Chapter 1-2

THE DETECTION OF CORROSION

CONTENTS

METHODS OF DETECTION

Introduction

1 Some of the methods of non-destructive testing can be applied in the detection of corrosion and a summary of the advantages and disadvantages of the principal non-destructive testing methods for this application is given in para 2 to 11. For more complete information reference should be made to the following publications:

AP 119A-20001-1 NDT General Information
AP 119A-20002-1 NDT Safety Precautions
AP 119A-20003-1 NDT Penetrant Flaw Detection

Visual and visual aided examination

2 Visual examination, aided where necessary by optical equipment, is the primary tool of the tradesman engaged in corrosion detection. The specialized non-destructive testing techniques described make it possible to detect and monitor defects in regions of suspected weakness. They do not provide the facility to search for defects over a wide area. Visual examination remains the principal method of detecting corrosion.

3 Visual examination must be carried out with meticulous attention to detail. Where the structure to be examined is enclosed or inaccessible, the use of intrascopes, mirrors and various optical aids is necessary.

4 Apart from readily apparent defects similar to the examples shown in Chapter 1-2, the presence of less obvious deterioration may be deduced from its secondary effects. Surface corrosion may produce lifting and blistering of the surface treatment. The products of interface corrosion may cause bulging of the skin, cracks, failed rivets and the opening of joint edges: these effects may eventually be accompanied by an exudation of corrosion products. Exfoliation corrosion within skin panels or planks will cause slight bulging on the surface of apparently sound material. Such signs may indicate an advanced state of concealed corrosion and further investigation by removal of protective finish or opening up the structure is essential. The effects of interskin corrosion are illustrated in fig 1.

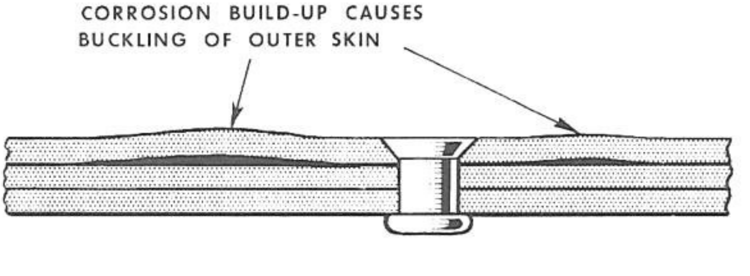

Fig 1 The effects of interskin corrosion

Flaw detection with penetrants

5 Penetrants are widely used in industry and in the Services for the detection of defects in metals. Although penetrants can be successfully used for flaw detection in many instances, they have their limitations when used for detecting corrosion on aircraft. The principal limitations of the use of penetrant flaw detection methods are:

5.1 The face from which corrosion starts must be accessible.

5.2 Rough surface finishes and protective treatment can hinder or prevent the use of penetrant crack detecting methods.

5.3 Detection of tight cracks such as those produced by intergranular corrosion is possible in good conditions, but should not be expected under Service conditions.

Specialized non-destructive testing techniques

6 Where it is not possible to visually monitor deterioration in regions known to be, or suspected of being, prone to corrosion, special techniques using the various NDT methods can be developed. These techniques require trained NDT operators and specialized equipment.

7 Specialized NDT methods may, in particular, be suitable for detecting cracks which may result from stress corrosion and corrosion fatigue. The suitability of the various methods for general corrosion is summarized in para 8 to 11.

Magnetic particle flaw detection

8 The magnetic particle method of examination is severely limited in all aircraft applications because:

8.1 The method is limited to magnetic materials.

8.2 Components must be made part of an electrical or magnetic circuit.

8.3 Magnetized components must be demagnetized after using the method and all magnetic particles must be removed.

8.4 Screw threads and changes in section, give spurious indications.

The conditions given in para 8.2 and 8.3 are difficult to satisfy without removing the component from the aircraft.

Radiography

9 Radiographic examinations are carried out by NDT operators to detect corrosion in areas of aircraft such as the internal surfaces of skins, stringers, engine bearer tubes and the mating surfaces of riveted structures. There are severe limitations to the use of radiographic techniques. They are:

9.1 Loss of material or changes in density must occur for radiographic methods to be successfully employed. This does not always take place, especially when the corrosion is between mating surfaces.

