Part 6 Structures

Leaflet 6-1 Inspection of Wooden Structures

1 Introduction

1.1 This Leaflet gives guidance on the inspection of wooden aircraft structures for evidence of deterioration of the timber and glued joints. It should be read in conjunction with the relevant aircraft manuals, approved Maintenance Schedules and manufacturers' instructions, from which details of particular structures may be obtained.

1.2 Information on the conversion of timber into aircraft parts is given in Leaflet 2–3 and on the use of synthetic resin adhesives in Leaflet 2–4.

2 CAA Policy

Airworthiness Notice No. 50 describes the extent of the deterioration which has been found in wooden structures and the dismantling which may be necessary to enable thorough inspections to be carried out.

2.1 While this Airworthiness Notice expresses concern at the extent of deterioration found in some aircraft, it is also pointed out that there is no reason why aircraft manufactured in these materials should not have a satisfactory life provided they are protected from the adverse effects of extreme temperature and humidity and are kept in suitable hangars when not in use.

3 Glued Structures

Provided that protective varnish was applied to all exposed wood surfaces after gluing and satisfactorily maintained during the life of an aircraft, rapid deterioration of timber and glued joints would be unlikely. However, access to internal structure is often difficult or even impossible and deterioration takes place for a variety of reasons.

3.1 Some of the main factors which may cause deterioration are:

a) Chemical reactions of the glue itself due to ageing or moisture, to extremes of temperature or to a combination of these factors.

b) Mechanical forces due mainly to timber shrinkage.

c) Development of mycological growths (i.e. fungus).

d) Oil percolating from the engine installation.

e) Fuel contamination due to system leaks or spillage in the tank bays.

f) Blockage of water drainage holes.

3.2 Aircraft which are exposed to large cyclic changes of temperature and humidity are especially prone to timber shrinkage which in turn may lead to glue deterioration. The amount of movement of timber members due to these changes varies with the volume of each member, the rate of growth of the tree from which the timber was cut and the way in which the timber was converted. Thus, two major members in an aircraft structure, secured to each other by glue, are unlikely to have identical characteristics and differential loads will, therefore, be transmitted across the glue film with changes of humidity. This will impose stresses in the glued joint which, in temperate zones, can normally be accommodated when the aircraft is new and for some years afterwards. However, with age the glue tends to deteriorate, even when the aircraft is maintained under ideal conditions and stresses at the glued joint, due to changes in atmospheric conditions, may cause failure of the joint.

3.2.1 In most wooden aircraft of monoplane manufacture the main spars are of box formation consisting of long top and bottom transverse members (i.e. spar booms) joined by plywood webs. The spar booms may be built up from laminations glued together and at intervals vertical wooden blocks are positioned between the two booms to add support to the plywood sides.

3.2.2 The main spars carry most of the loads in flight and are, at times, subject to flexing. The glued joints should, therefore, be free from deterioration but, unless the spar is dismantled or holes cut in the webs, internal inspection may be virtually impossible.

3.2.3 Long exposure to inclement weather or strong sunlight will tend to destroy the weatherproofing qualities of fabric coverings and of surface finishes generally. If fabric-covered ply structures are neglected under these conditions the surface finish will crack, allowing moisture to penetrate to the wooden structure and resulting in considerable deterioration through water soakage.

4 Survey of Structure

Before commencing a detailed examination of an aircraft structure, the aircraft should be inspected externally for signs of gross deformation, such as warped wing structures, tail surfaces out of alignment or evidence of obvious structural failure. In some cases of advanced deterioration this assessment may be sufficient to pronounce the aircraft beyond economical repair and thus avoid further work.

4.1 Whenever possible the aircraft should be housed in a dry, well ventilated hangar and all inspection panels, covers and hatches removed before continuing with the survey. The aircraft should be thoroughly dried out before examining glued joints or carrying out repairs.

4.1.1 Immediately after opening the inspection panels, etc., each component should be checked for smell. A musty smell indicates fungoid growth or dampness and, if present, necessitates further examination to establish which areas are affected.

4.1.2 Where the wings, fuselage or tail unit are designed as integral stressed structures, such as inner and outer ply skins glued and screwed to structural members (Figure 1) no appreciable departure from the original contour or shape is acceptable.

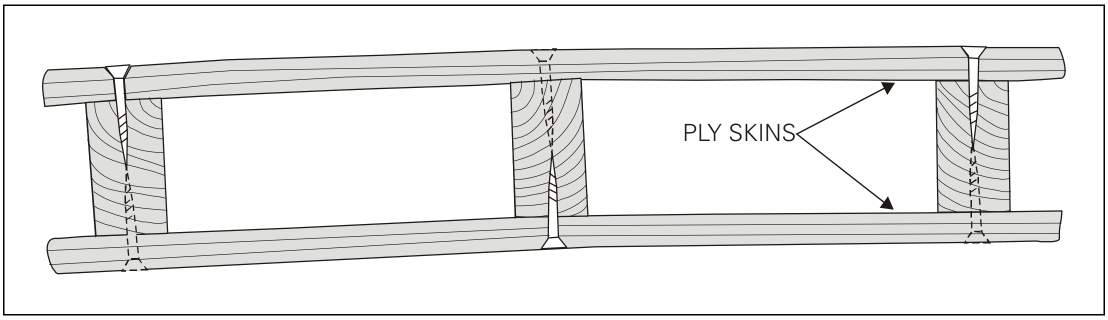

Figure 1 Double Skin Structure

4.1.3 Where single skin plywood structures are concerned, some slight sectional undulation or panting between panels may be permissible provided the timber and glue is sound. However, where such conditions exist, a careful check must be made of the attachment of the ply to its supporting structure and moderate pressure with the hand, to push the ply from the structure, should be used. A typical example of a distorted single skin structure is illustrated in Figure 2.

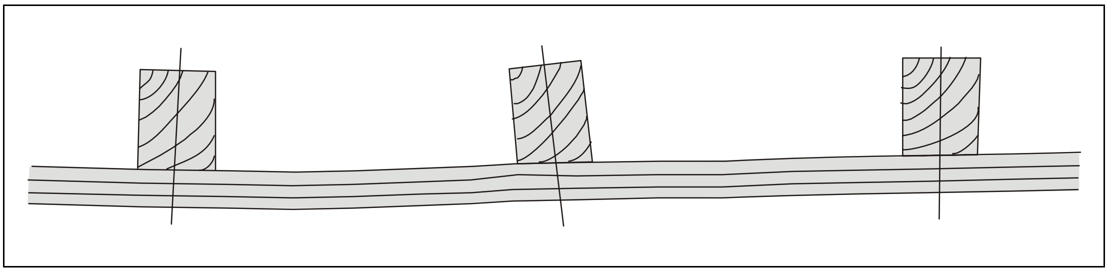

Figure 2 Single Skin Structure

4.1.4 The contours and alignment of leading and trailing edges are of particular importance and a careful check should be made for deformities. Any distortion of these light ply and spruce structures indicates deterioration and a careful internal inspection should be made for security of these parts to the main wing structure. If a general deterioration is found in these components the main wing structure may also be affected.

4.1.5 Where there are access panels or inspection covers on the top surfaces of wings or tailplane, care is necessary to ensure that water has not entered at these points where it can remain trapped to attack the surrounding structure.

4.2 Splits in the proofed fabric covering on plywood surfaces should be investigated by removing the defective fabric in order to ascertain whether the ply skin beneath is serviceable. It is common for a split in the ply skin to be the cause of a similar defect in the protective fabric covering.

4.3 Fabric having age cracks and thick with repeated dopings, may indicate that the structure underneath has not been critically examined for a considerable time. Insertion patches in the fabric could also indicate that structural repairs have been made at that point.

4.4 Whilst a preliminary survey of the external structure may be useful in roughly assessing the general condition of the aircraft, it should be noted that timber and glue deterioration often takes place inside a structure without any external indications. Where moisture can enter a structure, it will tend to find the lowest point, where it will stagnate and promote rapid deterioration. Other causes of glue deterioration are listed in paragraph 3.1.

5 Inspection of Timber and Glued Joints

Assessment of the integrity of glued joints in aircraft structures presents considerable difficulties since there is no positive non-destructive method of examination which will give a clear indication of the condition of the glue and timber inside a joint. The position is made more difficult by the lack of accessibility for visual inspection.

5.1 The inspection of a complete aircraft for glue or wood deterioration will necessitate checks on remote parts of the structure which may be known, or suspected trouble spots and, in many instances, are boxed in or otherwise inaccessible. In such instances, considerable dismantling is required and it may be necessary to cut access holes in ply structures to facilitate the inspection; such work must be done only in accordance with approved drawings or the repair manual for the aircraft concerned and, after the inspection has been completed, the structure must be made good and protected in an approved manner.

5.2 All known or suspected trouble spots must be closely inspected regardless of log book records indicating that the aircraft has been well maintained and properly housed throughout its life.

NOTE: Where access is required and no approved scheme exists, a scheme should be obtained from the aircraft manufacturer or an Organisation appropriately approved by the CAA for such work.

5.3 **Access Holes**

In general, access holes are circular in shape and should be cut with a sharp trepanning tool to avoid jagged edges. It is essential to avoid applying undue pressure to the tool, especially towards the end of the cut, otherwise damage may be caused to the inner face of the panel by stripping off the edge fibres or the ply laminations.

5.3.1 Where rectangular access holes are prescribed care is necessary to ensure that they are correctly located and that corner radii are in accordance with drawing requirements.

5.3.2 The edges of all access holes must be smoothed with fine glasspaper, preferably before inspection is commenced, since contact with the rough edges may cause wood fibres to be pulled away.

5.4 It is important that the whole of the aircraft structure, including its components, e.g. tailplane, elevators, etc., is inspected in detail before any decision is reached regarding general condition. It is possible for the main airframe to be in good condition but for a marked deterioration to have occurred in, for example, a control surface.

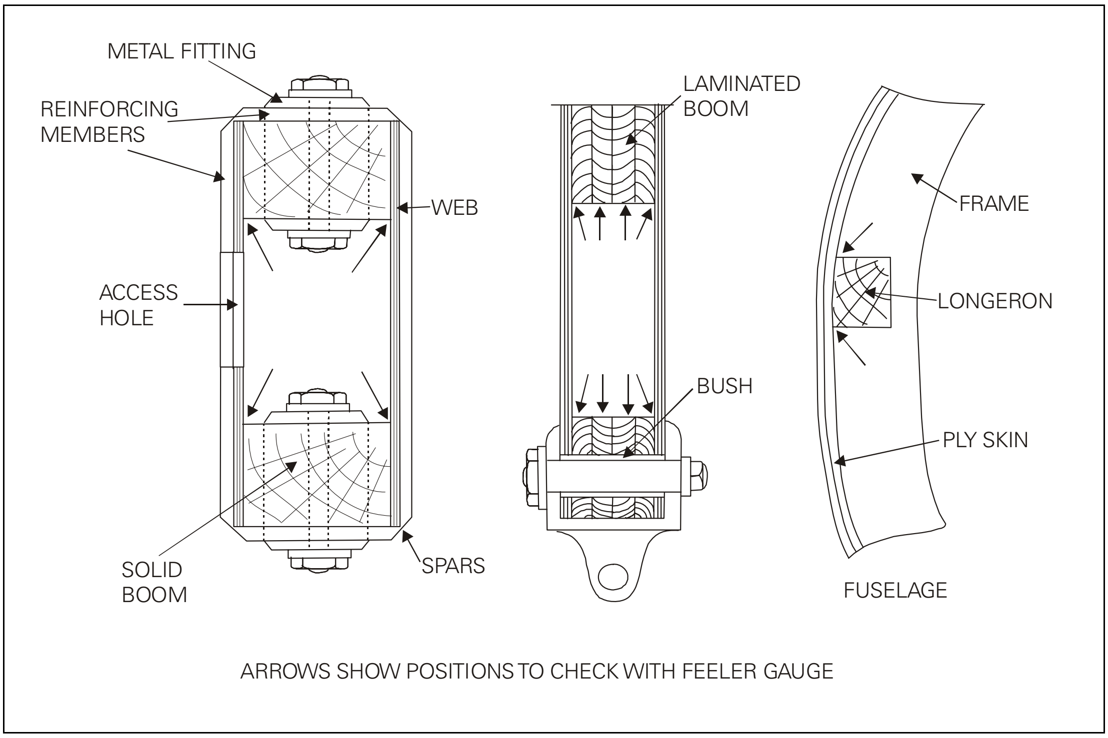

Figure 3 Glue Line Checks

5.5 **Glue Line**

When checking a glue line (i.e. the edge of the glued joint) for condition, all protective coatings of paint should be removed by careful scraping; it is important to ensure that the wood is not damaged during the scraping operation and scraping should cease immediately the wood is revealed in its natural state and the glue line is clearly discernible.

5.5.1 The inspection of the glue line is often facilitated by the use of a magnifying glass. Where the glue line tends to part or where the presence of glue cannot be detected or is suspect, then, providing the wood is dry, the glue line should be probed with a thin feeler gauge and, if any penetration is possible, the joint should be regarded as defective.

NOTE: It is important to ensure that the surrounding wood is dry, otherwise a false impression of the glue line would be obtained due to closing of the joint by swelling. In instances where pressure is exerted on a joint, either by the surrounding structure or by metal attachment devices such as bolts or screws, a false impression of the glue condition could be obtained unless the joint is relieved of this pressure before the glue line inspection is carried out.

5.5.2 The choice of feeler gauge thickness will vary with the type of structure, but a rough guide is that the thinnest possible gauge should be used. Figure 3 indicates the points where checks with a feeler gauge should be made.

5.6 **Timber Condition**

Dry rot and wood decay are not usually difficult to detect. Dry rot is indicated by small patches of crumbling wood, whilst a dark discolouration of the wood surface or grey streaks of stain running along the grain are indicative of water penetration. Where such discolouration cannot be removed by light scraping the part should be rejected, but local staining of the wood by the dye from a synthetic adhesive hardener can, of course, be disregarded.

5.6.1 **Water Penetration of Structure**

In some instances where water penetration is suspected, the removal of a few screws from the area in question will reveal, by their degree of corrosion, the condition of the surrounding joint (see Figure 4).

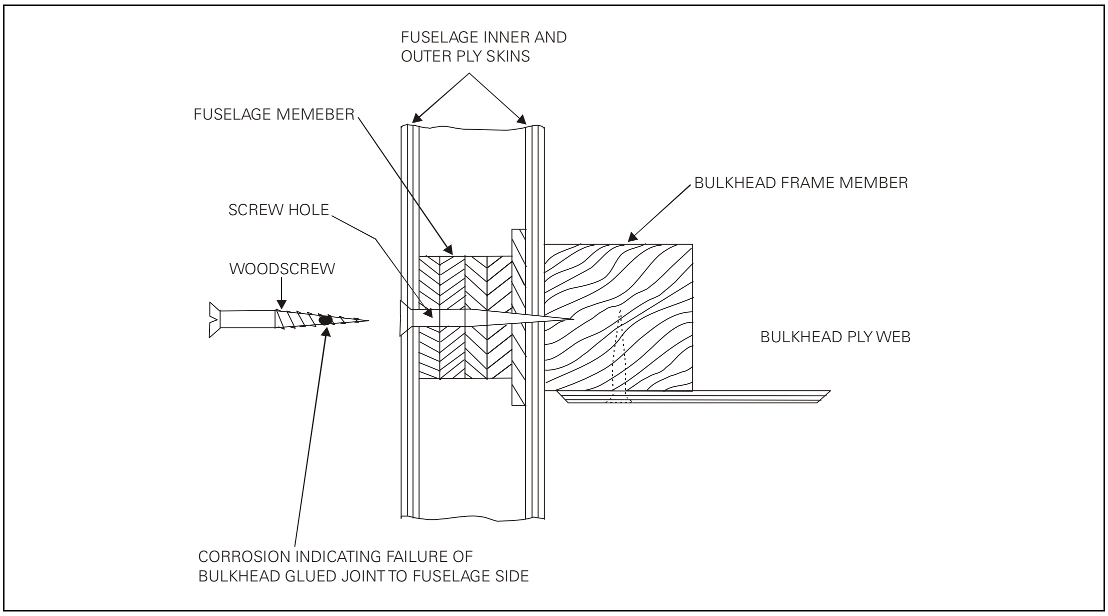

Figure 4 Check for Water Penetration

a) Slight corrosion of the screw due to the adhesive will occur following the original manufacture, therefore, the condition of the screw should be compared with that of a similar screw, removed from another part of the structure known to be free from water soakage.

