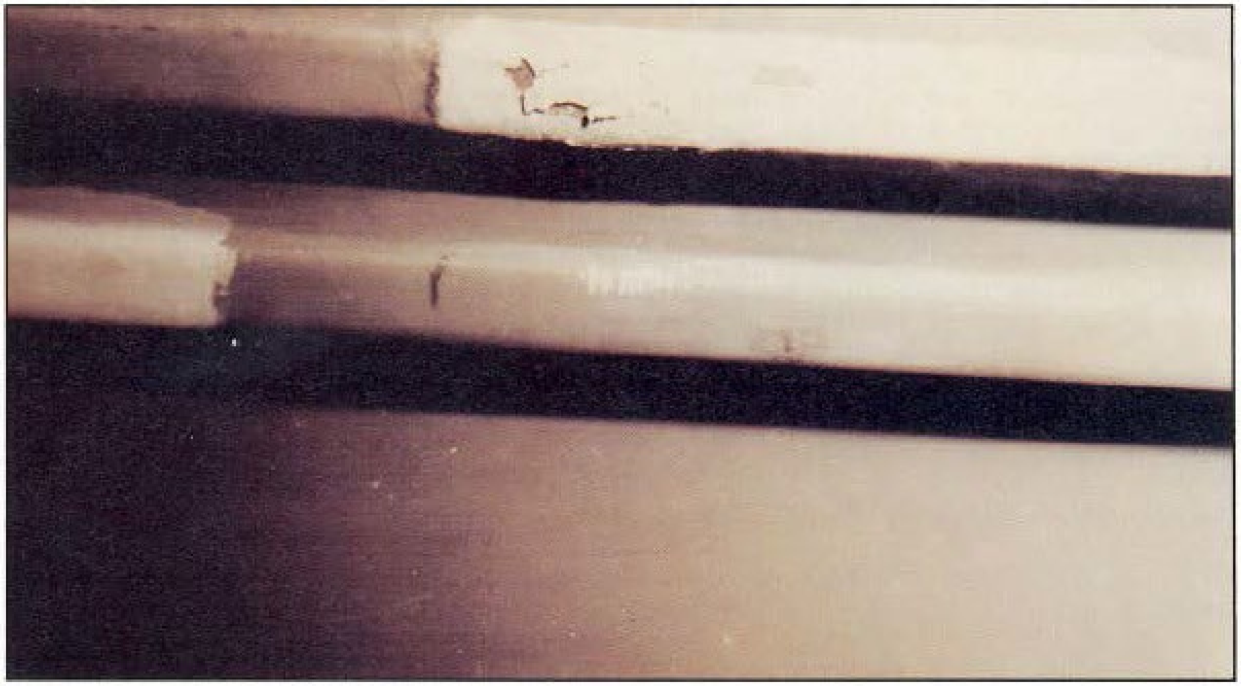
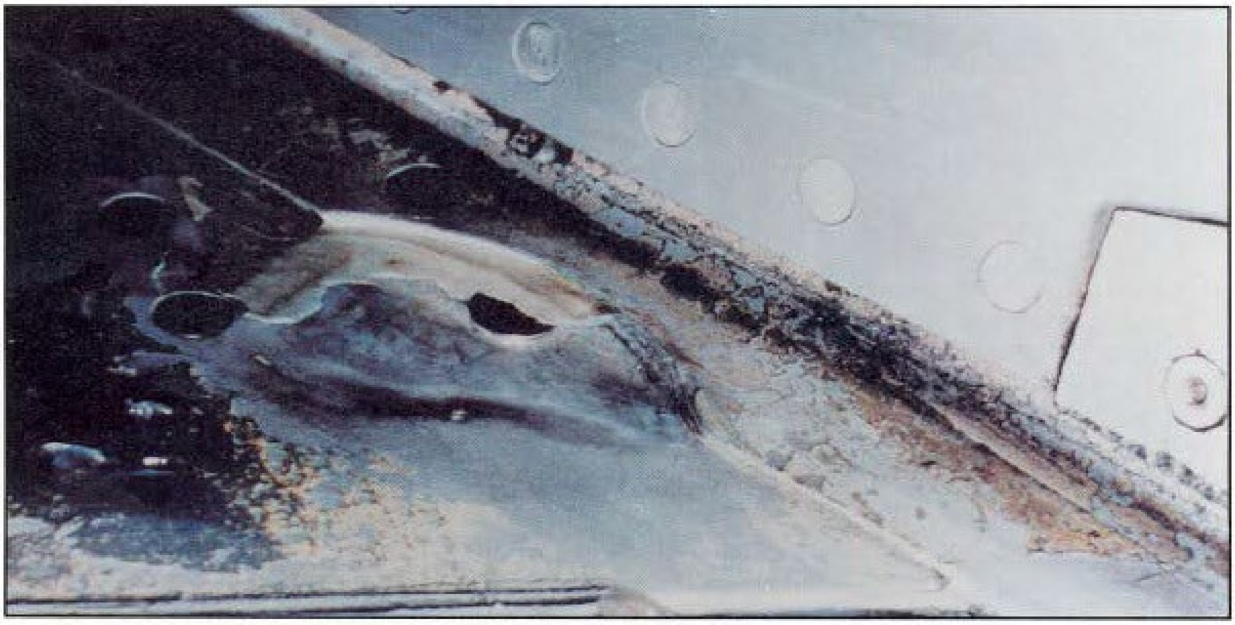


Figure 6-7. Incomplete Removal of Corrosion Products Resulted in Reoccurrence of Corrosion



6.16 Chemical Testing.

6.16.1 A serious problem in corrosion control is identification of the metal on which corrosion occurs. This identification is important because all metals possess certain chemical characteristics common only to themselves, and these characteristics vary greatly from metal to metal and from alloy to alloy of the same metal. Since these characteristics are common to all metals and their alloys, chemical cleaning solutions and chemical protective films will react differently with different metals. In some cases, this reaction produces adverse reactions which can severely weaken or destroy the structural capabilities of the metal.

6.16.1.1 The primary method of identifying metal is in the aircraft SRM. When the SRM is limited or when more information is required, such as with heat-treat and protective finishes, the best source of identification is the aircraft manufacturer, where an aircraft drawing can be reviewed.

6.16.1.2 Use chemical testing when all other methods have been exhausted and when the following precautions are followed:

- Personnel should become thoroughly familiar with the safety precautions and emergency safety procedures, prior to performing any chemical testing.
- Chemical spot testing should be accomplished by qualified personnel only.
- Fasteners should not be identified by chemical spot tests.
- High-strength steel should not be identified by chemical spot tests.

6.16.2 Use test samples for chemical testing for metals before testing the actual part. Determine the preliminary surface preparation and primary classification of the metal by the following procedure:

1. On the surface to be tested, choose an area where there is no corrosion and remove paint, if present, from a 1-inch square. Paint may be removed using hand sanding or an approved paint remover.

   CAUTION: Take adequate precautions to prevent paint remover from contacting composite parts.

2. Clean the surface of the test area.
3. Tentatively identify the exposed metal surface by visually comparing it with samples of previously identified materials, if available.

4. Identify the metal as ferrous or nonferrous by placing a magnet on the exposed surface. Magnetic attraction classifies the base metal as a ferrous magnetic material, which can be either iron or steel. The absence of magnetic attraction classifies the base metal as either an austenitic stainless steel or a nonferrous metal, such as aluminum or magnesium.
5. Have a qualified person test magnetic metals for hardness before chemical spot testing. If the metal is nonmagnetic, proceed with paragraph 6.18.

6.17 Chemical Spot Analysis of Magnetic Metals. Aircraft manufacturers usually use magnetic ferrous alloys, such as high-strength steels and some stainless steels, in aircraft construction. These magnetic alloys can be plated with chromium, nickel, zinc, cadmium, silver, or a combination of these platings.

6.17.1 If a magnetic alloy has a cadmium, zinc, or chromium plating, that plating will exert magnetic attraction. Nickel plating will show slight magnetic attraction even if the substrate or base metal is not magnetic.

6.17.2 If positive identification of the metal plating is necessary, the identification should be made after accomplishing a hardness test.

CAUTION: Do not perform a chemical spot test on steels heat-treated to 220,000 psi and above.

6.17.3 Place a drop of 10 percent hydrochloric acid (HCl) on the prepared metal surface. Ensure that the surface is dry before applying the acid.

- A rapid reaction producing a dark deposit indicates that the metal is zinc.
- A slow or no reaction indicates that the metal may be cadmium, chromium, nickel, or steel.

6.17.4 After 1 minute, add a drop of sodium sulfide (Na_2S) to the drop of HCl.

CAUTION: Adding Na_2S to any acid produces a poisonous gas. Provide adequate ventilation when performing these identification tests. Do not mix large quantities of Na_2S and acid.

- A white precipitate identifies the metal as zinc.
- A yellow ring formed around a white precipitate identifies the metal as cadmium.
- A black ring formed around a white precipitate identifies the metal as iron or steel.
- A black precipitate indicates that the metal is chromium or nickel.

6.17.5 Confirm the cadmium, zinc, iron, or steel test by placing a drop of 20 percent nitric acid (HNO_3) on a fresh spot. After 1 minute, add a drop of Na_2S to the drop of HNO_3.

- A white precipitate identifies the metal as zinc.

- A yellow precipitate identifies the metal as cadmium.
- A black spot identifies the metal as iron or steel.

6.17.6 Confirm the chromium test by placing a drop of 10 percent HCl on a fresh spot. Add a drop of concentrated sulfuric acid (H_2SO_4) to the drop of HCl. A color change to green after 1 or 2 minutes identifies the metal as chromium.

6.17.7 Confirm the nickel test by placing a drop of dimethylglyoxime ($C_4H_8N_2O_2$) solution on a fresh spot. Add a drop of ammonium hydroxide (NH_4OH) to the drop of $C_4H_8N_2O_2$ solution. A pink-to-red precipitate identifies the metal as nickel.

