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Corrosion Control

Many aircraft structures are made of metal, and the most insidious form of damage to those structures is corrosion. From the moment the metal is manufactured, it must be protected from the deleterious effects of the environment that surrounds it. This protection can be the introduction of certain elements into the base metal, creating a corrosion resistant alloy, or the addition of a surface coating of a chemical conversion coating, metal or paint. While in use, additional moisture barriers, such as viscous lubricants and protectants may be added to the surface.

The introduction of airframes built primarily of composite components has not eliminated the need for careful monitoring of aircraft with regard to corrosion. While the airframe itself may not be subject to corrosion, the use of metal components and accessories within the airframe means the aircraft maintenance technician must be on the alert for the evidence of corrosion when inspecting any aircraft.

This chapter provides an overview to the problems associated with aircraft corrosion. For more in-depth information on the subject, refer to the latest edition of FAA Advisory Circular (AC) 43-4A, Corrosion Control for Aircraft. The advisory circular is an extensive handbook, which deals with the sources of corrosion particular to aircraft structures, as well as steps the aircraft maintenance technician can take in the course of maintaining aircraft that have been attacked by corrosion.

Metal corrosion is the deterioration of the metal by chemical or electrochemical attack. This type of damage can take place internally as well as on the surface. As in the rotting of wood, this deterioration may change the smooth surface, weaken the interior, or damage or loosen adjacent parts.

Water or water vapor containing salt combines with oxygen in the atmosphere to produce the main source of corrosion in aircraft. Aircraft operating in a marine environment, or in areas where the atmosphere contains industrial fumes that are corrosive, are particularly susceptible to corrosive attacks. [Figure 6-1]

If left unchecked, corrosion can cause eventual structural failure. The appearance of corrosion varies with the metal. On the surface of aluminum alloys and magnesium, it appears as pitting and etching, and is

Figure 6-1. Seaplane operations.

often combined with a gray or white powdery deposit. On copper and copper alloys, the corrosion forms a greenish film; on steel, a reddish corrosion byproduct commonly referred to as rust. When the gray, white, green, or reddish deposits are removed, each of the surfaces may appear etched and pitted, depending upon the length of exposure and severity of attack. If these surface pits are not too deep, they may not significantly alter the strength of the metal; however, the pits may become sites for crack development, particularly if the part is highly stressed. Some types of corrosion burrow between the inside of surface coatings and the metal surface, and can spread until the part fails.

Figure 6-2. Direct chemical attack in a battery compartment.

Types of Corrosion

There are two general classifications of corrosion that cover most of the specific forms: direct chemical attack and electrochemical attack. In both types of corrosion, the metal is converted into a metallic compound such as an oxide, hydroxide, or sulfate. The corrosion process always involves two simultaneous changes: The metal that is attacked or oxidized suffers what may be called anodic change, and the corrosive agent is reduced and may be considered as undergoing cathodic change.

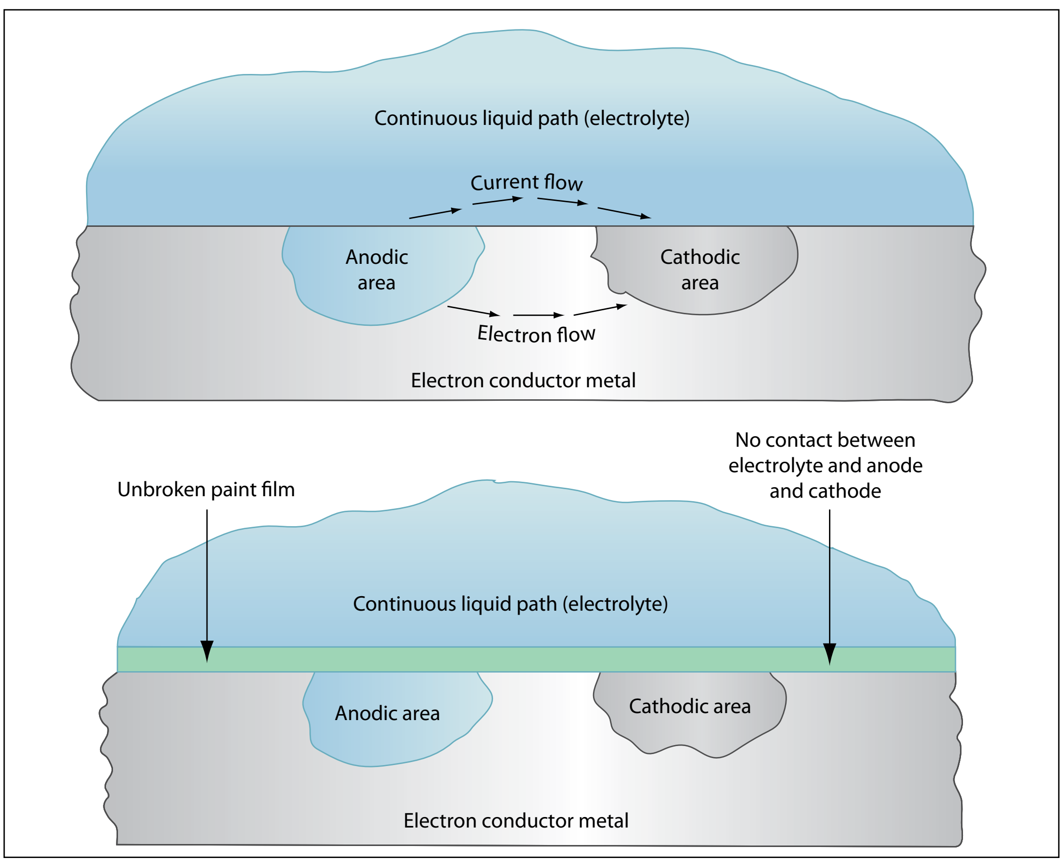


Figure 6-3. Electrochemical attack.

Direct Chemical Attack

Direct chemical attack, or pure chemical corrosion, is an attack resulting from a direct exposure of a bare surface to caustic liquid or gaseous agents. Unlike electrochemical attack where the anodic and cathodic changes may be taking place a measurable distance apart, the changes in direct chemical attack are occurring simultaneously at the same point. The most common agents causing direct chemical attack on aircraft are: (1) spilled battery acid or fumes from batteries; (2) residual flux deposits resulting from inadequately cleaned, welded, brazed, or soldered joints; and (3) entrapped caustic cleaning solutions. [Figure 6-2]

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

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

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

Electrochemical Attack

An electrochemical attack may be likened chemically to the electrolytic reaction that takes place in electroplating, anodizing, or in a dry cell battery. The reaction in this corrosive attack requires a medium, usually water, which is capable of conducting a tiny current of electricity. When a metal comes in contact with a corrosive agent and is also connected by a liquid or gaseous path through which electrons may flow, corrosion begins as the metal decays by oxidation. [Figure 6-3] During the attack, the quantity of corrosive agent is reduced and, if not renewed or removed, may completely react with the metal, becoming neutralized. Different areas of the same metal surface have varying levels of electrical potential and, if connected by a conductor, such as salt water, will set up a series of corrosion cells and corrosion will commence.

All metals and alloys are electrically active and have a specific electrical potential in a given chemical environment. This potential is commonly referred to as the metal's "nobility." [Figure 6-4] The less noble a metal is, the more easily it can be corroded. The metals chosen for use in aircraft structures are a studied compromise with strength, weight, corrosion resistance, workability, and cost balanced against the structure's needs.

The constituents in an alloy also have specific electrical potentials that are generally different from each other. Exposure of the alloy surface to a conductive, corrosive medium causes the more active metal to

+ Corroded End (anodic, or least noble)
Magnesium Magnesium alloy Zinc
Aluminum (1100) Cadmium Aluminum 2024-T4 Steel or Iron Cast Iron Chromium-Iron (active) Ni-Resist Cast Iron
Type 304 Stainless steel (active) Type 316 Stainless steel (active)
Lead-Tin solder Lead Tin
Nickel (active) Inconel nickel-chromium alloy (active) Hastelloy Alloy C (active)
Brass Copper Bronze Copper-nickel alloy Monel nickel-copper alloy
Silver Solder Nickel (passive) Inconel nickel-chromium alloy (passive)
Chromium-Iron (passive) Type 304 Stainless steel (passive) Type 316 Stainless steel (passive) Hastelloy Alloy C (passive)
Silver Titanium Graphite Gold Platinum
– Protected End (cathodic, or most noble)

Figure 6-4. The galvanic series of metals and alloys.

become anodic and the less active metal to become cathodic, thereby establishing conditions for corrosion. These are called local cells. The greater the difference in electrical potential between the two metals, the greater will be the severity of a corrosive attack, if the proper conditions are allowed to develop.

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

Forms of Corrosion

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

Surface Corrosion

Surface corrosion appears as a general roughening, etching, or pitting of the surface of a metal, frequently accompanied by a powdery deposit of corrosion products. Surface corrosion may be caused by either direct chemical or electrochemical attack. Sometimes corrosion will spread under the surface coating and cannot be recognized by either the roughening of the surface or the powdery deposit. Instead, closer inspection will reveal the paint or plating is lifted off the surface in small blisters which result from the pressure of the underlying accumulation of corrosion products. [Figure 6-5]

Filiform corrosion gives the appearance of a series of small worms under the paint surface. It is often seen on surfaces that have been improperly chemically treated prior to painting. [Figure 6-6]

Dissimilar Metal Corrosion

Extensive pitting damage may result from contact between dissimilar metal parts in the presence of a conductor. While surface corrosion may or may not be taking place, a galvanic action, not unlike electroplating, occurs at the points or areas of contact where the insulation between the surfaces has broken down or been omitted. This electrochemical attack can be very serious because in many instances the action is taking place out of sight, and the only way to detect it prior to structural failure is by disassembly and inspection. [Figure 6-7]

The contamination of a metal's surface by mechanical means can also induce dissimilar metal corrosion. The improper use of steel cleaning products, such as steel wool or a steel wire brush on aluminum or magnesium, can force small pieces of steel into the metal being cleaned, which will then further corrode and

Figure 6-5. Surface corrosion.

