Corrosion and Inspection of General Aviation Aircraft

CAP 1570

Contents

Chapter 1
Introduction

1.1   All designers, maintainers, inspectors and owners have a part to play in preventing aircraft being adversely affected by metallic corrosion. They must think about different types of corrosion and those factors that need to be considered during design, design approval and subsequent maintenance. Pilots, aircraft owners and inspectors should also be aware of the possible effects that corrosion might have on an aircraft, what to look for during their routine checks and the potential safety impact if corrosion is overlooked.

1.2   Aircraft designers and inspectors should also be aware of the relevant corrosion protection, inspection and related inspection access design requirements of BCAR Section S, EASA CS-VLA and Acceptable Means of Compliance, (that achieve an equivalent level of safety), when undertaking design approval and acceptance inspections respectively – references are included in the following text.

1.3   General guidance is provided in this publication on the design, assembly and inspection of various parts of an aircraft structure. Those areas that because of their remoteness, complexity or boxed-in nature and are not readily accessible during routine maintenance or require attention in the light of operational experience are highlighted.

1.4   Corrosion can result in a significant decrease in the thickness of original load bearing material that can lead to a loss of structural integrity and potentially to catastrophic failure. In the case of more highly stressed parts, finding and rectifying corrosion damage can help to prevent the early initiation of fatigue cracking from corrosion pits that can also lead to premature structural and catastrophic failures. This has been observed in aluminium alloy forgings and light aircraft landing gear components, where a mixture of exfoliation and pitting corrosion on the flash line initiated stress corrosion cracking that then lead to corrosion fatigue, normal fatigue and exfoliation.

1.5   Routine in-service inspections that lead to the early detection of corrosion and consequent rectification can also prevent more costly, extensive and invasive repair actions later. This can be achieved on Primary structures that are not concealed and can be easily inspected for condition in-service.

1.6   Deterioration of aircraft structure may arise from various causes and can affect all parts of the structure according to the design of the aircraft and the uses to which it is put. This publication should be read in conjunction with the appropriate manufacturer's publications, where provided i.e. OEM Standard Practices and

the Maintenance Programme for the aircraft concerned. In addition further information on corrosion can be found as referenced in chapter 14.

1.7   Although guidance may be given in publications as to suitable opportunities for inspecting normally inaccessible structures (e.g. when a wing tip is removed permitting access to the adjacent wing structure) experience should indicate to the operator further opportunities for such inspections which can be included in the Maintenance Programme. Apart from the airworthiness aspects, these combined inspections could often be to the operator's advantage, since they could reduce or remove the need for future dismantling that might otherwise be dedicated to periodic corrosion driven inspections. Thus when access has been gained to a part of the airframe which is normally inaccessible, advantage should be taken of this dismantling to inspect all parts of systems and structures thus exposed.

1.8   When evidence of corrosion is found it is critical that the full extent and nature of the corrosion be established and repaired, even if these means additional access, dismantling or a special inspection technique to facilitate such deeper inspection and subsequent rectification actions.

1.9   The presence of corrosion in aircraft will lead to deterioration in the aircraft's structure which may eventually lead to catastrophic failure. It is therefore essential that any signs of corrosion are detected in the earliest stages of its development, assessed and addressed as appropriate. Development of corrosion over time is influenced by a variety of factors as will be described subsequently.

1.10   Prevention is always better than cure, and by ensuring suitable corrosion protection on individual detail parts prior to and during assembly the onset of corrosion can be prevented or significantly delayed.

Note: Whilst this publication contains guidance principally aimed at General Aviation Aircraft, the content can also be seen as more widely relevant to non-GA types which are similarly vulnerable to corrosion. Accordingly a number of the corrosion examples described and associated photographs that follow involve non-GA types.

Chapter 2
Theory of corrosion

The following text has been extracted from the US Department of Transportation, Federal Aviation Administration (FAA), Flight Standards Service FAA-8083-30 Aviation Maintenance Technical Handbook, Chapter 6 Aircraft Cleaning and Corrosion Control (2008) - the FAA text has not been revised save for spelling changes to UK English and in order to provide correct cross-references in the text to embedded photographs and diagrams.

2.1   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.

2.2   Water or water vapour 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.

Photograph 1. Direct chemical attack in a battery compartment
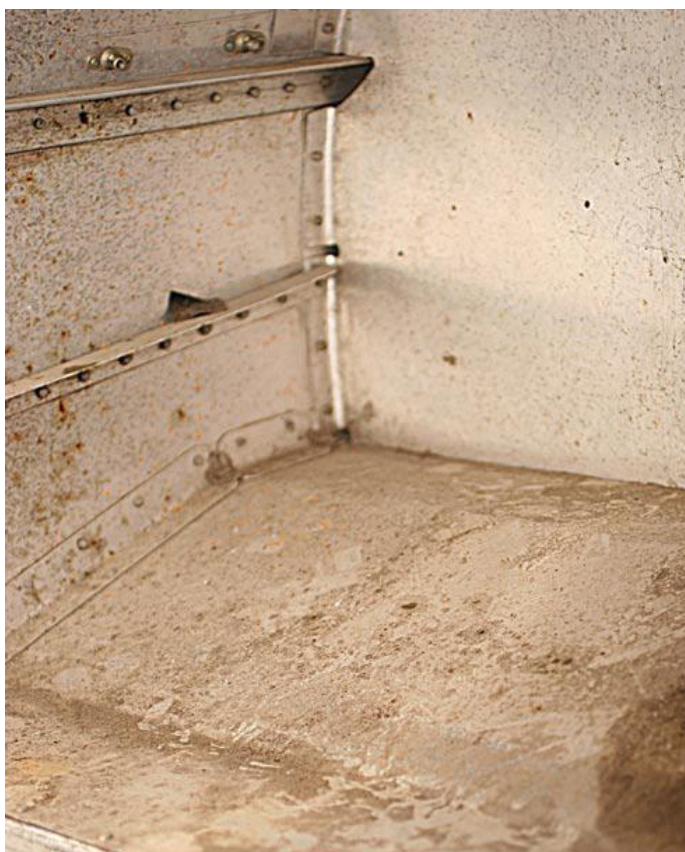
2.3   If left unchecked, corrosion can cause eventual structural failure. The appearance of corrosion varies with the metal. On the surface of aluminium alloys and magnesium, it appears as pitting and etching, and is often combined with a grey or white powdery deposit. On copper and copper alloys, the corrosion forms a greenish film; on steel, a reddish corrosion by-product commonly referred to as rust. When the grey, 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.

Types of Corrosion

2.4   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 sulphate. 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.

Diagram 1. Electrochemical attack
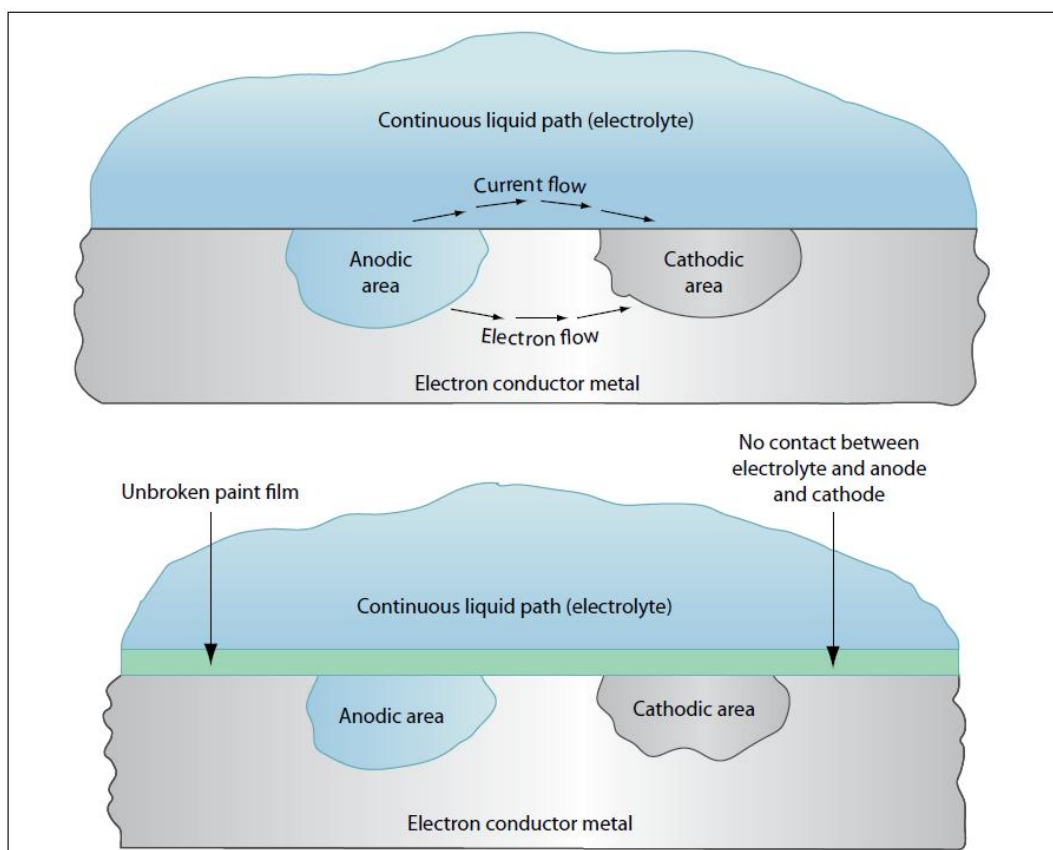
Direct Chemical Attack

2.5   Direct chemical attack, or pure chemical corrosion, is an attack resulting from a direct expo-sure 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:

- Spilled battery acid or fumes from batteries;

- Residual flux deposits resulting from inadequately cleaned, welded, brazed, or soldered joints; and

- Entrapped caustic cleaning solutions. [Photograph 1]

2.6   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.