NOTE: Plain brass screws are normally used for reinforcing glued wooden members, although zinc coated brass is sometimes used. Where hard woods such as mahogany or ash are concerned, steel screws are sometimes used. Unless otherwise specified by the aircraft manufacturer, it is usual to replace screws with new screws of identical length but one size larger.

b) Another means of ascertaining if water penetration has taken place is to remove the bolts holding fittings at spar root-end joints, aileron hinge brackets, etc. (see Figure 3). Primary joints may have bushed holes and the bushes should also be withdrawn. Corrosion on the surface of these bolts and bushes and timber discolouration, will provide a useful indication of any water penetration which has taken place. Bolts and bushes should be smeared with an approved protective treatment before being refitted through wooden members.

NOTE: When refitting bolts it is important to ensure that the same number of shrinkage washers are fitted as were fitted originally.

c) Experience of a particular aircraft will indicate those portions of the structure most prone to water penetration and moisture entrapment (e.g. at window rails or the bottom lower structure of entry doors), but it must be borne in mind that this is not necessarily indicative of the condition of the complete aircraft.

d) Where drain holes have become blocked, water soakage will invariably be found. Drain holes should be cleared during routine maintenance.

5.6.2 **Water Penetration of Top Surfaces**

As indicated in paragraph 3.2.3, the condition of the proofed-fabric covering on ply surfaces is of great importance. If any doubt exists regarding its proofing qualities or if there are any signs of poor adhesion, cracks, or other damage, it should be peeled back to reveal the ply skin.

a) The condition of the exposed ply surface should be examined and if water penetration has occurred, this will be shown by dark grey streaks along the grain and a dark discolouration at ply joints or screw countersunk holes, together with patches of discolouration. If these marks cannot be removed by light scraping or, in the case of advanced deterioration, where there are small surface cracks or separation of the ply laminations, then the ply should be rejected. Where evidence of water penetration is found, sufficient of the surfaces should be stripped to determine its extent.

b) Providing good care is taken of the protective covering from the beginning, much deterioration can be avoided.

5.6.3 **Miscellaneous Defects**

During the inspection of the aircraft, the structure should be examined for other defects of a more mechanical nature. Guidance on such defects is given in the following paragraphs.

a) **Shrinkage.** Shrinkage of timber, as well as inducing stresses in glued joints, can cause looseness of metal fittings or bolts and, if fluctuating loads are present, can result in damage to the wood fibres at the edges of the fittings or around the bolt holes. Shrinkage can be detected by removing any paint or varnish as described in paragraph 5.5 and attempting to insert a thin feeler gauge between the timber and the fitting or bolt head.

b) **Elongated Bolt Holes.** Where bolts secure fittings which take load-carrying members, or where the bolts are subject to landing or shear loads, the bolt holes should be examined for elongation or surface crushing of the wood fibres. The bolts should be removed to facilitate the examination and, in some cases, the bolt itself may be found to be strained. Rectification of elongated bolt holes must be carried out in accordance with the approved Repair Manual, the usual method being to open out the holes and fit steel bushes.

c) **Bruising and Crushing.** A check should be made for evidence of damage such as bruises or crushing of structural members, which can be caused, for example, by overtightening bolts. Repair schemes for such damage are governed by the extent and depth of the defect.

d) **Compression Failures.** Compression failures, sometimes referred to as compression 'shakes', are due to rupture across the wood fibres. This is a serious defect which at times is difficult to detect and special care is necessary when inspecting any wooden member which has been subjected to the abnormal bending or compression loads which may occur during a heavy landing. In the case of a member having been subjected to an excessive bending load, the failure will appear on the surface which has been compressed, usually at a position of concentrated stress such as at the end of a hardwood packing block; the surface subjected to tension will normally show no defects. In the case of a member taking an excessive direct compression load, the failure will usually be apparent on all surfaces. Where a compression failure is suspected, a hand torch shone along the member, with the beam of light running parallel to the grain, will assist in revealing this type of failure.

e) **Previous Repairs.** When examining a structure for signs of the defects mentioned above, particular attention should be paid to the integrity of repairs which may have been carried out previously.

6 Joint Failure

A glued joint may fail in service as a result of an accident or due to excessive mechanical loads having been imposed upon it, either in tension or in shear. It is often difficult to decide the nature of the load which caused the failure, but it should be borne in mind that glued joints are generally designed to take shear loads.

6.1 If a joint is designed to take tension loads, it will be secured by a number of bolts or screws (or both) fairly closely pitched in the area of tension loading. If a failure occurs in this area, it is usually very difficult to form an opinion of the actual reasons for it, due to the considerable break-up of the timber occurring in close proximity with the bolts.

6.2 In all cases of glued joint failure, whatever the direction of loading, there should be a fine layer of wood fibres adhering to the glue, whether or not the glue has come away completely from one section of the wood member. If there is no evidence of fibre adhesion, this may indicate glue deterioration, but if the imprint of wood grain is visible in the glue this is generally due to 'case hardening' of the glue during manufacture of the joint and the joint has always been below strength. If the glue exhibits a certain amount of crazing or star shaped patterns, this indicates too rapid setting, or the pot life of the glue having been exceeded. In these cases, the other glued joints in the aircraft should be considered suspect.

NOTE: The use of a magnifying glass will facilitate the above inspections.

6.3 Damage caused by a heavy landing may be found some distance away from the landing gear attachment points. Secondary damage can be introduced by transmission of shock from one end of a strut or bracing to its opposite end, causing damage well away from the point of impact. A thorough inspection of the existing paint or varnish at suspected primary or secondary impact points may reveal, by cracks or flaking, whether damage has actually occurred.

Leaflet 6-2 Inspection of Metal Aircraft Structures

1 Introduction

This Leaflet gives general guidance on the inspection of those parts of a metal aircraft structure which, because of their remoteness, complexity or boxed-in design, are not readily accessible for routine maintenance or require special attention in the light of operational experience.

2 General

Deterioration may arise from various causes and can affect various parts of the structure according to the design of the aircraft and the uses to which it is put. Therefore, this Leaflet should be read in conjunction with the appropriate manufacturer's publications and the Maintenance Schedule for the aircraft concerned.

2.1 Although considerable guidance may be given in the appropriate 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 Schedule. Apart from the airworthiness aspects, these combined inspections could often be to the operator's advantage, since they would obviate the need for future dismantling.

2.2 Where access has been gained to a part of the structure which is normally inaccessible, advantage should be taken of this dismantling to inspect all parts of systems thus exposed.

3 Corrosion

The presence of corrosion in aircraft structures is liable to result in conditions which may lead to catastrophic failures. It is therefore essential that any corrosive attack is detected and rectified in the earliest stages of its development.

3.1 In general, no corrosive attack on an aircraft structure will occur without the presence of water in some form. 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 this is one of the main causes of corrosion.

3.1.1 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 are subject to some form of 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 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.

3.1.2 Corrosion can be intergranular; therefore, the removal of the surface products of corrosion followed by reprotection is not necessarily effective. Once the surface is penetrated the reduction in strength due to corrosion is disproportionate to the reduction in thickness of the metal.

3.2 **Air-conditioned Compartments**

In air-conditioned compartments, condensation will occur where the warm inside air impinges on the colder areas of the structure such as the inner surfaces of a pressure cabin skin. Considerable quantities of water will tend to collect and run down the inside of the cabin walls.

3.2.1 To avoid corrosion it is important to ensure that the water is unimpeded in its flow down to the bilge area. The structure and all drain holes through stringers, etc., should be kept clean and free from obstructions and drainage ducts should be checked for clearance and damage. A check should be made to ensure that water or moisture is not being trapped by the thermal acoustic lining or any other form of upholstery.

3.2.2 Water collecting in the lower parts of the structure and in the bilge area can be highly contaminated. It will not only contain the corrosive agents mentioned in paragraph 3.1.1, but also other impurities due to fumes, spillages, etc., emanating from the galley, toilets and smoking compartments, thus intensifying the corrosive nature of the water. At specified periods these parts of the structure should be thoroughly cleaned and carefully inspected for signs of corrosion and for deterioration of the protective treatment.

3.2.3 Thermal acoustic linings usually have a waterproof covering on the side adjacent to the structure, or the thermal acoustic material may be completely enveloped in a waterproof covering. Any damage to the waterproof covering may lead to considerable absorption of water into the lining, setting up corrosion between the damaged lining and the surrounding structure.

NOTE: Water soakage of upholstery and especially of thermal acoustic linings can also result in an appreciable increase in aircraft weight. Instances have also occurred where saturated compartment linings have caused electrical failures.

3.3 **Structural Parts Susceptible to Corrosion**

The manufacturer’s publications 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 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.

3.3.1 In 'blind' or boxed-in structures where accessibility is difficult and where cleaning and maintenance are awkward, dirt and dust tend to collect and lodge in various parts. This dirt and dust acts as a 'wick' 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 dust and dirt to adhere to such surfaces. Hard gloss finishes, such as epoxy resin paints, will provide a more effective and lasting protection.

3.3.2 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.

3.3.3 Honeycomb structures, especially those in components of small cross-sectional area (e.g. wing flaps), 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 ingress of moisture. 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.

3.3.4 Fuselage keel areas, structures concealed by upholstery (see e.g. paragraph 3.2) and the double skin of freight bay floors, are typical areas liable to corrosion. Special attention should be given to all faying surfaces in these areas and particularly the faying surfaces of 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.

3.3.5 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 faying surfaces. Cases of serious corrosion have also been found in similar structures riveted together where the jointing compound has been found to be inadequate.

3.3.6 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, etc. 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.

3.4 **Exhaust Gases**

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.

3.5 **Stress Corrosion**

3.5.1 Stress corrosion in aluminium tends to occur mainly in the high-strength alloys and is due to locked-in stresses resulting from some aspects of heat treatment or inappropriate assembly practices. Stress corrosion takes the form of cracking which, in conjunction with other corrosion, can lead to the sudden and complete failure of structural parts.

3.5.2 Stress corrosion cracking in titanium depends on the composition of the alloy, its processing and its notch sensitivity. Some titanium alloys may develop rapid crack growth if contaminated with a saline solution after a crack has been initiated.

3.6 **Fretting**

Fatigue failures often result from fretting at structural bolted joints. Fretting is revealed by black or greyish brown powder or paste around the periphery of the faying surfaces 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.

4 Spillage

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, 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., have a particularly deleterious effect on floor structures.

4.1 With an aircraft in operation there are areas where spillages invariably occur, such as in galleys and toilet compartments. Here, careful cleaning and the maintenance of any special floor protection is important. The floor structures around and below these compartments should receive special attention to ensure protection against seepage and corrosion. Where animals are carried, special precautions are essential because corrosion due to animal fluid can cause rapid deterioration of metals. The floor and sides of compartments in which animals are housed should be protected by suitable means against seepage and the structure below the floor should be carefully inspected for any signs of seepage or corrosion.

NOTE: Where animals are not housed in containers specially designed for air transport, unbroken impervious sheeting such as waterproof canvas or heavy polythene sheet, should be laid on the floor and fixed at the required height on the fuselage sides and bulkheads to prevent any seepage into the aircraft structure. A form of matting, preferably made of absorbent material, should be laid on the sheeting to prevent damage due to animal movements.

4.2 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.

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 for further signs of corrosion and, if satisfactory, the protective treatment should be restored.

4.3 The spillage of mercury in an aircraft can have devastating effects on any aluminium alloy skin or structure with which it comes into contact.

5 Corrosive Effects of Agricultural Chemicals

On aircraft used for crop spraying or dusting, considerable attention and special care should be given to the inspection of the structure owing to the highly corrosive nature of certain of the chemicals used for these purposes. The corrosive effect of some of the chemicals used for agricultural purposes may not always be fully known. Some chemicals which were considered to be harmless to aircraft materials, have proved, in the course of time, to be corrosive.

5.1 Thorough cleaning of the whole aircraft structure after agricultural spraying operations is very important. Unless otherwise specified by the manufacturer of the chemical, the aircraft should be thoroughly washed, both internally and externally, with copious supplies of clean water. Engine intakes and exhausts and other openings, should be blanked during the washing to prevent the ingress of water. After washing, it is essential to check that no pockets of chemicals or water remain trapped in the structure, that all drains are clear and that all covers or devices used to prevent the ingress of chemicals are properly refitted.

5.2 A check should be made to ensure that the spray equipment tanks, pipes, pumps, etc., are leak-proof and that spray booms or spray nozzles are in their correct positions.

5.3 When filling up with chemical spray fluids care is necessary to avoid spillage. Where there is no provision to prevent spilled fluid finding its way into the structure, it is essential to avoid over-filling and the chance of accidental spillage can be reduced by using the proper filling equipment. If spillage does occur, it should be cleaned out immediately before it has penetrated into parts of the structure where cleaning would be more difficult.

6 Metal Fatigue

Metal fatigue can be briefly described as a weakening of a metal part under repeated applications of a cycle of stress. The weakening effect can be seriously accelerated by corrosion of the metal.

6.1 In the early stages, fatigue damage is difficult to detect by visual inspection and one of the methods of non-destructive examination outlined in the Part 4 series of Leaflets (see also paragraph 9) is usually specified; the method used depending on the type of structure and material concerned. In the majority of cases the presence of fatigue damage is revealed by the formation of a small hairline crack or cracks.

6.2 Those parts of a structure where fatigue damage may occur are determined by design calculations and tests based on the expected operational use of the aircraft and substantiated by operational experience. At the periods specified in the appropriate publications, examination or renewal of the parts will be required. These periods are usually in terms of flying time or the number of landings, or from readings logged by load recording instruments. With certain materials and structures, renewal or sampling checks may be required on a calendar basis.

6.3 It is important to note that some parts of a structure may be liable to fatigue damage resulting from unforeseen causes, e.g. parts damaged or strained on assembly, invisible damage to the structure during assembly or maintenance work, or fretting (see Leaflet 6–7). When carrying out inspections it is important to check carefully for any signs of cracks emanating from points of stress concentration such as bolt-holes, rivets, sharp changes in section, notches, dents, sharp corners, etc. Fatigue damage can also be caused by pits and notches created by corrosion, although the corrosion may no longer be active. During the application of repeated stress cycles, crevices can be opened up and may eventually result in a fatigue failure.

NOTE: Poor fitting or malassembly can reduce fatigue life considerably. A spar has been known to fail under tests at a fraction of its normal life as a result of the stress concentration caused by a tool mark in a bolt-hole. Defects such as a burr on a bolt can cause a scratch inside the bolt-hole, which can seriously accelerate fatigue damage in a stressed member.