6.17.8 Clean and refinish, as detailed in paragraph 6.20.

6.18 **Chemical Spot Analysis of Nonmagnetic Metals.** The most common nonmagnetic metals in aircraft construction are aluminum, magnesium, and austenitic steels, generally used as 18-8 stainless steel, where the “18-8” indicates a composition of 18 percent chromium and 8 percent nickel. Positively identify these nonmagnetic metals by the following procedure:

6.18.1 Place a drop of 10 percent HCl on the prepared metal surface and allow to stand for 1 minute. Ensure the surface is dry before applying the acid.

Note: Zinc deposits on nonmagnetic metals will react with 10 percent HCl but will not produce a black spot.

- A rapid or violent reaction that produces a black spot indicates the metal is magnesium.
- A slow reaction indicates the metal is aluminum.
- No reaction indicates the metal is an austenitic steel or a nonmagnetic plating material.

6.18.2 If a reaction did not produce a black spot as noted in the first bullet under paragraph 6.18.1, determine if zinc is present, as detailed in paragraph 6.17.5.

6.18.3 If the results of paragraph 6.18.2 are negative (zinc is not present) confirm the magnesium and aluminum tests by placing a drop of 10 percent sodium hydroxide (NaOH) on a fresh spot. Check for the following:

- No reaction will identify the metal as magnesium, or
- A reaction that produces a colorless spot will identify the metal as a bare-aluminum alloy.

6.18.4 If an aluminum alloy is identified as outlined in paragraph 6.18.3, further test to distinguish the different alloys by placing a drop of 10 percent cadmium chloride ($CdCl_2$) on a fresh spot.

- A dark gray deposit forming within a few seconds will identify the metal as 7075 or 7178 bare-aluminum alloy.
- A dark gray deposit forming within 2 minutes will identify the metal as 7075 or 7178 clad-aluminum alloy.
- No deposit formation in 2 minutes will identify the metal as 2024 aluminum alloy. A faint deposit will form after 15 or 20 minutes.

6.18.5 Confirm the austenitic steel test by dissolving 10 grams of cupric chloride ($CuC1_2$ $2H_2O$) in 100 cubic centimeters of HCl and placing a drop of the solution on a fresh spot. After 2 minutes, add three or four drops of distilled water to the drop of HCl solution and dry the surface. The appearance of a brown spot identifies the metal as an austenitic steel.

6.18.6 If no reaction was noted as outlined in paragraph 6.18.1 or 6.18.5, test for a plating material, as detailed in paragraph 6.17.

6.18.7 If paragraph 6.18.6 reveals plating on a nonmagnetic metal, the plating should be removed by mechanical abrasion and the base metal identified by the visual and/or chemical methods outlined in paragraph 6.17.

6.18.8 Clean and refinish as required in paragraph 6.20.

6.19 **Surface Treatment Testing.** Chemical conversion coatings, phosphate treatments for steels, and chromate treatments for aluminum are the most common surface treatment for metals in aircraft construction. Other surface treatments include lacquer and chromate films. Identify these surface treatments by the following procedures:

6.19.1 Phosphate Treatment. Confirm the presence of a phosphate treatment on steel, zinc, cadmium, or aluminum by placing a drop of 20 percent HNO_3 on the surface, then following with two drops of ammonium orthomolybdate ($(NH_4)2MoO_4$) solution. A yellow precipitate will form.

6.19.2 Chromate Treatment. Surface chromate treatments on zinc, cadmium, aluminum, or magnesium are highly colored and indicate the application of these treatments. However, a bleached chromate treatment may have been applied and then coated with lacquer to mask any residual iridescence for the sake of appearance. If so, visual detection of the chromate is impossible. To test for lacquer, proceed as directed in paragraph 6.19.3. Note that the bleaching process in a bleached chromate treatment lowers the corrosion resistance provided by the chromate film.

6.19.3 Lacquer Finish. To test for lacquer, place a drop of concentrated H_2SO_4 on the surface. If lacquer is present, the spot will rapidly turn brown with no effervescence or bubbling. If lacquer is not present, the spot will not turn brown. If the metal is zinc, there will be no rapid effervescence. If the metal is cadmium, there will be no reaction.

6.19.4 Chromate Film. To detect a chromate film on zinc and cadmium, place a drop of 5 percent aqueous solution of lead acetate ($Pb(C_2H_3O_2)2$) on the surface. If the metal has been treated, the surface will show no discoloration for 10 seconds. If there is no surface treatment, an immediate dark spot will appear.

6.20 Post-Identification Cleaning and Refinishing.

Note: The solutions used in chemical spot tests are extremely corrosive.

6.20.1 After identification of the metal is completed, clean the area as follows:

1. Blot any remaining chemicals with a dry cloth.
2. Swab the area several times with a water-moistened cloth.
3. Test the surface by placing a piece of litmus paper on the moistened surface. If the litmus paper changes color, repeat steps 1 and 2 until no color change occurs.
4. Dry surface thoroughly.
5. Remove corrosion, if present, and refinish the surface, as applicable.

6.21–6.25. RESERVED.

SECTION 3. MECHANICAL CORROSION REMOVAL BY BLASTING

6.26 General. Abrasive blasting is a cleaning or finishing process which directs a stream of abrasive particles against a surface, and can be used with metals, plastics, and other materials. Abrasive blasting can remove rust and corrosion and can clean a surface before further processing, such as painting or plating. Use standard blast cleaning practices, to include the following:

- Use any form of blast cleaning equipment, but in-cabinet blasting is preferred.
- Use external gun blasting if adequate abrasive confinement and recovery exists.

6.27 Safety Precautions. Operators should adequately protect themselves with complete face and head covering equipment, and use pure breathing air. Magnesium creates a fire hazard when abrasive blasted. Dry abrasive blasting of titanium alloys and high tensile strength steel creates sparking. Take care that no hazardous concentration of flammable vapors exists. Static ground the dry abrasive blaster and the material to be blasted.

Note: Refer to the OEM maintenance manual for abrasive blasting guidance.

6.27.1 Remove the part from the aircraft for blast cleaning, if possible. Otherwise, mask or protect areas adjacent to the part against abrasive impingement and system contamination. Examples are hydraulic, oil, or fuel systems.

6.27.2 Parts should be clean and dry prior to blast cleaning.

6.27.3 Mask close-tolerance surfaces, such as bushings or bearing shafts.

6.27.4 Blast clean only enough to remove corrosion coating. Proceed immediately with finishing requirement using surface treatments, as required.

6.28–6.39. RESERVED.

SECTION 4. CORROSION DAMAGE AND REWORK LIMITS

6.40 Discussion. Evaluate corrosion after general inspection and cleaning to determine the nature and extent of repair or rework. Local blending of corroded areas may be required to determine the total extent of the corrosion problem. See Figures 6-1, 6-2, 6-3, and 6-4. Corrosion damage classifications are defined as follows:

6.40.1 Corrosion Level 1:

1. Damage occurring between successive inspections that is within allowable damage limits;
2. Damage occurring between successive inspections that does not require structural reinforcements, replacement, or new damage tolerance-based inspections;
3. Corrosion occurring between successive inspections that exceeds allowable limits but can be attributed to an event not typical of operator usage of other aircraft in the same fleet; or
4. Light corrosion occurring repeatedly between inspections that eventually requires structural reinforcements, replacement, or new damage tolerance-based inspections.

6.40.2 Corrosion Level 2:

1. Corrosion occurring between any of the two successive corrosion inspection tasks that requires a single rework or blend-out which exceeds the allowable limit; or
2. Corrosion occurring between successive inspections that is widespread and requires a single blend-out approaching the allowable rework limit, i.e., it is not light corrosion as provided for in Corrosion Level 1, definition 3.

6.40.3 Corrosion Level 3: Corrosion occurring during the first or subsequent accomplishments of a corrosion inspection task that the operator determines to be an urgent airworthiness concern.

Figure 6-8. Severe Corrosion Requiring Trimming Out of Damaged Area

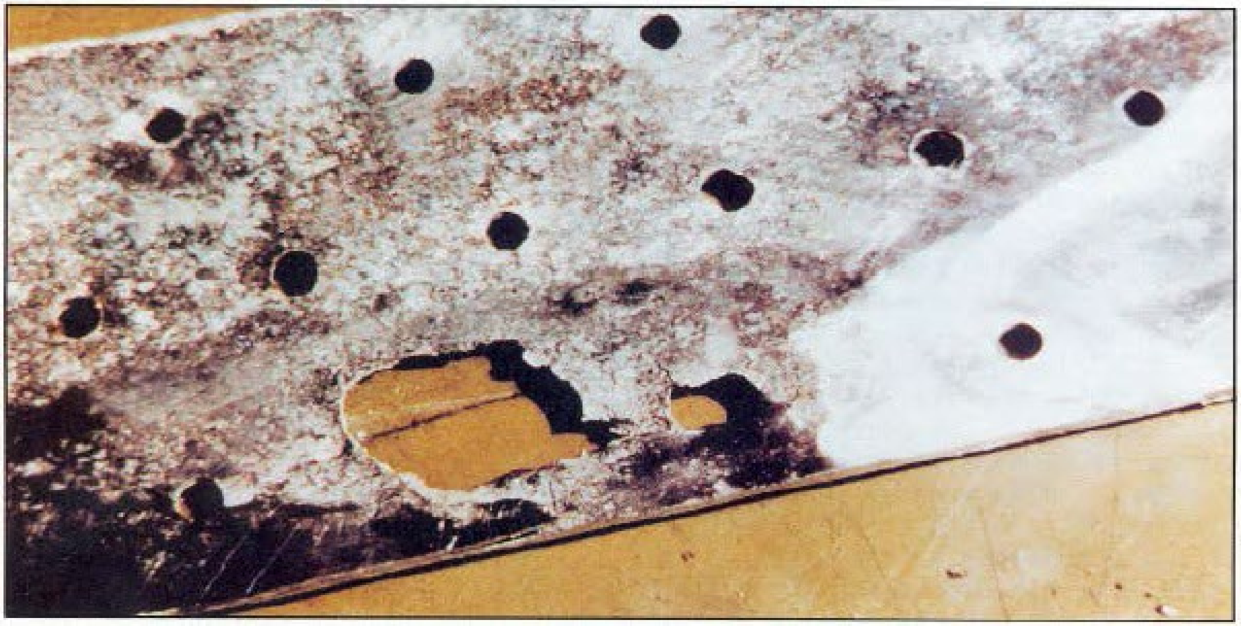


Figure 6-9. Corrosion at Fastener Holes Removed by Spot Facing

6.41 Removal of Corrosion. Two basic methods of corrosion removal include mechanical and chemical removal. The method used depends upon the type and location of a structure, the type and severity of corrosion, and the availability of maintenance equipment. Mechanical methods of corrosion removal are the most commonly used, and include sanding, buffing, grinding, and section removal. Avoid the use of soft metal wire brushes (with copper alloys in the wires) because residual traces of copper on cleaned metal will contribute to future corrosion. If using brushes, they should be stainless steel or nonmetallic. Mechanical methods of corrosion removal are used on all three levels (light, moderate, and severe) of corrosion damage. However, use chemical methods of corrosion removal only with light corrosion and only in areas where the chemicals cannot migrate to other areas.