2.7   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.

2.8   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

2.9   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. [Diagram 1] 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.

2.10   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." [Diagram 2] 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.

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

2.12   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.

Diagram 2. The galvanic series of metals and alloys.

| + 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) |

Chapter 3
Types of corrosion

3.1   Corrosion comes in many forms, (as is discussed in more detail in Section 3.2 below), and can be found on the surface and therefore can be penetrating inside the material; thus the removal of the surface products of corrosion followed by re-protection may not always be effective. Minor corrosion on the surface may hide more significant corrosion within the material structure, this can be true of intergranular corrosion, pitting corrosion as well as stress corrosion cracking. Once the surface is penetrated the reduction in strength due to loss of material can be disproportionate to the reduction in thickness of the metal as the corrosion initiates cracking mechanisms. Voids in structural joints that could allow water /condensate ingress leading to corrosion should be prevented. Means must be provided to allow inspection of Primary Structures in order to ensure that a satisfactory continued airworthy condition is maintained.

3.2   Initial presentation of exfoliation corrosion in components made from aluminium alloy extrusion, plate and bar may show itself as slight dark lines along the grain direction. Exfoliation corrosion is specific to wrought aluminium alloys and occurs due to developed grain structure 'flat pancake grains', this grain structure is not developed in any other metallic material. It is a form of intergranular corrosion. These lines are not to be confused with machining marks, as these corrosion marks will be along the axis of the material and not around the circumference. Left untreated this will develop into full scale Exfoliation or surface eruptions and material flakes. Component thickness will increase, as the grain separation forces the material apart, before complete structural failure occurs. Quilting or pin cushioning occurs because the volume of aluminium alloy corrosion is significantly greater than the metal volume. This is a phenomenon that is seen with aluminium alloy structures.

3.3   When general surface corrosion occurs within faying/fastened structures where layers of material are nested together in a joint, a similar characteristic quilting or pin cushion effect can be observed where the surface bulges and distorts outwards between the fasteners due to the expanding pressure of corrosion products.

Photograph 2. Pin cushion effect at a fuselage lap joint – in more extreme case and more particularly with countersunk fasteners the fastener heads can either pull through or fail entirely
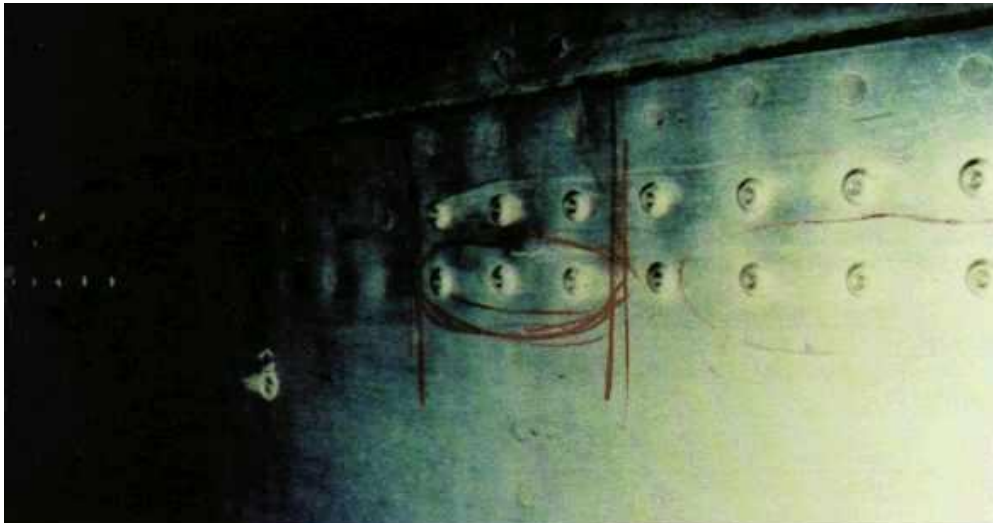
3.4   It may not be possible to determine the deterioration of material strength in Aluminium Alloy Primary Structure items, when assessing the extent of sub-surface corrosion using any known methods i.e. x-ray, ultrasound, and thus component replacement may be the only safe solution. Suitably effective individual part corrosion protection applied both before and during assembly can help to delay if not prevent corrosion in joints.

3.5   The following content is generally reflective of the typical types of corrosion as found with aluminium alloys, which tend to be more commonly used in the construction of light aircraft, however it should be borne in mind that most non-noble metals can corrode. Alloys including titanium alloys and steels can similarly be prone to corrosion. Even "non-corroding"/stainless types can corrode when exposed to particularly aggressive environments, (industrial chemical/saline etc., atmospheres under severe corrosion conditions), and stainless steel may also be prone to cracking when subjected to higher temperatures. Note that corrosion symptoms may present slightly differently in these other materials when compared to corrosion of aluminium alloys indeed it should be noted that different classes of alloy (2000 series, 6000 series, 7000 series) differ greatly in their corrosion resistance.

Anodic (Galvanic) corrosion

3.6   This form of corrosion arises when two dissimilar metals are in contact in the presence of an electrolyte, (usually present in the form of precipitation and condensation combined with atmospheric pollutants and spillages). Aluminium alloy is by its very nature of being an alloy, is comprised of dissimilar metals, (mainly aluminium, plus copper, magnesium and manganese), therefore any exposure of that base alloy material to water in service without suitable protection will produce corrosion which will not necessarily be restricted to the

surface where powder-like white or grey deposits can be observed. Note that carbon fibres in contact with aluminium can also set up a galvanic cell and an interfay material such a glass fibre / epoxy scrim on the surface of the carbon composite can be successfully employed as a barrier layer. Surface protection can generally assist in prevention, but using the same material in contact in a joint or a more careful choice of the materials that are closer on the electrochemical scale is generally seen as an effective preventative measure - it is not always feasible or practical to prevent dissimilar metal on metal contact when constructing traditional metallic fastener joined structures made of metals or carbon fibre reinforced materials. Joint protection provided by using a "surplus of approved jointing compound" for the prevention of joint internal voids as a preventative of water ingress into joint by capillary action can be employed.

Photograph 3. Aluminium alloy fitting attachments used to mount carbon fibre composite flying surfaces to fuselage - absence of paint / interfaying GRP shim has allowed aluminium on carbon contact creating a galvanic cell with the aluminium "sacrificed".

Intergranular Corrosion

3.7   This form of corrosion usually presents itself as cracking and tends to accelerate with the passage of time. A combination of chemical and electrolytic actions attack the material along the grain boundaries when the surface protective coating is damaged allowing moisture and corrosive agents to enter. A series of protective barriers comprising paint, primer and using a cladded aluminium sheet or plate material (i.e. a near pure aluminium outer clad layer) can help to protect the base structural material. All exposure of the Aluminium Alloy base metal from drilling or sheared edges produced during initial assembly, will remove or bypass the clad surface protection applied by the material manufacturer, and breaches in the cladding should be suitably re-protected from corrosion preferably by anodising or as a minimum by acid etch painting to be applied before final assembly with the use of, where applicable, an approved joint sealant. After final assembly, it is advisable that all joints should be sprayed with an acid etch primer, this will have the advantage of protecting newly formed rivet tails, exposed bolt threads and by leaching into any unprotected gaps/surfaces. This should prevent the capillary action of water condensate occupying those

potential voids, and has the additional benefit of providing a suitable keying surface for subsequent additional painting.