7 Cleanliness

It is important that aircraft should be thoroughly cleaned periodically and reference should be made to Leaflet 2–6.

7.1 Care should be taken not to damage protective treatments when using scrubbing brushes or scrapers and any cleaning fluids used should have been approved by the aircraft manufacturer. For final cleaning of a boxed-in type of structure an efficient vacuum cleaner, provided with rubber-protected adaptors to prevent damage, should be used. The use of air jets should 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.

8 Inspection

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, metal particles, etc., trapped during manufacture or repair, may be found after the aircraft has been in operation for some considerable time. It is important to examine these loose articles 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.

8.1 General

8.1.1 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.

NOTES: 1) A wing structure has been known to have had a rib sheared at its spar attachments due to the accidental application of an excessive load, without any external evidence of damage, because the skin returned to its original contour after removal of the load.

2) For the inspection of bolted joints see Leaflet 6–7.

8.1.2 The protective treatment should be examined for condition. On light alloys a check should be made for any traces of corrosion, marked discolouration 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.

8.1.3 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, the manufacturer should be consulted.

8.1.4 The edges of faying surfaces should receive special attention (see also paragraph 3.3.4); careful probing of the joint edge with a pointed instrument may reveal the products of corrosion which are concealed by paint. In some instances slight undulations or bumps between the rivets or spot welds, or quilting in areas of double skins 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 Leaflet, dismantling of parts of the structure to verify the condition of the joints may be required.

NOTES: 1) 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.

2) Where dismantling of parts of the structure is required, reference should be made to Leaflet 6–4.

8.2 **Visual Examination**

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 mirrors to 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.

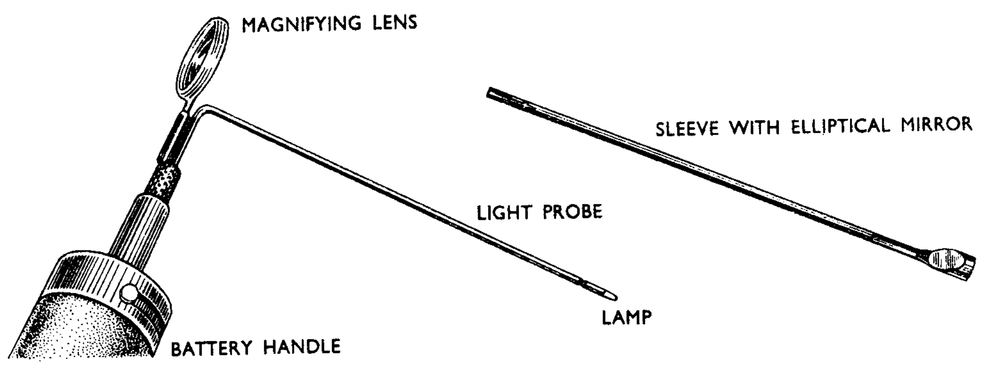

Figure 1 Typical Light Probe

8.2.1 **Light Probes**

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

a) 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 Figure 1, 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.

b) 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.

c) 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.

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 BS 229.

8.2.2 **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.

a) 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.

b) 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.

8.2.3 **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.

a) 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.

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

8.2.4 **Endoscopes** (Leaflet 4–9)

An endoscope (also known as an introscope, boroscope 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.

a) 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.

i) 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.

b) 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.

c) 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.

9 Non-destructive Examination

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.

9.1 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 series of Leaflets. 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.

9.2 **Penetrant Dye Processes** (Leaflet 4–2 and 4–4)

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 the developer and the resultant stain will indicate the presence and position of the defect.

NOTE: 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 microscopic cracks.

9.2.1 The 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.

9.2.2 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.

9.2.3 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.

9.3 **Radiographic Examination** (Leaflet 4–6)

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.

9.3.1 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.

9.3.2 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.

9.3.3 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.

9.3.4 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 advise on particular inspection techniques.

9.4 **Ultrasonic Examination** (Leaflet 4–5)

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.

9.5 **Eddy Current Examination** (Leaflet 4–8)

Eddy current methods can detect a large number of physical and chemical changes in a conducting material and equipment is designed specifically to perform particular types of test, e.g. flaw detection, conductivity measurement and thickness measurement.

9.5.1 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.

9.5.2 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.

9.6 **Magnetic Flaw Detection** (Leaflet 4–7)

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.

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Leaflet 6-3 Inspection of Metal Aircraft After Abnormal Occurrences

1 Introduction

1.1 Aircraft are designed to withstand flight and landing loads within specified limits; these limits are calculated to allow for all normal manoeuvres and exercises which may be undertaken by that aircraft and include safety factors to allow for unforeseen circumstances. If design limits are exceeded due to abnormal occurrences, the integrity of the structure may be jeopardised and safety impaired. Any report or evidence on the aircraft which suggests that the design limits have been exceeded or equipment damaged should, therefore, be followed by a careful inspection appropriate to the nature of the occurrence and in accordance with the Approved Maintenance Manual.

1.2 The types of occurrence which may lead to structural damage are considered in the following paragraphs, but these should be considered as a general guide and not as a complete list; additional inspections may be required on some aircraft and these will be described in the appropriate manuals. Inspections peculiar to helicopters are described in paragraph 8 of this leaflet and some guidance on the inspection of wooden aircraft structures is given in Leaflet 6–1.

1.3 **General**

The appropriate aircraft Maintenance Manual and other relevant literature, such as Service Bulletins, should be consulted to ascertain the particular inspections which are necessary and the areas where damage has been known to occur in similar circumstances on aircraft of the same type. The aircraft should then be viewed for obvious damage such as distortion or twisting of the main structure, before carrying out the detailed inspections applicable to the particular incident.

1.4 The repairs necessary, if damage is found during inspection, are outside the scope of this Leaflet and reference should be made to Leaflet 6–4 and to the manufacturer's Overhaul and Repair Manuals.

1.5 The subject headings are as follows:

1.6 Related CAAIP Leaflets:

6–1 Inspection of Wooden Structures

6–4 Repair of Metal Airframes

6–5 Rigging Checks on Aircraft

2 Heavy or Overweight Landings

2.1 An aircraft landing gear is designed to withstand landing at a particular aircraft weight and vertical descent velocity. If either of these parameters is exceeded during a landing, then it is probable that some damage may be caused to the landing gear or its supporting structure. Overstressing may also be caused by landing with drift or landing in an abnormal attitude, e.g. nose or tail wheel striking the runway before the main wheels.

2.2 Some aircraft are fitted with heavy landing indicators, which give a visual indication that specified 'g' forces have been exceeded, but in all cases of suspected heavy landings, the flight crew should be consulted for details of aircraft weight, fuel distribution, landing conditions and whether any noises indicative of structural failure were heard.

2.3 The damage which may be expected following a heavy landing would normally be concentrated around the landing gear, its supporting structure in the wings or fuselage, the wing and tailplane attachments and the engine mountings. Secondary damage may be found on the fuselage upper and lower skin and structure and wing skin and structure, depending on the configuration and loading of the aircraft. On some aircraft it is specified that, if no damage is found in the primary areas, the secondary areas need not be inspected; but if damage is found in the primary areas, then the inspection must be continued.

2.4 Because of the number of factors involved, it is not possible to lay down precise details of the inspections which must be made after any incident, on any type of aircraft, but a preliminary inspection should normally include the items detailed in paragraphs 2.5 to 2.10.

2.5 **Landing Gear**

a) Examine tyres for excessive creep, flats, bulges, cuts, pressure loss, excessive growth and security of balance weights/patches.

b) Examine wheels and brakes for cracks, other damage and fluid leaks.

c) Examine axles, struts and stays for distortion and other damage.

d) Check shock struts for fluid leaks, scoring and abnormal extension.

e) Examine landing gear attachments for signs of cracks, damage or movement. In some instances this may require removal of certain bolts in critical locations, for a detailed magnetic crack detection test.

f) Examine structure in the vicinity of the landing gear attachments for signs of cracks, distortion, movement of rivets or bolts and fluid leakage.

g) Examine doors and fairings for damage and distortion.

h) Jack the aircraft and carry out retraction and nose-wheel steering tests in accordance with the approved Maintenance Manual; check for correct operation of locks and warning lights, clearances in wheel bays, fit of doors and signs of fluid leaks.

2.6 **Mainplanes**

a) Examine the upper and lower skin surfaces for signs of wrinkling, pulled rivets, cracks and movement at skin joints. Inertia loading on the wing will normally result in wrinkles in the lower surface and cracks or rivet damage on the upper surface, but stress induced by wing-mounted engines may result in wrinkles on either surface.

b) Check for signs of fuel leaks and seepage from integral tanks.

c) Examine root end fillets for cracks and signs of movement.

d) Check flying controls for freedom of movement; power-controlled systems should be checked with the power off.

e) Check balance weights, powered flying control unit mountings and control surface hinges for cracks and the control surfaces for cracks or buckling.

f) Where possible, check the wing spars for distortion and cracks.

2.7 **Fuselage**

a) Examine fuselage skin for wrinkling or other damage, particularly at skin joints and adjacent to landing gear attachments and centre section.

b) Examine pressure bulkheads for distortion and cracks.

c) Examine, for distortion and cracks, the supporting structure for heavy components such as galley modules, batteries, water tanks, fire extinguishers, auxiliary power units, etc.

d) Check that the inertia switches for the fire extinguishers, emergency lights, etc., have not tripped.

e) Check instruments and instrument panels for damage and security.

f) Check ducts and system pipes for damage, security and fluid leaks.

g) Check fit of access doors, emergency exits, etc. and surrounding areas for distortion and cracks.

h) Check loading and unloading operation of cargo containers and condition of cargo restraint system.

i) Check gyroscopic instruments for erection time, precession and unusual noises.

2.8 **Engines**

a) Check engine controls for full and free movement.

b) Examine engine mountings and pylons for damage and distortion. Tubular members should be checked for bow greater than prescribed limits and cracks at welds. Mounting bolts and attachments should be checked for damage and evidence of movement.

c) On turbine engines check freedom of rotating assemblies and on piston engines check freedom of rotation with sparking plugs removed.

d) Examine engine cowlings for wrinkling and distortion and integrity of fasteners.

e) Check for oil, fuel and hydraulic fluid leaks.

f) Where applicable, check the propeller shaft for shock loading in accordance with the procedure in the Maintenance Manual.

g) Check propeller attachments and counterweight installations.

h) Check oil system filters/chip detectors.

2.9 Tail Unit

a) Check flying controls for freedom of movement.

b) Examine rudder and elevator hinges for cracks and control surfaces for cracks and distortion, particularly near balance weight fittings.

c) Examine tailplane attachments and fairings, screw jacks and mountings, for distortion and signs of movement.

2.10 Engine Runs

Provided that no major structural distortion has been found, engine runs should be carried out in accordance with the appropriate Maintenance Manual, in order to establish the satisfactory operation of all systems and controls. A general check for system leaks should be carried out while the engines are running and on turbine engines the run-down time should be checked.

2.11 Inspection of Damaged Areas

If any superficial damage is found during the preliminary inspection, the supporting structure should be examined for distortion, loose rivets, cracks or other damage and rigging and symmetry checks should be carried out; see Leaflet 6–5 to ascertain whether the damage has twisted or warped the main airframe structure. Where flying controls pass through supporting structure, cable tensions should be checked. On pressurised aircraft a cabin leak rate check should be carried out.

3 Burst Tyre Incidents

3.1 Tyre failures on large transport aircraft particularly wide-body types, have resulted in serious incidents and accidents. The principal problem is that if one tyre fails, its axle companion becomes overloaded and sometimes fails. If a tyre bursts during taxying, take-off or landing, fragments of the tyre may fly off the rotating wheel and cause damage to parts of the aircraft in line with the wheel disc. Where single wheels are employed, more serious damage may occur through the wheel rolling on the paved runway and transmitting shocks to the landing gear leg and supporting structure. Multiple wheel landing gears will generally be less seriously affected by a single burst tyre, but the axles, bogies, torque links or steering mechanism may become bowed or strained as a result of the effects of uneven loading. In some cases extensive damage, including fire, has resulted from tyre and wheel degradation and there has been an attendant reduction in braking performance.

3.2 In most cases the wheel on which the burst occurred will generally be damaged and must be returned for overhaul. In addition, the following inspections should be carried out:

a) Examine for damage, the wheels and tyres which have not burst.

NOTE: Where one of the tyres on a multi-wheel undercarriage has burst, it may be specified that all tyres on that leg or axle should be discarded, or removed for detailed examination.

b) Examine the brake units on the affected leg for damage. On those wheels which are not fitted with fusible plugs, the tyre burst may have resulted from overheating caused by a binding brake and when the replacement wheel is fitted attention should be given to the operation of the associated brake including, in particular, freedom of rotation of the wheel with brakes released.

c) Examine the landing gear bay for damage and hydraulic fluid leaks.

d) Examine the affected leg, including pipelines, operating jacks, etc., for damage and hydraulic fluid leaks.

e) Inspect the supporting structure and attachments of the affected leg, for cracks, warped panels and loose rivets. In some instances it may be specified that certain highly-stressed bolts in the supporting structure or retraction mechanism should be removed for non-destructive crack detection tests.

f) Examine the adjacent fuselage or wing skinning and landing gear doors, for damage.

g) Check rear-mounted engines for possible ingestion of debris.

4 Tyre Explosion

4.1 The majority of in-flight tyre bursts have been attributed to the tyre carcass being weakened by foreign object damage, scuffing, etc., such that a rapid release of pressure takes place. Such failures are usually experienced when the gear has been retracted for some time and the effects of brake heat transfer, internal tyre temperature and differential pressure are combined. However, a tyre inflated with air and subjected to excessive heating, possibly caused by a dragging brake, can experience a chemical reaction resulting in release of volatile gases. Such a chemical reaction in the presence of the oxygen in the contained air may result in a tyre explosion in a landing gear bay and/or an in-flight fire since it appears that the protection normally afforded by conventional pressure relief devices in the wheel would be incapable of responding adequately to the rapid increases in temperature and gas pressure associated with auto-ignition.

4.2 Laboratory material and tyre burst testing indicated that the risk of auto-ignition could be reduced by using an inert gas for tyre inflation and servicing. Accordingly, Airworthiness Notice No. 70 (since transferred to CAP 747 Mandatory Requirements for Airworthiness as Generic Requirement (GR) No. 16) was issued prescribing that all braked wheels of retractable landing gear units on aeroplanes exceeding 5700 kg will be required to have tyres inflated with Nitrogen, or other suitable inert gas, and maintain such as to limit the Oxygen content of the compressed gases to not greater than 5% by volume.

4.2.1 Other potential benefits may accrue from the use of Nitrogen as it will tend to reduce wheel corrosion, tyre fatigue and the risk of fire when fusible plugs melt due to brake overheating.

4.2.2 At airfields where suitable inert gases are not normally available, it is acceptable to use air for inflation or servicing provided that a suitable entry is made in the aeroplane Technical Log and that the tyre is reinflated or serviced in accordance with the agreed procedure at the earliest opportunity or within 25 flight hours, whichever is the sooner.