6.42 **Determining Degree of Corrosion Damage.** Use the following equipment to decide to measure corrosion damage: depth dial gauge, straight edge, or a molding compound. Corrosion must be removed before the corroded area can be measured. Before making measurements, see if corrosion is in a reworked area which has previously been repaired. If corrosion is in a recess of a faired or blended area, measure damage to include the material which has previously been reworked. The following method outlines the procedure for taking measurements with the depth gauge:

1. Remove loose corrosion products, if present.
2. Position depth gauge, as illustrated in Figure 6-10, Corrosion Damage and Rework Measurement Using Depth Dial Gauge, and determine the measurement reading.

   Note: The base of the depth gauge should be flat against the undamaged surface on each side of the corrosion. When taking measurements on concave or convex surfaces, place the base perpendicular to the radius of the surface, as shown in Figure 6-10.

3. Take several additional depth readings.
4. Select the deepest reading as the depth of the corrosion damage.

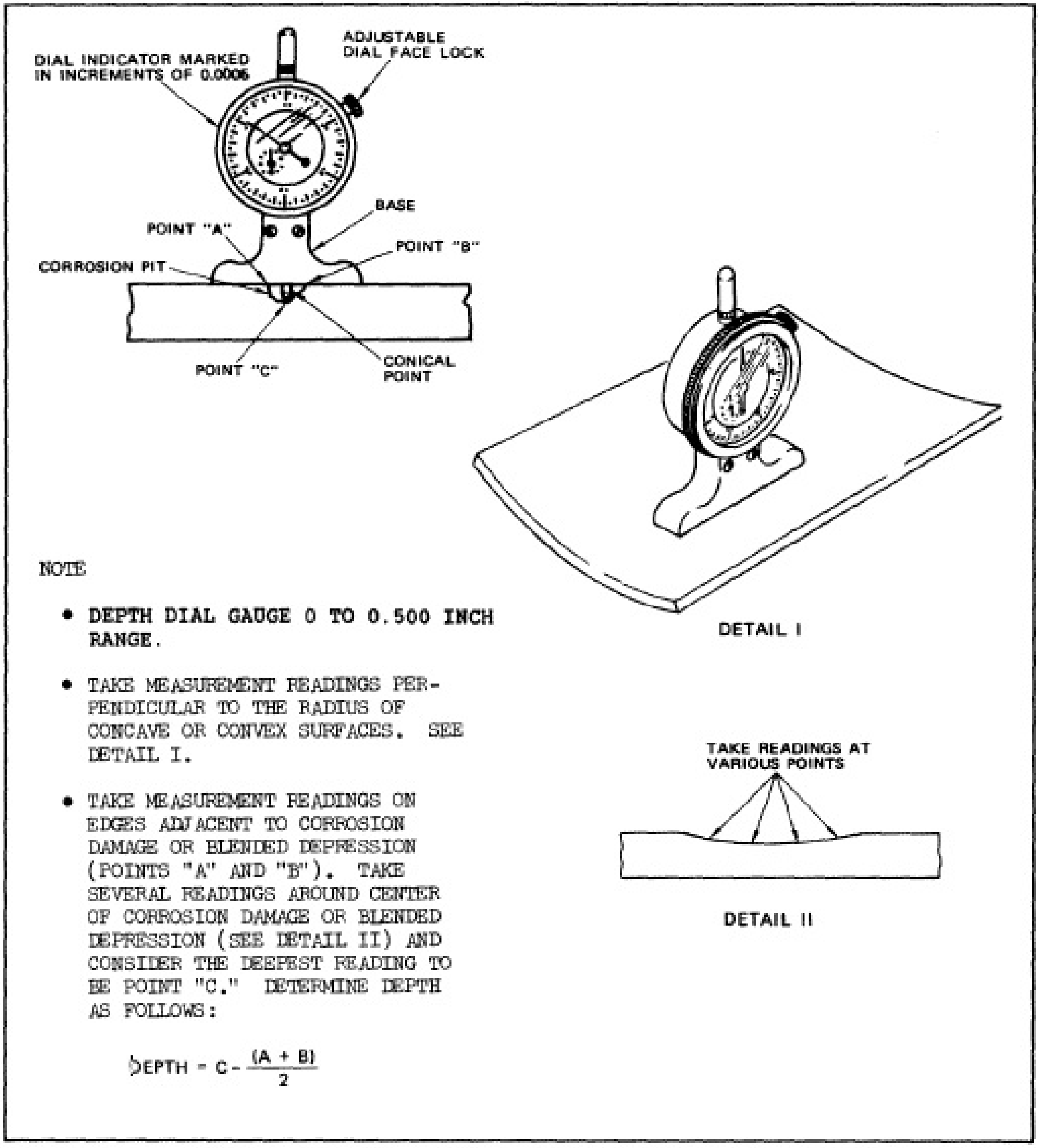
6.43 **Determining Rework Limits.** The allowable damage limit chart of the manufacturer's repair manual documents the maximum amount of material that can be removed from any damaged surface. If no criteria are given, contact the aircraft manufacturer for cleanup limits.

6.44 **Determining Material Thickness Reduction After Corrosion Cleanup.** Allowable material removal from a part or panel during corrosion cleanup is usually in the manufacturer's allowable damage limit charts. An accurate measurement should be made of the material removed or material thickness remaining in the reworked area to prevent exceeding allowable limits.

6.44.1 Ultrasonic testers can measure panel thickness after rework. This method requires a qualified nondestructive inspection (NDI) operator and suitable test standards for calibration.

6.44.2 Measurement of the material removed, which is the depth of blended pits, can be made using a depth dial gauge (see Figure 6-10). If the depth dial gauge will not work, clay impressions, liquid rubber, or other similar means of getting accurate results may be used to determine material removed. In the event that material removal limits have been exceeded, the area or part should be repaired or replaced. If replacement or repair criteria is not contained in the repair manual, contact the manufacturer.

Figure 6-10. Corrosion Damage and Rework Measurement Using Depth Dial Gauge



NOTE

- **DEPTH DIAL GAUGE 0 TO 0.500 INCH RANGE.**
- TAKE MEASUREMENT READINGS PERPENDICULAR TO THE RADIUS OF CONCAVE OR CONVEX SURFACES. SEE DETAIL I.
- TAKE MEASUREMENT READINGS ON EDGES ADJACENT TO CORROSION DAMAGE OR BLENDED DEPRESSION (POINTS "A" AND "B"). TAKE SEVERAL READINGS AROUND CENTER OF CORROSION DAMAGE OR BLENDED DEPRESSION (SEE DETAIL II) AND CONSIDER THE DEEPEST READING TO BE POINT "C." DETERMINE DEPTH AS FOLLOWS:

$$\text{DEPTH} = C - \frac{(A + B)}{2}$$

6.45–6.49. RESERVED.

SECTION 5. ALUMINUM AND ALUMINUM ALLOYS

6.50 Treatment. In general, corrosion of aluminum can be treated more effectively in place than by removing structural parts from the aircraft. Treatment includes the mechanical removal of the corrosion products, the inhibition of residual materials by chemical means, and the restoration of permanent surface coating. Details of treatment vary depending on whether the aluminum surfaces are bare in use or protected by paint coatings.

6.51 Processing of Aluminum Surfaces.

6.51.1 Bare Aluminum Surfaces. While few unpainted aircraft operate in maritime conditions, we include general information on the nature of Alclad surfaces and their treatment. Pure aluminum has greater corrosion resistance than the stronger aluminum alloys. Manufacturers usually take advantage of this by laminating a thin sheet of relatively pure aluminum, 1 to 5 mils thick, over the base higher-strength aluminum alloy surface. Corrosion protection is good, and operators can maintain the Alclad surface in a polished condition (see Figure 6-12, Polishing and Brightening Alclad Surfaces). In cleaning such surfaces, however, take care to prevent staining and marring of the exposed aluminum. More importantly, from a protection standpoint, avoid unnecessary mechanical removal of the protective Alclad layer and exposing the more susceptible base material.

6.51.2 Additional Processing of Aluminum Surfaces Prior to Paint Finishes. Before applying paint to aluminum surfaces, more severe cleaning procedures and more thorough corrective treatments can be used before painting. Application of a paint finish requires proper prepaint treatment for good paint adhesion.

6.51.3 Special Treatment of Anodized Surfaces. Anodizing is the most common surface treatment of aluminum alloy surfaces. Manufactured or reworked parts or components undergo tank processing during and frequently before fabrication from sheet stock. The aluminum sheet or casting becomes a positive pole in an electrolytic bath, in which chromic acid or similar oxidizing agent produces a supplemental protective oxide film on the aluminum surface. Aluminum oxide is naturally protective, and anodizing merely increases the thickness and density of the natural oxide film. When this coating is damaged in service, it can only be partially restored by chemical surface treatment, so avoid unnecessary destruction of the oxide film while processing anodized surfaces.