Figure 6-6. Filiform corrosion.

Figure 6-7. Dissimilar metal corrosion.

ruin the adjoining surface. Carefully monitor the use of nonwoven abrasive pads, so that pads used on one type of metal are not used again on a different metal surface.

Intergranular Corrosion

This type of corrosion is an attack along the grain boundaries of an alloy and commonly results from a lack of uniformity in the alloy structure. Aluminum alloys and some stainless steels are particularly susceptible to this form of electrochemical attack. [Figure 6-8] The lack of uniformity is caused by changes that occur in the alloy during heating and cooling during the material's manufacturing process. Intergranular corrosion may exist without visible surface evidence. Very severe intergranular corrosion may sometimes cause the surface of a metal to "exfoliate." [Figure 6-9] This is a lifting or flaking of the metal at the

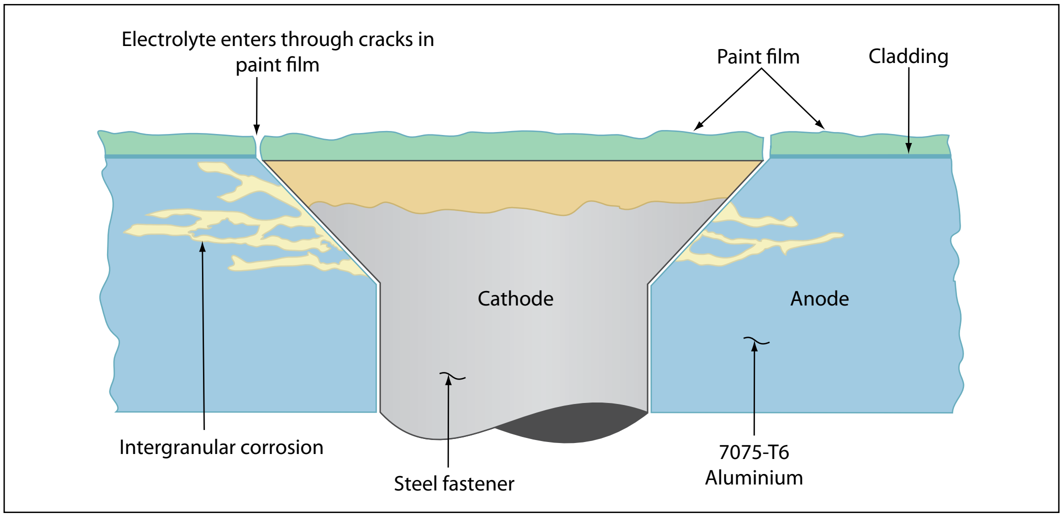


Figure 6-8. Intergranular corrosion of 7075-T6 aluminum adjacent to steel fastener.

surface due to delamination of the grain boundaries caused by the pressure of corrosion residual product buildup. This type of corrosion is difficult to detect in its initial stage. Extruded components such as spars can be subject to this type of corrosion. Ultrasonic and eddy current inspection methods are being used with a great deal of success.

Stress Corrosion

Stress corrosion occurs as the result of the combined effect of sustained tensile stresses and a corrosive environment. Stress corrosion cracking is found in most metal systems; however, it is particularly characteristic of aluminum, copper, certain stainless steels, and high strength alloy steels (over 240,000 psi). It usually occurs along lines of cold working and may be transgranular or intergranular in nature. Aluminum alloy bellcranks with pressed in bushings, landing gear shock struts with pipe thread type grease fittings, clevis pin joints, shrink fits, and overstressed tubing B-nuts are examples of parts which are susceptible to stress corrosion cracking.

Fretting Corrosion

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

Figure 6-9. Exfoliation.

ized abrasion occurs. [Figure 6-10] The presence of water vapor greatly increases this type of deterioration. If the contact areas are small and sharp, deep grooves resembling brinell markings or pressure indentations may be worn in the rubbing surface. As a result, this type of corrosion (on bearing surfaces) has also been called false brinelling.

Factors Affecting Corrosion

Many factors affect the type, speed, cause, and seriousness of metal corrosion. Some of these factors can be controlled and some cannot.

Climate

The environmental conditions under which an aircraft is maintained and operated greatly affect corrosion characteristics. In a predominately marine environment (with exposure to sea water and salt air), moisture-laden air is considerably more detrimental to an aircraft than it would be if all operations were conducted in a dry climate. Temperature considerations are important because the speed of electrochemical attack is increased in a hot, moist climate.

Foreign Material

Among the controllable factors which affect the onset and spread of corrosive attack is foreign material that adheres to the metal surfaces. Such foreign material includes:

- Soil and atmospheric dust.
- Oil, grease, and engine exhaust residues.
- Salt water and salt moisture condensation.
- Spilled battery acids and caustic cleaning solutions.
- Welding and brazing flux residues.

It is important that aircraft be kept clean. How often and to what extent an aircraft should be cleaned depends on several factors, including geographic location, model of aircraft, and type of operation.

Preventive Maintenance

Much has been done to improve the corrosion resistance of aircraft: improvements in materials, surface treatments, insulation, and in particular, modern protective finishes. All of these have been aimed at reducing the overall maintenance effort, as well as improving reliability. In spite of these improvements, corrosion and its control is a very real problem that requires continuous preventive maintenance. During any corrosion control maintenance, consult the Material Safety Data Sheet (MSDS) for information on any chemicals used in the process.

Corrosion preventive maintenance includes the following specific functions:

1. Adequate cleaning
2. Thorough periodic lubrication

Figure 6-10. Fretting corrosion.

3. Detailed inspection for corrosion and failure of protective systems
4. Prompt treatment of corrosion and touchup of damaged paint areas
5. Keeping drain holes free of obstructions
6. Daily draining of fuel cell sumps
7. Daily wipe down of exposed critical areas
8. Sealing of aircraft against water during foul weather and proper ventilation on warm, sunny days
9. Maximum use of protective covers on parked aircraft

After any period during which regular corrosion preventive maintenance is interrupted, the amount of maintenance required to repair accumulated corrosion damage and bring the aircraft back up to standard will usually be quite high.

Inspection

Inspection for corrosion is a continuing problem and should be handled on a daily basis. Overemphasizing a particular corrosion problem when it is discovered and then forgetting about corrosion until the next crisis is an unsafe, costly, and troublesome practice. Most scheduled maintenance checklists are complete enough to cover all parts of the aircraft or engine, and no part of the aircraft should go uninspected. Use these checklists as a general guide when an area is to be inspected for corrosion. Through experience it will be learned that most aircraft have trouble areas where, despite routine inspection and maintenance, corrosion will set in.

In addition to routine maintenance inspections, amphibians or seaplanes should be checked daily and critical areas cleaned or treated, as necessary.

Corrosion Prone Areas

Discussed briefly in this section are most of the trouble areas common to all aircraft. However, this coverage is not necessarily complete and may be amplified and expanded to cover the special characteristics of the particular aircraft model involved by referring to the applicable maintenance manual.

Exhaust Trail Areas

Both jet and reciprocating engine exhaust deposits are very corrosive and give particular trouble where gaps, seams, hinges, and fairings are located downstream from the exhaust pipes or nozzles. [Figure 6-11] Deposits may be trapped and not reached by normal cleaning methods. Pay special attention to areas around rivet heads and in skin lap joints and other crevices. Remove and inspect fairings and access plates in the exhaust areas. Do not overlook exhaust deposit buildup in remote areas, such as the empennage surfaces. Buildup in these areas will be slower and may not be noticed until corrosive damage has begun.

Figure 6-11. Exhaust nozzle area.

Battery Compartments and Battery Vent Openings

Despite improvements in protective paint finishes and in methods of sealing and venting, battery compartments continue to be corrosion prone areas. Fumes from overheated electrolyte are difficult to contain and will spread to adjacent cavities and cause a rapid corrosive attack on all unprotected metal surfaces. Battery vent openings on the aircraft skin should be included in the battery compartment inspection and maintenance procedure. Regular cleaning and neutralization of acid deposits will minimize corrosion from this cause.

Bilge Areas

These are natural sumps for waste hydraulic fluids, water, dirt, and odds and ends of debris. Residual oil quite often masks small quantities of water that settle to the bottom and set up a hidden chemical cell.

Instead of using chemical treatments for the bilge water, current float manufacturers recommend the diligent maintenance of the internal coatings applied to the float's interior during manufacture. In addition to chemical conversion coatings applied to the surface of the sheet metal and other structural components, and to sealants installed in lap joints during construction, the interior compartments are painted to protect the bilge areas. When seaplane structures are repaired or restored, this level of corrosion protection must be maintained.

Inspection procedures should include particular attention paid to areas located under galleys and lavatories and to human waste disposal openings on the aircraft exteriors. Human waste products and the chemicals used in lavatories are very corrosive to common aircraft metals. Clean these areas frequently and keep the paint touched up.

Wheel Well and Landing Gear

More than any other area on the aircraft, this area probably receives more punishment due to mud, water, salt, gravel, and other flying debris.

Because of the many complicated shapes, assemblies, and fittings, complete area paint film coverage is difficult to attain and maintain. A partially applied preservative tends to mask corrosion rather than prevent it. Due to heat generated by braking action, preservatives cannot be used on some main landing gear wheels. During inspection of this area, pay particular attention to the following trouble spots:

1. Magnesium wheels, especially around bolt heads, lugs, and wheel web areas, particularly for the presence of entrapped water or its effects
2. Exposed rigid tubing, especially at B-nuts and ferrules, under clamps and tubing identification tapes
3. Exposed position indicator switches and other electrical equipment
4. Crevices between stiffeners, ribs, and lower skin surfaces, which are typical water and debris traps

Water Entrapment Areas

Design specifications require that aircraft have drains installed in all areas where water may collect. Daily inspection of low point drains should be a standard requirement. If this inspection is neglected, the drains may become ineffective because of accumulated debris, grease, or sealants.