5 Flight Through Severe Turbulence

5.1 If an aircraft has been flown through conditions of severe turbulence, the severity of the turbulence may be difficult to assess and report upon, but an indication may be obtained from the accelerometers or fatigue meters fitted to some aircraft. However, these instruments are designed to record steady loads and force peaks recorded during flight through turbulence may be exaggerated due to instrument inertia and should not be taken as actual loads. Generally, if readings exceeding –0·5 g and +2·5 g are recorded on transport aircraft, then some damage may be found. With other types of aircraft (e.g. aerobatic or semi-aerobatic), accelerometers and fatigue meters are seldom fitted and reported flight through turbulence should always be investigated.

5.2 Severe turbulence may cause excessive vertical or lateral forces on the aircraft structure and the effects may be increased by the inertia of heavy components such as engines, fuel tanks, water tanks and cargo. Damage may be expected at main assembly points such as the wing-to-fuselage joints, tail-to-fuselage joints and engine mountings. Damage may also occur in those areas of the wings, fuselage, tailplane and control surfaces where the greatest bending moment takes place, i.e. part way along their length and may be indicated by skin wrinkles, pulled rivets or similar faults.

5.3 An inspection for damage, after a report of flight through severe turbulence, should include the inspections detailed in paragraph 2, except, in most cases, those covering the landing gear.

NOTE: Further dismantling and, in some cases, removal of some portions of the skin, may be necessary in order to inspect supporting structure where skin damage has been found.

6 Lightning Strikes

6.1 Lightning is a discharge of electricity between highly charged cloud formations, or between a charged cloud and the ground. If an aircraft is flying, or on the ground in the vicinity of such a cloud formation, the discharge may strike the aircraft and result in very high voltages and currents passing through the structure. All separate parts of an aircraft are electrically bonded together to conduct a lightning strike away from areas where damage may hazard the aircraft, e.g. fuel tanks or flying controls and during manufacture special precautions are often taken with non-metallic components such as wing tips, external fuel tanks and nose cones.

6.2 Lightning strikes may have two effects on an aircraft; strike damage where the discharge enters the aircraft and static discharge damage subsequent to the strike. Strike damage is generally found at the wing tips, leading edges of wings and tail unit and at the fuselage nose, but on some aircraft types other areas may be particularly susceptible and this information should be obtained from the appropriate Maintenance Manual. Static discharge damage will usually be found at wing tips, trailing edges and antennae.

6.3 Strike damage is usually in the form of small circular holes in the exterior skin, either in clusters or spread out over a wide area and often accompanied by burning or discolouration, blisters on radomes and cracks in glass fibre. Static discharge damage is usually in the form of local pitting and burning at trailing edges.

6.4 Inspection

Since both lightning and turbulence occur in thunderstorms, an inspection for lightning damage will often coincide with an inspection following reported flight through severe turbulence. The areas stated in paragraph 6.2 should be examined for signs of strike or static discharge damage and bonding strips and static discharge wicks should be examined for burning and disintegration. All control surfaces, including flaps, spoilers and tabs, should be inspected for damage at their hinge bearings; unsatisfactory bonding may have allowed static discharge and tracking across the bearings, causing burning, break-up or seizure. A check for roughness and resistance to movement at each bearing, will usually indicate damage at such points. In addition, the following inspections should be carried out:

a) Examine engine cowlings and engines for signs of burning or pitting. If a lightning strike is evident, tracking through the bearings may have occurred and some manufacturers recommend that the oil filters and chip detectors should be examined for signs of contamination; this check should be repeated periodically for a specified number of running hours after the occurrence.

b) Examine the fuselage skin and rivets generally, for burning or pitting.

c) If the landing gear was extended when the lightning strike occurred, examine the lower parts of the gear for static discharge damage. Check for residual magnetism and demagnetise where necessary.

6.5 The inspections outlined in paragraph 6.4 should be followed by functional checks of the radio and radar equipment, instruments, compasses, electrical circuit and flying controls, in accordance with the relevant chapters of the approved Maintenance Manual. On some aircraft a bonding resistance check on radomes may also be specified.

7 Damage from Jet Blast

7.1 Considerable damage may be caused to an aircraft through the action of another aircraft turning or taxying in the vicinity. The damage may be caused by blast or impact from debris and may be particularly severe in the case of light aircraft.

7.2 Flying control surfaces should be inspected for distortion, particularly where they were unlocked and may have been driven hard against their stops.

7.3 An inspection for impact damage in the form of skin dents and cracked or chipped windscreens or windows, should be made and the air intakes for engines, heat exchangers, etc., should be examined for debris which may have blown into them.

7.4 With light aircraft, further inspections may be necessary to ensure that no structural damage has been sustained, particularly when the jet blast has been sufficiently strong to move the whole aircraft.

8 Helicopters

8.1 The inspections necessary on helicopters following unusual occurrences, are broadly similar to those detailed in the preceding paragraphs, but additional checks are normally specified for the main rotor blades, head and shaft, tail rotor and transmission, following heavy landings or flight through severe turbulence. Inspections are also required following overspeeding of the rotors. The inspections outlined below are typical.

8.2 Heavy Landings or Flight Through Severe Turbulence

8.2.1 Rear Fuselage or Tail Boom

Examine for evidence of strike damage from the main rotor blades and if damage is found check for cracks, security and symmetry.

8.2.2 **Main Rotor Blades**

Remove the rotor blades and examine them for twisting and distortion. Check the surface for cracks, wrinkles, or other damage and check the security of the skin attachment rivets or structural bonding. If the main rotor blades are badly damaged through impact with the tail boom or ground, certain components in the transmission may be shock-loaded and it is sometimes specified that, for example, the main rotor shaft, pitch change rods and main gearbox mounting bolts, should also be removed for inspection.

8.2.3 **Main Rotor Head**

Disconnect pitch change rods and dampers and check that the flapping hinges, drag hinges and blade sleeves move freely, without signs of binding or roughness. Examine the rotor head and blade stops for cracks or other damage and the dampers for signs of fluid leaks. Damage in this area may be an indication of further damage inside the main gearbox.

8.2.4 **Tail Rotor**

Examine the blades for damage and security and the coning stops for evidence of damage. Damage to the tail rotor blades which is beyond limits, will normally entail either inspection or replacement of the hub, pitch change links, tail rotor gearbox and drive shaft.

8.2.5 **Skid Type Landing Gear**

With the helicopter jacked clear of the ground, check cross tubes for excessive bowing, fasteners for integrity and security and abrasion plates for wear. Where Float Gear is fitted, check for leaks, fabric scuffing and integrity of attachment straps.

8.3 **Rotor Overspeeding**

The extent of the inspection will normally depend on the degree of overspeeding. Overspeeding below a specified limit will usually entail checking the rotor blades for distortion and damage and the rotor head for cracks and smooth operation, but, if this limit is exceeded it is usually specified that both the main rotor head and tail rotor head should be removed for overhaul. If damage has occurred to the main rotor blades, the rotor head, shaft, pitch control rods, tail rotor and transmission should also be removed for overhaul and the gearbox attachments should be inspected for damage.

9 Other Occurrences

Occurrences not covered in the preceding paragraphs, or peculiar to a particular aircraft type, may necessitate a special inspection and this is often specified in the appropriate Maintenance Manual. Where no specific instructions exist, experience on the type of aircraft, combined with a knowledge of the structure and stress paths, will normally enable a satisfactory inspection to be carried out. As an example, if the flap limiting speed has been exceeded, the flaps should be examined for twisting and buckling, the hinge brackets on the wings and flaps should be examined for damage such as cracks and strained attachment rivets and bolts and the operating mechanism should be examined for general distortion, bowing, cracks and security. Provided these checks are satisfactory and operation of the system reveals no evidence of malfunction, or excessive friction, then the aircraft may be considered airworthy.

Leaflet 6-4 Repair of Metal Airframes

1 Introduction

1.1 This Leaflet gives general guidance on repairs to the structure of metal aircraft and should be read in conjunction with the relevant approved publications.

1.2 Repairs must be carried out in accordance with the appropriate Repair Manual or approved repair drawings relative thereto, in conjunction with any other related information contained in other documents recognised or approved by the CAA.

NOTE: For American manufactured general aviation aircraft, where specific repair manuals or repair documentation is not available, the FAA publication 'Advisory Circular AC 43.13–1A Acceptable Methods and Techniques–Aircraft Inspection and Repair' may be used for guidance.[1]

1.3 Chapter A6–7 for UK Manufactured Aircraft and B6–7 for Foreign Manufactured Aircraft of British Civil Airworthiness Requirements (BCAR) prescribes that in the case of structural repairs to aircraft where the repairs are of a major nature or not covered in the particular approved manual, the approved organisation or the appropriately licensed aircraft maintenance engineer concerned should advise the nearest CAA area office of the nature of the repair or repairs before work commences (see Airworthiness Notice No. 29 for addresses). Repair schemes not previously approved by the CAA will normally be investigated as modifications in accordance with the procedures in BCAR Chapter A2–5 or B2–5 for Foreign Manufactured Aircraft.

2 Preparation for Repair

2.1 General

Details of the inspections necessary before repair and the methods of assessing the extent of damage, supporting the structure, checking alignment and geometry and assessing allowance for dressing of damage and limits of wear are generally given in the Repair Manual.

2.1.1 In the case of damage not covered by the Repair Manual but which, nevertheless, is thought to be repairable, a suitable repair scheme can often be obtained by application to the aircraft manufacturer (or to a Drawing Office holding the appropriate Design Approval). When supplying information of the damage to the manufacturer, photographs showing details of the damage are often helpful and may save both time and expense.

2.2 Preliminary Survey of Damage

A preliminary survey enables the damage to be classified (e.g. negligible, repairable or necessitating replacement) and a decision to be made as to the preparations necessary before commencing the repair. How the aircraft was damaged or overloaded should be determined as accurately as possible and perusal of the flight crew's or engineering staff's accident report will give guidance to the necessary checks.

2.2.1 Structure distortion which can be evident at the site of the incident, may not be apparent when the aircraft is lifted and the locally imposed loads have been removed. Therefore, the aircraft should normally be inspected on the site where the damage

1. Obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, U.S.A.

occurred and the damage and distortion plotted on a station chart and ideally photographed before the aircraft is moved, providing a valuable indicator as to areas that require a more detailed inspection.

2.2.2 Depending on the results of the preliminary survey, the expected duration of the repair work and the precautions necessary as a result of local conditions, it may be necessary (among other things) to remove the batteries, drain the fuel system and/or inhibit the engines.

2.3 **Supporting the Aircraft**

If the aircraft requires lifting to facilitate the repair operations or supporting to avoid distortion of structural parts during dismantling, the aircraft should preferably be placed in the rigging position (see Leaflet 6–5). To ensure that the aircraft has not moved during the progress of the repair a daily check should be carried out by a responsible person, such checks being based on inspections to ensure that seals placed on jacks have not broken and, at the other end of the range, theodolite checks carried out against established references.

2.3.1 Trestling and jacking equipment is usually designed for this operation by the aircraft manufacturer and will facilitate any alignment, rigging or functioning checks necessary during or after repair. With large aircraft it is essential to follow the jacking instructions laid down by the aircraft manufacturer and to use the recommended equipment. The jacks used for these aircraft are usually fitted with a pressure gauge, so that each jack load can be calculated during the lifting operation. In some cases extension and retraction of all jacks used in a lifting operation are controlled from a central source

NOTE: If the fuel system is not drained, the maximum permissible jacking weight should be verified before lifting.

2.3.2 **Additional Support**

In some instances it may be necessary to provide additional support or temporary bracing in order to prevent distortion or movement of the airframe during removal of primary structure such as stressed skin and other load bearing panels; this is usually provided by means of adjustable trestles and/or jury bracing devices.

2.3.3 **Adjustable Trestles**

Adjustable trestles are often made up from specially designed sets of steel members which can be bolted together to form trestles of various sizes. The sets usually contain top cross-beams, adjustable at each end by means of screw jacks, which can be fitted with wooden formers shaped to the contour of the structure they are required to support. To avoid damage to the structure, the formers should be lined with a layer of felt or similar cushioning material, which must be dry and free from extraneous matter (particularly swarf) and covered with polythene sheeting. Rubber should not be used for lining.

a) Prior to use, the trestles should be checked for correct assembly and it is important to ensure that the maximum permissible load will not be exceeded.

b) Trestling positions or 'strong points' where trestles may be positioned are given in the Maintenance and Repair Manuals and may also be stencilled on the aircraft. The positioning of the trestles in relation to these points should be carefully supervised, since supporting an aircraft at other than recognised load-bearing positions may result in considerable damage.

2.3.4 When adjustable trestles or jacks are being used to support a structure during repair, the adjusting mechanism, controls, etc., of such should be locked to prevent inadvertent movement whilst repairs are in progress.

2.3.5 **Jury Structures**

Special bracing devices, often referred to as 'Jury' structures, are sometimes needed to take the loads carried by structural parts before they are removed or cut for repair purposes. A jury structure may consist of no more than a length of timber cramped or bolted to the structure, or it may be a specially made strut or jig designed to prevent movement and distortion by holding various key points of the structure in their correct positions. When such devices are made up locally, it must be ensured that they conform in every way with the requirements of the Repair Manual, especially with regard to strength and accuracy of dimensions.

2.4 **Alignment and Geometry Checks**

In instances where the airframe has sustained unusually high loading, structural distortion may have occurred. Although in most instances there will be visual evidence (e.g. skin wrinkling, cracking of paint at the joints of structural members, loose rivets, etc.), this is not always the case and alignment and geometry checks should be made. Similarly, if the aircraft has been damaged by impact, malalignment and distortion of the structure may have occurred in areas remote from the initial impact point in addition to the damage which may be clearly visible at the impact point.

2.4.1 The control and structural integrity of an aircraft are, to a large extent, dependent on the correct alignment of its separate components, not only in themselves but in their relationship one to another and malalignment may result in the imposition of stresses of such magnitude that a premature structural failure could occur. It is therefore essential that alignment is checked before, during and after repair work and guidance on this is given in Leaflet 6–5.

2.5 **Cleaning**

When the structure requires cleaning, this should be carefully supervised, otherwise useful evidence may be lost (e.g. the products of corrosion will help in locating corroded parts and the presence of a dark dusty substance at a structural joint will indicate fretting). Where mud, oil or other extraneous matter has to be removed, the cleaning solutions should be those given in the Repair or Maintenance Manual. Where a fire has occurred, it is important to remove all traces of fire extinguishant and smoke deposits as soon as possible, as some of these products promote rapid corrosion.

2.5.1 It is important that the cleaning fluids specified in the manual are used in the strengths recommended and in applications where their use has been specified. Cases have arisen where cleaning fluid in combination with kerosene has had a deleterious effect on aircraft structure, the penetrating quality of kerosene promoting seepage into skin joints. Such cases are particularly troublesome and it becomes difficult to diagnose the cause of corrosion. Unspecified cleaning fluids may contaminate or destroy pressure cabin and fuel tank sealing media and should not be used.

3 Inspection Before Repair

Structural damage can result from a variety of causes, such as impact, corrosion, fatigue, fire and overloads due to heavy landings or turbulence. In every case careful inspections must be made to ascertain the full extent of the damage and to ensure that other damage not necessarily associated with the particular incident is also rectified. The applicability of all repair schemes involved should be established as soon as possible by reference to the Repair Data, so that if none is given to cover the case in point, delay is avoided in making application to the aircraft manufacturer for a suitable scheme. Guidance on the nature of the inspections to be made and subsequent repairs is given in the following paragraphs.

3.1 Cracks

Care should be taken that cracks, however minor they appear to be, are not overlooked. Where visual inspection is not completely satisfactory, especially at points of concentrated stress, one of the methods of non-destructive examination described in the Part 4 series of Leaflets should be used.