6.51.3.1 Do not use steel wool, steel wire brushes, copper alloy brushes, or severe abrasive materials on any aluminum surface. Aluminum wool, fiber bristle brushes, and mild abrasives are acceptable tools for cleaning anodized surfaces, but exercise care in any cleaning process to avoid unnecessary breaking of the protective film, particularly at the edges of the aluminum sheet. See Figures 6-11, Removing Oil and Surface Dirt, and 6-13, Cleaning and Stripping Paint.

6.51.3.2 Tampico fiber brushes are preferred and are adequate to remove most corrosion. Producing a buffed or wire brush finish by any means should be prohibited. Take every precaution to maintain as much of the protective coating as practicable. Otherwise, treat anodized surfaces in the same manner as other aluminum finishes. Vacuum blasting is an acceptable corrosion removal method to remove surface corrosion. Vacuum blasting should not be used to remove intergranular corrosion.

Figure 6-11. Removing Oil and Surface Dirt

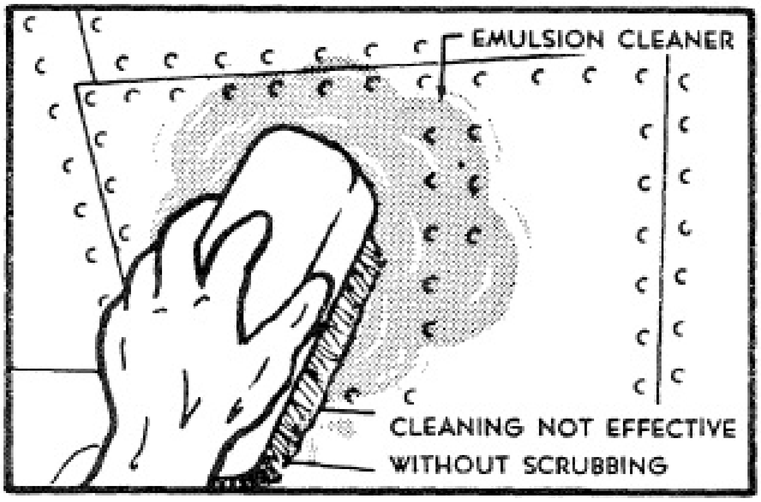
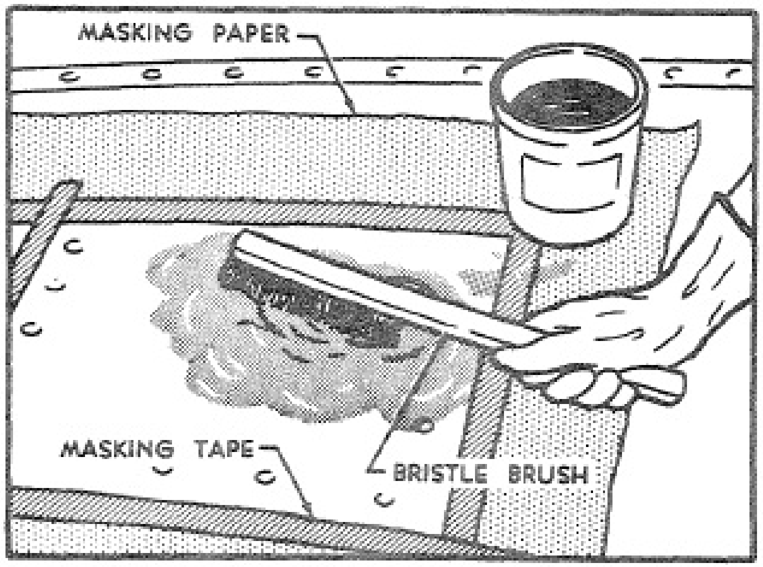


Figure 6-12. Polishing and Brightening Alclad Surfaces

Figure 6-13. Cleaning and Stripping Paint



6.51.3.3 Chemical conversion coating, detailed by Military Specification (MIL-SPEC) MIL-C-81706, Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys, is a chemical surface treatment used on aluminum alloys to provide a proper surface for paint finishing.

6.51.4 Special Processing of Intergranular Corrosion in Heat-Treated Aluminum Alloy Surfaces. Intergranular corrosion is usually more severe in heat-treated aluminum alloys and exhibits a corrosive attack along grain boundaries of the alloyed aluminum, where grain boundaries differ from the metal within the grain. When in contact with an electrolyte, rapid corrosion occurs at the grain boundaries. In its most severe form, actual lifting of metal layers, or exfoliation, occurs. Mechanically remove all corrosion products and visible delaminated metal layers to determine the extent of damage and evaluate the remaining structural strength of the component. NDI inspection is necessary to determine the full extent of corrosion. For aluminum, eddy current NDI mapping is used. For stainless steel, penetrant or magnetic particle NDI is used.

6.51.4.1 Use metal scrapers, rotary files, or abrasive wheels to remove all corrosion products and retain only structurally sound aluminum.

Note: A rotary file is recommended only for severe intergranular or exfoliation corrosion removal.

6.51.4.2 Rotary files should be sharp to cut metal without excessive smearing. A dull cutting tool will smear the metal over corrosion cracks or fissures, giving the appearance that it has removed the corrosion, but has not.

6.51.4.3 Use carbide-tip rotary files or metal scrapers, since they stay sharp longer. Do not use abrasive blasting to remove intergranular corrosion.

6.51.4.4 Inspection with a 5X to 10X magnifying glass or using a dye penetrant will help determine if all unsound metal and corrosion products are removed.

6.51.4.5 When corrosion is completely removed, blend or fair using a length-to-depth ratio of 20:1 in the area of corrosion removal. Blend where required, by using aluminum oxide impregnated, rubber-base wheels.

6.51.4.6 Chemical conversion coat exposed surfaces completely and restore paint coatings in the same manner as on any other aluminum surface. See Figures 6-14, Cleaning and Inhibiting Corroded Aluminum Surfaces; 6-15, Removing Excess Inhibitor Solution; and 6-16, Applying Wax to Cleaned Surfaces.

6.51.4.7 Corrosion damage beyond SRM limits should be repaired per a cognizant engineer or aircraft manufacturer's FAA-approved instructions.

Figure 6-14. Cleaning and Inhibiting Corroded Aluminum Surfaces

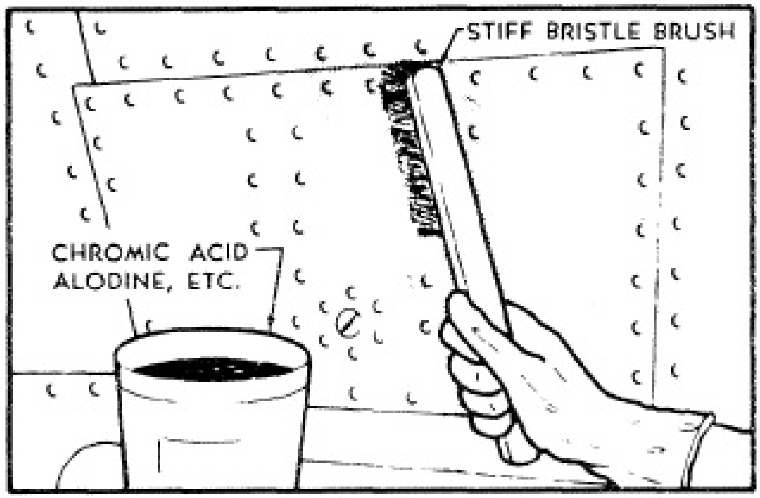


Figure 6-15. Removing Excess Inhibitor Solution

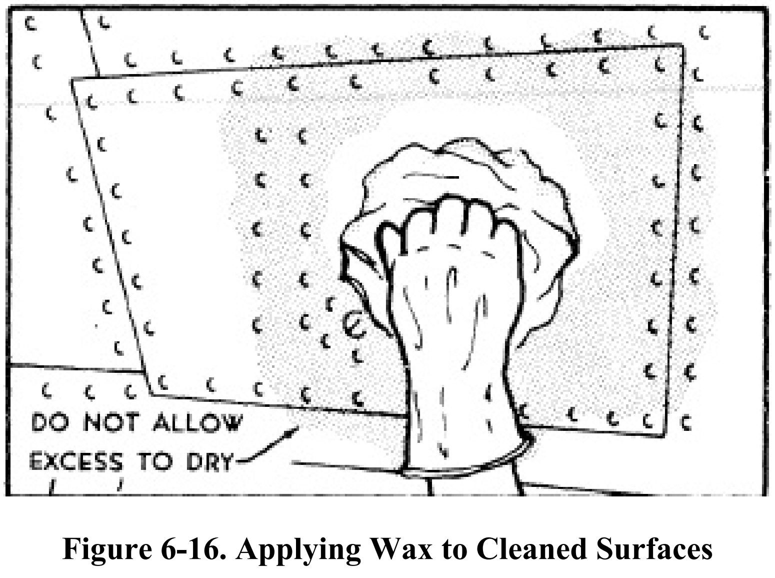
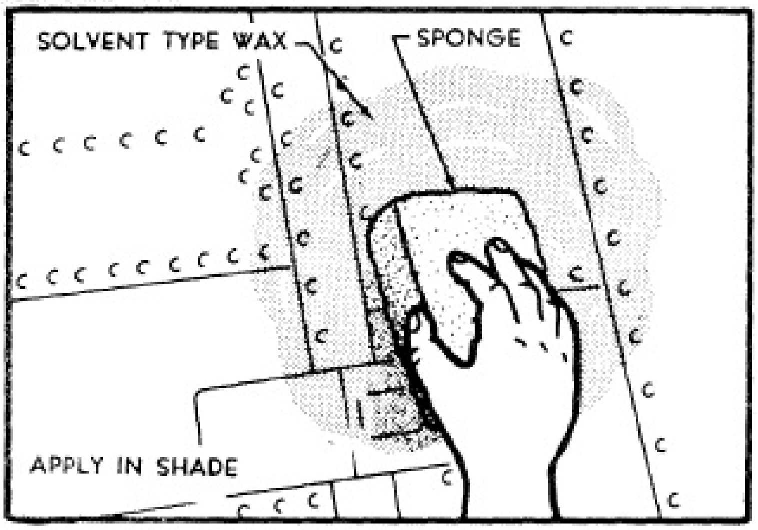


Figure 6-16. Applying Wax to Cleaned Surfaces



6.52 Repair of Aluminum Alloy Sheet Metal. After extensive corrosion removal, follow the below procedures:

1. If water can be trapped in blended areas, chemical conversion coat and fill the area with structural adhesive or sealant to the same level and contour as the original skin. When areas are small enough that structural strength has not been significantly decreased, proceed to applying the protective finish.
2. When corrosion removal exceeds SRM limits, contact a cognizant engineer or the aircraft manufacturer for repair instructions.
3. Where exterior doublers exist, seal and insulate them adequately to prevent further corrosion.