9.2 The presence of chromate paints, Redux bonding and various jointing compounds, reduces the sensitivity of the technique.

9.3 As a consequence of para 9.1 and 9.2, the early stages of corrosion are difficult to detect. The complex structure of an aircraft limits the coverage which can be obtained and consequently radiographic corrosion detection techniques are restricted to areas of relatively simple construction.

Ultrasonics

10 Although ultrasonic examination can be used in some applications to detect stress corrosion and corrosion fatigue, the method does not readily lend itself to corrosion detection in aircraft because:

10.1 The conventional ultrasonic method for detecting flaws cannot be used on thin gauge material.

10.2 Generally where conventional ultrasonic methods are used only severe corrosion can be detected.

10.3 In order to detect corrosion with ultrasonic methods on one surface of a component, access to the other side of the component or exceptionally to the same side must be available. This access is not always available.

Eddy current methods

11 With the introduction of variable low frequency eddy current equipment such as Alcoprobe the capability exists to detect corrosion, whether surface or exfoliation, and fatigue cracking in single and multiple skins. The depth range is governed by the available search frequencies and there is a practical limit to the depth of signal penetration.

DESCRIPTION AND IDENTIFICATION OF COMMON CORROSION PRODUCTS

General

12 One of the problems involved in corrosion control, is the recognition of corrosion products when they occur. The following brief description is of typical corrosion products common to materials used in aircraft construction.

Iron and steel

13 The most common and easily recognised form of corrosion is red rust. The way it is formed is not fully understood. The initial oxide film formed on freshly exposed steel is very thin and is invisible. In the presence of water or a damp atmosphere, especially if sulphur dioxide (in an industrial atmosphere) or salt (in a marine atmosphere or in the sea) are present, thick layers of hydrated oxide form. These vary in colour from brown to black depending on their composition. Rust promotes further corrosion by retaining salts (sulphate or chloride) and water. Mill scale, a type of oxide formed at high temperatures, also promotes rusting by forming an electrolytic cell with the underlying steel. Heavy rust can be removed only by abrasive blasting or by immersion in rust removing solutions, often with the aid of an applied electric current.

14 Surface rust can develop on steel nuts, bolts and other fasteners and may not adversely affect the operational integrity of the equipment. Its appearance is an indication that adequate maintenance has not been observed.

Aluminium and its alloys

15 The corrosion of aluminium and its alloys takes a number of different forms. It may vary from general etching of the surface, to the localized intergranular attack characteristic of some strong aluminium alloys in some states of heat treatment. The corrosion products of aluminium are white to grey and are powdery when dry. Superficial corrosion products can be removed by scouring, light abrasive blasting or by chemical methods.

16 In general, pure aluminium sheet or alclad surfaces have good corrosion resistance, except in marine areas. In a salt water environment, aluminium and its alloys need protection, and high strength aircraft alloys are always given a substantial protective treatment.

Magnesium and its alloys

17 Magnesium corrosion products are white and voluminous compared to the base metal being corroded. When failure of protective coatings on magnesium occurs, corrosive attack tends to be severe in the exposed areas and may penetrate a magnesium structure in a short time. Any corrosion of magnesium requires prompt attention. In contrast to high strength aluminium alloys, the strong magnesium alloys used in aircraft do not suffer intergranular attack. Any corrosion that has occurred is always visible on the surface.

Titanium

18 Titanium is highly corrosion resistant and should be insulated from other metals to avoid corrosion of the other metals by dissimilar metal corrosion. Titanium alloys can suffer stress corrosion at temperatures above 300°C (572°F) in the presence of salt.

19 Cracks initiated by fatigue can propagate more rapidly under static or dynamic loading if salt water is present. If stress corrosion of titanium alloys is suspected, expert advice should be sought from the Design Authority.