3.2 Corrosion

Particular attention should be given to evidence of corrosion.

3.3 Scores and Abrasions

Where a score or abrasion in a stressed part is within the limits specified in the Repair Data for blending out into a smooth surfaced shallow depression, it is often necessary to submit the part to one of the non-destructive testing processes described in the Part 4 series of Leaflets. This will ensure that minute cracks are detected and included in the assessment of damage.

3.4 Bolted Joints

Checks should be made on all bolted joints in the locality of the damaged area, or where overstressing is suspected, for evidence of bolt and associated hole damage. Where no obvious sign of movement is detected, sample inspection by removal of bolt(s) is often advised. (For bolted joint inspection see also Leaflet 6–7).

3.5 Skin Panels

3.5.1 Where buckling of a skin panel is apparent, a careful check of the area and related structure should be made for loose bolts, loose or sheared rivets, cracks and distortion. This should include any remote positions where the loads induced by the particular incident may have spread. In some instances where buckling is within limits specified in the Repair Manual, schemes are provided for fitting a strengthening member, otherwise a new panel should be fitted after any associated structure has been repaired.

NOTE: Loose rivets are often indicated by grey or brown stains around the head.

3.5.2 Where denting in skin panelling is in the form of a smooth and fairly circular depression and no other damage is present, it may in some cases, be considered negligible provided the ratio between the depth and area of the depression is within the limits given in the Repair Data. For example, if a depression of 1·2 mm (0·05 in) is within the limits of the depth permitted, then provided the smallest linear dimension across the depression is not less than fifteen times the depth of the depression the damage may be considered negligible. In the example given above the smallest linear dimension permitted would be 1·2 mm x 15 = 18 mm (0·05 in x 15 = 0·75 in).

3.6 Internal Inspection

The internal inspection of a structure is particularly important since damage or defects can often be present without any outward indication. In instances where the damage is extensive, the whole structure should be inspected. Guidance on the internal inspection of structures, together with the various aids which may be used to facilitate the inspection, is given in Leaflet 6–2, which should be read in conjunction with this Leaflet.

NOTE: In areas where sealants are used (i.e. integral tanks and pressure cabins), structure inspection is made more difficult and it may be necessary to remove the sealant at sample areas to ensure that the structure is free from damage. The sealant should be removed using only the solvent specified and eventually restored strictly in accordance with the instructions given in the relevant manual or repair scheme.

3.7 Removal of Damage

In some instances it will be necessary to cut away the damaged material and dress back the surrounding structure. Although it should be ensured that no more material than is necessary is removed, it is necessary to make sure that the adjacent structure to which the repair is to be applied is in a sound condition.

3.7.1 When removing riveted structure, care must be taken not to damage those rivet holes which are to be used again (e.g. by burring, enlargement or undercutting) since circular, smooth-edged holes are essential if the risk of failure by fatigue is to be kept to a minimum.

NOTE: A method widely used for removing rivets is to centre-punch the middle of the preformed rivet head and then, using a drill equal in diameter to that of the rivet, drill only to the depth of the rivet head. The area surrounding the rivet should then be supported on the reverse side and the rivet punched out with a parallel pinpunch slightly smaller in diameter than the rivet.

3.7.2 Bolt holes should be treated with equal care, it being particularly important that the holes in stressed parts should be free from scores or burrs. Where necessary, bolts should be eased with penetrating oil before extraction but it is also necessary to ensure that the oil does not damage adjacent sealing media. Bolts on which the nuts were locked by a peening over process must have the burrs removed to remove the nuts and these bolts must not be used again.

NOTE: A check should be made to note whether the structure 'springs' as bolts are withdrawn. If this occurs interchangeability fixtures should be used when rebuilding the structure to ensure correct alignment and prevent the introduction of locked-in stresses.

3.7.3 When damaged panels are to be removed by cutting (i.e. not by dismantling at a production joint) all edges must be free from burrs and notches and trimmed to a smooth finish. It is important that the corner radii of stressed panels are correct and that the dimensions and locations of cuts are within the limits specified in the repair drawing.

3.7.4 Special care is necessary when damaged parts are removed by cutting, to ensure that the remaining structure or material is not damaged by drills, rotary cutting tools, hack-saw blades, etc.

3.7.5 Repairs in pressure cabin and integral fuel tank areas may involve separation of members riveted and sealed together. Some sealants have considerable adhesion and may cause difficulty in separating the members after the rivets have been removed. Where such separation is necessary, the solvents specified and methods of separation detailed in the Repair or Maintenance Manual must be strictly followed.

NOTE: After repairs in a pressurised area or a fuel tank, either a leak test or a pressure test may be specified in the appropriate manual.

3.8 **Wear**

Where holes are found to be elongated by stress the part must be renewed. However, if elongation is due to wear and is beyond the limits permitted by the Repair Manual, rectification schemes are usually given.

3.8.1 The corresponding pin or bolt assemblies should be inspected for wear, distortion, 'pickingup' and shear and where necessary renewed. Lubricating ducts should be checked for obstruction.

3.8.2 Where bushed holes are fitted it is usual to renew the worn bush, but where the hole in the fitting has become enlarged so that the new bush is loose, a repair scheme is usually available for reaming out the hole and fitting an oversize bush.

3.8.3 When excessive wear has taken place in unbushed holes the fitting should be renewed unless there is an approved scheme available whereby the hole can be reamed oversize and a bush fitted; in some cases an oversize bolt or pin may be specified.

3.8.4 Wear in ball and roller bearings should be checked.

3.9 **Fire Damage**

It is extremely difficult to assess the damage caused to a structure which has been exposed to an abnormally high temperature, since apart from the more obvious damage, such as buckling, the mechanical properties of some of the light alloys may be adversely affected, without any apparent indication. In some instances non-blistering of the paint is a good guide that temperatures have not been unduly high but this cannot be taken as a general rule.

3.9.1 In some cases an eddy current test can determine the extent of fire or heat damage by measuring the change in conductivity in the material (see Leaflet 4–8), but where doubt exists, sample portions of panels, ribs or frames should be cut out for mechanical testing by an approved test house. Where it is not possible to remove such samples the advice of the aircraft manufacturer should be sought.

3.9.2 It is generally necessary to renew any parts made from magnesium, plastics or rubber which were in the vicinity of a fire. This applies, for example, to the bag type of fuel tank in contact with a tank bay wall, the other side of which was affected by the fire.

3.10 **Damage by Lightning**

In a properly bonded aircraft, lightning damage is not usually of a major character and can generally be rectified by the application of one of the standard repairs. However, it is important to note that because of the unpredictable nature of the damage it is important to make a thorough inspection of the whole aircraft, its engines, systems and equipment. The most common form of damage is numerous small burns or punctures in the skin of the aircraft, or the disintegration or burning of non-metallic materials on the exterior, e.g. radomes, radio aerial covers and navigation light covers.

3.10.1 Where a control surface has been struck, the bearings and hinges should be checked for pitting and/or stiffness due to the passage of the lightning discharge and all control surfaces should be checked for full and free movement.

3.10.2 The bonding of the aircraft should be checked as described in Leaflet 9–1.

3.10.3 The compasses may have been affected by the magnetising of steel parts near to them and should be check swung. If the compasses are found to be affected, a landing compass should be used to locate the disturbing magnetic fields and steel parts found to be magnetised should be demagnetised, as described in Leaflet 4–7.

3.10.4 When a structure is de-magnetised, the compasses and any instruments having permanent magnets in their mechanisms should be temporarily removed from areas in which degaussing is being carried out.

3.11 **Repair Report**

A report detailing all the repair work and the procedures involved should be compiled. The details of the rectification work necessary should be based on approved repair schemes, the reference numbers and any other relevant details of which should be quoted.

3.11.1 In addition, the report should record any maintenance work, such as mentioned in paragraph 3.8, which could usefully be carried out during the repair work, since this may obviate the need for further dismantling after a relative short period.

3.11.2 According to the nature of the repair, stage inspections will be necessary during the progress of the repair work (e.g. inspection of rivet or bolt holes, inspection of structures before covering for workmanship, protection, security, locking of screw-threaded parts and duplicate inspection of controls. These inspections should be listed on an Inspection Record Sheet in a sequence related to the repair report and should give details of the inspection required.

NOTE: Before any disturbed parts of the aircraft or engine control systems are concealed, they must be inspected in duplicate as prescribed in BCAR Section A, Chapter A6–2, or Section B, Chapter B6–2 for foreign manufactured aircraft.

4 Repairs

A repair to a stressed structure usually involves the removal of damaged panels, the complete or partial removal of structural members such as frames, ribs and stringers and the rebuilding of the structure in accordance with the repair scheme. The particular procedure involved will obviously vary with the design of the aircraft but paragraphs 4.1 to 4.3 cover the general aspects of a repair.

NOTE: If the repair is at all extensive it is often advantageous to have the approved repair drawings duplicated and displayed at the site of the repair.

4.1 Materials used for the repair should be checked for correct specification and gauge thickness and, where applicable, heat treated in accordance with specification requirements.

4.2 On completion of bending or forming operations the material must be free from defects such as scratches, scribe marks, hairline fractures on the outside of bends, cracks at edges adjacent to bends, tool marks, twisting and warping.

NOTE: Complete detail parts must be manufactured by suitably Approved Organisations in accordance with the appropriate drawings. The holder of an Aircraft Maintenance Engineer's Licence in Category B is not authorised to certify the manufacture of aircraft parts.

4.3 Where panels are concerned, care is necessary to prevent buckling and distortion, particularly in the case of large panels, which should be allowed to attain the ambient temperature of the repair site before being fitted. Where the application of heat (e.g. by means of an electric blanket) during the fitting of a panel is specified, it is important that the heat application and control should be strictly in accordance with the requirements of the applicable Repair Data.

4.3.1 In some instances the aircraft manufacturer may provide preformed and partially built-up parts for incorporation into the repair (e.g. sections of leading edge fitted with nose ribs, panels fitted with stringers, saddle pieces, bridging joints in stringers, etc.) and it should be ensured that such parts are correctly identified and bear evidence of prior inspection.

4.3.2 Particular attention should be given to the drilling of holes, which should be circular and free from scores and sharp edges in order to satisfy design requirements. In some cases it may be specified or recommended that holes in stressed parts should be drilled with a drill reamer, or drilled and then reamed to size. It is also important that drills are sharpened correctly so as to produce the intended hole diameter; a drill running off-centre will produce an oversize hole.

4.3.3 Where existing rivet holes are to be used again, repair schemes may often call for special repair rivets to be used. These rivets have a slightly larger shank diameter but the same size head. However, when necessary (e.g. due to hole damage), the use of rivets the next size larger than the original may be permitted, in which case it should be ensured that the landing limits between the new rivets and the sheet edge or other rivets are maintained. In instances where blind rivets are used it is usually necessary to replace the original rivet by the next size larger and the same precautions regarding landing limits apply.

4.3.4 With some repair schemes the method of riveting may be very similar for a wide range of applications, but may vary in detail according to the location of the repair (e.g. the type of rivet or the pitch may vary). Similar variations may also apply to the type of jointing compound used (e.g. in pressurised areas) and to the protective treatment required. The repair drawing should therefore be studied very carefully for any special instructions.

4.3.5 Care is necessary, particularly with large repairs, in keeping swarf out of places where it may present a hazard. This applies to joints, wiring looms, exposed moving surfaces (e.g. jack rams and pulley assemblies) and unsealed bearings, all of which should be protected before work is commenced. When drilling through laminations or lap joints which cannot subsequently be separated for cleaning, it is essential to ensure that the parts comprising the joint are held firmly together during the drilling operation.

4.3.6 Before assembling a joint it should be ensured that the contacting surfaces are clean and free from swarf and that all holes and edges are deburred. If specified, jointing compound should be applied evenly before final assembly and riveting and should form a fillet at the edges of the joint when assembly is complete. The manufacturer's instructions regarding the mixing, working and curing time of the jointing compound should be carefully followed.

4.3.7 Guidance on the assembly of bolted joints is given in Leaflet 6–7.

4.3.8 When repairs have been made to control surfaces, the balance may have been upset by the additional weight of metal or paint. Such surfaces should be checked for balance by the method given in the appropriate manual and the balance corrected as necessary. For reasons of balance the repairs permitted on control surfaces are often limited in area and position.

5 Metal-to-Metal Adhesive

5.1 Since a metal adhesive often requires special heating and pressing equipment, its use may be impracticable for repair work. The damaged part should therefore be cut out as shown in the approved Repair Scheme and a new part riveted in position.

5.2 It is possible, however, in certain large repairs to obtain from the aircraft manufacturer a built-up section or pre-formed skin panel with parts secured in position by adhesive.

The repair then consists of removing the damaged section complete and riveting the replacement section into position.

5.3 When it is necessary to remove parts which are secured with adhesive, e.g. a stringer, this can be done as shown in Figure 1. Care should be taken to avoid damaging any parts or material other than those to be removed.

NOTE: When paint is removed in the area of a metal-to-metal adhesive joint, only the paint stripper stipulated should be used. Some strippers may have a deleterious effect on metal-to-metal adhesives.

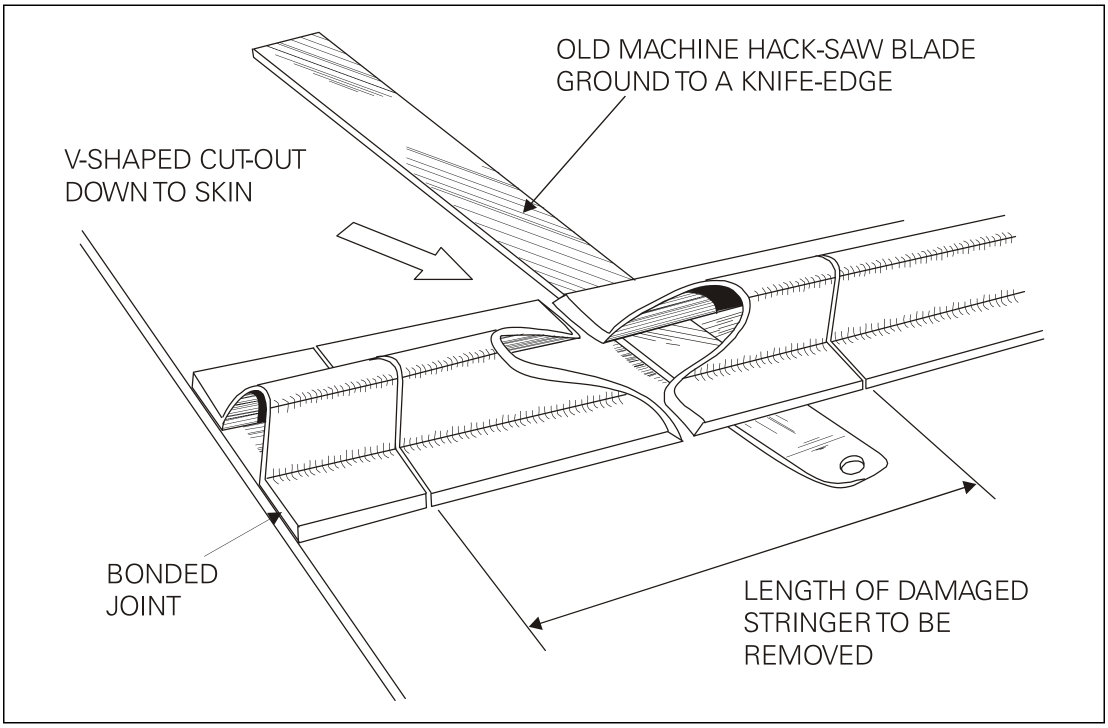

Figure 1 Removal of Bonded Component

6 Repairs by Welding

Repairs by means of welding are often specified for welded structures such as landing gear structures, engine mountings, etc. The welding procedure to be used will depend on the design and manufacture of the structure and will be fully detailed in the Repair Data. It will often be necessary to use jigs or jury structures to ensure that the main structure is held in the correct position during welding.