4. Doublers should be made from Alclad, when available, and the sheet should be anodized (this is preferred) or chemical conversion coated after finishing all cutting, drilling, and countersinking.
5. Drill, countersink, surface treat, and prime all rivet holes prior to installation of the doubler.
6. Apply a suitable sealing compound in the area to be covered by the doubler. Apply sufficient thickness of sealing compound to fill all voids in the area being repaired.
7. Install rivets wet with sealant. Sufficient sealant should be squeezed out into holes so that all fasteners, as well as all edges of the repair plate, will be sealed against entrance of moisture.
8. Remove all excess sealant after fasteners are installed. Apply a fillet sealant bead around the edge of the repair. After the sealant has cured, apply a protective paint finish to the reworked area.

6.53 Corrosion Removal Around Countersunk Fasteners in Aluminum Alloy. In aluminum alloys, intergranular corrosion often originates at countersunk areas where steel fasteners are used. Corrosion removal in a countersink is impossible with the fastener in place.

6.53.1 When corrosion is found around a fixed fastener head, remove the fastener to ensure corrosion removal, prevent further corrosion, and prevent loss of structural strength. To reduce the reoccurrence of corrosion, the panel should receive a chemical conversion coating, be primed, and have the fasteners installed wet with sealant.

6.53.2 Each time removable steel fasteners are removed from access panels, inspect them for material condition, including the condition of the plating. If mechanical or plating damage is evident, replace the fastener. Upon installation, follow one of the below fastener installation methods:

6.53.2.1 A preferred method is to brush a corrosion preventive compound on the substructure around and in the fastener hole, start the fastener, apply a bead of sealant to the fastener countersink, then set and torque the fastener within the working time of the sealant;

6.53.2.2 Apply the corrosion preventive compound to the substructure and fastener, set and torque the fastener; or

6.53.2.3 Apply a coating of primer to the fastener, and, while wet with primer, set and torque the fastener.

6.54 Examples of Removing Corrosion from Aluminum and Aluminum Alloys.

6.54.1 Prepare the Aircraft. Prepare the aircraft for corrosion rework, as provided in paragraph 6.12, and remove corrosion products as follows. Observe the work procedures of paragraph 6.2.

6.54.2 Identify the Metal. Positively identify the metal as aluminum.

6.54.3 Clean the Area. Clean the area to be reworked. Strip paint, if required.

6.54.4 Determine the Extent of the Corrosion. Determine extent of corrosion damage, as covered in paragraph 6.42. To remove light corrosion, proceed with paragraph 6.54.5. To remove moderate or severe corrosion, proceed with paragraph 6.54.6.

6.54.5 Light Corrosion Removal. Do not use the chemical removal process at temperatures above 100 °F or below 40 °F. Remove light corrosion by hand rubbing the corroded surface with tools, abrasives, or by chemical means, as follows:

6.54.5.1 Protectively mask adjacent areas to prevent brighteners from contacting magnesium, anodized aluminum, glass, Plexiglas, fabric surfaces, and all steel. Wear acid-resistant gloves, protective mask, and protective clothing when working with corrosion removing compounds. If corrosion removing compounds accidentally contact the skin or eyes, flush off immediately with plenty of clear water. See the safety procedures in Section 1, Safety Procedures.

6.54.5.2 Dilute a corrosion removing compound (SAE AMS1640, Corrosion Removing Compound for Aircraft Surfaces, Type I) with an equal volume of water. Mix the compound only in wood, plastic, or plastic-lined containers. Apply the diluted solution of corrosion removing compound by flowing, mopping, sponging, brushing, or wiping.

6.54.5.3 Apply the diluted solution to large areas with a circular motion to disturb the surface film and ensure proper coverage. The diluted solution should be applied starting at the lowest area and working upwards. The solution will be more effective if applied warm, 140 °F maximum, followed by vigorous agitation with a nonmetallic, acid resistant brush or aluminum oxide abrasive nylon mat.

6.54.5.4 Leave the solution on the surface for about 12 minutes. Do not let the solution dry on the surface; streaking will result. On large exterior surfaces, remove solution by high-pressure water rinse.

6.54.5.5 Wipe off solution with a clean, moist cloth. Frequently rinse the cloth in clear water. Wipe the area several times with a fresh cloth, dampened and rinsed frequently in clear water.

6.54.5.6 Dry the area with a clean, dry cloth and inspect for corrosion.

6.54.5.7 Repeat the procedure outlined in paragraph 6.54.5 if any corrosion remains.

Note: If corrosion still remains after the second attempt, mechanically remove corrosion, as detailed in paragraph 6.54.6.

6.54.5.8 After all corrosion has been removed, proceed with paragraph 6.54.6.4.

6.54.6 Moderate and Severe Corrosion Removal. Mechanically remove moderate or severe corrosion by the appropriate methods, as follows:

Note: Wear goggles or face shield to protect against corrosion particles that break loose and fly off. Protect adjacent areas and prevent additional damage from corrosion products removed during mechanical removal.

6.54.6.1 Remove loose corrosion products by hand rubbing the corroded surface with tools or abrasives. Dry abrasive blasting using MIL-SPEC MIL-G-9954, Glass Beads: For Cleaning and Peening, use glass bead sizes 10, 11, 12, 13, or A-A-1722, Grain, Abrasive (Soft Blasting), Types I and III may be used as an alternate method to remove corrosion from clad and nonclad aluminum alloys. Do not abrasively blast to remove heavy corrosion products. Direct-pressure machines should have the nozzle pressure set at 30 to 40 psi for clad aluminum alloys, and 40 to 45 psi for nonclad aluminum alloys. Get engineering approval from the aircraft manufacturer before abrasive blasting metal thinner than 0.0625 inches.

6.54.6.2 Remove residual corrosion by hand sanding or with an approved hand-operated power tool. Power tools can generally be used to remove corrosion with flap-brush, rotary file, sanding pad, or abrasive wheel attachments. Do not use rotary files on skin thinner than 0.0625 inches. Select an appropriate abrasive from Table 6-1.

6.54.6.3 Using a blend length-to-depth ratio of 20:1, finish the corrosion rework area with progressively finer abrasive paper until getting to 400 grit abrasive paper.

6.54.6.4 Clean the reworked area using dry cleaning solvent; do not use kerosene.

6.54.6.5 Determine depth of faired depressions to confirm rework limits have not been exceeded.

6.54.6.6 Apply a chemical conversion coating to the rework area.

6.54.6.7 Apply paint finish to the rework area.

6.55–6.59. RESERVED.

SECTION 6. MAGNESIUM ALLOYS

6.60 Treatment of Wrought Magnesium Sheets and Forgings. Corrosive attack on magnesium skins will usually occur around edges of skin panels, underneath hold-down washers, or in areas physically damaged by shearing, drilling, abrasion, or impact. Entrapment of moisture under and behind skin crevices is frequently a contributing factor. If the skin section is easy to remove, do this to ensure complete inhibition and treatment.

Note: Refer to the OEM maintenance manual for treatment of magnesium sheets and forgings.

6.60.1 Mechanically remove corrosion products when practicable. Use stiff bristle brushes and similar nonmetallic cleaning tools for such mechanical cleaning, particularly during treatment in field conditions.

6.60.2 Any entrapment of steel particles from steel wire brushes, steel tools, or contamination of treated surfaces by dirty abrasives can cause more trouble than the initial corrosive attack.

6.60.3 When aluminum insulating washers no longer adhere to magnesium panels, corrosion is likely to occur under the washers if corrective measures are not taken.

6.60.3.1 Remove machine screw fasteners from all loose insulating washer locations to surface treat the magnesium panel.

6.60.3.2 Where permanent fasteners are in place, remove the insulating washer and fastener for complete corrosion removal.

6.60.3.3 When water can collect in a counterbored area where the washer was located, use sealants to fill the counterbore. If necessary to fill several areas adjacent to each other, it may be advantageous to cover with a strip of sealant.

6.61 Repair of Magnesium Sheet Metal After Extensive Corrosion Removal. The same general instructions apply when making repairs in magnesium as in aluminum alloy skin, except two coats of epoxy primer may be needed on both the doubler and skin being patched instead of only one coat. Where it is difficult to form magnesium alloys in the contour, aluminum alloy may be utilized. When this is done, it is necessary to ensure effective dissimilar metal insulation. Vinyl tape will ensure positive separation of dissimilar metals, but edges will still have to be sealed to prevent entrance of moisture between mating surfaces at all points where repairs are made. It is recommended that only noncorrosive type sealant be used, since it serves a dual purpose of material separation and sealing.

6.62 In-Place Treatment of Magnesium Castings. Magnesium castings, in general, are more porous and more prone to penetrating attack than wrought magnesium skin. Treatment in the field is usually the same for all magnesium areas. Engine cases are among the most common examples of cast magnesium in modern aircraft. Bell cranks, fittings, and numerous covers, plates, and handles may also be magnesium castings. When attack occurs on a casting, apply the earliest practicable treatment to avoid dangerous corrosive penetration. Engine cases in saltwater can develop “moth holes” and complete penetration overnight.