20 Cadmium can penetrate the surface of titanium alloys and embrittle them at temperatures as low as ambient temperature. This effect can occur when the cadmium is plated directly onto the titanium, or when the titanium is in contact with cadmium plated steel parts. Contact between cadmium and titanium should be avoided whenever these conditions may arise. The conditions under which penetration of titanium occurs, appear to be:

20.1 When there are tensile stresses in the surface of the titanium alloy.

20.2 When surface pressure of the cadmium, perhaps accompanied by strain of the titanium, acts to break the natural oxide film and so allows lattice contact of the two metals.

Copper and copper alloys

21 Copper and its alloys are relatively resistant to corrosion. Tarnishing has no serious consequences in most applications. Long term exposure to industrial or marine atmospheres, gives rise to the formation of blue-green corrosion products. Brasses can suffer selective removal of zinc (dezincification). In aircraft, copper base alloys are frequently cadmium plated to prevent bimetallic corrosion of other metals in contact.

Cadmium and zinc

22 Cadmium and zinc are used as coatings to protect the parts to which they are applied. Both confer sacrificial protection to the underlying metal. Cadmium is normally chosen for use in aircraft as it is the more durable under tropical and marine conditions. Attack of cadmium and zinc gives rise to a white corrosion product.

Nickel and chromium

23 Electroplated nickel is used as a heat resistant coating, chromium for its wear resistance. Both protect steel only by excluding the corrosive atmosphere; once the underlying steel is exposed, the coatings accelerate rusting. The degree of protection is proportional to the thickness of the coating.

24 Chromium is highly resistant to corrosion. Nickel corrodes slowly in industrial and marine atmospheres to give a blue-green corrosion product.

Silver, platinum and gold

25 Silver, platinum and gold are noble metals and do not corrode in the ordinary sense, although silver tarnishes in the presence of sulphur. The tarnish on silver is the brown to black silver sulphide that forms on table silverware.

LOCATION OF CORROSION IN AIRCRAFT

General

26 Certain locations on aircraft, are more prone to corrosion than others. The rate of deterioration varies widely with aircraft design, build, operational use and environment. Some of the principal corrosion prone areas are discussed in para 27 to 51 which should be read in conjunction with fig 2 to 4, which show common corrosion prone areas of various types of aircraft. More detailed information applicable to particular aircraft may be found in special-to-type APs.

27 External surfaces are open to inspection and usually protectively painted. Surfaces of magnesium or aluminium alloy are particularly susceptible to corrosion along rivet lines, lap joints, fasteners, faying surfaces and where protective coatings have been damaged or neglected.

Exhaust areas

28 Fairings located in the path of exhaust gases of jet or reciprocating engines are subject to highly corrosive influences. This is particularly so where exhaust deposits may be trapped in fissures, crevices, seams or hinges. Such deposits are difficult to remove by ordinary cleaning methods. During maintenance the fairings in critical areas should be removed for cleaning and examination, and those fairings in other areas where exhaust deposits may build up slowly should also receive close attention. On some aircraft a chemical soil barrier is applied to exhaust trail areas to prevent surface contamination by corrosion deposits and to facilitate cleaning.

Rocket and gun blast areas

29 Gun compartment venting systems, spent ammunition collection chutes and rocket and missile exhaust paths are particularly subject to deterioration and attack from heat (which may blister protective surfaces), corrosive gases and abrasion from spent cases or solid particles. These areas require cleaning after firing and should be carefully and frequently inspected for corrosion. Gun bays may be potential water traps and should be kept sealed to prevent the entry of water, especially during adverse weather aboard ships.

Engine intakes, cooling air vents

30 The protective finish on engine frontal areas is abraded by dust and eroded by rain. Radiator cores and cylinder fins may also be vulnerable to corrosion. Special attention should be given, particularly in a marine environment, to obstructions and crevices in the path of the cooling air; corrosion or loss of protective finish in these areas should be treated as soon as it is detected.

Helicopter rotating assemblies

31 The rotor heads, main rotor blades, tail rotor blades, gearboxes, transmission shafts and bearings are susceptible to corrosion by exposure to the elements and to dissimilar metal corrosion. They require frequent inspection, especially at sea.