Photograph 4. Intergranular corrosion in austenitic cold rolled stainless steel[1]
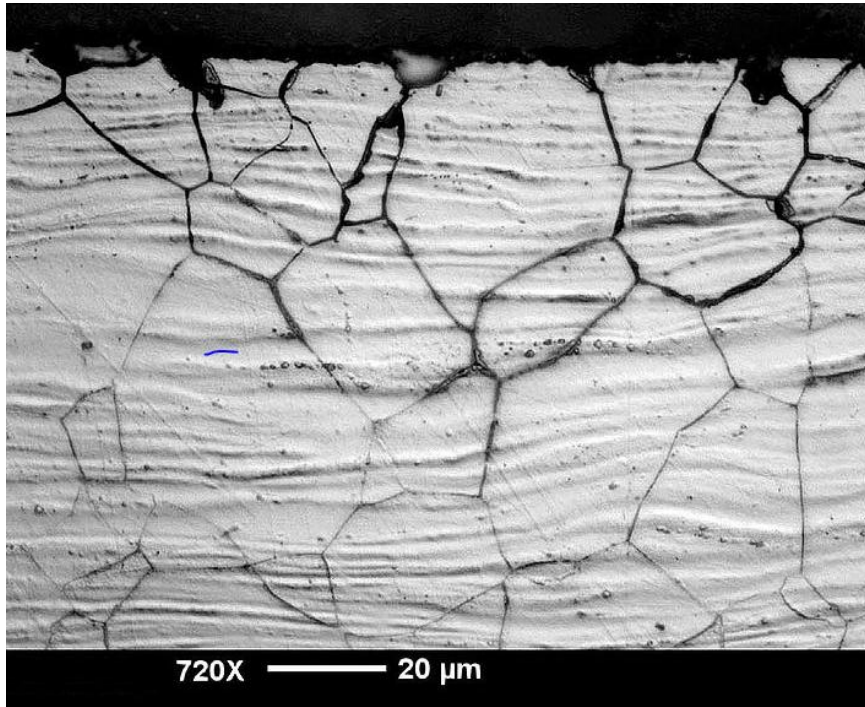
Filiform surface corrosion

3.8   In this case the corrosion presents as random threadlike filaments under the paint often with the paint bulging in blisters raised by the corrosion products. Cracks or damage to the paint allow corrosive moisture ingress and surface localized active corrosion cells. More severe in high humidity, marine and industrially polluted environments.

---

[1]   https://commons.wikimedia.org/wiki/File:Intergranular_corrosion.JPG

Photograph 5. Filiform corrosion example[2]

Photograph 6. Filiform corrosion spreading from scribe on painted aluminium after complete accelerated corrosion testing[3]
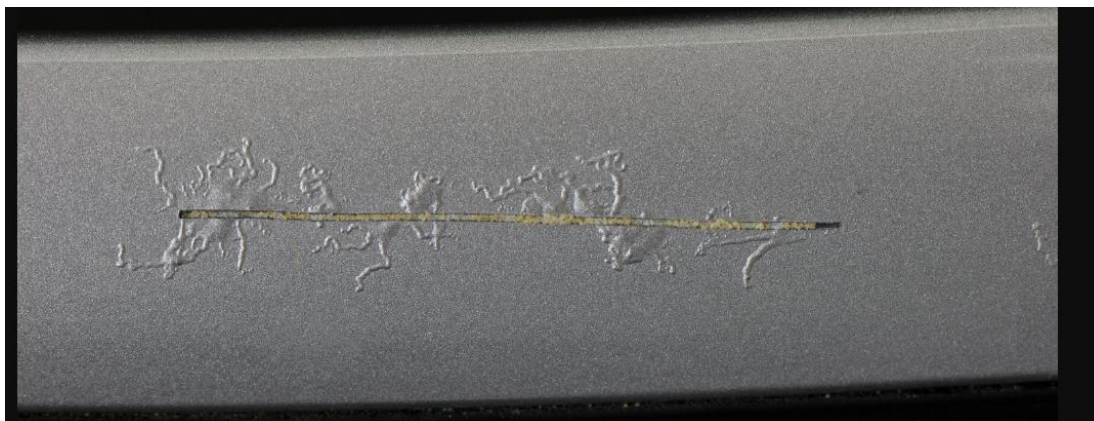
Pitting or General Surface Corrosion

3.9   As the name implies the former involves the creation of localized pits / small holes in the material surface which can be deep and significant to structural integrity whilst the latter corrosion form starts with a more widely dispersed uniform surface etching that dulls the surface and can progress to generate a rougher or frosted surface appearance.

3.10   Corrosive agents create a local electrolytic cell when the protective surface coating is no longer in a good condition particularly in conjunction with unclean surface conditions that help to harbour moisture / corrosive medium. Pitting traps the electrolyte within the pit and the composition of the electrolyte will change as the corrosion progresses. With the change in electrolyte composition the

---

2   FAA-8083-30 Aviation Maintenance Technical Handbook, Chapter 6 Aircraft Cleaning and Corrosion Control (2008)

3   https://commons.wikimedia.org/wiki/File:Filiform_corrosion_on_painted_aluminum.jpg

corrosion can accelerate and/or change form to stress corrosion cracking or corrosion fatigue.

Photograph 7. GA aircraft empennage structure – surface and pitting corrosion of tailplane internal rib section found after accident damaged parts were removed for component replacement.

Photograph 8. Pitting seen on vintage aircraft engine crankshaft[4]

Stress Corrosion Cracking

3.11   Presents generally as cracking only, (usually fast crack growth), especially in higher strength alloy materials with negligible corrosion product. This phenomenon arises due to a combination of high tensile stresses, (standing

---

[4]   Photo credit – Malcolm McBride LAA

and/or alternating stress usually approaching the tensile yield strength of the material), together with a corrosive environment. Such stresses can arise due to locked-in stresses resulting from some aspects of material heat treatment, incorrect fits and tolerances on mating parts or inappropriate assembly practices. Rapid crack growth can lead to sudden and complete failure of structural parts. (Reference photographs 17 and 18 at chapter 8, section 8.21).

Fretting

3.12   Fatigue failures often result from movement or fretting at structural bolted joints. Fretting is revealed by black or greyish brown powder or paste around the periphery of the faying surfaces, (observed as for example in the case of so called "smoking rivets"), and may result in the formation of cracks at the outer edge of the fretted area; these cracks may develop across the component and will not necessarily pass through the bolt hole. Dismantling of suspect parts is usually necessary and an inspection by penetrant dye, magnifying lens, eddy current or ultrasonic (surface wave) methods should be carried out.

Photograph 9. Upper half / third of photo shows fretting and galling damage (brownish areas) on the material surface of a bolt that has helped initiate a fatigue failure, (failure surface across bolt x-section seen in the lower portion of photo with evidence of fatigue striations).

Exfoliation

3.13   Unprotected machined edges or damaged edges of structural member's present exposed grain ends that can allow corrosion to proceed into the material along planes in the material parallel the grain surfaces and to the original material surfaces. The expanding corrosion product separates the surrounding layers of base material into characteristic layers or leaves as corrosion proceeds.

Photographs 10 and 11. Boeing 757 lower flap angle – found in sealed–up structure after inspector found bulging along the lower skin rivet line and then opened up the structure for further inspection to reveal extensive exfoliation corrosion, and necessitating component replacement.
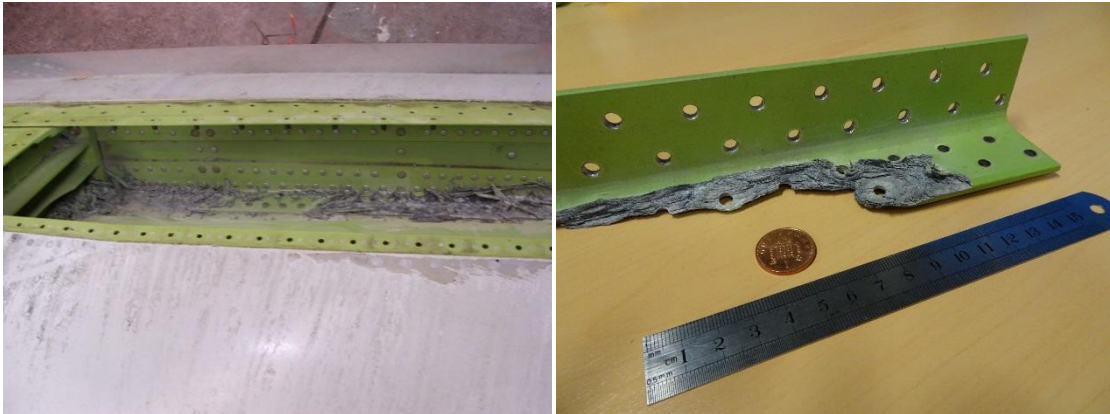
Photograph 12. A further example of exfoliation corrosion as found on a Fuji FA-200 left wing main spar lower U extrusion ~3 feet from the wing root. The corrosion was found when the fuel tank was removed. The Service Bulletin issued by the TC holder was subsequently AD'd by the JCAB in Japan.

Crevice (Concentration Cell) Corrosion

3.14   Characterised by severe localized corrosion at narrow gaps between assemblies of faying metal components where corrosive agent has penetrated in to the joint region - joint flexing can often assist the process of penetration of the joint area. Appropriate faying surface shims and / or sealants properly applied can help to prevent. Apply a surplus of jointing compound into the joint region, and after assembly wipe off the exuded surplus leaving a bead of jointing compound around edges of assemblies as further edge protection.

Note: Do not use Duralac in contact with Perspex, as an adverse chemical reaction causes premature crazing of the Perspex surface that can lead to more extensive cracking.

Micro-Biological

3.15   Mainly experienced in integral aluminium fuel tanks and pipes where the fuel is in direct contact with the surrounding structure in the presence of entrapped water. Water can be inadvertently introduced as a contaminant in the fuel storage and delivery process but can also arise from absorption of and condensation from moist air into the aircraft fuel, with fresh air being drawn into the tanks each time as the fuel is used, with temperature changes also helping to drive the process. This form or corrosion is more prone to occurring with kerosene /diesel fuel systems when fungi or microbes are allowed to grow on the fuel to entrained water boundary (petrol/gasoline fuel systems tend to be less susceptible). Micro - biological corrosion tends to develop particularly in entrapped or relatively undisturbed areas of the aircraft fuel system, particularly during extended periods of aircraft storage, and can progress with and without the presence of air. Products of organism digestion attack can breach the surface protection layer exposing the underlying metal to further electrolytic attack which is promoted by the organism.