6.62.1 If it is at all practicable, separate faying surfaces involved to effectively treat the existing attack and prevent its further progress. Follow the same general treatment sequence detailed for magnesium skin. Where engine cases are concerned, baked enamel overcoats are usually involved rather than other topcoat finishes. A good air drying enamel can restore protection.

6.62.2 If extensive removal of corrosion products from a structural casting is involved, request the aircraft manufacturer to evaluate the adequacy of remaining structural strength. SRMs usually include dimensional tolerance limits for critical structural members. The FAA should be consulted if any questions of safety are involved.

6.63 **Example of Removing Corrosion from Magnesium.** If possible, corroded magnesium parts should be removed from the aircraft. When impossible to remove the part, make aircraft preparations detailed in paragraph 6.12. When using that procedure, observe the safety precautions and procedures of Section 1.

6.63.1 Positively identify metal as magnesium (see paragraph 6.18).

6.63.2 Clean area to be reworked.

6.63.3 Strip paint, if required.

6.63.4 Determine extent of corrosion damage, as detailed in paragraph 6.42. To remove light corrosion, proceed to paragraph 6.63.5. To remove moderate or severe corrosion, go to paragraph 6.63.6.

6.63.5 Do not use the following procedure for adhesive bonded parts or assemblies, areas where the brush-on solution might become lodged, or local areas bared specifically for grounding or electrical bonding purpose. Remove light corrosion by light hand sanding or chemically, as follows:

6.63.5.1 Remove loose corrosion with aluminum wool or abrasive mat, paper, or cloth.

6.63.5.2 Mask off other materials and parts, especially rubber parts, bearings, and cast or pressed inserts to prevent contact with the treating solution or its fumes.

6.63.5.3 Prepare corrosion treating solution in the following proportions: 1.5 pounds of sodium dichromate and 1.5 pints of concentrated HNO_3 per gallon of water. Prepare and store the solution in clean polyethylene or glass containers. Mix as follows:

1. Fill a container with a volume of water equal to 1/4 the desired total quantity of solution.

2. Add full quantity of sodium dichromate in proportions indicated and agitate solution until the chemical is dissolved.
3. Add water until quantity of solution is equal to approximately 2/3 the desired total quantity.
4. Slowly add total volume of HNO_3 to the solution and mix thoroughly.
5. Add remaining water until total desired quantity of solution is reached and stir until entire solution concentration is equal.

6.63.5.4 Remove remaining corrosion by swabbing the corroded surface 1 to 2 minutes with the HNO_3 solution, then wipe dry.

6.63.5.5 Rinse thoroughly with clean water while scrubbing with a mop, brush, or abrasive mat and wipe dry.

6.63.5.6 Repeat the preceding sequence, as necessary, until all corrosion has been removed.

6.63.5.7 After all corrosion has been removed, proceed with paragraph 6.63.7.

6.63.6 Mechanically remove moderate or severe corrosion. Wear goggles or a face shield to preclude injury from corrosion particles breaking loose and flying off. Protect adjacent areas to prevent additional damage from corrosion products removed when using this procedure.

6.63.6.1 Remove heavy corrosion products by hand brushing with a stainless steel or fiber brush followed by vacuum abrasive blasting with MIL-SPEC MIL-G-9954 glass bead sizes 10, 11, 12, 13 or A-A-1722 grain abrasive Types I or III. An air pressure at the nozzle of 10 to 35 psi should be used for direct-pressure machines. For suction type blast equipment, use 50 percent higher pressure.

6.63.6.2 Remove residual corrosion by hand sanding or with an approved hand-operated power tool.

6.63.6.3 After removing all corrosion visible through a magnifying glass, apply a corrosion treating solution.

6.63.7 Fair depressions resulting from rework using a blend ratio of 20:1. Clean rework area using 240 grit abrasive paper. Smooth with 300 grit and final polish with 400 grit abrasive paper.

6.63.8 Determine depth of faired depressions and confirm the depth does not exceed rework limits.

6.63.9 Clean reworked area using a solvent to provide a water breakfree surface. Do not use kerosene.

6.63.10 Prepare and apply magnesium conversion coat conforming to AMS-M-3171, Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion On, Type VI (DOW-19) as follows:

1. Measure 1 gallon of distilled water into a clean polyethylene or glass container.
2. Add 1.3 ounces (dry) of chromium trioxide or 1.3 ounces of technical grade chromic acid.
3. Add 1 ounce of calcium sulfate dihydrate ($CaSO_4.2H_2O$).
4. Vigorously stir for at least 15 minutes; ensure that the solution is saturated with calcium sulfate. Let chromate solution stand for 15 minutes prior to decanting.
5. Prior to use, decant solution (avoid transfer of undissolved calcium sulfate) into suitable usage containers (polyethylene or glass).
6. Apply solution by swabbing until the metal surface becomes a dull color, which can vary from green-brown, brassy, or yellow-brown to dark brown. Under optimum conditions of temperature at 70 °F or above and fresh materials, the time required to properly apply magnesium pretreatment is usually 1 to 5 minutes. Under these conditions, 1 to 2 minutes of treatment should produce a brassy film, and 3 to 5 minutes of treatment a dark brown coating. Under adverse conditions, and if the desired specified finish color is not seen in the specified time, the treatment may have to be prolonged to 20 to 30 minutes until the proper finish is seen. For good paint adhesion, a dark brown color, free of powder, is considered best. The color may vary in using different vendor materials. Too long exposure to the brush-on solution produces a coating which will powder and impair adhesion of applied paint finishes/films. Use caution in swabbing on the solution. Severe rubbing of the wet surface will damage the coating.

   Note: High pressure spraying or rubbing abrasion will damage the fresh coating.

7. Rinse with clean water, then allow to dry at ambient temperature for a minimum of 1 hour. Allow more time in high humidity areas.

6.63.11 Apply primer and topcoat finish.

6.63.12 Remove masking and protective covering.

6.64–6.69. RESERVED.

SECTION 7. FERROUS METALS

6.70 General. One of the most familiar kinds of corrosion is red iron rust, generally resulting from atmospheric oxidation of steel surfaces. Some metal oxides protect the underlying base metal, but red rust is not a protective coating. Its presence actually promotes additional attack by attracting moisture from the air and acting as a catalyst in causing additional corrosion to take place.

6.70.1 Red rust first shows on bolt heads, hold-down nuts, and other unprotected aircraft hardware. Red rust will often occur under nameplates secured to steel parts. Its presence in these areas is generally not dangerous and has no immediate effect on the structural strength of any major components. However, it is indicative of a general lack of maintenance and possible attack in more critical areas.

6.70.2 When paint failures occur, or mechanical damage exposes highly stressed steel surfaces to the atmosphere, even the smallest amount of rusting is potentially dangerous in these areas and should be removed and controlled.

6.71 Mechanical Removal of Iron Rust. The most practicable means of controlling the corrosion of steel is the complete removal of corrosion products by mechanical means (see Figures 6-17, Removing Corrosion Products from Ordinary Steel Surfaces, and 6-18, Removing Corrosion Products from Highly Stressed Steel Parts). On high-strength steel, corrosion removal by hand sanding is recommended. The use of powered tools is not recommended on high strength steel because of the danger of local overheating and the formation of notches, which could lead to failure. However, in any such use of abrasives, residual iron rust usually remains in the bottom of small pits and other crevices.

6.71.1 The best method to use on exterior surfaces is abrasive blasting, which can remove nearly all rust.

6.71.2 Paint the cleaned metal surface as soon as possible after corrosion removal. In any event, do not allow the surface to become wet before painting.

Figure 6-17. Removing Corrosion Products from Ordinary Steel Surfaces

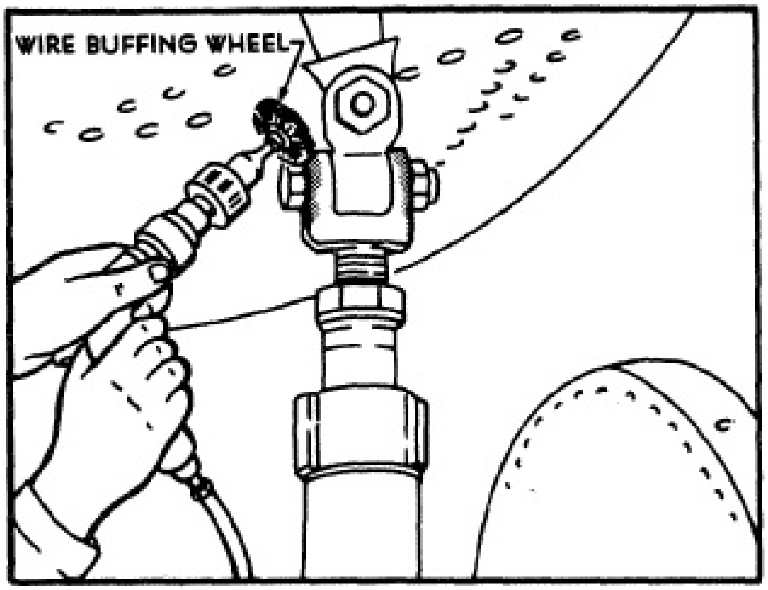
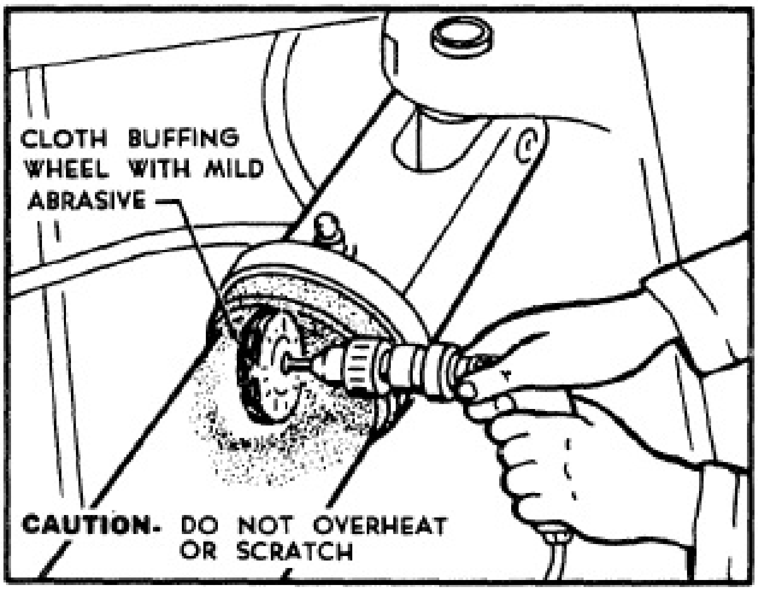


Figure 6-18. Removing Corrosion Products from Highly Stressed Steel Parts



6.72 Chemical Surface Treatment of Steel Surfaces.

Note: Secure engineering authorization to use chemical surface treatment on high-strength steel parts.