Undercarriages

32 Wheel wells are exposed to flying debris (water, mud, gravel) and require frequent cleaning and touching up. Attention should be given to crevices, (where debris can lodge between stiffeners) ribs and lower-skin surfaces. Undercarriage assemblies should be examined with particular attention to magnesium wheels, paintwork, bearings, exposed switches and electrical equipment. Frequent cleaning, PX-24 treatment and relubrication is required. When relubricating, ensure that bearings are not contaminated with water or cleaning fluids.

Bilges and water entrapment areas

33 Although specifications call for drains wherever water is likely to collect, the drains can be blocked by debris, sealant or grease. Inspection must be frequent.

34 In particular, the bilge area of any aircraft is a collection point for dirt, loose fasteners, shavings, debris and hydraulic fluids which may conceal water.

Recesses at folds, flaps and hinges

35 Potential corrosion areas are found at flap and speed-brake recesses where water and dirt may go unnoticed because the movable part is normally in the closed position. Conversely, wings may be folded on board ship and complicated assemblies, difficult to coat with paint or preservative, exposed to salt spray. Full inspection demands mirror checking of the backs of tubes and fittings. Preventive procedures include frequent cleaning and lubrication, the maintenance of paint or preservation coatings, attention to alloy wing-lock fittings and the use of wing-root covers when aircraft are aboard ship.