Engine Frontal Areas and Cooling Air Vents

These areas are being constantly abraded with airborne dirt and dust, bits of gravel from runways, and rain erosion, which tends to remove the protective finish. Inspection of these areas should include all sections in the cooling air path, with special attention to places where salt deposits may be built up during marine operations. It is imperative that incipient corrosion be inhibited and that paint touchup and hard film preservative coatings are maintained intact on seaplane and amphibian engine surfaces at all times.

Wing Flap and Spoiler Recesses

Dirt and water may collect in flap and spoiler recesses and go unnoticed because they are normally retracted. For this reason, these recesses are potential corrosion problem areas. Inspect these areas with the spoilers and/or flaps in the fully deployed position.

External Skin Areas

External aircraft surfaces are readily visible and accessible for inspection and maintenance. Even here, certain types of configurations or combinations of materials become troublesome under certain operating conditions and require special attention.

Relatively little corrosion trouble is experienced with magnesium skins if the original surface finish and insulation are adequately maintained. Trimming, drilling, and riveting destroy some of the original surface treatment, which is never completely restored by touchup procedures. Any inspection for corrosion should include all magnesium skin surfaces with special attention to edges, areas around fasteners, and cracked, chipped, or missing paint.

Piano-type hinges are prime spots for corrosion due to the dissimilar metal contact between the steel pin and aluminum hinge. They are also natural traps for dirt, salt, and moisture. Inspection of hinges should include lubrication and actuation through several cycles to ensure complete lubricant penetration. Use water-displacing lubricants when servicing piano hinges. [Figures 6-12 and 6-13]

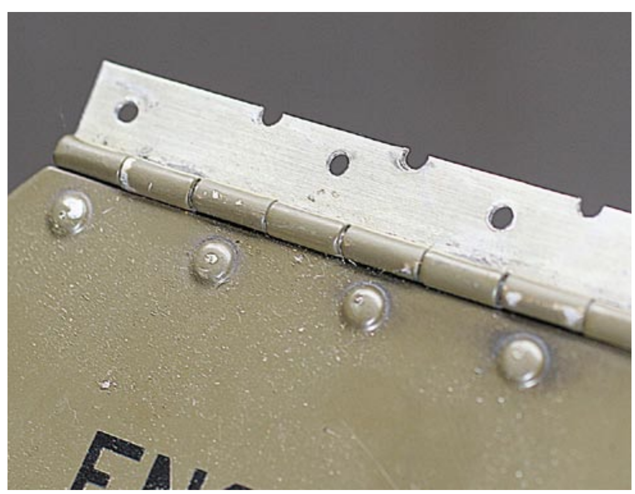


Figure 6-12. Piano hinge.

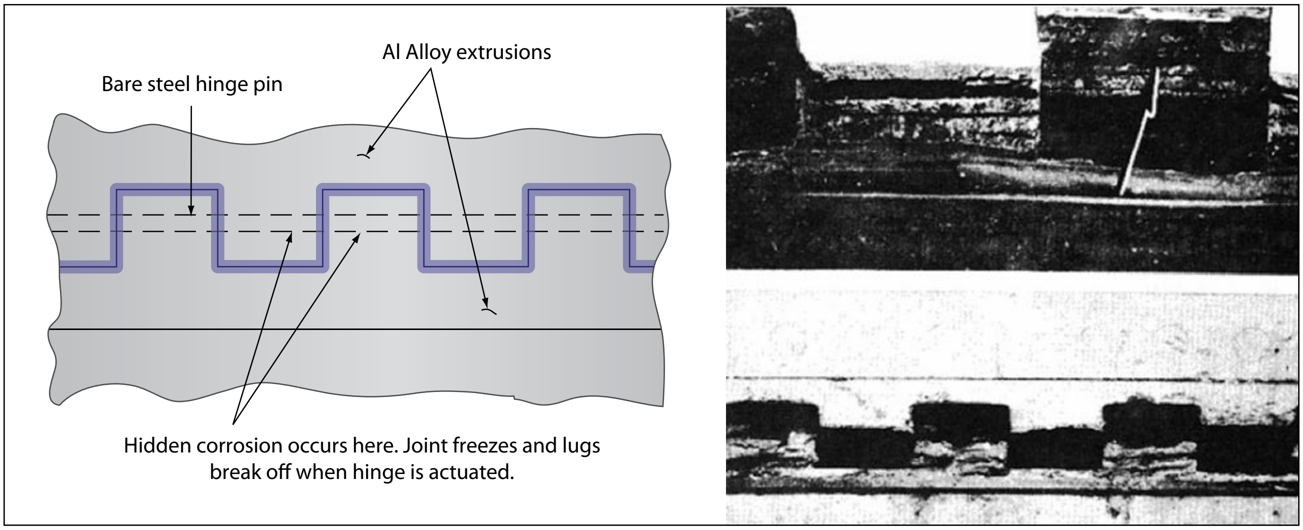


Figure 6-13. Hinge corrosion points.

Corrosion of metal skins joined by spot welding is the result of the entrance and entrapment of corrosive agents between the layers of metal. This type of corrosion is evidenced by corrosion products appearing at the crevices through which the corrosive agents enter. More advanced corrosive attack causes skin buckling and eventual spot weld fracture. Skin buckling in its early stages may be detected by sighting along spot welded seams or by using a straightedge. The only technique for preventing this condition is to keep potential moisture entry points, including seams and holes created by broken spot welds, filled with a sealant or a suitable preservative compound.

Miscellaneous Trouble Areas

Helicopter rotor heads and gearboxes, in addition to being constantly exposed to the elements, contain bare steel surfaces, many external working parts, and dissimilar metal contacts. Inspect these areas frequently for evidence of corrosion. The proper maintenance, lubrication, and the use of preservative coatings can prevent corrosion in these areas.

All control cables, whether plain carbon steel or corrosion resistant steel, should be inspected to determine their condition at each inspection period. In this process, inspect cables for corrosion by random cleaning of short sections with solvent soaked cloths. If external corrosion is evident, relieve tension and check the cable for internal corrosion. Replace cables that have internal corrosion. Remove light external corrosion with a nonwoven abrasive pad lightly soaked in oil or, alternatively, a steel wire brush. When corrosion products have been removed, recoat the cable with preservative.

Corrosion Removal

In general, any complete corrosion treatment involves the following: (1) cleaning and stripping of the corroded area, (2) removing as much of the corrosion products as practicable, (3) neutralizing any residual materials remaining in pits and crevices, (4) restoring protective surface films, and (5) applying temporary or permanent coatings or paint finishes.

The following paragraphs deal with the correction of corrosive attack on aircraft surface and components where deterioration has not progressed to the point requiring rework or structural repair of the part involved.

Surface Cleaning and Paint Removal

The removal of corrosion necessarily includes removal of surface finishes covering the attacked or suspected area. To assure maximum efficiency of the stripping compound, the area must be cleaned of grease, oil, dirt, or preservatives. This preliminary cleaning operation is also an aid in determining the extent of the spread of the corrosion, since the stripping operation will be held to the minimum consistent with full exposure of the corrosion damage. Extensive corrosion spread on any panel should be corrected by fully treating the entire section.

The selection of the type of materials to be used in cleaning will depend on the nature of the matter to be removed. Modern environmental standards encourage the use of water-based, non-toxic cleaning compounds whenever possible. In some locations, local or state laws may require the use of such products, and prohibit the use of solvents that contain volatile organic compounds (VOCs). Where permitted, dry cleaning solvent (P-D-680) may be used for removing oil, grease, or soft preservative compounds. For heavy-duty removal of thick or dried preservatives, other compounds of the solvent emulsion type are available.

The use of a general purpose, water rinsable stripper can be used for most applications. There are other methods for paint removal that have minimal impact upon the aircraft structure, and are considered "environmentally friendly."

Wherever practicable, chemical paint removal from any large area should be accomplished outside (in open air) and preferably in shaded areas. If inside removal is necessary, adequate ventilation must be assured. Synthetic rubber surfaces, including aircraft tires, fabric, and acrylics, must be thoroughly protected against possible contact with paint remover. Care must be exercised in using paint remover. Care must also be exercised in using paint remover around gas or watertight seam sealants, since the stripper will tend to soften and destroy the integrity of these sealants.

Mask off any opening that would permit the stripping compound to get into aircraft interiors or critical cavities. Paint stripper is toxic and contains ingredients harmful to both skin and eyes. Therefore, wear rubber gloves, aprons of acid repellent material, and goggle-type eyeglasses. The following is a general stripping procedure:

1. Brush the entire area to be stripped with a cover of stripper to a depth of $\frac{1}{32}$ to $\frac{1}{16}$ inch. Any paintbrush makes a satisfactory applicator, except that the bristles will be loosened by the effect of paint remover on the binder, and the brush should not be used for other purposes after being exposed to paint remover.
2. Allow the stripper to remain on the surface for a sufficient length of time to wrinkle and lift the paint. This may be from 10 minutes to several hours, depending on both the temperature and humidity, and the condition of the paint coat being removed. Scrub the surface with a bristle brush saturated with paint remover to further loosen finish that may still be adhering to the metal.
3. Reapply the stripper as necessary in areas where the paint remains tightly adhered or where the stripper has dried, and repeat the above process. Only nonmetallic scrapers should be used to assist in removing persistent paint finishes. Nonwoven abrasive pads intended for paint stripping may also prove to be useful in removing the loosened paint.
4. Remove the loosened paint and residual stripper by washing and scrubbing the surface with water and a broom, brush or fresh nonwoven abrasive pad. If water spray is available, use a low to medium pressure stream of water directly on the area being scrubbed. If steam-cleaning equipment is available and the area is sufficiently large, cleaning may be accomplished using this equipment together with a solution of steam-cleaning compound. On small areas, any method may be used that will assure complete rinsing of the cleaned area. Use care to dispose of the stripped residue in accordance with environmental laws.