3.16   Generally the corrosion observed is either general surface corrosion or pitting. Regular use and flushing of fuel systems, using fuel drains regularly to remove collected water, and the use of approved fuel additives containing biocides can act as effective preventative measures. Note that in addition to the corrosion risks there is the significant potential for blockage of fuel system filters and components, and in more severe cases the microbial growth can cause fuel instrumentation / indication system failures, engine power loss or total propulsion system failure. Operation of the gascolator fuel/water drains after selection of each fuel tank will have a dual purpose of not only enabling any water to be drained, but will confirm that full fuel flow, is visible and available, from each tank selected at the gascolator before flight.

Photograph 13 - Gascolator installation – mounted at lowest point possible on fuel system to act as fuel drain for water and small particles of sediment.
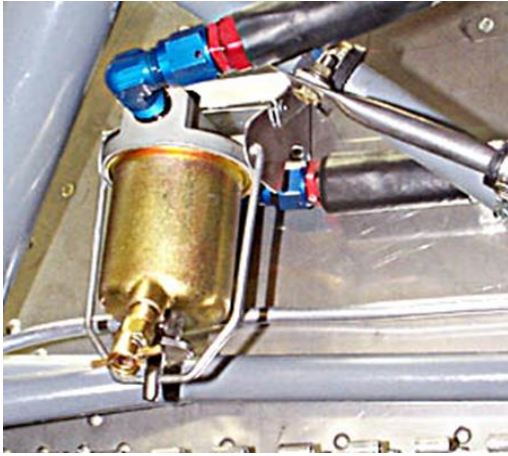
Chapter 4
Causes of corrosion

The following text that comprises Chapter 4 has been extracted from the US Department of Transportation, Federal Aviation Administration (FAA), Flight Standards Service FAA-8083-30 Aviation Maintenance Technical Handbook, Chapter 6 Aircraft Cleaning and Corrosion Control (2008) - the FAA text has not been revised save for spelling changes to UK English:

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

Climate

4.2   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

4.3   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.

4.4   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, (more information on cleaning is contained under Chapter 9).

Chapter 5
Environment

5.1   Low temperature corrosive attack on an aircraft structure will not occur without the presence of water in some form in contact with an exposed metallic surface as corrosion requires the presence of an electrolyte to conduct electrons and positive ions for it to occur. However, a fact less well appreciated is that, in a wide variety of ambient conditions, condensation will form on various parts of the structure and inside structure members i.e. tube assemblies, both welded and bolted and this moisture is one of the main causes of corrosion. This type of corrosion may exhibit no external evidence of the internal deterioration presenting particular inspection and detection challenges.

5.2   By the nature of their operation, aircraft are exposed to frequent changes of atmospheric temperature and pressure and to varying conditions of relative humidity; therefore, all parts of the structure , even those considered as "closed" or "sealed" can be subject over time to the progressive ingress of moist air leading to condensation. The resultant water takes into solution a number of corrosive agents from the atmosphere or from spillages (which convert the water into a weak acid) and which will corrode most metal surfaces where the protective treatment has been damaged or is inadequate. Cases of serious corrosion have been found in both closed and exposed parts of structures of aircraft operated under a wide variety of conditions.

Chapter 6
Spillage

6.1   Spillage or system leaks of extraneous fluids which may penetrate the structure during maintenance, repair or operation of the aircraft, should be carefully traced and thoroughly cleaned out. Where required, any protective treatment should be restored. Fluids such as ester-based engine oils, Hydraulic oils, coolant fluid, glycol defrosting fluids, etc., will damage most protective treatments not intended to be in contact with them. Accidental spillage of refreshments such as mineral waters, coffee, etc., can have a particularly deleterious effect on floor structures.

6.2   Battery compartments should be examined for any signs of acid corrosion. Compartment vents should be clean and undamaged and the anti-sulphuric protective treatment should be carefully maintained. Special attention should be given to the structure in the immediate vicinity of the battery for any signs of corrosion caused by acid spillage or a damaged battery. It should be noted that heavy concentrations of battery fumes, resulting from faulty compartment venting or a runaway battery, may also lead to corrosion in the surrounding structure, (see BCAR S 1353(c) and CS-VLA 1353 (e) regarding suitable design precautions).

Note: If there is any indication of corrosion, the parts affected should be cleaned with a solution of water and washing soda, then rinsed with fresh water and dried out. After 24 hours a re-check should be made to further test all joints suspected of contact with spillage of acid with litmus paper, this area may be treated with alkaline, baking powder, checked for signs of corrosion and, if satisfactory, the protective treatment should then be restored.

6.3   The spillage of mercury in an aircraft can have devastating effects on any aluminium alloy skin or structure with which it comes into contact, (the mercury creates an amalgam with any exposed aluminium, removing the normal protective aluminium oxide layer and commences a cycle of rapid chemical degradation which can result in a write-off for the structure). Thus carriage of mercury or items containing mercury by aircraft should generally be avoided or handled with appropriate "dangerous goods" precautions for packaging, handling etc., in order to minimize the probability of a spill.

Chapter 7
Exhaust gasses

7.1   Structural parts which are exposed to exhaust gases are prone to corrosion due
         to the sulphur content of exhaust gases and jet efflux. Although this problem can
         be reduced by regular and thorough cleaning, particular attention should be
         given to the condition of the protective treatment of these structures.

Photograph 14. Auxiliary Power Unit (APU) exhaust as well as engine exhaust areas need
particular protection and regular inspection.

Chapter 8
Corrosion prevention

8.1   The manufacturer's publications may give general guidance on the inspection of those parts of the structure which are most likely to be attacked by corrosion. Nevertheless, it should be noted that, in the light of operational experience, other parts of the structure may require special attention. Engineers and Inspectors should be on the alert for any signs of corrosion in parts of the structure not specifically mentioned in the manufacturer's publications or instructions. Amateur builders/designers may not always be fully aware of the BCAR Section S609, 611 and EASA CS VLA 609, 611, 627 design requirements, and therefore those organizations charged with Inspecting and approving those designs as suitable for the issue of a Permit to Fly should check to ensure compliance with those requirements particularly with respect to Primary Structure items. Where direct compliance with the design requirements cannot be shown an Alternative Means of Compliance which has a comparable level of safety should be established.

8.2   GRP bonding to painted surfaces should be avoided as the painted surface may be adversely affected during the subsequent GRP resin cure with the resultant bond strength restricted to that provided by the impaired painted surface.

8.3   Where primary structural items are bonded (for example metallic fittings attached to Glass Reinforced Polymer (GRP) structural assemblies), it is essential that precautions are taken to ensure all surfaces within bonded areas comply with suitable and compatible corrosion protection procedures.

8.4   In 'blind' or boxed-in structures where accessibility is difficult and where cleaning and maintenance are awkward, swarf, dirt and dust tend to collect and lodge in various parts. This material can act as a 'wick' resulting in capillary action for moisture which, in the course of time, will work through any inadequate protective treatment and penetrate to the metal to act as an electrolyte. Even on new aircraft the problem is still present in some boxed-in or intricate structures.

Note: Protective treatments with a rough surface finish, such as primer paints, tend to hold dust and dirt and cleaning is rendered more difficult because of this tendency of swarf, dust and dirt to adhere to such surfaces. Dust allows a Wick effect to collect condensate, which is why steel tubes corrode on the top surfaces first. Hard gloss finishes, such as epoxy resin paints, will provide a more effective and lasting protection. Water based paints by their very nature are less tolerant of joint sealant and oils and grease on surfaces, and they may also not be compatible with previous coats of paint on the structure such as acid etch primer or cellulose-based primers. In addition water based paints tend to have lower joint penetration capability due to water surface tension. Therefore it is preferred

that after structural assembly that further corrosion protection is provided by acid etch and cellulose based paints, this will allow joint penetration by capillary action of that corrosion preventive and will therefore be more effective.

8.5   Completely boxed-in structures should be adequately vented to prevent stagnation of the internal air. It is important to ensure that vents and drain holes are clear, are of the correct size and are unobstructed by ice in freezing conditions on the ground, nor obstructed by any dirt or debris, excess paint or protective compounds. Designs should aim if possible, to provide positive ventilation to reduce condensation.

8.6   Honeycomb structures, especially those in components of small cross-sectional area (e.g. wing flaps, rudders, ailerons and spoilers), are often prone to the collection of water if careful attention has not been given to the sealing around attachment screw holes and at skin joints to prevent the ingress of moisture. Water can also accumulate from condensation of moist air when drawn into the structure by changes in operating altitude and pressure, when sealing of the structure has not been initially achieved or as a result of deterioration of that sealing, Cases are known where the trapped water in the structure has frozen and caused distortion of the outer skin of the component due to internal expansion – both this expansion and internal corrosion can lead to separation of the skin from the internal honeycomb which means that the sandwich panel loses structural stiffness and structural integrity can be lost leading to component failure. In addition it should be noted that water trapped inside trailing edges can affect the balance of control surfaces that could potentially lead to control flutter, surface failure and loss of control. Similarly it should be noted that GRP covered foam core structures and control surfaces can also be susceptible to water ingress particularly when the surface protection is damaged or degraded and when aircraft are stored outside.