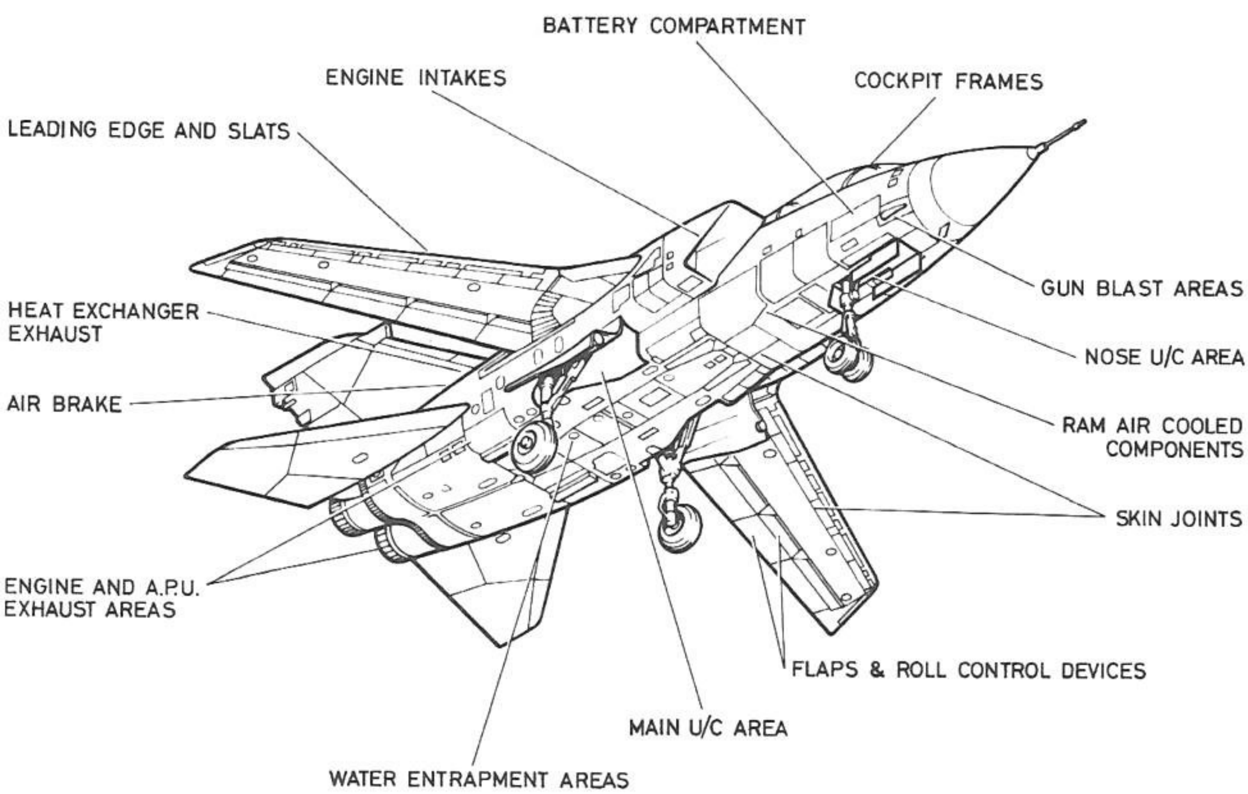

Fig 2 Corrosion prone areas on fighter type aircraft

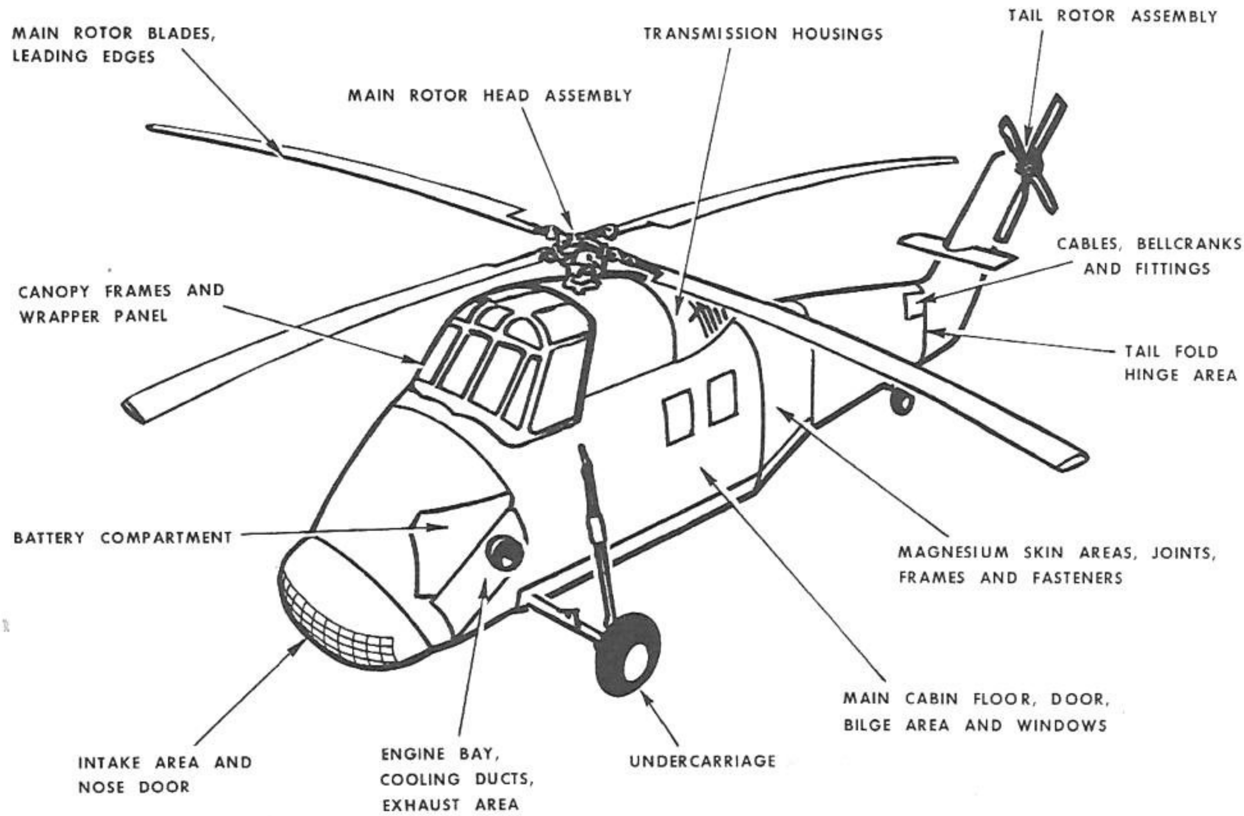

Fig 3 Corrosion prone areas on helicopters

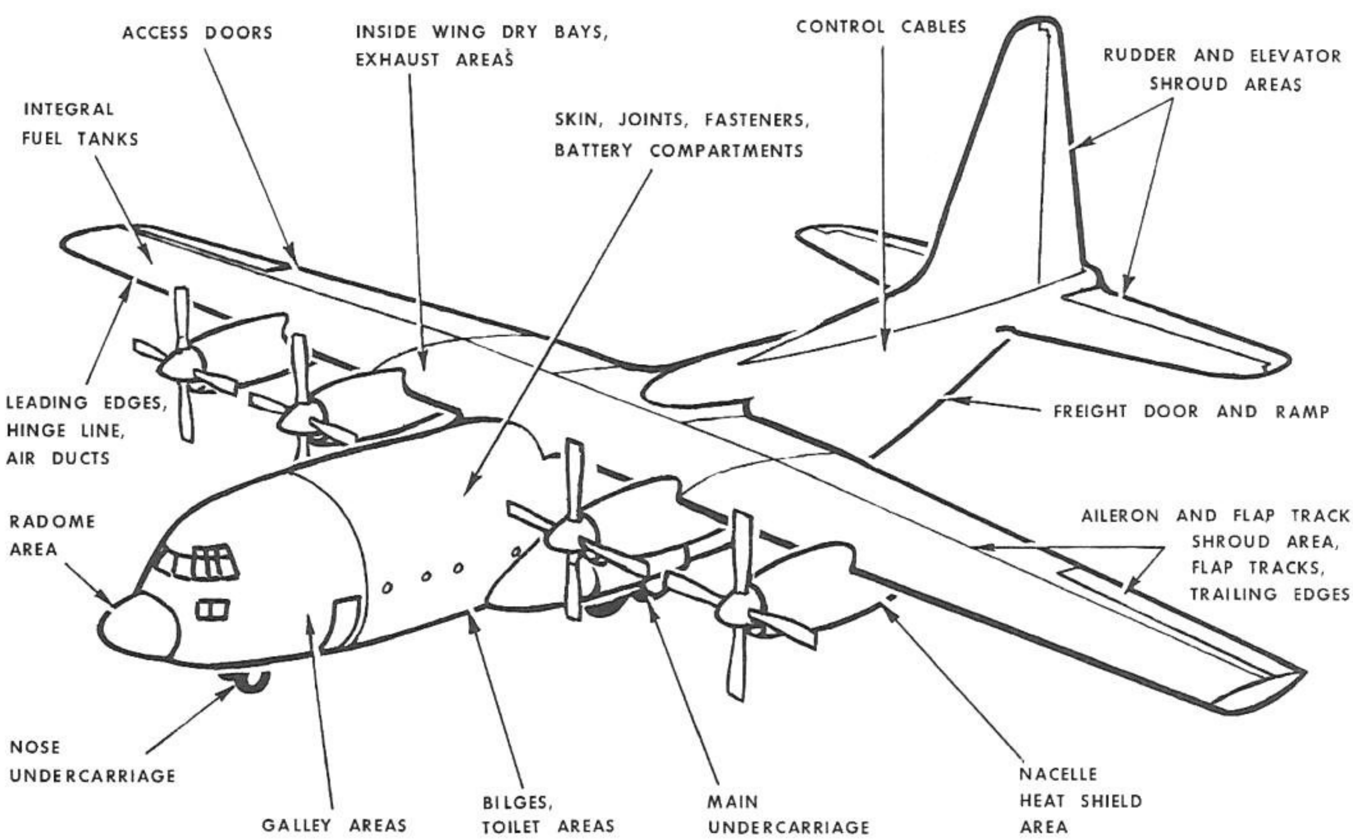

Fig 4 Corrosion prone areas on transport type aircraft

36 Hinges are vulnerable to dissimilar metal corrosion between steel pins and aluminium hinge tangs. They are traps for dirt and moisture. Seizure can occur at the hinges of access doors and panels that are seldom used.

Magnesium alloy skins

37 Magnesium skins give little trouble if the original surface finish and insulation is intact, but touch-up procedures after drilling, riveting and trimming never fully restore the protection afforded by tank treatment. Poorly insulated steel fasteners and the thinning of paint at abrupt changes of contour constitute corrosion hazards and call for the inspection of all magnesium-skin surfaces and parts, with close attention to edge localities, fasteners and faulty painting.