Corrosion of Ferrous Metals

One of the most familiar types of corrosion is ferrous oxide (rust), generally resulting from atmospheric oxidation of steel surfaces. Some metal oxides protect the underlying base metal, but rust is not a protective coating in any sense of the word. Its presence actually promotes additional attack by attracting moisture from the air and acting as a catalyst for additional corrosion. If complete control of the corrosive attack is to be realized, all rust must be removed from steel surfaces.

Rust first appears on bolt heads, hold-down nuts, or other unprotected aircraft hardware. [Figure 6-14] Its presence in these areas is generally not dangerous and has no immediate effect on the structural strength of any major components. The residue from the rust may also contaminate other ferrous components, promoting corrosion of those parts. The rust is indicative of a need for maintenance and of possible corrosive attack in more critical areas. It is also a factor in the general appearance of the equipment. 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 must be removed and controlled.

Rust removal from structural components, followed by an inspection and damage assessment, must be done as soon as feasible. [Figure 6-15]

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 and restoring corrosion preventive coatings. Except on highly stressed

Figure 6-14. Rust.

Figure 6-15. Rust on structural components.

steel surfaces, the use of abrasive papers and compounds, small power buffers and buffing compounds, hand wire brushing, or steel wool are all acceptable cleanup procedures. However, it should be recognized that in any such use of abrasives, residual rust usually remains in the bottom of small pits and other crevices. It is practically impossible to remove all corrosion products by abrasive or polishing methods alone. As a result, once a part cleaned in such a manner has rusted, it usually corrodes again more easily than it did the first time.

The introduction of variations of the nonwoven abrasive pad has also increased the options available for the removal of surface rust. [Figure 6-16] Flap wheels, pads intended for use with rotary or oscillating power tools, and hand-held nonwoven abrasive pads all can be used alone or with light oils to remove corrosion from ferrous components.

Figure 6-16. Nonwoven abrasive pads.

Chemical Removal of Rust

As environmental concerns have been addressed in recent years, interest in noncaustic chemical rust removal has increased. A variety of commercial products, which actively remove the iron oxide without chemically etching the base metal, are available and should be considered for use. Generally speaking, if at all possible, the steel part should be removed from the airframe for treatment, as it can be nearly impossible to remove all residues. The use of any caustic rust removal product will require the isolation of the part from any nonferrous metals during treatment, and will probably require inspection for proper dimensions.

Chemical Surface Treatment of Steel

There are approved methods for converting active rust to phosphates and other protective coatings. Other commercial preparations are effective rust converters where tolerances are not critical and where thorough rinsing and neutralizing of residual acid is possible. These situations are generally not applicable to assembled aircraft, and the use of chemical inhibitors on installed steel parts is not only undesirable but also very dangerous. The danger of entrapment of corrosive solutions and the resulting uncontrolled attack, which could occur when such materials are used under field conditions, outweigh any advantages to be gained from their use.

Removal of Corrosion from Highly Stressed Steel Parts

Any corrosion on the surface of a highly stressed steel part is potentially dangerous, and the careful removal of corrosion products is required. Surface scratches or change in surface structure from overheating can also cause sudden failure of these parts. Corrosion products must be removed by careful processing, using mild abrasive papers such as rouge or fine grit aluminum oxide, or fine buffing compounds on cloth buffing wheels. Nonwoven abrasive pads can also be used. It is essential that steel surfaces not be overheated during buffing. After careful removal of surface corrosion, reapply protective paint finishes immediately.

Corrosion of Aluminum and Aluminum Alloys

Corrosion on aluminum surfaces is usually quite obvious, since the products of corrosion are white and generally more voluminous than the original base metal. Even in its early stages, aluminum corrosion is evident as general etching, pitting, or roughness of the aluminum surfaces.

NOTE: Aluminum alloys commonly form a smooth surface oxidation that is from 0.001 to 0.0025 inch thick. This is not considered detrimental; the coating provides a hard shell barrier to the introduction of corrosive elements. Such oxidation is not to be confused with the severe corrosion discussed in this paragraph.

General surface attack of aluminum penetrates relatively slowly, but is speeded up in the presence of dissolved salts. Considerable attack can usually take place before serious loss of structural strength develops.

At least three forms of attack on aluminum alloys are particularly serious: (1) the penetrating pit-type corrosion through the walls of aluminum tubing, (2) stress corrosion cracking of materials under sustained stress, and (3) intergranular corrosion which is characteristic of certain improperly heat-treated aluminum alloys.

In general, corrosion of aluminum can be more effectively treated in place compared to corrosion occurring on other structural materials used in aircraft. Treatment includes the mechanical removal of as much of the corrosion products as practicable, and the inhibition of residual materials by chemical means, followed by the restoration of permanent surface coatings.

Treatment of Unpainted Aluminum Surfaces

Relatively pure aluminum has considerably more corrosion resistance compared with the stronger aluminum alloys. To take advantage of this characteristic, a thin coating of relatively pure aluminum is applied over the base aluminum alloy. The protection obtained is good, and the pure-aluminum clad surface (commonly called "Alclad") can be maintained in a polished condition. In cleaning such surfaces, however, care must be taken to prevent staining and marring of the exposed aluminum and, more important from a protection standpoint, to avoid unnecessary mechanical removal of the protective Alclad layer and the exposure of the more susceptible aluminum alloy base material. A typical aluminum corrosion treatment sequence follows:

1. Remove oil and surface dirt from the aluminum surface using any suitable mild cleaner. Use caution when choosing a cleaner; many commercial consumer products are actually caustic enough to induce corrosion if trapped between aluminum lap joints. Choose a neutral Ph product.
2. Hand polish the corroded areas with fine abrasives or with metal polish. Metal polish intended for use on clad aluminum aircraft surfaces must not be used on anodized aluminum since it is abrasive enough to actually remove the protective anodized film. It effectively removes stains and produces a highly polished, lasting surface on unpainted Alclad. If a surface is particularly difficult to clean, a cleaner and brightener compound for aluminum can be used before polishing to shorten the time and lessen the effort necessary to get a clean surface.
3. Treat any superficial corrosion present, using an inhibitive wipe down material. An alternate treatment is processing with a solution of sodium dichromate and chromium trioxide. Allow these solutions to remain on the corroded area for 5 to 20 minutes, and then remove the excess by rinsing and wiping the surface dry with a clean cloth.
4. Overcoat the polished surfaces with waterproof wax.

Aluminum surfaces that are to be subsequently painted can be exposed to more severe cleaning procedures and can also be given more thorough corrective treatment prior to painting. The following sequence is generally used:

1. Thoroughly clean the affected surfaces of all soil and grease residues prior to processing. Any general aircraft cleaning procedure may be used.
2. If residual paint films remain, strip the area to be treated. Procedures for the use of paint removers and the precautions to observe were previously mentioned in this chapter under "Surface Cleaning and Paint Removal."
3. Treat superficially corroded areas with a 10 percent solution of chromic acid and sulfuric acid. Apply the solution by swab or brush. Scrub the corroded area with the brush while it is still damp. While chromic acid is a good inhibitor for aluminum alloys, even when corrosion products have not been completely removed, it is important that the solution penetrate to the bottom of all pits and underneath any corrosion that may be present. Thorough brushing with a stiff fiber brush should loosen or remove most existing corrosion and assure complete penetration of the inhibitor into crevices and pits. Allow the chromic acid to remain in place for at least 5 minutes, and then remove the excess by flushing with water or wiping with a wet cloth. There are several commercial chemical surface treatment compounds, similar to the type described above, which may also be used.
4. Dry the treated surface and restore recommended permanent protective coatings as required in accordance with the aircraft manufacturer's procedures. Restoration of paint coatings should immediately follow any surface treatment performed. In any case, make sure that corrosion treatment is accomplished or is reapplied on the same day that paint refinishing is scheduled.

Treatment of Anodized Surfaces

As previously stated, anodizing is a common surface treatment of aluminum alloys. When this coating is damaged in service, it can only be partially restored by chemical surface treatment. Therefore, any corrosion correction of anodized surfaces should avoid destruction of the oxide film in the unaffected area. Do not use steel wool or steel wire brushes. Do not use severe abrasive materials.

Nonwoven abrasive pads have generally replaced aluminum wool, aluminum wire brushes, or fiber bristle brushes as the tools used for cleaning corroded anodized surfaces. Care must be exercised in any cleaning process to avoid unnecessary breaking of the adjacent protective film. 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. Chromic acid and other inhibitive treatments can be used to restore the oxide film.

Treatment of Intergranular Corrosion in Heat-Treated Aluminum Alloy Surfaces

As previously described, intergranular corrosion is an attack along grain boundaries of improperly or inadequately heat-treated alloys, resulting from precipitation of dissimilar constituents following heat treatment. In its most severe form, actual lifting of metal layers (exfoliation, *see* Figure 6-9) occurs.

More severe cleaning is a must when intergranular corrosion is present. The mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished to determine the extent of the destruction and to evaluate the remaining structural strength of the component. Corrosion depth and removal limits have been established for some aircraft. Any loss of structural strength should be evaluated prior to repair or replacement of the part. If the manufacturer's limits do not adequately address the damage, a designated engineering representative (DER) can be brought in to assess the damage.