6.1 Welding Procedures

Some of the welding procedures most commonly used for aircraft repairs are the following: Oxy-Acetylene Welding, Arc Welding and Spot Welding.

6.1.1 As prescribed in Chapter A8–10 of BCAR, welders must be approved by the CAA.

6.1.2 Where highly stressed components have been repaired by welding they should be submitted to one of the non-destructive examination tests outlined in the Part 4 series of Leaflets.

6.1.3 Before welding is commenced any protective treatment in the area of the repair must be completely removed and the parts prepared in accordance with the repair scheme applicable.

6.2 **Typical Oxy-Acetylene Welding Repairs**

The oxy-acetylene welding technique is more widely used than any of the other methods and in the following paragraphs a brief outline of some oxy-acetylene welding repairs is given.

6.2.1 **Welded-Patch Repair**

This type of repair illustrated in Figures 2 and 3 is often used for rectifying such damage as cracks, dents, or holes in tubes, provided certain limitations are not exceeded.

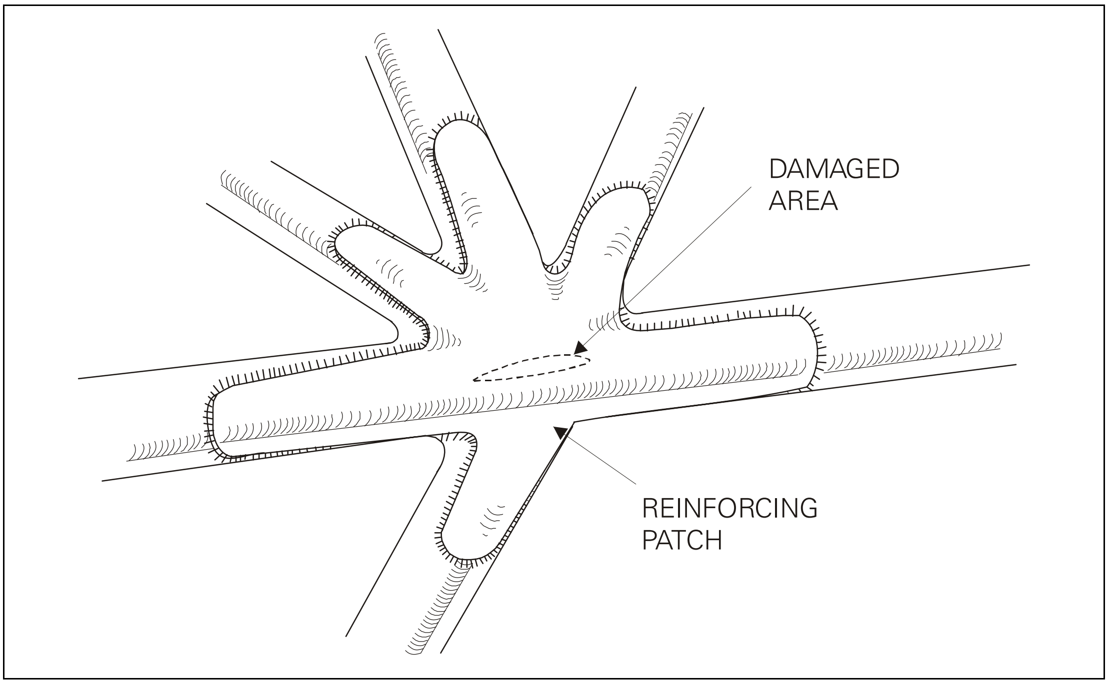

Figure 2 Patch at Tube Joint

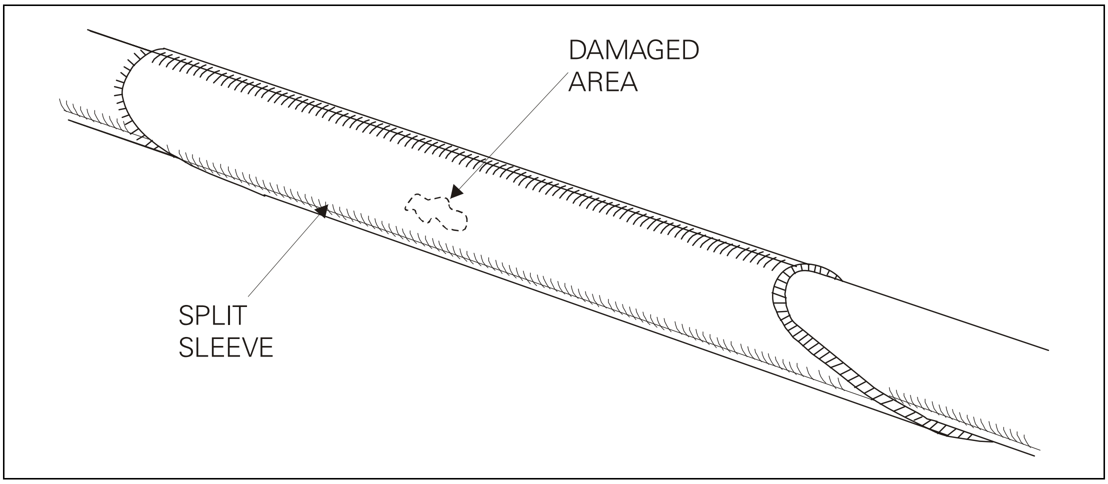

Figure 3 External Sleeve Repair

6.2.2 **Partial Replacement – Inner Sleeves**

Fairly extensive damage to a tube is often repaired by the use of an inner sleeve splice as shown in Figure 4.

a) The condition and location of the associated structure should be checked and secured to prevent movement when the damaged portion is removed.

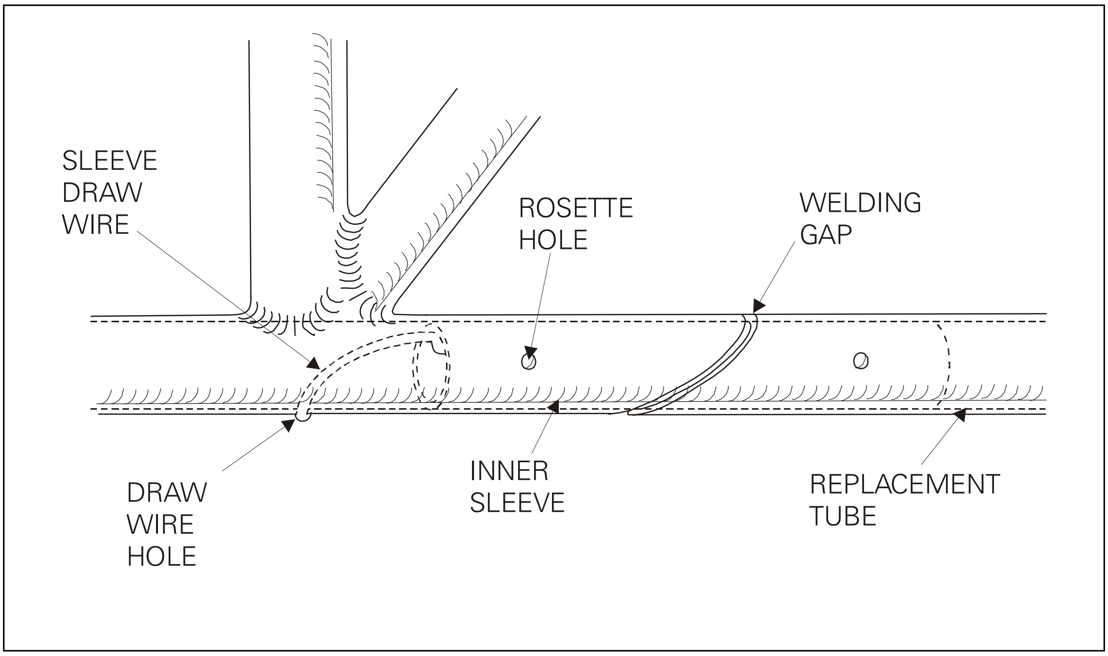

Figure 4 Internal Sleeve Repair

b) The damaged portion of the tube should be cut out using 30° or 45° diagonal cuts and the burrs inside the tube should be removed.

c) A replacement piece of tube should be cut to fit where the damaged portion was removed and a gap of approximately 2·4 mm ($^3/_{32}$in) should be left for welding.

d) The inner sleeves should be cut to length and a check made to ensure that they slide smoothly in both tubes. If rosette holes are required they should next be cut and the burrs removed; when a draw wire is required it should be welded into position.

e) The inner sleeves should be marked at the half-way position, fitted into the replacement tube and positioned with the midpoint at the diagonal cut.

f) The repair should be completed by welding at the diagonal cuts and at the rosette holes or the draw wire hole as applicable.

6.3 **Partial Replacement – Outer Sleeves**

This method should only be used where it is impracticable to use inner sleeves. The procedure is basically the same as for inner sleeves except that the replacement tube should be cut square at both ends and the outer sleeves scarfed at 30° or 45°.

6.4 **Protective Treatment**

After welding, the parts concerned should be thoroughly descaled, cleaned and the protective treatment restored.

7 Gauging Damage

7.1 Where a score, dent, or corrosion damage in a stressed part has been removed by blending out into a smooth surfaced hollow depression, the maximum depth of the depression will have to be measured to ensure that it is within the limits given in the Repair Data. This should be done before applying any protective treatment.

7.1.1 A method of gauging the depth of such a depression is by mounting a dial test indicator on a special adaptor block as illustrated in Figure 5. The bottom edge of the block should be straight and radiused to about 1·2 mm (0·05 in) and the dial test indicator (DTI) stem should be at right angles to this edge. The point of the conical anvil should be lightly stoned to avoid scratching the surface of the depression.

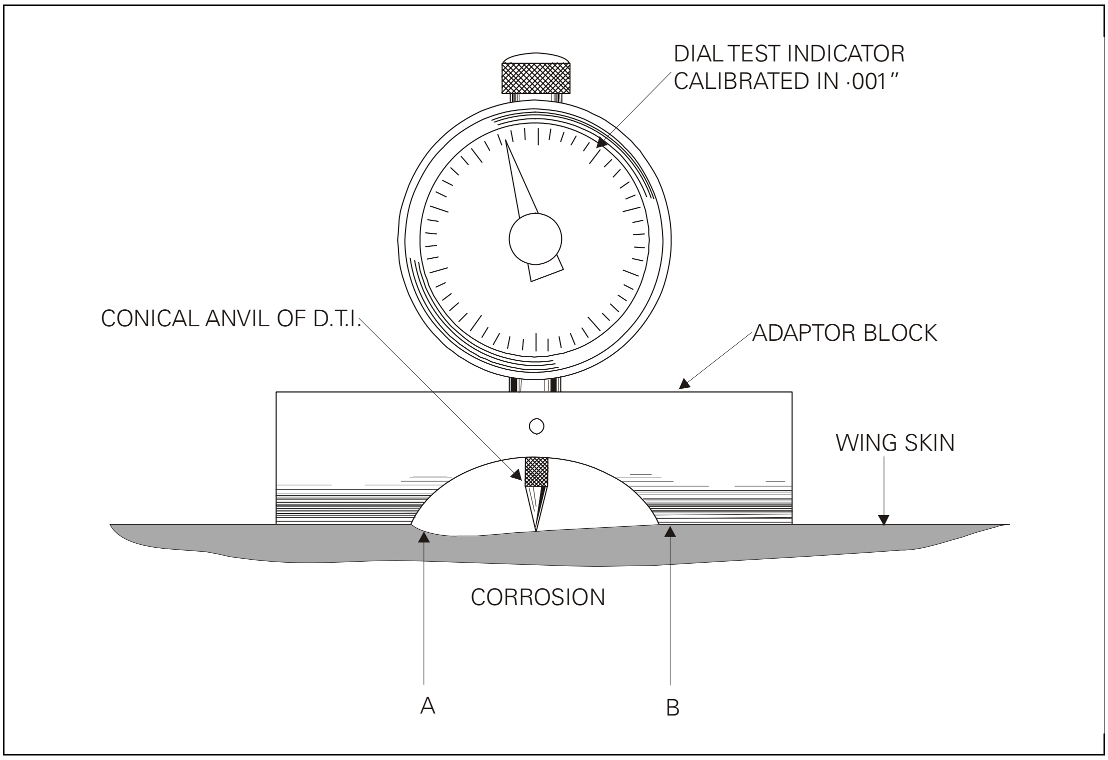

Figure 5 Measurement of Surface Damage

7.1.2 When gauging the depth of a depression, a reading should first be taken at two points, adjacent to but unaffected by the depression (such as A and B in Figure 5), then the maximum depth reading (D) should be taken. By subtracting the average of the two point readings $\frac{A+B}{2}$ from the depth reading (D) the actual depth of the depression will be obtained thus:

$$\text{depth of depression} = D - \frac{A + B}{2}$$

7.2 Bowing Limits

To measure the amount of bow in a structural member (e.g. a strut), a straight edge and a set of feeler gauges can be used, providing the part to be measured is free from protruding fittings and the straight edge can be applied directly along the surface of the member. The straight edge should be placed along the entire length of the member and parallel to its axis, then by inserting feeler gauges at the point of maximum clearance the amount of bow can be calculated by the formula:

$$\text{Bow} = \frac{\text{Clearance measured by feeler gauges}}{\text{Length of member}}$$

7.2.1 For example, if the length of the member is 2 ft and the clearance measured by the feeler gauge is 0·040 in, the amount of bow is:

$$\text{Bow} = \frac{0{\cdot}040}{24{\cdot}0} = \frac{4}{2400} = \frac{1}{600} \text{ or 1 in 600}$$

NOTE: In general a maximum bow of 1 in 600 is normally acceptable unless otherwise stated in the Repair Manual. However, in some instances the manual may permit tolerances for bow greater than this figure.

7.2.2 To measure a member which has protruding fittings, a trammel fitted with three pointers can be used to bridge the fittings. The three points should be checked for truth against a straight edge or surface table and adjusted if necessary. The outer points should be placed at the ends of the member and any clearance between the member and the centre point checked with a feeler gauge, the amount of bow being calculated as in paragraph 7.2.1.

7.2.3 For more accurate measurement the central trammel point can be replaced by a depth gauge in which case the neutral reading on the depth gauge in relation to the outer points should be carefully noted by checking on a surface table.

7.3 Curved Sections

When checking the maximum depth of a depression in a curved surface (e.g. a leading edge), the adaptor block or the trammel must be placed over a line at right-angles to the curvature of the part, i.e. parallel to the longitudinal axis of the curve.

8 Certification

The CAA's requirements regarding certification after repair are given in BCAR Section A, Chapter A6–7 or Section B, Chapter B6–7 for foreign manufactured aircraft.

8.1 Full particulars of the work done should be entered in the appropriate log book and a Certificate of Release to Service should be signed.

8.2 According to the nature of the repair made, the aircraft should be weighed, the Weight and Centreof- Gravity Schedule should be amended or replaced by a revised Schedule, a certificate of fitness for flight should be issued and the aircraft should be tested in flight. Particulars and results of such testing must be provided.