8.7   Fuselage keel areas, structures concealed by upholstery and the double skin of baggage or freight bay floors, are typical areas liable to corrosion. Special attention should be given to all faying surfaces in these areas where layers of material are nested together in a joint and particularly the faying surfaces of bulkheads and stringers to skin panels and skin lap joints. In general, visual inspection supplemented by radiological methods of examination is a satisfactory way of detecting corrosion, provided it is expertly carried out and proper correlation between the findings of each method is maintained. In some instances, however, normal methods of visual inspection supplemented by radiological examination have not proved satisfactory and dismantling of parts of the structure may be required to verify the condition of the faying surfaces.

8.8   Structures manufactured from light gauge materials which are spot-welded together, such as the faying surfaces of stringers mentioned in the previous paragraph, are liable to serious and rapid corrosion as this method of attachment

precludes the normal anti-corrosive treatments (e.g. jointing compound) at the joined surfaces. Cases of serious corrosion have also been found in similar structures riveted together where the jointing compound has been found to be inadequate or non-existent. It is recommended that all mechanically fastened joints should be assembled with a surplus of approved jointing compound, and after compression of the joint upon assembly any surplus jointing compound is then wiped away, to leave a small bead of jointing compound around the joint, this will have an added protection for any Alclad sheet exposed alloy material edges on items forming the structure. The application of acid etch paint by spraying after assembly is recommended; this paint penetrates by capillary action into joint gaps, filling voids and protecting any untreated edges. Acid etch primer will also provide a strong key to secure further paint coatings.

8.9   In some instances, where stringers are of top-hat section and are bonded to the panel by a thermosetting adhesive, corrosion has been known to affect the stringers, the panel and the bonding medium; such stringers are often sealed at their ends to prevent the ingress of moisture. Unfortunately moisture can be drawn and trapped inside these components This can trap water inside the stringer and corrosion can develop should any breach of protection occur, Where adhesive is used to attach a doubler to a skin, corrosion can occur between the surfaces and will eventually be indicated by a quilted appearance. It is preferable for designers to use L or Z section stringers for structural support which do not have internal cavities

8.10   Where light alloy is spot-welded and for other assemblies that cannot be assembled with a jointing compound such as Duralac or JC5, to consider the use of a water dispersant such as ACF 50 on the completed structure.

8.11   Avoid over over-painting joints with only top coat paint, especially when the joint corrosion protection is not entirely suitable. Over-coating with poorly adhered top coating paint may allow water to penetrate by capillary action under that top coat paint and result in more severe joint corrosion forming under and concealed by that paint in service.

8.12   A basic level of corrosion protection is inherent on aluminium alloy parts by surface oxidation. This may be significantly enhanced by surface conversion i.e. anodising. Further protection may be achieved by application of acid etch or chromate primer and paint. Application of Alocrom 1200 process protection by brush, swab, spay or dip methodology is also worth noting as an easier alternative to anodizing. Any degradation of any one of these layers of protection, when cutting or machining during construction, repair or modification, needs to be reinstated in an appropriate manner. If this cannot be achieved for example at fastener holes, suitable protection for prevention of water contact at those areas without surface corrosion protection may be achieved by using an approved jointing compound, also called "wet assembly". This will reduce water

penetration which would otherwise allow corrosion between dissimilar metals used in that assembly due to the formation of galvanic cells inside that joint.

8.13   Alloy steels may be protected by cadmium or zinc plating – disruption of these layers during assembly or manufacture should also be similarly repaired with joints protected from water ingress. Note that cadmium plating of high strength steels and subsequent hydrogen de-embrittlement processes need to be tightly controlled by an approved heat treatment supplier in order to prevent premature internal component failures due to hydrogen embrittlement.

8.14   Alclad alloy sheet or plate material as previously noted is manufactured with a very thin layer of almost pure aluminium for surface corrosion protection on each face which can be damaged by careless storage, handling, scribing etc.,. Additional protection can be afforded by suitable painting to provide a barrier to guard against condensation and moisture ingress etc., in service. Care should be taken prior to or during assembly to paint and protect the sheet/plate material edges where the core load bearing alloy material would otherwise be exposed. Internal wing and fuselage tailplane skin and frame surfaces that are not generally accessible in service should be painted to prevent corrosion salt spots forming at dust accumulations in service.

8.15   Care is needed in anodizing high strength alloys as this can lead to reduced fatigue characteristics. Anodising is more often used on machined parts rather than Alclad sheet. Welded steel tube assemblies ideally should be internally treated with lanolin or similar materials and then sealed off to prevent corrosion. Unprotected welded steel tube assemblies may corrode internally and display no external evidence of corrosion and thus may require X/Ray inspections to validate. Many aircraft, in particular of foreign construction, do not receive such internal surface protective treatments, so need careful frequent inspection during the aircraft life. Corrosion progresses even during storage, as well as during active operation.

8.16   Protection against crevice corrosion can be afforded by ensuring that joints are assembled using a suitable jointing compound, avoiding voids in the assembly to prevent water ingress caused by the capillary action. Crevice corrosion arises due to the increased concentration of the electrolyte within a crevice due to repeated wetting and evaporation. This may result in oxygen concentration cells concealed within the joint faying surfaces.

Photographs 15 and 16 - Example of Harvard spar corrosion - ref., MPD 2013-004 intergranular/ exfoliation corrosion of upper and lower main spar caps. Initially the only indication that a problem existed was when the owner noticed two rivet heads had popped from the external skin, further investigation revealed a slight bulge of the skin - an internal inspection initially showed no indication of corrosion, and it was only when the capping was removed that the full extent of the corrosion was revealed. No evidence is apparent of any joint sealant used in the initial assembly. [5]

8.17   Galvanic corrosion should be avoided by ensuring that dissimilar metal contact is avoided by suitable material selection, use of material coatings, sealants or interfay compounds. Examples of pairings particularly prone to galvanic action are aluminium & carbon (aluminium corrodes), aluminium and copper alloys (again the aluminium corrodes), alloy steel and aluminium (steel corrodes) in this case an interfay medium, such as glass fibre scrim, can be used as an interfaying medium. FAA AC 43.13-1B Chapter 6 "Corrosion Inspection and Protection" contains further advice on this.

8.18   Powder Coating requires suitable surface preparation such as surface conversion i.e. anodising prior to powder paint application. Powder coating by its nature can conceal fractures and once damage to the coating has occurred can allow the propagation of filiform corrosion under the surface coating. Note that BCAR S627 does not allow flexible paints or coatings as this can hide fatigue cracking and therefore designs incorporating flexible coatings on Primary Structure items should generally not be accepted.

8.19   Heat treatment used during powder paint curing may also have a detrimental effect on some materials, and can cause distortion on thin wall steel tubes. Sealed lift struts by their very nature of being sealed are in particular susceptible to distortion during the subsequent temperature attained during the heat treatment required to cure powder coated paint.

---

[5] Photo credit – Dick Davison

8.20   Any structural aluminium alloy should be protected against corrosion prior to bonding into fibre-glass resin structure and must be suitably protected against water penetration of the joints in service. Protection can be by surface conversion process e.g. anodizing or Alocrom processes, however there is a risk that the painted finish could be compromised during the resin curing action, unless an epoxy paint is used that is compatible with the epoxy used for the laminate. Aluminium alloy 'Alclad' items that have sheared and machined surfaces should be protected by anodising or by an compatible epoxy-based paint prior to resin bonding, to prevent joint penetration and subsequent corrosion of the bonded joint at unprotected surfaces.

Photograph 15. Badly Corroded Lift Strut. Poor surface protection using external surfaces top coat paint and joint sealant only, with no component corrosion protection provided inside the strut.[6]

---

[6] Photo credit – Dick Davison

Photograph 16. Badly Corroded Bracket which was not Protected Prior to Bonding into a GRP Structure – Water Ingress Promoted Corrosion of The Bracket and separation caused by corrosion products[7]

8.21   Construction and assembly should avoid the introduction of stress riser practices that induce significant stress concentrations e.g. the staking of bearings, or high interference fit tolerances which introduce stress during assembly (and may also remove all corrosion protection). Similarly fouling of adjacent structures, or bolt holes with smaller radii than the bolt head, (where the wedge action of each larger bolt head radius in its respective hole introduces a line of stress in the assembly) should be avoided - the latter has caused in service fractures to progress along a line of bolts resulting eventually in spar failure.