Corrosion of Magnesium Alloys

Magnesium is the most chemically active of the metals used in aircraft construction and is the most difficult to protect. When a failure in the protective coating does occur, the prompt and complete correction of the coating failure is imperative if serious structural damage is to be avoided. Magnesium attack is probably the easiest type of corrosion to detect in its early stages, since magnesium corrosion products occupy several times the volume of the original magnesium metal destroyed. The beginning of attack shows as a lifting of the paint films and white spots on the magnesium surface. These rapidly develop into snow-like mounds or even "white whiskers." [Figure 6-17] Reprotection involves the removal of corrosion products, the partial restoration of surface coatings by chemical treatment, and a reapplication of protective coatings.

Figure 6-17. Magnesium corrosion.

Treatment of Wrought Magnesium Sheet and Forgings

Magnesium skin corrosion usually occurs around edges of skin panels, underneath washers, or in areas physically damaged by shearing, drilling, abrasion, or impact. If the skin section can be removed easily, this should be done to assure complete inhibition and treatment. If insulating washers are involved, screws should at least be sufficiently loosened, to permit brush treatment of the magnesium under the insulating washer. Complete mechanical removal of corrosion products should be practiced insofar as practicable. Limit such mechanical cleaning to the use of stiff, hog bristle brushes, and similar nonmetallic cleaning tools (including nonwoven abrasive pads), particularly if treatment is to be performed under field conditions. Like aluminum, under no circumstances are steel or aluminum tools, steel, bronze or aluminum wool or other cleaning abrasive pads used on different metal surfaces to be used in cleaning magnesium. Any entrapment of particles from steel wire brushes or steel tools, or contamination of treated surfaces by dirty abrasives, can cause more trouble than the initial corrosive attack.

Corroded magnesium may generally be treated as follows:

1. Clean and strip the paint from the area to be treated. (Paint stripping procedures were discussed earlier in this chapter, and are also addressed in FAA Advisory Circular (AC) 43.13-1B, *Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair*.)
2. Using a stiff, hog bristle brush or nonwoven abrasive pad, break loose and remove as much of the corrosion products as practicable. Steel wire brushes, carborundum abrasives, or steel cutting tools must not be used.
3. Treat the corroded area liberally with a chromic acid solution, to which has been added sulfuric acid, and work into pits and crevices by brushing the area while still wet with chromic acid, again using a nonmetallic brush.
4. Allow the chromic acid to remain in place for 5 to 20 minutes before wiping up the excess with a clean, damp cloth. Do not allow the excess solution to dry and remain on the surface, as paint lifting will be caused by such deposits.
5. As soon as the surfaces are dry, restore the original protective paint.

Treatment of Installed Magnesium Castings

Magnesium castings, in general, are more porous and more prone to penetrating attack than wrought magnesium skins. For all practical purposes, however, treatment is the same for all magnesium areas. Engine cases, bellcranks, fittings, numerous covers, plates, and handles are the most common magnesium castings.

When attack occurs on a casting, the earliest practicable treatment is required if dangerous corrosive penetration is to be avoided. In fact, engine cases submerged in saltwater overnight can be completely penetrated. If it is at all practicable, parting surfaces should be separated to effectively treat the existing attack and prevent its further progress. The same general treatment sequence in the preceding paragraph for magnesium skin should be followed.

If extensive removal of corrosion products from a structural casting is involved, a decision from the manufacturer may be necessary to evaluate the adequacy of structural strength remaining. Specific structural repair manuals usually include dimensional tolerance limits for critical structural members and should be referred to, if any question of safety is involved.

Treatment of Titanium and Titanium Alloys

Attack on titanium surfaces is generally difficult to detect. Titanium is, by nature, highly corrosion resistant, but it may show deterioration from the presence of salt deposits and metal impurities, particularly at high temperatures. Therefore, the use of steel wool, iron scrapers, or steel brushes for cleaning or for the removal of corrosion from titanium parts is prohibited.

If titanium surfaces require cleaning, hand polishing with aluminum polish or a mild abrasive is permissible, if fiber brushes only are used and if the surface is treated following cleaning with a suitable solution of sodium dichromate. Wipe the treated surface with dry cloths to remove excess solution, but do not use a water rinse.

Protection of Dissimilar Metal Contacts

Certain metals are subject to corrosion when placed in contact with other metals. This is commonly referred to as electrolytic or dissimilar metals corrosion. Contact of different bare metals creates an electrolytic action when moisture is present. If this moisture is salt water, the electrolytic action is accelerated. The result of dissimilar metal contact is oxidation (decomposition) of one or both metals. The chart shown in Figure 6-18 lists the metal combinations requiring a protective separator. The separating materials may be metal primer, aluminum tape, washers, grease, or sealant, depending on the metals involved.

Contacts Not Involving Magnesium

All dissimilar joints not involving magnesium are protected by the application of a minimum of two coats of zinc chromate or, preferably, epoxy primer in addition to normal primer requirements. Primer is applied by brush or spray and allowed to air dry 6 hours between coats.

Contacts Involving Magnesium

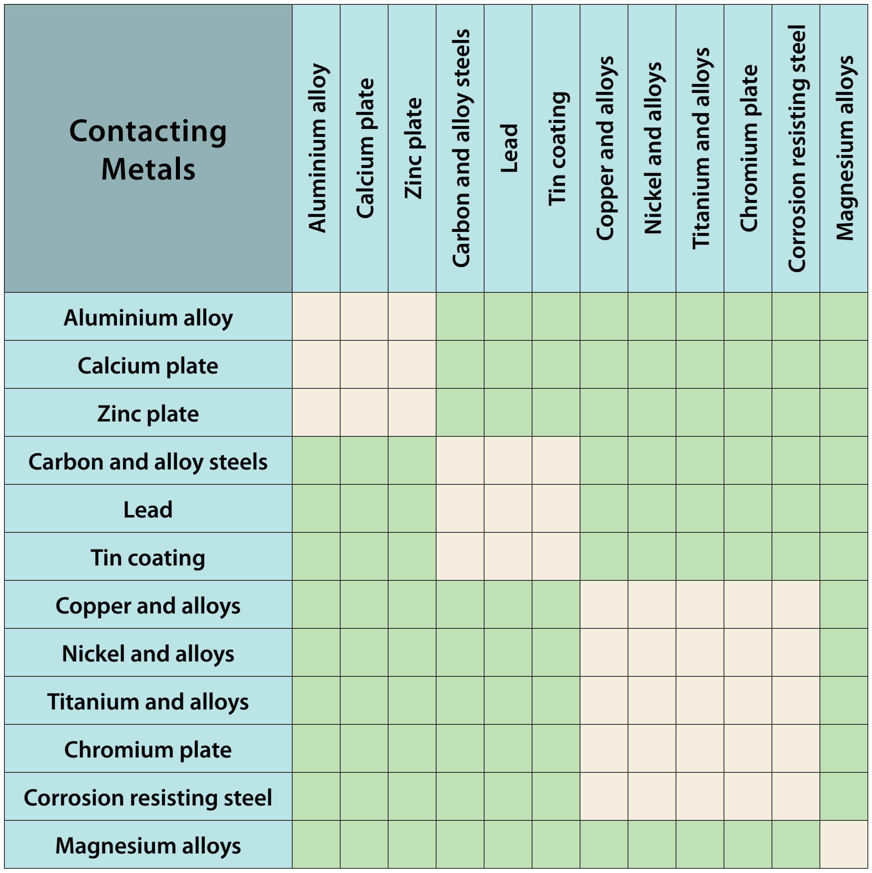
To prevent corrosion between dissimilar metal joints in which magnesium alloy is involved, each surface is insulated as follows:

At least two coats of zinc chromate or, preferably, epoxy primer are applied to each surface. Next, a layer of pressure sensitive vinyl tape 0.003 inch thick is applied smoothly and firmly enough to prevent air bubbles and wrinkles. To avoid creep back, the tape is not stretched during application. When the thickness of the tape interferes with the assembly of parts, where relative motion exists between parts, or when service temperatures above 250 °F are anticipated, the use of tape is eliminated and extra coats (minimum of three) of primer are applied.

Corrosion Limits

Corrosion, however slight, is damage. Therefore, corrosion damage is classified under the four standard types, as is any other damage. These types are: (1) negligible damage, (2) damage repairable by patching, (3) damage repairable by insertion, and (4) damage necessitating replacement of parts.

The term "negligible," as used here, does not imply that little or nothing should be done. The corroded surface should be cleaned, treated, and painted as appropriate. Negligible damage, generally, is corrosion that has scarred or eaten away the surface protective coats and begun to etch the metal. Corrosion damage extending to classifications of "repairable by patching" and "repairable by insertion" should be repaired in accordance with the applicable structural repair manual. When corrosion damage exceeds the damage limits to the extent that repair is not possible, the component or structure should be replaced.



Green areas indicate dissimilar metal contact

Figure 6-18. Dissimilar metal contacts that will result in electrolytic corrosion.

Processes and Materials Used in Corrosion Control

Metal Finishing

Aircraft parts are almost always given some type of surface finish by the manufacturer. The main purpose is to provide corrosion resistance; however, surface finishes may also be applied to increase wear resistance or to provide a suitable base for paint.

In most instances, the original finishes described in the following paragraphs cannot be restored in the field due to unavailable equipment or other limitations. However, an understanding of the various types of metal finishes is necessary if they are to be properly maintained in the field and if the partial restoration techniques used in corrosion control are to be effective.

Surface Preparation

Original surface treatments for steel parts usually include a cleaning treatment to remove all traces of dirt, oil, grease, oxides, and moisture. This is necessary to provide an effective bond between the metal surface and the final finish. The cleaning process may be either mechanical or chemical. In mechanical cleaning, the following methods are employed: wire brush, steel wool, emery cloth, sandblasting, or vapor blasting.

Chemical cleaning is preferred over mechanical since none of the base metal is removed by cleaning. There are various chemical processes now in use, and the type used will depend on the material being cleaned and the type of foreign matter being removed.