Aluminium alloy skins

38 Integrally machined aluminium alloys are often used in mainplane structures. The alloys used can be susceptible to intergranular and exfoliation corrosion. Small bumps, or raised areas under the paint, sometimes indicate exfoliation of the metal itself and treatment requires removal of all exfoliated metal followed by blending and restoration of the finish.

Spot welded skins and sandwich construction

39 Corrosive agents may become trapped between the metal layers of spot welded skins and moisture entering the seams may set up electrolytic corrosion that eventually corrodes the spot welds, or causes the skin to bulge. Generally, spot welding is not good practice on aircraft structures.

40 Cavities, gaps, punctures or damaged places in honeycomb sandwich panels should be sealed to exclude water or dirt and water should not be permitted to accumulate in the structure adjacent to sandwich panels. Inspection of honeycomb sandwich panels and box structures is difficult and generally requires that the structure is dismantled.

Electrical equipment

41 Sealing, venting and protective paint systems cannot wholly obviate corrosion in battery compartments. Spray from electrolytes spreads to adjacent cavities and causes rapid attack on unprotected surfaces. Inspection and maintenance should also extend to battery compartment vents. Air cooled compartments may be subject to conditions akin, to those at engine intakes and cooling vents.

42 Circuit breakers, contacts and switches are extremely sensitive to the effects of corrosion (their function is affected) and need close inspection. This can generally be done more thoroughly when the components are removed from the aircraft and dismantled.

Toilet and galley areas

43 Fluid spillage occurs in toilets and galleys, behind pedestals and sinks, where access is difficult. Human waste products corrode aircraft metals and contamination must be avoided where possible. Bilge areas below lavatories and galley areas are particularly corrosion prone areas. The corrosion of toilet and galley area is further discussed in Chapter 2-1.

Fuel tanks

44 Microbiological contamination may result from the growth of micro-organisms resembling fungi or algae which are present in sea and other types of water. The contamination may occur as a result of the entry of water into aircraft fuel systems and related structures. Micro-organisms may also be present in water which is normally present in jet type fuels. The micro-organisms may obtain nutriment from certain constituents of the fuel.

45 Growth of fungus has occurred in aircraft fuel tanks (particularly in large transport type aircraft) operating in many parts of the world, especially in climates with temperatures of 30°C (86°F).

46 The organisms collect as a lacy scum or slime along the interface between the water and fuel. This scum eventually adheres to the walls of the fuel tanks. Some wing tanks, as a protection against corrosion, have been lined with protective materials, but some coatings have been found to act as nutriment for the micro-organisms so they multiply. In due course the slime breaks away from the lining and flows through the system and contaminates pumps, valves, switches and other components. Ordinary cleaning methods will not remove this contamination (refer to Chapter 2-3 for cleaning methods).

47 Where the slime sticks to the surface of the fuel cell it acts as an electrically conductive, semi-permeable membrane, through which dissolved salts and gases pass slowly. The lowest concentration of salts and gases, occurs at the centre of the sludge mass. Protection from corrosion in the fuel tanks lasts until the protective skin is eaten away to expose the underlying metal.

48 Experience has shown that fuel tank content units may be operationally affected by microbiological growth. Growth across a unit will cause it to short circuit electrically and give erroneous gauge readings.

49 Design efforts should be aimed at the provision of resistant coatings on the inside of fuel tanks and other parts subject to micro-biological attack. This, together with control to prevent fuel contamination with water, should help to minimize the effects of microbiological contamination.

Miscellaneous items

50 Breaks in the preservative coatings on carbon-steel control cables, cause trouble eventually and even corrosion resistant cables succumb to marine attack. When corrosion is found on the outside of cables, the internal strands should be examined and the cables replaced if corroded. Particular attention should be given to cables in the vicinity of bellcranks, sheaves and other places where the cables bend. Wear limits for control cables should be determined from AP 101A-0206-1, Flexible Wire Cables in Aircraft Control Systems.

51 Hose assemblies containing wire reinforcement, are sometimes exposed to water and should be examined to ensure the hoses have not deteriorated and the wire parts have not corroded.


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