Photograph 17 and 18. Staked bearing – note staking indentations adjacent to bearing - this promoted a stress corrosion failure of the lug. (Note that BCAR Section S, S 627 "Fatigue Strength" seeks that points of stress concentration be avoided as far as practicable)[8]

---
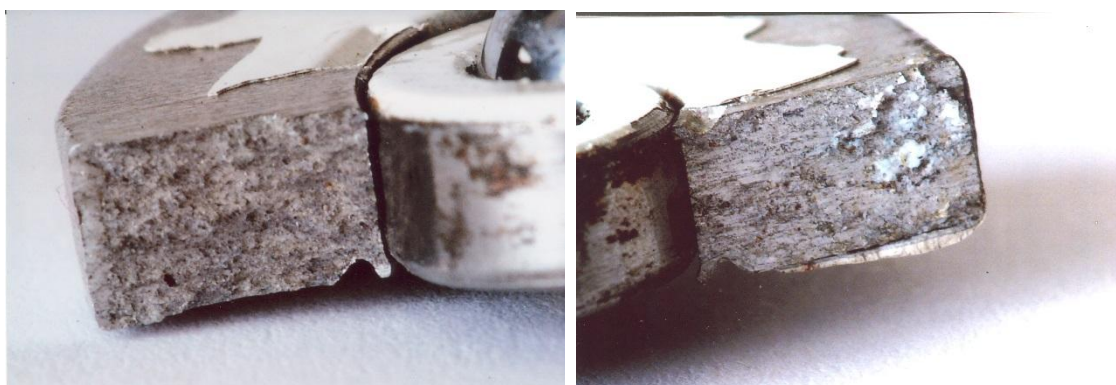
[7] Photo credit - Malcolm McBride LAA

[8] Photo credit – UK AAIB

Chapter 9
In-service aspects

Aircraft Cleaning

9.1   In order to minimize the likelihood of corrosion occurring it is important that aircraft should be thoroughly cleaned periodically to remove damaging contaminants and restore a moisture-resistant finish. Reference should be made to CAP 562 Leaflet 12–10 "Cleanliness of Aircraft". It is important that all cleaning mediums should not have any adverse effect on the structural items being cleaned, for example avoid using aviation fuel on rubber and on Lexan windscreens, and avoidance of thinners etc., (however white spirit is benign to most rubber and structural items, and leaves a dry surface upon evaporation).

9.2   Care should be taken not to damage protective treatments when using scrubbing brushes or scrapers. Significant scribe damages can be introduced by the use of inappropriately hard scrapers and one should the avoid use of wire brushes or metal scrubbers to prevent surface contamination with dissimilar metals, and any cleaning fluids used should have been approved by the aircraft manufacturer. Damage to surface cladding of Alclad materials and deeper scribe damages can promote both fatigue and corrosion failures subsequently. For final cleaning of a boxed-in type of structure an efficient vacuum cleaner, provided with rubber-protected adaptors to prevent surface damage, should be used. However electrical vacuum cleaners which could provide an ignition source should be avoided where any inflammable fluids may be present. The use of air jets should also be avoided as this may lead to dirt, the products of corrosion, or loose articles, being blown from one part of the structure to another.

The sections 9.3 to 9.47 inclusive that follow are reproduced from the US Department of Transportation, Federal Aviation Administration (FAA), Flight Standards Service FAA-8083-30 Aviation Maintenance Technical Handbook, Chapter 6 Aircraft Cleaning and Corrosion Control (2008) with spelling changes to UK English.

References within the text are specific to the FAA text and are retained to maintain the integrity of the text. The references should not be regarded as mandatory in the UK.

9.3   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.

9.4   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.

9.5   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 non-flammable, 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

9.6   There are three methods of cleaning the aircraft exterior: wet wash, dry wash, and 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.

9.7   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.

9.8   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.

9.9   Polishing restores the lustre 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.

9.10   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.

9.11   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.

9.12   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.

9.13   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 de-icer 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.

9.14   These polishes can minimize small surface scratches and will also help keep static charges from building up on the surface of the windows.

9.15   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

9.16   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.

9.17   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.

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

9.19   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 build-up of flammable vapour/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."

9.20   Wherever possible, use non-flammable agents in these operations to reduce to the minimum the fire and explosion hazards.

Types of Cleaning Operations

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

- Aircraft passenger cabin areas (seats, carpets, side panels, headliners, overhead racks, curtains, ash trays, windows, doors, decorative panels of plastic, wood or similar materials).

- 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).

- 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).

Non-flammable Aircraft Cabin Cleaning Agents and Solvents

9.22   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 colourfast and non-shrinkable. 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 aluminium 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.

9.23   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.

9.24   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.

9.25   Deodorizing or disinfecting agents. A number of proprietary agents useful for aircraft cabin de-odorizing or disinfecting are non-flammable. Most of these are designed for spray application (aerosol type) and have a non-flammable pressurizing agent, but it is best to check this carefully as some may contain a flammable compressed gas for pressurization.

9.26   Abrasives. Some proprietary non-flammable mild abrasive materials are available for rejuvenating painted or polished surfaces. They present no fire hazard.

9.27   Dry cleaning agents. Perchlorethylene and trichloroethylene as used at ambient temperatures are examples of non-flammable 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

9.28   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.

9.29   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).

9.30   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

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

Fire Prevention Precautions

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

- Aircraft cabins should be provided with ventilation sufficient at all times to prevent the accumulation of flammable vapours. 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 vapours above 25 percent of the lower flammability limit of the particular vapour being used, measured at a point 5 feet from the location of use, shall result in emergency revisions of operations in progress.

- All open flame and spark producing equipment or devices that might be brought within the vapour hazard area should be shut down and not operated during the period when flammable vapours may exist.

- 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.

- 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.

- 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

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

- 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.

- 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 aluminium 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.

- 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

9.34   Cleaning the power plant 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.

9.35   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.

9.36   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.

9.37   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 aluminium alloy blades. Steel blades, if rubbed down with oil after each flight, retain a smooth surface for a long time.

9.38   Examine the propellers regularly because cracks in steel or aluminium 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.

9.39   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.

9.40   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, bell-cranks, and moving parts should be lubricated according to instructions in the applicable maintenance manual.

Solvent Cleaners

9.41   In general, solvent cleaners used in aircraft cleaning should have a flashpoint of not less than 105 °F / 41 °C if explosion proofing of equipment and other special precautions are to be avoided. Chlorinated solvents of all types meet the non-flammable 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.

9.42   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.

9.43   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 (41 °C) 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 (21 °C) 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 non-flammable 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, (-4 °C). 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

9.44   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 non-phenolic 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 a round rubber, plastics, or other non-metallic materials. Wear rubber gloves and goggles for protection when working with phenolic base cleaners.

Soaps and Detergent Cleaners

9.45   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. Non-glare (flat) finishes should not be cleaned more than necessary and should never be scrubbed with stiff brushes.

- Non-ionic 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

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

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

- Three grades of aluminium wool, coarse, medium, and fine, are used for general cleaning of aluminium surfaces. Impregnated nylon webbing material is preferred over aluminium wool for the removal of corrosion products and stubborn paint films and for the scuffing of existing paint finishes prior to touch-up. 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 needle like 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. Aluminium 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 aluminium 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 aluminium or magnesium can cause serious corrosion of the metal by imbedded iron oxide.

Chemical Cleaners

9.47　　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 aluminium 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.

Chapter 10
Inspection for corrosion

10.1   The structure should be maintained in a clean condition and a careful check should be made for any signs of dust, dirt or any extraneous matter, especially in the more remote or 'blind' parts of the structure. Loose articles such as rivets, swarf, metal particles, etc., trapped during manufacture or repair, may be found after the aircraft has been in operation for some considerable time such loose items can damage the protective surface coatings promote galvanic corrosion and help harbour moisture. It is important to examine any loose articles that may be found during inspections to ensure that they did not result from damaged structure. It is generally easy to determine if a loose article has formed part of the structure by its condition, e.g. an unformed rivet could be considered as a loose article, but a rivet which had been formed would be indicative of a failure.

10.2   The structure should be examined for any signs of distortion or movement between its different parts at their attachment points, for loose or sheared fasteners (which may sometimes remain in position) and for signs of rubbing or wear in the vicinity of moving parts, flexible pipes, etc. In addition to inspection and NDT methods, damage is often revealed through applying hand pressures to structures and seeing how they flex, i.e. a fitting may come loose or skins may flex where there something internal has broken. The broken bracket on a tail plane attachment was revealed by an unexpected amount of free play felt at the tail plane tip. Also listen out for suspicious creaks and clicks when flexing the structure.

10.3   The protective treatment should be examined for condition. On light alloys a check should be made for any traces of corrosion, marked by Exfoliation, Surface Pitting, or Filiform, (a worm like structure under paint finish) or a scaly, blistered or cracked appearance. If any of these conditions is apparent the protective treatment in the area concerned should be carefully removed and the bare metal examined for any traces of corrosion or cracks. If the metal is found satisfactory, the protective treatment should be restored.

Note: To assist in the protection of structures against corrosion some manufacturers may attach calcium chromate and/or strontium chromate sachets to the vulnerable parts of the structure. The presence of chromate in the sachets can be checked by feel during inspection. After handling these materials, the special precautions, e.g. hand washing, given in the manufacturer's manual, should be followed.