Steel parts are pickled to remove scale, rust, or other foreign matter, particularly before plating. The pickling solution can be either muriatic (hydrochloric) or sulfuric acid. Cost wise, sulfuric acid is preferable, but muriatic acid is more effective in removing certain types of scale.

The pickling solution is kept in a stoneware tank and is usually heated by means of a steam coil. Parts not to be electroplated after pickling are immersed in a lime bath to neutralize the acid from the pickling solution.

Electrocleaning is another type of chemical cleaning used to remove grease, oil, or organic matter. In this cleaning process, the metal is suspended in a hot alkaline solution containing special wetting agents, inhibitors, and materials to provide the necessary electrical conductivity. An electric current is then passed through the solution in a manner similar to that used in electroplating.

Aluminum and magnesium parts are also cleaned by using some of the foregoing methods. Blast cleaning using abrasive media is not applicable to thin aluminum sheets, particularly Alclad. Steel grits are not used on aluminum or corrosion resistant metals.

Polishing, buffing, and coloring of metal surfaces play a very important part in the finishing of metal surfaces. Polishing and buffing operations are sometimes used when preparing a metal surface for electroplating, and all three operations are used when the metal surface requires a high luster finish.

Chemical Treatments

Anodizing

Anodizing is the most common surface treatment of nonclad aluminum alloy surfaces. It is typically done in specialized facilities in accordance with Mil-C-5541E or AMS-C-5541. The aluminum alloy sheet or casting is the positive pole in an electrolytic bath in which chromic acid or other oxidizing agent produces an aluminum oxide film on the metal 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 treatments. Therefore, when an anodized surface is cleaned including corrosion removal, the technician should avoid unnecessary destruction of the oxide film.

The anodized coating provides excellent resistance to corrosion. The coating is soft and easily scratched, making it necessary to use extreme caution when handling it prior to coating it with primer.

Aluminum wool, nylon webbing impregnated with aluminum oxide abrasive, fine grade nonwoven abrasive pads or fiber bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminum surfaces is prohibited. Producing a buffed or wire brush finish by any means is also prohibited. Otherwise, anodized surfaces are treated in much the same manner as other aluminum finishes.

In addition to its corrosion resistant qualities, the anodic coating is also an excellent bond for paint. In most cases, parts are primed and painted as soon as possible after anodizing. The anodic coating is a poor conductor of electricity; therefore, if parts require bonding, the coating is removed where the bonding wire is to be attached. Alclad surfaces that are to be left unpainted require no anodic treatment; however, if the Alclad surface is to be painted, it is usually anodized to provide a bond for the paint.

Alodizing

Alodizing is a simple chemical treatment for all aluminum alloys to increase their corrosion resistance and to improve their paint bonding qualities. Because of its simplicity, it is rapidly replacing anodizing in aircraft work.

The process consists of precleaning with an acidic or alkaline metal cleaner that is applied by either dipping or spraying. The parts are then rinsed with fresh water under pressure for 10 to 15 seconds. After thorough rinsing, Alodine® is applied by dipping, spraying, or brushing. A thin, hard coating results which ranges in color from light, bluish green with a slight iridescence on copper free alloys to an olive green on copper bearing alloys. The Alodine is first rinsed with clear, cold or warm water for a period of 15 to 30 seconds. An additional 10 to 15 second rinse is then given in a Deoxylyte® bath. This bath is to counteract alkaline material and to make the alodined aluminum surface slightly acid on drying.

Chemical Surface Treatment and Inhibitors

As previously described, aluminum and magnesium alloys in particular are protected originally by a variety of surface treatments. Steels may have been treated on the surface during manufacture. Most of these coatings can only be restored by processes that are completely impractical in the field. But, corroded areas where such protective films have been destroyed require some type of treatment prior to refinishing.

The labels on the containers of surface treatment chemicals will provide warnings if a material is toxic or flammable. However, the label might not be large enough to accommodate a list of all the possible hazards which may ensue if the materials are mixed with incompatible substances. The Material Safety Data Sheet (MSDS) should also be consulted for information. For example, some chemicals used in surface treatments will react violently if inadvertently mixed with paint thinners. Chemical surface treatment materials must be handled with extreme care and mixed exactly according to directions.

Chromic Acid Inhibitor

A 10 percent solution by weight of chromic acid, activated by a small amount of sulfuric acid, is particularly effective in treating exposed or corroded aluminum surfaces. It may also be used to treat corroded magnesium.

This treatment tends to restore the protective oxide coating on the metal surface. Such treatment must be followed by regular paint finishes as soon as practicable, and never later than the same day as the latest chromic acid treatment. Chromium trioxide flake is a powerful oxidizing agent and a fairly strong acid. It must be stored away from organic solvents and other combustibles. Either thoroughly rinse or dispose of wiping cloths used in chromic acid pickup.

Sodium Dichromate Solution

A less active chemical mixture for surface treatment of aluminum is a solution of sodium dichromate and chromic acid. Entrapped solutions of this mixture are less likely to corrode metal surfaces than chromic acid inhibitor solutions.

Chemical Surface Treatments

Several commercial, activated chromate acid mixtures are available under Specification MIL-C-5541 for field treatment of damaged or corroded aluminum surfaces. Take precautions to make sure that sponges or cloths used are thoroughly rinsed to avoid a possible fire hazard after drying.

Protective Paint Finishes

A good, intact paint finish is the most effective barrier between metal surfaces and corrosive media. The most common finishes include catalyzed polyurethane enamel, waterborne polyurethane enamel, and two-part epoxy paint. As new regulations regarding the emission of volatile organic compounds (VOCs) are put into effect, the use of waterborne paint systems have increased in popularity. Also still available are nitrate and butyrate dope finishes for fabric-covered aircraft. In addition, high visibility fluorescent materials may also be used, along with a variety of miscellaneous combinations of special materials. There may also be rain erosion resistant coatings on metal leading edges, and several different baked enamel finishes on engine cases and wheels.

Aircraft Cleaning

Cleaning an aircraft and keeping it clean are extremely important. From an aircraft maintenance technician's viewpoint, it should be considered a regular part of aircraft maintenance. Keeping the aircraft clean can mean more accurate inspection results, and may even allow a flight crewmember to spot an impending component failure. A cracked landing gear fitting covered with mud and grease may be easily overlooked. Dirt can hide cracks in the skin. Dust and grit cause hinge fittings to wear excessively. If left on the aircraft's outer surface, a film of dirt reduces flying speed and adds extra weight. Dirt or trash blowing or bouncing around the inside of the aircraft is annoying and dangerous. Small pieces of dirt blown into the eyes of the pilot at a critical moment can cause an accident. A coating of dirt and grease on moving parts makes a grinding compound that can cause excessive wear. Salt water has a serious corroding effect on exposed metal parts of the aircraft, and should be washed off immediately.

There are many different kinds of cleaning agents approved for use in cleaning aircraft. It is impractical to cover each of the various types of cleaning agents since their use varies under different conditions, such as the type of material to be removed, the aircraft finish, and whether the cleaning is internal or external.

In general, the types of cleaning agents used on aircraft are solvents, emulsion cleaners, soaps, and synthetic detergents. Their use must be in accordance with the applicable maintenance manual. The types of cleaning agents named above are also classed as light or heavy duty cleaners. The soap and synthetic detergent type cleaners are used for light duty cleaning, while the solvent and emulsion type cleaners are used for heavy duty cleaning. The light duty cleaners, which are nontoxic and nonflammable, should be used whenever possible. As mentioned previously, cleaners that can be effectively rinsed and neutralized must be used, or an alkaline cleaner may cause corrosion within the lap joints of riveted or spot-welded sheet metal components.

Exterior Cleaning

There are three methods of cleaning the aircraft exterior: (1) wet wash, (2) dry wash, and (3) polishing. Polishing can be further broken down into hand polishing and mechanical polishing. The type and extent of soiling and the final desired appearance determine the cleaning method to be used.

Wet wash removes oil, grease, or carbon deposits and most soils, with the exception of corrosion and oxide films. The cleaning compounds used are usually applied by spray or mop, after which high pressure running water is used as a rinse. Either alkaline or emulsion cleaners can be used in the wet wash method.

Dry wash is used to remove airport film, dust, and small accumulations of dirt and soil when the use of liquids is neither desirable nor practical. This method is not suitable for removing heavy deposits of carbon, grease, or oil, especially in the engine exhaust areas. Dry wash materials are applied with spray, mops, or cloths, and removed by dry mopping or wiping with clean, dry cloths.

Polishing restores the luster to painted and unpainted surfaces of the aircraft, and is usually performed after the surfaces have been cleaned. Polishing is also used to remove oxidation and corrosion. Polishing materials are available in various forms and degrees of abrasiveness. It is important that the aircraft manufacturer's instructions be used in specific applications.

The washing of aircraft should be performed in the shade whenever possible as cleaning compounds tend to streak the surface if applied to hot metal, or are permitted to dry on the area. Install covers over all openings where water or cleaners might enter and cause damage. Pay particular attention to instrument system components such as pitot-static fittings and ports.

Various areas of aircraft, such as the sections housing radar and the area forward of the cockpit that are finished with a flat-finish paint, should not be cleaned more than necessary and should never be scrubbed with stiff brushes or coarse rags. A soft sponge or cheesecloth with a minimum of manual rubbing is advisable. Any oil or exhaust stains on the surface should first be removed with a solvent such as kerosene or other petroleum base solvent. Rinse the surfaces immediately after cleaning to prevent the compound from drying on the surface.