6.72.1 There are acceptable methods for converting iron rust to phosphates and other protective coatings. Parco Lubrizing and phosphoric zinc preparations are examples of such treatment. However, these processes require shop-installed hot tanks and are impracticable for use in the field.

6.72.2 Other preparations, such as phosphoric acid or naval jelly, are effective rust converters, where tolerances are not critical and personnel can thoroughly rinse and neutralize residual acid.

6.72.3 These situations are generally not applicable to assembled aircraft. Chemical inhibitors on installed steel parts are not only undesirable, but very dangerous. The possibility of entrapping corrosive solutions, resulting in uncontrolled attack when such materials are used under field conditions, outweighs any advantage to be gained from their use.

6.73 Removal of Corrosive Products from High-Stressed Steel Parts. Do not use wire brushes on high-stressed steel parts. Any corrosion on the surface of a highly stressed steel part is potentially dangerous; carefully remove corrosion products. Surface scratches or change in surface structure from overheating can cause sudden failure of these parts. Instead, carefully use mild abrasive papers, such as fine grit aluminum oxide, or fine buffing compounds, such as rouge, on cloth buffing wheels to remove corrosion products.

- It is critical to not overheat steel surfaces.
- Abrasive blasting is also a satisfactory corrosion removal method for high-strength steel on aircraft exteriors.
- After careful removal of surface corrosion, immediately apply protective paint finishes.

6.74 Special Treatment of Stainless Steel Alloys. Do not use chemical cleaners on stainless steels. Stainless steels are of two general types: magnetic and nonmagnetic. Magnetic steels are of the ferritic or martensitic types and are identified by numbers in the 400 series. Corrosion often occurs on 400-series stainless steels and treatment is the same as specified in paragraph 6.73. Nonmagnetic steels are of the austenitic type and are identified by numbers in the 300 series. They are much more corrosion resistant than the 400-series steels, particularly in a marine environment.

6.74.1 Austenitic steels develop corrosion resistance by an oxide film which should not be removed even though the surface is discolored. The original oxide film is normally formed at time of fabrication by passivation. If this film is broken by accident or abrasion, it may not restore itself without repassivation.

6.74.2 If any deterioration or corrosion does occur on austenitic steels, and the structural integrity or serviceability of the part is affected, it will be necessary to remove the part.

6.75 Example of Process for Removal of Corrosion from Steel Parts. If possible, corroded steel parts should be removed from the aircraft. When impossible to remove the part, observe the aircraft preparations and safety precautions in paragraphs 6.1, 6.2, and 6.10. Chemical removal or chemical conversion coatings are not allowed on steel parts.

6.75.1 Positively identify the metal as steel, as detailed in paragraph 6.17, and establish its heat-treated value.

6.75.2 Clean area to be reworked.

CAUTION: Do not use acid-based strippers on high-strength steel parts.

6.75.3 Strip paint, if required.

6.75.4 Removing corrosion from steels treated to 220,000 psi and above should be accomplished only by hand sanding or dry abrasive blasting (see Section 6, Magnesium Alloys).

6.75.5 Mechanically remove all degrees of corrosion from steel parts heat treated below 220,000 psi as follows:

CAUTION: Use goggles or face shield to preclude injury from flying particles. Protect adjacent areas to prevent additional damage from corrosion products removed by mechanical process.

6.75.5.1 Remove heavy deposits of corrosion products using a stainless steel hand brush. Abrasive blasting is an alternate method of corrosion removal. For abrasive blasting, use aluminum oxide (A-A-59316, Abrasive Materials; for Blasting) Type I, Grades A or B, grit sizes 25, 50, or 120; or size 13 glass beads (MIL-SPEC MIL-G-9954). Use an air pressure at the nozzle of 40 to 50 psi for direct-pressure machines when removing corrosion by abrasive blasting. Engineering approval from the aircraft manufacturer should be obtained prior to abrasive blasting metal thinner than 0.0625 inch.

6.75.5.2 Remove residual corrosion by hand sanding or with an approved hand-operated power tool.

6.75.5.3 The surface is highly reactive immediately following corrosion removal, so apply primer coats within 1 hour after sanding. After removing all corrosion visible through a magnifying glass, continue with paragraph 6.75.6.

6.75.6 Fair depressions resulting from rework using a blend ratio of 20:1. Clean rework area using 240 grit abrasive paper. Smooth with 300 grit and final polish with 400 grit abrasive paper.

6.75.7 Determine depth of faired depressions and confirm that the depth has not exceeded rework limits.

6.75.8 Clean reworked area with dry cleaning solvent. Do not use kerosene.

6.75.9 Apply protective finish or specific organic finish, as required.

6.75.10 Remove masking and protective covering.

6.76–6.79. RESERVED.

SECTION 8. PLATED PARTS

6.80 Chromium and Nickel Plated Parts. Nickel and chromium platings are used extensively as protective and wear-resistant coatings over high-strength steel parts, such as landing gear journals or shock strut pistons. Chromium and nickel plate provide protection by forming a somewhat impervious physical coat over the underlying base metal. When breaks occur in the surface, the protection is destroyed.

6.80.1 Reworking of chromium and nickel plated components is limited due to the critical requirements to which such components are subjected.

6.80.2 The rework should consist of light buffing to remove corrosion products and produce the required smoothness. This is permissible, provided the buffing does not reduce the plating's depth below the minimum allowable thickness.

6.80.3 Whenever a chromium or nickel plated component requires buffing, coat the area with a corrosion preventive compound, if possible.

6.80.4 Remove and replace the component when buffing exceeds the minimum thickness, or when the base metal has sustained corrosive attack.

6.80.5 The removed component can be restored to serviceable condition by having trained personnel in a specialized shop completely stripping the old plating and replating it per acceptable methods and specifications.

6.81 Cadmium and Zinc Plated Parts. Cadmium plating is used extensively in aircraft construction as a protective finish over both steel and copper alloys. Protection is provided on a sacrificial basis in which the cadmium is the sacrificial material rather than the underlying base material. Properly functioning cadmium surface coatings may well show mottling, ranging from white-to-brown-to-black spots on their surfaces. These are indicative of the sacrificial protection being offered by the cadmium coat, and under no condition should such spotting be removed merely for appearance's sake. In fact, cadmium will continue to protect even when actual breaks in the coating develop and bare steel or exposed copper surfaces appear.

6.81.1 Where actual failures of the cadmium plate occur and corrosion products of the base metal initially appear, there may be some necessary mechanical cleaning of the area, but limit it to removal of the corrosion products from the underlying base material.

6.81.2 Under no condition should such a coating be cleaned with a wire brush. If protection is needed, apply a touch-up with primer or a temporary preservative coating. Restoration of the plate coating is impracticable in the field.

6.81.3 Zinc coatings offer protection in an identical manner to cadmium, and the corrective treatment for failure is generally the same as for cadmium plated parts.

6.82–6.89. RESERVED.

SECTION 9. OTHER METALS AND ALLOYS

6.90 Noble Metal Coatings—Cleanup and Restoration. Silver, platinum, and gold finishes are generally used in aircraft assemblies because of their resistance to ordinary surface attack and their improved electrical or heat conductivity. Silver plated electrodes can be cleaned of brown or black sulfide tarnish, as necessary, by placing them in contact with a piece of magnesium sheet stock while immersed in a warm water solution of common table salt mixed with baking soda or by using a fine grade abrasive mat or pencil eraser followed by solvent cleaning. If assemblies are involved, careful drying and complete displacement of water is necessary. In general, cleaning of gold or platinum coatings is not recommended in the field.

6.91 Copper and Copper Alloys. Copper and copper alloys are relatively corrosion resistant, and attacks on such components will usually be limited to staining and tarnish. Generally, such change in surface condition is not dangerous and should ordinarily have no effect on the function of the part. However, if it is necessary to remove such staining, a chromic acid solution of 8 to 24 ounces per gallon of water containing a small amount of battery electrolyte, not to exceed 50 drops per gallon, is an effective brightening bath. Staining may also be removed using a fine grade abrasive mat or pencil eraser followed by solvent cleaning.

6.91.1 Immerse the stained part in the cold solution. Surfaces can also be treated in place by applying the solution to the stained surface with a small brush.

6.91.2 Be careful to avoid any entrapment of the solution after treatment. The part should be cleaned thoroughly following treatment with all residual solution removed.

6.91.3 Serious copper corrosion is evident by the accumulation of green-to-blue copper salts on the corroded part. These products should be removed mechanically using a stiff bristle brush, brass wire brush, 400-grit abrasive paper or bead blast with glass beads, MIL-SPEC MIL-G-9954, size 13. When bead blasting, air pressure at the nozzle should be 20 to 30 psi for direct-pressure machines. Do not bead blast braided copper flexible lines. A surface coating should be reapplied over the reworked area. Again, chromic acid treatment will tend to remove the residual corrosion products.