10.4   In most cases where corrosion is detected in its early stages, corrective treatment will permit the continued use of the part concerned. However, where

the strength of the part may have been reduced beyond the design value, repair or replacement may be necessary. Where doubt exists regarding the permissible extent of corrosion deterioration the manufacturer or design approving authority should be consulted, in particular Intergranular Corrosion can be extremely difficult to assess with conventional NDT testing and replacement of affected components may be the only option.

10.5 The edges of faying surfaces should receive special attention; careful probing of the joint edge with a pointed instrument may reveal the products of corrosion which are concealed by paint. In an Alclad structure corrosion usually starts from unprotected edges or in fastener holes or in folds in the material. In some instances slight undulations or bumps between the rivets or spot welds, or quilting in areas of double skins of wing ribs or fuselage frames due to pressure from the products of corrosion, will indicate an advanced state of deterioration. In some cases this condition can be seen by an examination of the external surface, but as previously mentioned in this publication, dismantling of parts of structure to verify the condition of the joints may be required.

Notes: To avoid damage to the structure, the probing of a joint with a pointed instrument should be carried out with discretion by an experienced person. Any damage done to the protective paint coating, however small, should be made good. Where dismantling of parts of the structure is required reference should be made to CAP 562 Leaflet 51-90 "Repair of Metal Airframes" so that appropriate preparations and processes are followed.

Chapter 11
Examination

Visual

11.1   Nearly all the inspection operations on aircraft structures are carried out visually and, because of the complexity of many structures, special visual aids are necessary to enable such inspections to be made. Visual aids vary from the familiar torch and mirror to more complex instruments based on optical principles and, provided the correct instrument is used, it is possible to examine almost any part of the structure.

Note: Airworthiness Requirements normally prescribe that adequate means shall be provided to permit the examination and maintenance of such parts of the aeroplane as require periodic inspection. (E.g. reference BCAR Section S 611 "Inspection", CS-VLA 611 "Accessibility" & CS 23.611 "Accessibility provisions"). Inspection standards can be found in OEM Documents and Aircraft Maintenance Planning Documents.

Light Probes

11.2   It is obvious that good lighting is essential for all visual examinations and special light probes are often used.

- For small boxed-in structures or the interior of hollow parts such as the bores of tubes, special light probes, fitted with miniature lamps, as shown in photograph 19, are needed. Current is supplied to the lamp through the stem of the probe from a battery housed in the handle of the probe. These small probes are made in a large variety of dimensions, from 5 mm (3/16 in) diameter with stem lengths from 50 mm (2 in) upwards.

- Probes are often fitted with a magnifying lens and attachments for fitting an angled mirror. Such accessories as a recovery hook and a recovery magnet may also form part of the equipment.

11.3   For the larger type of structure, but where the design does not permit the use of mains-powered inspection lamps, it is usually necessary to use a more powerful light probe. This type of light probe consists of a lamp (typically an 18 watt, 24 volt type) which is protected by a stiff wire cage and mounted at one end of a semi-flexible tube or stem. On the other end is a handle with a light switch and electrical connections for coupling to a battery supply or mains transformer. As the diameter of the light probe is quite small it can be introduced through suitable apertures to the part of the structure to be inspected.

Photograph 19. Inspection camera with LED light probe

11.4   Inspection Mirrors. Probably the most familiar aid to the inspection of aircraft structures is a small mirror mounted at one end of a rod or stem, the other end forming a handle. Such a mirror should be mounted by means of a universal joint so that it can be positioned at various angles thus enabling a full view to be obtained behind flanges, brackets, etc.

Note: Where spillage or leakage of flammable fluids may have occurred or when inspecting fuel tanks, etc., it is important to ensure that the lighting equipment used is flameproof, e.g. to BSI Standard BS 229.

- A useful refinement of this type of mirror is where the angle can be adjusted by remote means, e.g. control of the mirror angle by a rack and pinion mechanism inside the stem, with the operating knob by the side of the handle, thus permitting a range of angles to be obtained after insertion of the instrument into the structure.

- Mirrors are also made with their own source of light mounted in a shroud on the stem and are designed so as to avoid dazzle. These instruments are often of the magnifying type, the magnification most commonly used being 2X.

11.5   Magnifying Glasses. The magnifying glass is a most useful instrument for removing uncertainty regarding a suspected defect revealed by eye, for example, where there is doubt regarding the presence of a crack or corrosion. Instruments vary in design from the small simple pocket type to the stereoscopic type with a magnification of 20X. For viewing inside structures, a hand instrument with 8X magnification and its own light source is often used.

- Magnification of more than 8X should not be used unless specified. A too powerful magnification will result in concentrated viewing of a particular spot and will not reveal the surrounding area. Magnification of more than 8X may be used, however, to re-examine a suspected defect which has been revealed by a lower magnification.

- When using any form of magnifier it is most important to ensure that the surface to be examined is sufficiently illuminated.

11.6   Endoscopes (Leaflet F-90 of CAP 562 CAAIPS). An endoscope (also known as an introscope, borescope or fibrescope, depending on the type and the manufacturer) is an optical instrument used for the inspection of the interior of structure or components. Turbine engines, in particular, are often designed with plugs at suitable locations in the casings, which can be removed to permit insertion of an endoscope and examination of the interior parts of the engine. In addition, some endoscopes are so designed that photographs can be taken of the area under inspection, by attaching a camera to the eyepiece; this is useful for comparison and record purposes.

- One type of endoscope comprises an optical system in the form of lenses and prisms, fitted in a rigid metal tube. At one end of the tube is an eyepiece, usually with a focal adjustment and at the other end is the objective head containing a lamp and a prism. Depending on the design and purpose of the instrument a variety of objective heads can be used to permit viewing in different directions. The electrical supply for the lamp is connected near the eyepiece and is normally supplied from a battery or mains transformer.

- These instruments are available in a variety of diameters from approximately 6 mm (¼in) and are often made in sections which can be joined to make any length required. Right-angled instruments based on the periscope principle are also available for use where the observer cannot be in direct line with the part to be examined.

- A second type of endoscope uses 'cold light', that is, light provided by a remote light source box and transmitted through a flexible fibre light guide cable to the eyepiece and thence through a fibre bundle surrounding the optical system to the objective head. This type provides bright illumination to the inspection area, without the danger of heat or electrical sparking and is particularly useful in sensitive or hazardous areas.

- A third type of endoscope uses a flexible fibre optical system, thus enabling inspection of areas which are not in line with the access point.

Non-Destructive

11.7   In cases where examination by visual means is not practicable or has left some uncertainty regarding a suspect part, the use of one of the methods of non-destructive examination will normally determine the condition of the part. All NDT must be undertaken by appropriately qualified and competent personnel that is personnel qualified and authorized in accordance with EN4179.

11.8   A brief outline of the methods of non-destructive examination most commonly used on aircraft structures is given in the following paragraphs. For further information on these and other methods reference should be made to the Part 4 Chapter F series of Leaflets within CAP 562. The selection of the method to be used will depend largely on the design of the structure, its accessibility and the nature of the suspected defect.

11.9   Penetrant Dye Processes (Leaflet F-20 and F-40). These processes are used mainly for checking areas for those defects which break the surface of the material, which may be too small for visual detection by 2X magnification and where checking at higher magnifications would be impractical. Basically, the process consists of applying a red penetrant dye to the bare surface under test, removing after a predetermined time any excess dye and then applying a developer fluid containing a white absorbent. Any dye which has penetrated into a defect (e.g. crack) is drawn to the surface by capillary action into the developer and the resultant stain will indicate the presence and position of the defect.

Notes: Penetrant dye processes of inspection for the detection of surface defects require no elaborate equipment or specialised personnel. It is emphasised that the cleanliness of the surface to be tested is of prime importance if this process is to reveal small cracks. Colour contrast penetrant inspection is often used as a support to visual inspection.

Colour contrast dye penetration must not be used on components where fluorescence penetrant is to be used later as the dyes are incompatible, the former masking the latter.

Colour contrast dye penetrants are banned by Boeing, Airbus, Bombardier, RR, GE and many more TCHs.

11.10   The dye manufacturer's detailed instructions regarding the applications of the process should be carefully followed. The most suitable processes for testing parts of aircraft structures 'in situ' are those which employ water-washable dye penetrants, with the penetrant and developer contained in aerosol packs.

11.11   The characteristics of the red marks, such as the rapidity with which they develop and their final size and shape, provide an indication as to the nature of the defect revealed.

11.12   After test, the developers should be removed by the method prescribed by the process manufacturer and the protective treatment should be restored.

Note: A similar process to the Penetrant Dye Process is the Fluorescent Penetrant Process. However, this process is less adaptable for testing aircraft parts 'in situ' because portable 'black light' lamps are used to view the parts and dark room conditions are generally required.

11.13   Radiographic Examination (Leaflet F-60). The use of radiography will often facilitate the examination of aircraft structures and it is used for the detection of defects in areas which cannot be examined by other means because of inaccessibility or the type of defect.

11.14   Radiography can be a valuable aid to visual inspection and the examination of certain parts of an aircraft structure by an X-ray process will often result in a more comprehensive inspection than would otherwise be possible. However, radiographic methods can be both unsatisfactory and uneconomical unless great care is taken in the selection of suitable subjects. In this respect the opinion of the aircraft manufacturer should be sought.