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Leaflet 6-5 Rigging Checks on Aircraft

1 Introduction

This Leaflet gives guidance on methods of checking the relative alignment and adjustment of aircraft main components and should be read in conjunction with the appropriate manual for the aircraft concerned. Guidance on checking the rigging of aircraft after abnormal flight loads or heavy landings is given in Leaflet 6-3.

2 Levelling the Aircraft

The position or angle of main components is related to a longitudinal datum line parallel to the aircraft centre line and a lateral datum line parallel to a line joining the wing tips. Before these positions or angles are checked, the aircraft should (generally) be brought to the rigging position (i.e. with the lateral and longitudinal datum lines horizontal) by means of jacks or trestles, depending on the particular aircraft type, with the wheels just clear of the ground.

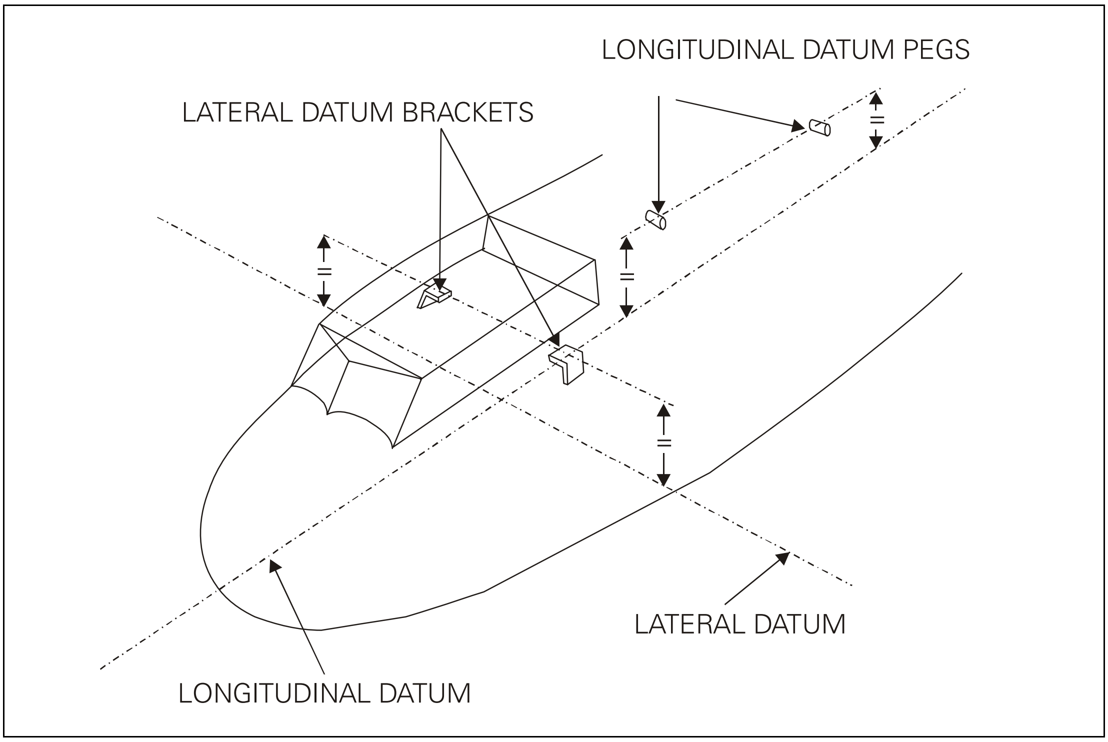

Figure 1 Datum Lines and Levelling Points

2.1 For the purpose of checking the level of smaller types of aircraft, fixed or portable datum pegs or blocks, on which can be rested a straight-edge and spirit level and which are generally attached to the fuselage parallel to or co-incident with the datum lines, are used, although in some instances parts of the structure which run parallel with the datum lines (e.g. top longerons or canopy rails of some aircraft) may be utilised. A typical levelling arrangement is shown in Figure 1.

2.2 The methods of checking the levelling given in paragraph 2.1 are also applicable to many of the larger types of aircraft, but other methods are sometimes used, e.g. the 'grid' method illustrated in Figure 2. The grid plate is a permanent fixture on the floor of the aircraft and, when the aircraft is to be levelled, a plumb bob is suspended from a predetermined position in the roof of the aircraft over the grid plate. The adjustments necessary to the lifting gear to bring the aircraft to the level position are indicated by the grid scale, true level being obtained when the plumb bob is immediately over the centre point of the grid .

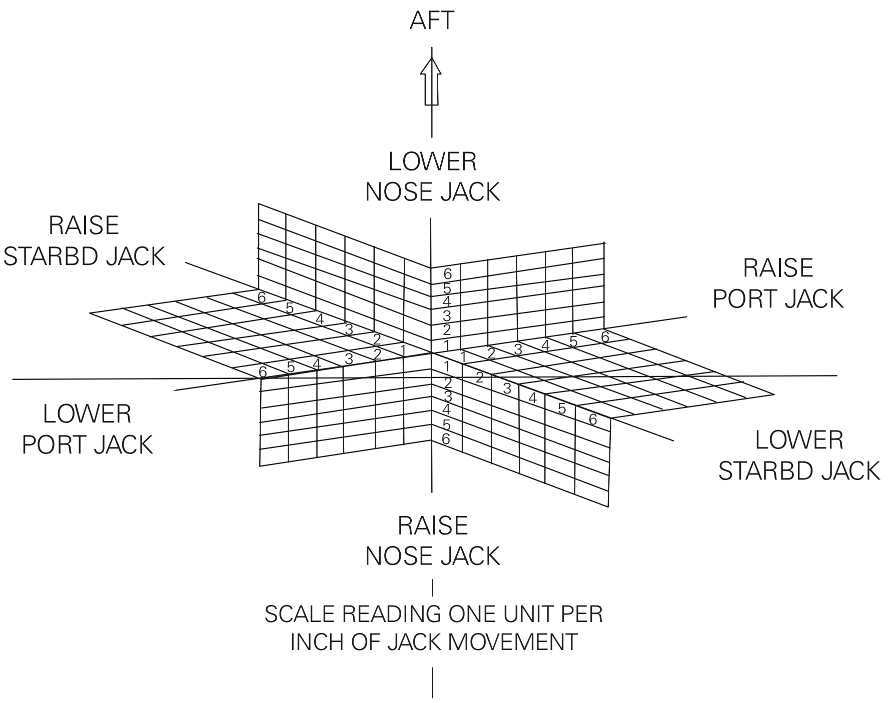

Figure 2 Typical Grid Plate

2.3 The method of bringing the aircraft to the rigging position depends largely on the size and type of aircraft and whether a nose wheel or tail wheel configuration applies, the general procedures applicable to each case being given in paragraphs 2.9 and 2.10 respectively. However, there are certain precautions which must be observed in all instances and guidance on these is given in paragraphs 2.4 to 2.8. Guidance on precautions to be taken when lowering the aircraft is given in paragraph 4.

2.4 A level site capable of bearing the load to be applied should be selected for the operation otherwise, where trestles are used, it may not be possible to level the aircraft and where jacks are used, the danger of the jacks toppling and dropping the aircraft would exist.

2.5 Rigging checks should not normally be undertaken in the open, but if this is unavoidable the aircraft should be positioned nose into wind. In any case the aircraft should not be lifted in strong winds or gusts.

2.6 The weight and loading of the aircraft for the rigging check should be exactly as described in the manual or as quoted on the original rigging chart supplied by the manufacturer. Variations from this condition, especially in the case of larger aircraft, will prohibit a comparison with the original figures. In any case the aircraft should not be lifted until it is ensured that the maximum jacking weight (if any) specified by the manufacturer will not be exceeded.

2.7 All equipment which may cause damage to the aircraft during the lifting operation should be moved away before lifting is commenced and no personnel other than those directly connected with the rigging check should be permitted on or around the aircraft for the duration of the complete operation.

2.8 For most aircraft the brakes should be OFF and the wheels chocked prior to lifting but for aircraft fitted with levered suspension undercarriage units the wheels should be left unchocked.

2.9 **Tail Wheel Aircraft**

2.9.1 The tail should be raised to an approximately level position by means of the appropriate jacks or adjustable trestle accurately positioned under the rear lifting position. Where single-engine aircraft in particular are concerned, it may be necessary to weight down the tail to prevent the aircraft nosing over due to the weight of the engine. This weight must not be allowed to swing but must touch the ground and be secured by a taut rope to that part of the aircraft specified by the manufacturer.

2.9.2 The appropriate jacks or adjustable trestles should be accurately positioned under the main lifting points and the aircraft raised evenly by operating both jacks or trestle gears together until the wheels are just clear of the ground and the aircraft is in the (approximate) rigging position.

2.9.3 The lateral and longitudinal levels should be checked and adjusted as necessary by means of the lifting gear. Where hydraulic jacks are used, the locking devices provided must be applied immediately the aircraft has been correctly positioned and, to ensure the safety of personnel, at any time when the jack is not actually being operated during the lifting of the aircraft.

2.9.4 If steady trestles are placed under the wings after the aircraft has been supported in the rigging position, it must be ensured that they are not in contact with the wings when incidence or dihedral checks are being made, that no adjustments are made to the lifting gear with the steady trestles in position and that the trestles are removed before any attempt is made to lower the aircraft (see paragraph 4).

2.10 **Nose Wheel Aircraft**

The appropriate trestles or jacks should be accurately positioned under the main, nose and (if applicable) tail positions. The main and nose lifting gear should be operated simultaneously and evenly until the aircraft is just clear of the ground and the operation completed as described in paragraphs 2.9.3 and 2.9.4.

3 Rigging Checks

Although the dihedral (see paragraph 5.2) and incidence (see paragraph 5.5) angles of conventional modern aircraft cannot be adjusted (with the possible exception of adjustable tailplanes) they should be checked at specified periods and after heavy landings or abnormal flight loads (see also Leaflet 6–3) to ensure that the components are not distorted and that the angles are within permitted limits. The relevant figures together with permitted tolerances are specified in the appropriate manual for the aircraft concerned, but the actual figures relevant to an individual aircraft are recorded in the aircraft log book.

3.1 The usual method of checking rigging angles is by the use of special boards (or the equivalent) in which are incorporated or on which can be placed an instrument for determining the angle, i.e. a spirit level or clinometer as appropriate. On a number of aircraft the rigging can be checked by means of sighting rods and a theodolite. Guidance on rigging checks with rigging boards is given in paragraphs 3.3 and 3.4 and on the use of sighting rods in paragraph 3.5.

3.2 **Sequence of Rigging Checks**

A suitable sequence for checking the rigging is as follows; it is essential that the checks should be made at all the positions specified in the relevant manual.

a) Wing dihedral angle(s)

b) Wing incidence angle(s)

c) Engine alignment

d) Tailplane lateral level or dihedral

e) Tailplane incidence angle

f) Verticality of fin

g) Symmetry check

3.3 **Checking Aircraft with Rigging Boards**

3.3.1 **Dihedral**

The dihedral angle should be checked in the specified positions with the special boards provided by the aircraft manufacturer or, if no such boards are provided, with a straight-edge and clinometer. The methods of checking with both types of board are shown in Figure 3.

NOTE: Certain portions of the wings or tailplanes may sometimes be horizontal or, on rare occasions, anhedral angles may be present.

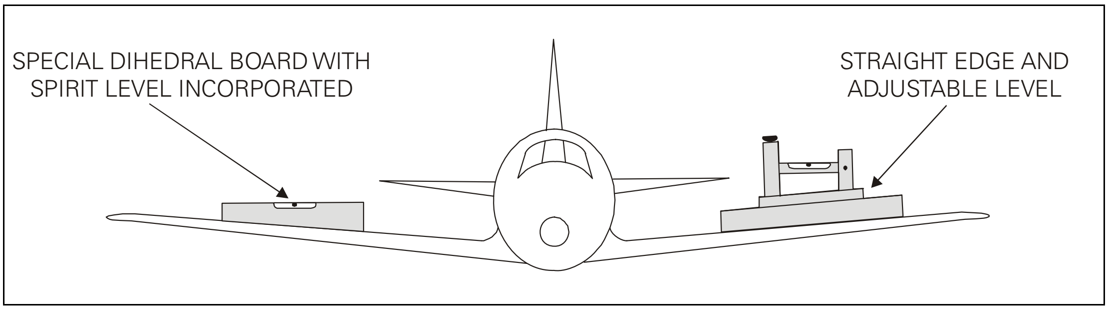

Figure 3 Checking Dihedral

3.3.2 **Incidence**

The incidence is usually checked in at least two specified positions, inboard and outboard, on the component to ensure that it is free from twist.

a) There are a variety of types of incidence boards, some having stops at the forward edge which must be placed in contact with the leading edge of the wing, whilst others are provided with location pegs which fit into some specified part of the structure, but the main purpose in each case is to ensure the board is fitted in exactly the position intended and, if the rigging is correct, that a clinometer on the top of the board will register zero or within a permitted tolerance about zero. In most instances the boards are kept clear of the wing contour (so that the incidence check is not influenced by any irregularities which may occur in the contour) by means of short feet attached to the board. A typical wooden incidence board is shown in Figure 4 although, of course, some are manufactured of metal.

b) It must be borne in mind that modifications in areas where incidence boards are located may affect results. For example, if leading-edge deicing shoes were fitted this might seriously affect the position taken up by a board having a leading edge stop as shown in Figure 4.

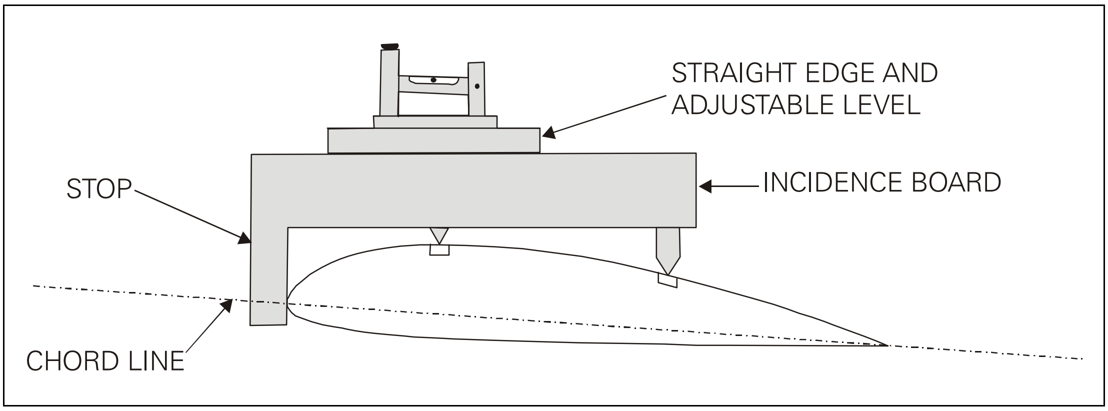

Figure 4 Typical Incidence Board

c) Where possible, the verticality of the incidence board should be checked with a plumb bob. Where the checks are being taken in the open (see paragraph 2.5) and it is difficult to steady the plumb bob due to wind, the suspension of the plumb bob in a container of oil or water will be of assistance.

3.3.3 **Verticality of Fin**

After the rigging of the tailplanes has been checked, the verticality of the fin relative to a lateral datum can be checked from a given point on either side of the top of the fin to a given point on the port and starboard tailplanes respectively; the measurements should be similar within prescribed limits. When the verticality of the fin stern post has to be checked, it may be necessary to remove the rudder and drop a plumb bob through the rudder hinge attachment holes, when the cord should pass centrally through all the holes. It should be noted that some aircraft have the fin offset to the longitudinal centre line to counteract engine torque.