6.91.4 Most brass and bronze structural parts will be protected by a cadmium surface plate. The mottling of the protective cadmium coat should not be removed, and mechanical surface cleaning should not be attempted unless actual copper corrosion products are beginning to appear. Under these conditions, any mechanical removal of the protective cadmium should be held to a minimum and limited to the immediate area of the copper attack.

6.92 Titanium Alloys. Titanium and its alloys are highly corrosion resistant because a protective oxide film forms on alloy surfaces upon contact with air. When titanium is heated, different oxides having different colors form on the surface. A blue oxide coating will form at 700 to 800 °F, a purple oxide at 800 to 950 °F, and a gray or black oxide at 1,000 °F or higher. Corrosive attack on titanium surfaces is difficult to detect. It may show deterioration from the presence of salt deposits and metal impurities at elevated temperatures, so periodic removal of surface deposits is required.

6.92.1 Clean titanium surfaces until all traces of corrosion or surface deposits are removed using one of the following:

- Stainless steel wire brush;
- Hand sand with aluminum oxide abrasive paper or abrasive mat;
- Dry blast with glass beads, (MIL-SPEC MIL-G-9954) sizes 10, 11, 12, or 13, or aluminum oxide (A-A-59316, Type I) Grades A or B, using 40 to 50 psi air pressure at the nozzle for direct-pressure machines; or
- Hand polish with aluminum polish and soft cloth.

6.92.2 Chlorinated hydrocarbon cleaners should not be used on titanium alloys, which are subject to elevated temperatures in service. Such solvents can cause stress-corrosion in titanium.

6.93–6.99. RESERVED.

CHAPTER 7. SPECIAL PROBLEMS

7.1 Mercury Spills/Corrosion Damage.

7.1.1 The presence of mercury and mercury salts in air cargo is a definite possibility. Loading, unloading, and general shifting of such cargo can and does result occasionally in such situations as damaged containers, cartons, or electronic tubes, with subsequent possible leakage of mercury on aircraft structure.

7.1.2 Spillage of mercury or mercury compounds within an airplane requires immediate action for isolation and recovery to prevent possible corrosion damage and embrittlement of aluminum alloy structural components, 300-series and 400-series stainless steels, and unplated brass components, such as cable turnbuckle barrels.

7.1.3 Mercury, by the amalgamation process, can penetrate any break in the finish (anodize/bonderite), paint, and seal coating of a metal structural component. Bright, polished, shining, or scratched surfaces will hasten the process, as well as moisture. Mercury or mercury compounds attack the metal grain boundaries and seriously embrittle and reduce the strength of parts. Corrosive attack of freshly scratched aluminum alloy is very rapid, and complete penetration of sheet material is known to occur within 3 or 4 minutes.

7.1.4 Mercury is highly toxic and spreads very easily from one surface to another. It adheres to hands, shoes, clothes, and tools. The following precautions for mercury spills should be strictly followed:

7.1.4.1 Avoid contact with surfaces suspected of being contaminated. Use wood or fiber sheets to support body while working in the area.

WARNING: Do not attempt to pick up mercury by hand.

7.1.4.2 Wear wing socks (shoe protectors) and protective disposable clothing in contaminated area to prevent scratching metal surfaces. Properly dispose of socks after use.

7.1.4.3 Do not wear clothing used in contaminated areas on jobs in uncontaminated areas. Dispose of wing socks and protective clothing in an unused metal container outside of aircraft. Contact the waste management service or similar authority of the local state health department for instructions on proper disposal procedures for mercury.

7.1.4.4 Have personal clothing cleaned. Wash shoes with soap and water. Clean all tools used in the contaminated area with steam or hot water and soap. Discard any drill bits used on mercury-contaminated areas. Thoroughly clean vacuum cleaner, if used.

7.1.4.5 Always wash hands thoroughly with soap and water after contacting mercury. Keep hands away from mouth. Do not eat, smoke, or blow nose without first washing hands thoroughly.

7.1.4.6 Appreciable amounts of mercury will vaporize at normal temperatures. Stagnant air will become dangerous to personal health.

WARNING: Always provide good ventilation while cleaning mercury-contaminated areas.

7.1.4.7 Do not use cleaning aids such as solvents, solids, or polishes on contaminated areas. Such materials may promote corrosion.

7.1.4.8 If hands become contaminated with mercury while working with cleaning equipment, do not touch any exposed metal in the surrounding area to prevent contamination.

7.1.5 Mercury spills, in some cases, have caused no adverse effects because of protective films of paint, dirt, grease, or oil. Do not rely on the fact that mercury spillage may not, in all cases, result in serious damage. Each instance of mercury or mercury compound spillage should be considered hazardous, and immediate action should be taken to safeguard the aircraft. Inspect for mercury and corrosion as follows:

7.1.5.1 Determine point at which mercury was spilled. Remove any mercury on the floor covering, and then remove covering.

7.1.5.2 When mercury is found on the floor, do not remove access/inspection plates, screws, rivets, bolts, etc., from the floor. Any hole which is left open in the contaminated area of the floor may allow mercury to spread to the structure underneath the floor.

7.1.5.3 Inspect the metal floor, seat tracks, cargo rails, and adjacent structure for mercury and corrosion. Inspect skin and internal structure below the point of spillage. Also inspect the lowest point in fuselage below cargo compartment floor if mercury spill has occurred in the cargo area. Mercury liquid will flow to the lowest level.

7.1.5.4 Inspect areas suspected of having mercury contamination using a 10-power magnifying glass. If corrosion of aluminum has started, there will be a light grayish “Christmas Tree” fuzz or gray powdery dust deposit, and severe structural damage may follow.

7.1.5.5 If corrosion is evident and cleanup cannot be completed immediately, coat contaminated area with corrosion preventive compound or engine oil. This helps to slow down the corrosion rate and also helps to prevent spreading of mercury contamination.

7.1.5.6 When mercury spills occur in a lower cargo compartment, use a portable x ray machine, if available, along the outside lower surface of the fuselage to check suspected hidden corrosion areas between the skin, stringers, and frames below the floor. Droplets of mercury will show on an x ray image as small, white spots. Corrosion and embrittlement will appear as tree-like forms completely penetrating a structural component.

7.1.5.7 Inspect bronze/brass control cable turnbuckle barrels for mercury discoloration. Replace if the slightest discoloration is detected.

7.1.6 Removal procedure and precautions necessary when mercury is spilled are:

WARNING: Vacuum air passing over the mercury deposited in the glass container picks up mercury vapors and exhausts them from the vacuum cleaner. Avoid breathing mercury vapors.

CAUTION: An air hose should not be used to dislodge mercury from aircraft under any circumstances.

7.1.6.1 Use a high-capacity vacuum cleaner with a trap-type glass container attached to the large vacuum hose. The size of the pickup hose from the container should be about 1/4 inch in diameter to increase the amount of suction applied to the mercury. Due to the weight of mercury, the container will catch the mercury before it can enter the vacuum cleaner hose.

7.1.6.2 An all-rubber storage battery water syringe, or a medicine dropper, may be used to remove mercury if the trap-type glass container and vacuum cleaner are not available. Cellulose tape may be used to pick up very tiny particles of mercury.

7.1.6.3 General cleanup and inspection, using the equipment available, should be made immediately after spillage occurs or is detected.

7.2 Corrosion Protection for Agricultural Aircraft.

7.2.1 General. Practically all chemicals used in dusting and spraying operations are corrosive by nature and hasten deterioration of fabric, metal, and wood. It is essential to safe operation that precautions be taken to prevent corrosion and deterioration of wood, metal, and fabric. Cleanliness of the airplane is one of the most important precautions of all. If it were practicable and feasible to clean the airplane thoroughly, that is, give it a thorough dry washing inside and out after each day's work, probably no special corrosive preventive measures would be necessary.

7.2.2 Precautions. Since thorough daily cleaning is not practicable, take the following precautions:

7.2.2.1 All fittings and metal structures should be covered with two coats of epoxy primer, a heavy preservative, conforming to MIL-SPEC MIL-C-16173, Corrosion Preventive Compound, Solvent Cutback, Cold-Application, Grade 2 (paralketone), or equivalent material. This coating should be applied to items such as wing-root fittings, wing-strut fittings, control-surface hinges, horns, or mating edges of fittings and attach bolts.

7.2.2.2 Non-stainless steel control cables should be coated with paralketone or equivalent protective coating, or should be replaced with corrosion-resistant cables.

7.2.2.3 Periodic inspection of all critical portions of the aircraft structure should be made. Structural parts showing corrosion should be cleaned and refinished if the corrosion attack is superficial. If the part is severely corroded, it should be replaced.

7.2.2.4 Experience has shown that additional access openings, enabling ready inspection of lower and rearward portions of the fuselage, are particularly desirable.

7.2.2.5 Provide additional drainage and ventilation for all interiors to prevent collection of moisture.

7.2.2.6 At the time of recovering, both metal and wood airplane structural members should be coated with two coats of epoxy primer, followed by dope-proof paint or wrapping with cellophane tape.

7.2.2.7 Spray interiors of metal-covered wings and fuselages with an adherent corrosion inhibitor.

7.2.2.8 Wash exterior surfaces with clear fresh water at least once a week. Interior surfaces should also be washed, taking care to prevent damage to electrical circuits or other items subject to malfunctioning due to moisture.

7.2.2.9 Opening in the wings, fuselage, and control-surface members, such as tail-wheel wells or openings for control cables, should be sealed as completely as possible to prevent entry of dust or spray.

7.3–7.99. RESERVED.

Advisory Circular Feedback Form

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by contacting the Flight Standards Directives Management Officer at 9-AWA-AFB-120-Directives@faa.gov.

Subject: AC 43-4B, Corrosion Control for Aircraft

Date: ____________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph ____________ on page _______.

☐ Recommend paragraph _____________ on page __________ be changed as follows:

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☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

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☐ Other comments:

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☐ I would like to discuss the above. Please contact me.

Submitted by: ________________________________ Date: ______________________