11.15   During routine inspections, the use of radiography based on reliable techniques of examination can result in more efficient and rapid detection of defects. In some instances, defects such as cracking, loosening of rivets, distortion of parts and serious corrosion of the pitting type can be detected by this method. It should be borne in mind, however, that a negative result given by a general NDT method such as radiography is no guarantee that the part is free from all defects.

11.16   Where radiography is used for the detection of surface corrosion it is recommended that selected areas should be radiographed at suitable intervals, each time simulating the original radiographic conditions, so that the presence of corrosion will become apparent by a local change in the density of succeeding radiographs.

11.17   The accurate interpretation of the radiographs is a matter which requires considerable skill and experience if the maximum benefits are to be obtained. It is essential that the persons responsible for preparing the technique and viewing the results have an intimate knowledge of the structure.

Note: Close contact should be maintained with the aircraft manufacturer who will be aware of problem areas on an aircraft and be able to advice on particular inspection techniques.

11.18   Ultrasonic Examination (Leaflet F-50). In some instances ultra-sonic examination is the only satisfactory method of testing for certain forms of defects. Ultrasonic flaw detectors can be used to check certain aircraft parts 'in situ' and it is sometimes an advantage to use this method to avoid extensive dismantling which would be necessary in order to use some other method. The chief value of

ultrasonic examination in such circumstances is that cracks on surfaces which are not accessible to visual examination should be revealed. Thus solid extrusions, forgings and castings which are backed by skin panels, but which have one suitably exposed smooth surface, can be tested for flaws on their interface surface without breaking down the interface joint. On some aircraft, spar booms and similar extruded members require periodic examination for fatigue cracks, but the areas of suspected weakness may be inaccessible for examination by the penetrant dye method. In such cases radiography may be recommended, but where ultrasonic testing can be used it will give quicker results on those parts which lend themselves to this form of testing and may also be useful to confirm radiographic evidence.

11.19   Eddy Current Examination (Leaflet F-80). Eddy current methods can detect a large number of physical and chemical changes in a conducting material and equipment is designed specifically to perform a particular type of test, e.g. flaw detection, conductivity measurement and thickness measurement.

11.20   The main advantages of this method of inspection are that it does not require extensive preparation of the surface or dismantling of the part to be tested and does not interfere with other work being carried out on an aircraft. In addition, small, portable, battery-operated test sets can be used in comparatively inaccessible parts of the structure.

11.21   Eddy current testing is usually of the comparative type, indications from a reference piece or standard being compared with indications from the part under test. A technique for detecting a particular fault is established after trials have indicated a method which gives consistent results.

11.22   Magnetic Flaw Detection (Leaflet F-70). Magnetic flaw detection methods are seldom used on aircraft structures and are generally restricted to the manufacturing, fabrication and inspection of parts. The method has, however, sometimes been used where other non-destructive testing methods have proved to be unsatisfactory. Before using the method, the effects of magnetisation on adjacent structure, compasses and electronic equipment should be considered and it should be ensured that the magnetic ink or powder can be satisfactorily removed. If this method is used, demagnetisation and a test for remnant magnetism must be carried out to ensure that there will be no interference with the aircraft avionic systems and magnetic compasses.

Chapter 12
Treatment of corrosion

This is a significant topic which is dependent on the materials and configurations concerned – there is a large volume of relevant text in other CAP562 CAAIPS leaflets, (including Leaflets 51-90 and 51-110) and principally under Leaflet 51-140 Paint finishing of metal aircraft. (Note also that engine storage and corrosion issues are also discussed under Leaflet 70-10, and corrosion / ageing issues under Leaflet 70-80). In addition there is further relevant text within the FAA Technician Handbook (and in AC 43-13-1 "Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair" - see Chapter 6 "Corrosion, Inspection and Protection", and also in more depth within the FAA AC 43-4A "Corrosion Control for Aircraft"). Aircraft Structural Repair Manual (SRM) data, when available, can also provide rectification information specific to a particular aircraft type.

12.1   Once detected corrosion should be addressed at the earliest opportunity before deeper and more widespread damage is allowed to develop that would require more invasive and extensive rectification action, possibly requiring dedicated repair and part replacement. Thus prompt treatment and touch-up of damaged painted areas should be seen as high priority.

12.2   Light superficial corrosion can often be removed using mild and gentle abrasive mechanical techniques without significant loss of the parent material prior to surface re-protection with brush Alochrom epoxy primer and painting as appropriate.

The sections that follow on "Chemical Treatments" are reproduced from the US Department of Transportation, Federal Aviation Administration (FAA), Flight Standards Service FAA-8083-30 Aviation Maintenance Technical Handbook, Chapter 6 Aircraft Cleaning and Corrosion Control (2008) with spelling changes to UK English.

Chemical Treatments

Anodizing

12.3   Anodizing is the most common surface treatment of non-clad aluminium alloy surfaces. It is typically done in specialized facilities in accordance with Mil-C-5541E or AMS-C-5541. The aluminium alloy sheet or casting is the positive pole in an electrolytic bath in which chromic acid or other oxidizing agent produces an aluminium oxide film on the metal surface. Aluminium 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.

12.4   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.

12.5   Aluminium wool, nylon webbing impregnated with aluminium oxide abrasive, fine grade nonwoven abrasive pads or fibre bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminium 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 aluminium finishes.

12.6   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

12.7   Alodizing is a simple chemical treatment for all aluminium 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.

12.8   The process consists of pre-cleaning 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 colour 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 aluminium surface slightly acid on drying.

Chemical Surface Treatment and Inhibitors

12.9   As previously described, aluminium 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.

12.10   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

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

12.12   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

12.13   A less active chemical mixture for surface treatment of aluminium 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

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

Chapter 13
Categories and limits of corrosion

13.1   Corrosion of any degree, even slight constitutes damage and as such corrosion damage can be classified into four basic standard categories: 1) negligible damage, 2) damage repairable by local patching, 3) damage reparable by insertion, and 4) damage necessitating replacement of parts.

13.2   It should not be inferred that "negligible" corrosion should be left untreated as generally this indicates the beginning of an electrochemical attack where protective treatments and coatings have been breached and the underlying metallic surface has started to oxidise – once detected and as soon as practicable the area concerned should be cleaned, treated and painted as appropriate to prevent further damage resulting in corrosion damage category 2, 3 or 4 that require more extensive repair or replacement. Generally category 1) damage can be reworked / blended out within allowable limits as defined by the manufacturer.

13.3   The damage of category 2) and 3) should be repaired by reference to approved design information furnished by the aircraft OEM including structural repair manuals and aircraft type / case specific repair data, or by using CS-STAN repair procedures etc., as applicable in order to restore the aircraft to the original airworthiness design standard. Depending on acceptable damage limits and in cases where the full nature and extent of the corrosion cannot be fully established then part replacement may be the only option as per category 4), (note that repair by replacement if undertaken with appropriate parts and in accordance with appropriate maintenance practices would not need to be considered as a design activity).

Photograph 20. Structural repair manuals – provide blend limits and repair data and can be supplemented by specific OEM data, with further information under CS-STAN, AC 43-13-1 as applicable.

Chapter 14
Bibliography

FAA Aviation Maintenance Technician Handbook - Airframe, FAA-H-8083-31 Chapter 06 Aircraft Cleaning & Corrosion Control

FAA AC 43.13-1B Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair Chapter 6 'Corrosion Inspection and Protection'

Flyer Magazine, ACF-50 & Adams Aviation "Guide to Aircraft Corrosion and how to fight it"

FAA AC 43-4A Corrosion Control for Aircraft

Chapter 15
Design references

15.1   Examples of basic design measures related to design against corrosion for GA aircraft:

- BCAR Section S 605, BCAR Section T para T605, EASA CS-VLA 605 - Fabrication methods – production of consistently sound structures to maintain original strength under reasonable service conditions.

- BCAR Section S 609, BCAR Section T para T609, EASA CS-VLA 609 – Protection of Structure – each part of structure must be suitably protected against deterioration or loss of strength in service.

- BCAR Section S S611, Section T T611, EASA CS-VLA 611 – Inspection/Accessibility - means must be provided to allow inspection including principal structural elements, control systems.

- BCAR Section S S627, BCAR Section T T627, EASA VLA-627 - Fatigue strength - avoidance of stress concentrations and high stress points, readily inspectable primary structure in service. Flexible paints or coatings shall not be used.

- BCAR. S1353, BCAR Section T T1353, EASA VLA-1353 – Storage battery design and installation - battery design and installation requirements - no corrosive fluids or gases that may escape are allowed to damage surrounding structures.

Note: EASA CS 22, EASA CS 23, and EASA CS-LSA also include similar and in some cases more demanding and /or supplementary design requirement material to those paragraphs identified above. In addition FAA FAR 23 has identical design requirements to BCAR Section S, EASA CS/VLA and applies to all designs approved in the USA, i.e. Cessna, Piper, Luscombe and US design/manufactured aircraft supplied in kit form for assembly in the UK.