Before applying soap and water to plastic surfaces, flush the plastic surfaces with fresh water to dissolve salt deposits and wash away dust particles. Plastic surfaces should be washed with soap and water, preferably by hand. Rinse with fresh water and dry with a chamois, synthetic wipes designed for use on plastic windshields, or absorbent cotton. In view of the soft surface, do not rub plastic with a dry cloth since this is not only likely to cause scratches, but it also builds up an electrostatic charge that attracts dust particles to the surface. The charge, as well as the dust, may be removed by patting or gently blotting with a clean, damp chamois. Do not use scouring powder or other material that can mar the plastic surface. Remove oil and grease by rubbing gently with a cloth wet with soap and water. Do not use acetone, benzene, carbon tetrachloride, lacquer thinners, window cleaning sprays, gasoline, fire extinguisher or deicer fluid on plastics because they soften the plastic and will cause crazing. Finish cleaning the plastic by coating with a plastic polish intended for aircraft windows and windshields. These polishes can minimize small surface scratches and will also help keep static charges from building up on the surface of the windows.

Surface oil, hydraulic fluid, grease, or fuel can be removed from aircraft tires by washing with a mild soap solution. After cleaning, lubricate all grease fittings, hinges, and so forth, where removal, contamination, or dilution of the grease is suspected during washing of the aircraft.

Interior Cleaning

Keeping the interior of the aircraft clean is just as important as maintaining a clean exterior surface. Corrosion can establish itself on the inside structure to a greater degree because it is difficult to reach some areas for cleaning. Nuts, bolts, bits of wire, or other metal objects carelessly dropped and neglected, combined with moisture and dissimilar metal contact, can cause electrolytic corrosion.

When performing structural work inside the aircraft, clean up all metal particles and other debris as soon as possible. To make cleaning easier and prevent the metal particles and debris from getting into inaccessible areas, use a drop cloth in the work area to catch this debris.

A vacuum cleaner can be used to pick up dust and dirt from the interior of the cockpit and cabin.

Aircraft interior present certain problems during cleaning operations. The following is taken from The National Fire Protection Association (NFPA) Bulletin #410F, Aircraft Cabin Cleaning Operation.

"Basic to an understanding of the problem is the fact that aircraft cabin compartments constitute relatively small enclosures as measured by their cubic footage. This presents the possibility of restricted ventilation and the quick buildup of flammable vapor/air mixtures where there is any indiscriminate use of flammable cleaning agents or solvents. Within the same volume there may also exist the possibility of an ignition source in the form of an electrical fault, a friction or static spark, an open flame device, or some other potential introduced by concurrent maintenance work."

Wherever possible, use nonflammable agents in these operations to reduce to the minimum the fire and explosion hazards.

Types of Cleaning Operations

The principal areas of aircraft cabins which may need periodic cleaning are:

1. Aircraft passenger cabin areas (seats, carpets, side panels, headliners, overhead racks, curtains, ash trays, windows, doors, decorative panels of plastic, wood or similar materials).
2. Aircraft flight station areas (similar materials to those found in passenger cabin areas plus instrument panels, control pedestals, glare shields, flooring materials, metallic surfaces of instruments and flight control equipment, electrical cables and contacts, and so forth).
3. Lavatories and buffets (similar materials to those found in passenger cabin areas plus toilet facilities, metal fixtures and trim, trash containers, cabinets, wash and sink basins, mirrors, ovens, and so forth).

Nonflammable Aircraft Cabin Cleaning Agents and Solvents

1. Detergents and soaps. These have widespread application for most aircraft cleaning operations involving fabrics, headliners, rugs, windows, and similar surfaces that are not damageable by water solutions since they are colorfast and nonshrinkable. Care is frequently needed to prevent leaching of water-soluble fire retardant salts which may have been used to treat such materials in order to reduce their flame spread characteristics. Allowing water laced with fire retardant salts to come in contact with the aluminum framework of seats and seat rails can induce corrosion. Be careful to ensure only the necessary amount of water is applied to the seat materials when cleaning.
2. Alkaline cleaners. Most of these agents are water soluble and thus have no fire hazard properties. They can be used on fabrics, headliners, rugs, and similar surfaces in the same manner as detergent and soap solutions with only minor added limitations resulting from their inherent caustic character. This may increase their efficiency as cleaning agents but results in somewhat greater deteriorating effects on certain fabrics and plastics.
3. Acid solutions. A number of proprietary acid solutions are available for use as cleaning agents. They are normally mild solutions designed primarily to remove carbon smut or corrosive stains. As water-based solutions, they have no flash point but may require more careful and judicious use not only to prevent damage to fabrics, plastics, or other surfaces but also to protect the skin and clothing of those using the materials.
4. Deodorizing or disinfecting agents. A number of proprietary agents useful for aircraft cabin deodorizing or disinfecting are nonflammable. Most of these are designed for spray application (aerosol type) and have a nonflammable pressurizing agent, but it is best to check this carefully as some may contain a flammable compressed gas for pressurization.
5. Abrasives. Some proprietary nonflammable mild abrasive materials are available for rejuvenating painted or polished surfaces. They present no fire hazard.
6. Dry cleaning agents. Perchlorethylene and trichlorethylene as used at ambient temperatures are examples of nonflammable dry cleaning agents. These materials do have a toxicity hazard requiring care in their use, and in some locations, due to environmental laws, their use may be prohibited or severely restricted. In the same way, water-soluble agents can be detrimental. Fire retardant treated materials may be adversely affected by the application of these dry cleaning agents.

Flammable and Combustible Agents

1. High flash point solvents. Specially refined petroleum products, first developed as "Stoddard solvent" but now sold under a variety of trade names by different companies, have solvent properties approximating gasoline but have fire hazard properties similar to those of kerosene as commonly used (not heated). Most of these are stable products having a flash point from 100 °F to 140 °F with a comparatively low degree of toxicity.

2. Low flash point solvents. Class I (flash point at below 100 °F) flammable liquids should not be used for aircraft cleaning or refurbishing. Common materials falling into this "class" are acetone, aviation gasoline, methyl ethyl ketone, naphtha, and toluol. In cases where it is absolutely necessary to use a flammable liquid, use high flash point liquids (those having a flash point of 100 °F or more).
3. Mixed liquids. Some commercial solvents are mixtures of liquids with differing rates of evaporation, such as a mixture of one of the various naphthas and a chlorinated material. The different rates of evaporation may present problems from both the toxicity and fire hazard viewpoints. Such mixtures should not be used unless they are stored and handled with full knowledge of these hazards and appropriate precautions taken.

Container Controls

Flammable liquids should be handled only in approved containers or safety cans appropriately labeled.

Fire Prevention Precautions

During aircraft cleaning or refurbishing operations where flammable or combustible liquids are used, the following general safeguards are recommended:

1. Aircraft cabins should be provided with ventilation sufficient at all times to prevent the accumulation of flammable vapors. To accomplish this, doors to cabins shall be open to secure maximum advantage of natural ventilation. Where such natural ventilation is insufficient, approved mechanical ventilation equipment shall be provided and used. The accumulation of flammable vapors above 25 percent of the lower flammability limit of the particular vapor being used, measured at a point 5 feet from the location of use, shall result in emergency revisions of operations in progress.
2. All open flame and spark producing equipment or devices that might be brought within the vapor hazard area should be shut down and not operated during the period when flammable vapors may exist.
3. Electrical equipment of a hand portable nature used within an aircraft cabin shall be of the type approved for use in Class I, Group D, Hazardous Locations as defined by the National Electrical Code.
4. Switches to aircraft cabin lighting and to the aircraft electrical system components within the cabin area should not be worked on or switched on or off during cleaning operations.
5. Suitable warning signs should be placed in conspicuous locations at aircraft doors to indicate that flammable liquids are being or have been used in the cleaning or refurbishing operation in progress.

Fire Protection Recommendations

During aircraft cleaning or refurbishing operations where flammable liquids are used, the following general fire protection safeguards are recommended:

1. Aircraft undergoing such cleaning or refurbishing should preferably be located outside of the hangar buildings when weather conditions permit. This provides for added natural ventilation and normally assures easier access to the aircraft in the event of fire.
2. It is recommended that during such cleaning or refurbishing operations in an aircraft outside of the hangar that portable fire extinguishers be provided at cabin entrances having a minimum rating of 20-B and, at minimum, a booster hose line with an adjustable water spray nozzle being available capable of reaching the cabin area for use pending the arrival of airport fire equipment. As an alternate to the previous recommendations, a Class A fire extinguisher having a minimum rating of 4-A plus or a Class B fire extinguisher having a minimum rating of 20-B should be placed at aircraft cabin doors for immediate use if required.

   NOTE 1: All-purpose ABC (dry chemical) type extinguishers should not be used in situations where aluminum corrosion is a problem if the extinguisher is used.

   NOTE 2: Portable and semi-portable fire detection and extinguishing equipment has been developed, tested, and installed to provide protection to aircraft during construction and maintenance operations. Operators are urged to investigate the feasibility of utilizing such equipment during aircraft cabin cleaning and refurbishing operations.
3. Aircraft undergoing such cleaning or refurbishing where the work must be done under cover should be in hangars equipped with automatic fire protection equipment.

Powerplant Cleaning

Cleaning the powerplant is an important job and should be done thoroughly. Grease and dirt accumulations on an air-cooled engine provide an effective insulation against the cooling effect of air flowing over it. Such an accumulation can also cover up cracks or other defects.

When cleaning an engine, open or remove the cowling as much as possible. Beginning with the top, wash down the engine and accessories with a fine spray of kerosene or solvent. A bristle brush may be used to help clean some of the surfaces.

Fresh water and soap and approved cleaning solvents may be used for cleaning propeller and rotor blades. Except in the process of etching, caustic material should not be used on a propeller. Scrapers, power buffers, steel brushes, or any tool or substances that will mar or scratch the surface should not be used on propeller blades, except as recommended for etching and repair.

Water spray, rain, or other airborne abrasive material strikes a whirling propeller blade with such force that small pits are formed in the blade's leading edge. If preventive measures are not taken, corrosion causes these pits to rapidly grow larger. The pits may become so large that it is necessary to file the blade's leading edge until it is smooth.

Steel propeller blades have more resistance to abrasion and corrosion than aluminum alloy blades. Steel blades, if rubbed down with oil after each flight, retain a smooth surface for a long time.

Examine the propellers regularly because cracks in steel or aluminum alloy blades can become filled with oil, which tends to oxidize. This can readily be seen when the blade is inspected. Keeping the surface wiped with oil serves as a safety feature by helping to make cracks more obvious.

Propeller hubs must be inspected regularly for cracks and other defects. Unless the hubs are kept clean, defects may not be found. Clean steel hubs with soap and fresh water, or with an approved cleaning solvent. These cleaning solvents may be applied by cloths or brushes. Avoid tools and abrasives that scratch or otherwise damage the plating.

In special cases in which a high polish is desired, the use of a good grade of metal polish is recommended. Upon completion of the polishing, all traces of polish must be removed immediately, the blades cleaned, and then coated with clean engine oil. All cleaning substances must be removed immediately after completion of the cleaning of any propeller part. Soap in any form can be removed by rinsing repeatedly with fresh water. After rinsing, all surfaces should be dried and coated with clean engine oil. After cleaning the powerplant, all control arms, bellcranks, and moving parts should be lubricated according to instructions in the applicable maintenance manual.

Solvent Cleaners

In general, solvent cleaners used in aircraft cleaning should have a flashpoint of not less than 105 °F, if explosion proofing of equipment and other special precautions are to be avoided. Chlorinated solvents of all types meet the nonflammable requirements but are toxic, and safety precautions must be observed in their use. Use of carbon tetrachloride should be avoided. The Material Safety Data Sheet (MSDS) for each solvent should be consulted for handling and safety information.

AMT's should review the Material Safety Data Sheet (MSDS) available for any chemical, solvent or other materials they may come in contact with during the course of their maintenance activities. In particular, solvents and cleaning liquids, even those considered "environmentally friendly" can have varied detrimental effects on the skin, internal organs and/or nervous system. Active solvents such as methyl ethyl ketone (MEK) and acetone can be harmful or fatal if swallowed, and can be harmful when inhaled or absorbed through the skin in sufficient quantities.

Particular attention should be paid to recommended protective measures including gloves, respirators and face shields. A regular review of the MSDS will keep the AMT updated on any revisions that may be made by chemical manufacturers or government authorities.

Dry Cleaning Solvent

Stoddard solvent is the most common petroleum base solvent used in aircraft cleaning. Its flashpoint is slightly above 105 °F and can be used to remove grease, oils, or light soils. Dry cleaning solvent is preferable to kerosene for all cleaning purposes, but like kerosene, it leaves a slight residue upon evaporation, which may interfere with the application of some final paint films.

Aliphatic and Aromatic Naphtha

Aliphatic naphtha is recommended for wipe down of cleaned surfaces just before painting. This material can also be used for cleaning acrylics and rubber. It flashes at approximately 80 °F and must be used with care.

Aromatic naphtha should not be confused with the aliphatic material. It is toxic and attacks acrylics and rubber products, and must be used with adequate controls.

Safety Solvent

Safety solvent, trichloroethane (methyl chloroform), is used for general cleaning and grease removal. It is nonflammable under ordinary circumstances, and is used as a replacement for carbon tetrachloride. The use and safety precautions necessary when using chlorinated solvents must be observed. Prolonged use can cause dermatitis on some persons.

Methyl Ethyl Ketone (MEK)

MEK is also available as a solvent cleaner for metal surfaces and paint stripper for small areas. This is a very active solvent and metal cleaner, with a flashpoint of about 24 °F. It is toxic when inhaled, and safety precautions must be observed during its use. In most instances, it has been replaced with safer to handle and more environmentally friendly cleaning solvents.

Kerosene

Kerosene is mixed with solvent emulsion type cleaners for softening heavy preservative coatings. It is also used for general solvent cleaning, but its use should be followed by a coating or rinse with some other type of protective agent. Kerosene does not evaporate as rapidly as dry cleaning solvent and generally leaves an appreciable film on cleaned surfaces, which may actually be corrosive. Kerosene films may be removed with safety solvent, water emulsion cleaners, or detergent mixtures.

Cleaning Compound for Oxygen Systems

Cleaning compounds for use in the oxygen system are anhydrous (waterless) ethyl alcohol or isopropyl (anti-icing fluid) alcohol. These may be used to clean accessible components of the oxygen system such as crew masks and lines. Fluids should not be put into tanks or regulators.

Do not use any cleaning compounds which may leave an oily film when cleaning oxygen equipment. Instructions of the manufacturer of the oxygen equipment and cleaning compounds must be followed at all times.

Emulsion Cleaners

Solvent and water emulsion compounds are used in general aircraft cleaning. Solvent emulsions are particularly useful in the removal of heavy deposits, such as carbon, grease, oil, or tar. When used in accordance with instructions, these solvent emulsions do not affect good paint coatings or organic finishes.

Water Emulsion Cleaner

Material available under Specification MIL-C-22543A is a water emulsion cleaning compound intended for use on both painted and unpainted aircraft surfaces. This material is also acceptable for cleaning fluorescent painted surfaces and is safe for use on acrylics. However, these properties will vary with the material available, and a sample application should be checked carefully before general uncontrolled use.

Solvent Emulsion Cleaners

One type of solvent emulsion cleaner is nonphenolic and can be safely used on painted surfaces without softening the base paint. Repeated use may soften acrylic nitrocellulose lacquers. It is effective, however, in softening and lifting heavy preservative coatings. Persistent materials should be given a second or third treatment as necessary.

Another type of solvent emulsion cleaner has a phenolic base that is more effective for heavy duty application, but it also tends to soften paint coatings. It must be used with care around rubber, plastics, or other nonmetallic materials. Wear rubber gloves and goggles for protection when working with phenolic base cleaners.

Soaps and Detergent Cleaners

A number of materials are available for mild cleaning use. In this section, some of the more common materials are discussed.

Cleaning Compound, Aircraft Surfaces

Specification MIL-C-5410 Type I and II materials are used in general cleaning of painted and unpainted aircraft surfaces for the removal of light to medium soils, operational films, oils, or greases. They are safe to use on all surfaces, including fabrics, leather, and transparent plastics. Nonglare (flat) finishes should not be cleaned more than necessary and should never be scrubbed with stiff brushes.

Nonionic Detergent Cleaners

These materials may be either water soluble or oil soluble. The oil-soluble detergent cleaner is effective in a 3 to 5 percent solution in dry cleaning solvent for softening and removing heavy preservative coatings. This mixture's performance is similar to the emulsion cleaners mentioned previously.

Mechanical Cleaning Materials

Mechanical cleaning materials must be used with care and in accordance with directions given, if damage to finishes and surfaces is to be avoided.

Mild Abrasive Materials

No attempt is made in this section to furnish detailed instructions for using various materials listed. Some do's and don'ts are included as an aid in selecting materials for specific cleaning jobs.

The introduction of various grades of nonwoven abrasive pads (a common brand name produced by the 3M company is Scotch-Brite™) has given the aircraft maintenance technician a clean, inexpensive material for the removal of corrosion products and for other light abrasive needs. The pads can be used on most metals (although the same pad should not be used on different metals) and are generally the first choice when the situation arises. A very open form of this pad is also available for paint stripping, when used in conjunction with wet strippers.

Powdered pumice can be used for cleaning corroded aluminum surfaces. Similar mild abrasives may also be used.

Impregnated cotton wadding material is used for removal of exhaust gas stains and polishing corroded aluminum surfaces. It may also be used on other metal surfaces to produce a high reflectance.

Aluminum metal polish is used to produce a high luster, long lasting polish on unpainted aluminum clad surfaces. It should not be used on anodized surfaces because it will remove the oxide coat.

Three grades of aluminum wool, coarse, medium, and fine, are used for general cleaning of aluminum surfaces. Impregnated nylon webbing material is preferred over aluminum wool for the removal of corrosion products and stubborn paint films and for the scuffing of existing paint finishes prior to touchup.

Lacquer rubbing compound material can be used to remove engine exhaust residues and minor oxidation. Avoid heavy rubbing over rivet heads or edges where protective coatings may be worn thin.

Abrasive Papers

Abrasive papers used on aircraft surfaces should not contain sharp or needlelike abrasives which can imbed themselves in the base metal being cleaned or in the protective coating being maintained. The abrasives used should not corrode the material being cleaned. Aluminum oxide paper, 300 grit or finer, is available in several forms and is safe to use on most surfaces. Type I, Class 2 material under Federal Specification P-C-451 is available in 1½ and 2 inch widths. Avoid the use of carborundum (silicon carbide) papers, particularly on aluminum or magnesium. The grain structure of carborundum is sharp, and the material is so hard that individual grains will penetrate and bury themselves even in steel surfaces. The use of emery paper or crocus cloth on aluminum or magnesium can cause serious corrosion of the metal by imbedded iron oxide.

Chemical Cleaners

Chemical cleaners must be used with great care in cleaning assembled aircraft. The danger of entrapping corrosive materials in faying surfaces and crevices counteracts any advantages in their speed and effectiveness. Any materials used must be relatively neutral and easy to remove. It is emphasized that all residues must be removed. Soluble salts from chemical surface treatments, such as chromic acid or dichromate treatment, will liquefy and promote blistering in the paint coatings.

Phosphoric-Citric Acid

A phosphoric-citric acid mixture (Type I) for cleaning aluminum surfaces is available and is ready to use as packaged. Type II is a concentrate that must be diluted with mineral spirits and water. Wear rubber gloves and goggles to avoid skin contact. Any acid burns may be neutralized by copious water washing, followed by treatment with a diluted solution of baking soda (sodium bicarbonate).

Baking Soda

Baking soda may be used to neutralize acid deposits in lead-acid battery compartments and to treat acid burns from chemical cleaners and inhibitors.