3.3.4 **Engine Mountings**

Engines attached to the wings are usually mounted with the thrust line parallel to the horizontal longitudinal plane of symmetry but not always parallel to the vertical longitudinal plane, since, due to their disposition along the wing, the outboard engines are often offset a degree or so to enable the slipstream from the propellers to converge on the tailplane. The check to ensure that the position of the engine, including the degree of offset, is correct depends largely on the type of mounting, but usually entails a measurement from the centre line of the mounting to the longitudinal centre line of the fuselage at a point specified in the relevant manual. (See also Figure 5).

3.3.5 **Symmetry Check**

Figure 5 illustrates the principle of a typical symmetry check, the relevant figures and tolerances for which will be found in the appropriate manual, although the actual measurements relating to the aircraft concerned are given in the aircraft log book.

a) For the smaller types of aircraft the measurements between points are usually taken by means of a steel tape. It is recommended that a spring balance should be used on the longer distances to obtain an equal tension, 5lb usually being sufficient.

b) Where the larger types of aircraft are concerned, it is more usual to chalk the floor locally under the positions where the dimensions are to be taken, to drop plumb bobs from the checking points, marking the floor with an 'X' immediately under the point of each plumb bob and then to measure the distance between the centre of the markings. This method has the advantages of ensuring more accurate measurement and reducing the amount of walking necessary on main planes and tailplanes.

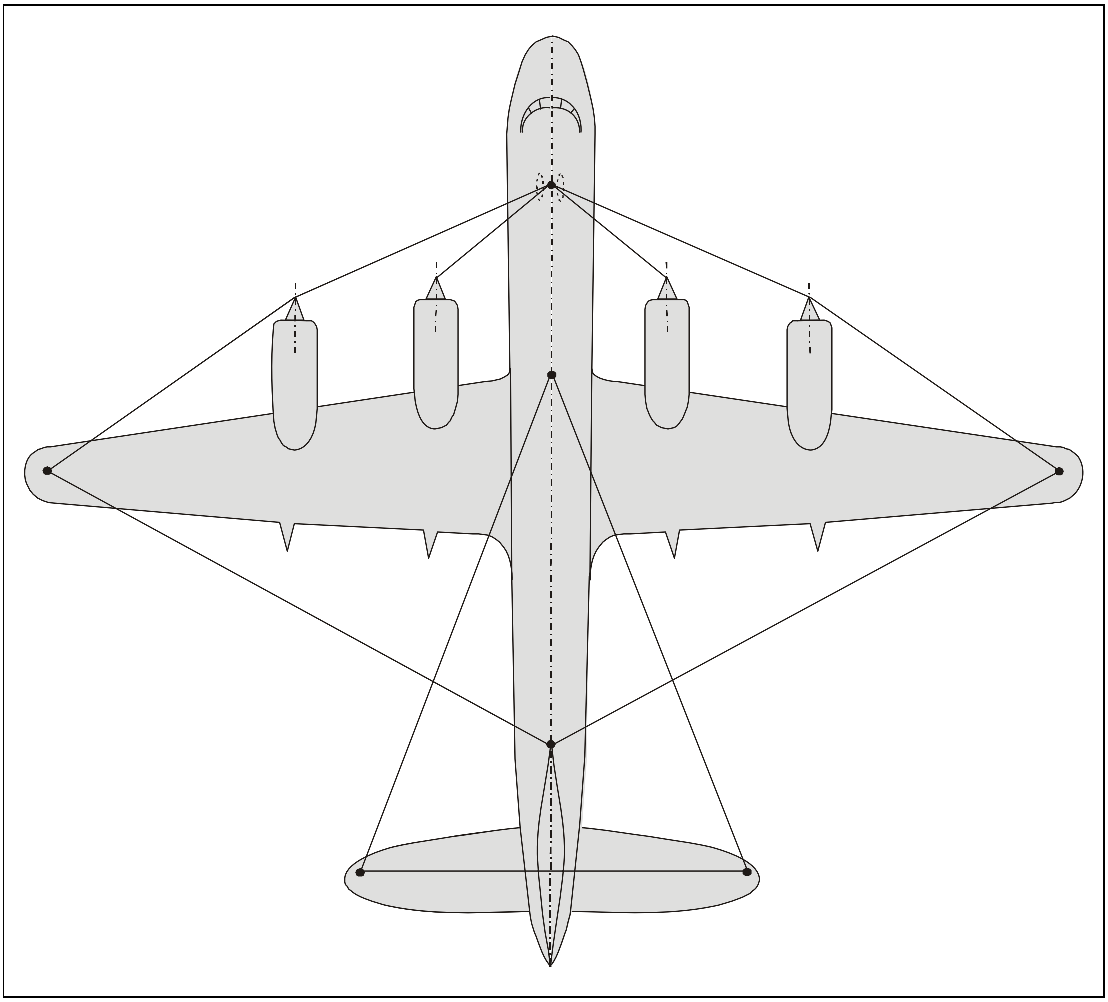

Figure 5 Symmetry Check

3.4 **Rigging Checks on Biplanes**

In general the rigging checks applicable to single-engined biplanes during reassembly after overhaul are as follows, but specific requirements relating to a particular type of aircraft should be ascertained from the relevant approved manual. The use of rigging boards, etc., is described in paragraph 3.3, as are other checks (such as the symmetry check) which are not peculiar to biplanes.

3.4.1 The fuselage should be levelled laterally and longitudinally as described in paragraph 2. The centre-section should be placed on suitable trestles and the centre-section struts and wires (complete with fork-ends) attached.

NOTE: It is important that the fork-ends should be screwed the same number of turns on each end of the wire to provide for subsequent adjustment.

3.4.2 The centre-section should be erected onto the fuselage and the stagger (paragraph 5.7) and lateral symmetry checked. The stagger should be checked by dropping plumb bobs from the leading edge of the upper portion of the centre-section (or other defined position) and measuring the distance from the plumb bobs to the leading edge of the lower portion of the centre-section (or other defined position). If necessary, the stagger can be adjusted by means of the front centre-section struts on most aircraft of this type. The symmetry about the centre line should be checked by measuring from plumb bobs to the sides of the fuselage and can be adjusted, if necessary, by means of the bracing wires.

NOTE: It is essential that the centre-section rigging checks should be accurately carried out, since small errors in the centre-section bracing can result in large errors in the general rigging.

3.4.3 The port (or starboard) top main plane should be attached to the centre-section, care being taken to ensure that the main plane is adequately supported during the assembly. The landing wires (see paragraph 5.4) should then be attached to the centre-section, the port (or starboard) lower main plane attached to the centre-section, the interplane struts, flying wires (paragraph 5.3) and incidence wires (see paragraph 5.6) fitted and the whole assembly lightly tensioned up. The completed side of the aircraft should be steadied with a trestle whilst the opposite side is assembled in the same order.

NOTE: Although usually of similar appearance, front and rear interplane struts are usually of slightly different lengths to compensate for wing contour, thus it is important to ensure that the correct strut has been fitted in the correct position.

3.4.4 After assembly the fuselage level should be re-checked and adjusted as necessary, after which the main planes should be trued-up by adjustments to the appropriate wires, the aim being to achieve the correct dihedral first and then to work the incidence and stagger together. Care must be taken during rigging to ensure that the main flying and landing wires are not over-tensioned to the extent of bowing the main plane spars or interplane struts.

NOTE: The specified lengths and permitted tolerances applicable to all wires are given in the rigging diagrams appropriate to the aircraft type, but the actual figures to which the aircraft had previously been rigged is recorded in the aircraft log book. If using the same components it is advisable to re-rig to the log book figures, since these may have been determined specifically to counteract a flying fault.

3.4.5 After the rigging of the main planes has been completed, it should be ensured that all fork- ends, etc., are in safety, are not 'butting' against the ends of the fitting and have been correctly locked, that the wires are in streamline and that anti-chafing discs and spreader bars are correctly fitted to prevent vibration of the wires.

3.4.6 **Empennage**

The empennage should be attached in accordance with the instructions contained in the relevant manual and adjusted (where this is possible) to within the limits specified in the relevant rigging diagram. It should be noted that the tailplane struts are usually handed and, unless these are correctly positioned, the fairings will not be in line of flight.

NOTE: Tailplanes provided with an adjustment mechanism must be set to the neutral position before checking is commenced.

3.4.7 **Twin-Engine Biplanes**

The general procedure for rigging twin-engined biplanes is basically similar to that described above for single-engined biplanes but it must be ensured that the weight of the engines is taken up on the appropriate struts before completing the general rigging.

3.5 **Checking Rigging with Sighting Rods**

This method of checking rigging is used mainly on the larger types of aircraft and consists basically of sighting with a theodolite the positions of datum marks on a series of rods of graduated lengths, each of which is inserted into a specified jigged position on the underside of the aircraft.

3.5.1 For the initial check, the aircraft should be brought to the rigging position (see paragraph 2) and the sighting rods inserted at the appropriate stations.

NOTE: Since any rod can be fitted into any socket, it is important to ensure that the rods are inserted in their correct positions.

3.5.2 A theodolite, erected at an appropriate distance and position from the aircraft should be levelled up with the datum mark on the master sighting rod (usually the shortest rod fitted under the fuselage) and then readings should be taken from this sighting line at each rod station and recorded. A typical method of taking the readings is illustrated in Figure 6.

NOTES: 1) A method which provides accurate vertical adjustment and rigidity for a theodolite is to mount it on a hydraulic jack.

2) It may not be possible in every instance to obtain a reading on every sighting rod from one theodolite position, in which case the theodolite should be appropriately repositioned, realigned on the master rod and the check continued in the same manner as before.

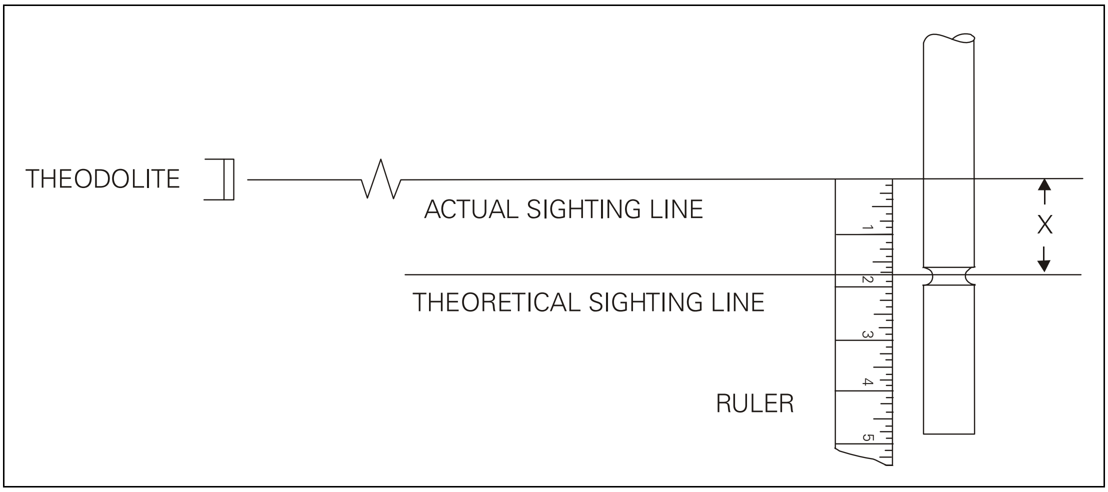

Figure 6 Typical Method of Taking Readings

3.5.3 The readings thus obtained must be within the tolerances permitted by the manufacturer (details of which are usually included in the rigging drawing) and entered in the aircraft log book for permanent record.

3.5.4 There are two basic methods applicable to the use of sighting rods and these are described below.

a) On some types of aircraft the sockets into which the sighting rods are inserted are adjustable in the vertical direction so that once variations from nominal figures have been recorded, the rods can be 'zeroed' and permanently locked. Thus the sighting line on all subsequent checks should in fact coincide with the datum marks on all the rods if the rigging is correct. Rods used for this method have the single datum as illustrated in Figure 6.

b) The second method is to use sighting rods on which are marked the datum line, on either side of which is also marked graduations indicating the permissible tolerance on the nominal figure in increments of 1/4 degrees. With this method the sockets into which the rods are inserted are not adjustable and subsequent readings should give the actual figures recorded on the initial check.

NOTE: When rods of the 'screw-in' type are used it should be ensured that they are fully screwed home before the check is commenced.

3.5.5 When a component (e.g. wing or tailplane) is changed, it will be necessary to again carry out the initial check to ascertain actual figures.

4 Lowering the Aircraft

Before any attempt is made to lower the aircraft to the ground it must be ensured that wing supports and any other equipment which might foul and damage the aircraft are moved clear. The aircraft should be lowered evenly and, when the aircraft weight is accepted on the undercarriage, the jacks should be further lowered to ensure that they can be removed without fouling the aircraft structure.

5 Definitions

5.1 **Anhedral.** An inclination outwards and downwards relative to the lateral datum.

5.2 **Dihedral.** The angle (or angles) at which the wings and tailplanes are inclined outward and upward relative to the lateral datum.

5.3 **Flying Wires.** Wires the principal function of which is to transfer the lift of the main planes to the main structure. These wires are sometimes termed 'lift wires'.

5.4 **Landing Wires.** Wires which brace the main plane against forces opposite in direction to the direction of lift, as occur, for example, in landing. These wires are sometimes termed 'anti-lift wires'.

5.5 **Incidence.** The angle between the chord line of the wing or tailplane and the longitudinal datum.

5.6 **Incidence Wires.** Wires bracing the main plane structure in the plane of a pair of front and rear struts.

5.7 **Stagger.** The distance between the leading edge of the lower plane and the projection of the leading edge of the upper plane on the chord of the lower plane.

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Leaflet 6-6 The Effect of Disturbed Airflow on Aeroplane Behaviour

1 Introduction

1.1 This Leaflet gives general guidance on the cause and effect of disturbed airflow on aeroplane behaviour, with particular reference to high-performance aeroplanes. It emphasises the need for special care in the preservation of correct airframe contours because of the serious effect on aeroplane behaviour, particularly at high speeds, of seemingly trivial discontinuities in contour, profile, etc.

1.2 It is important that the point of transition from laminar to turbulent airflow on aerofoil surfaces occurs at the position intended in the design. At high subsonic speeds the transition point may be designed to be effective at a position some 30 to 50% along the wing chord from the leading edge and can be very sensitive to even small protuberances or discontinuities on the wing surface.

1.3 Faulty contours can have dangerous effects on an aeroplane flying at or near the stalling speed, whilst rough surfaces, badly fitting joints, gaps, etc., will adversely affect, to some extent, performance in all regimes of flight. However, defects which may be considered of minor importance to low-speed aeroplanes may have a considerable influence on aeroplanes flying at higher speeds. For example, the behaviour of the airflow over an aileron can be seriously affected by those departures from design which influence the position of the transition point, thus affecting the response, or the rate of response, of the aeroplane, the trim and the drag.

1.4 No attempt is made in this Leaflet to describe any aerodynamic principle or theory; any description or illustration given is solely to help clarify the 'cause and effect' of the defect and is not considered to be a formal aerodynamic representation.

1.5 Since the methods used to determine the causes of flying faults (and the methods of rectification) vary considerably with different types of aeroplanes, it is essential that the manufacturer’s instructions, as specified in the relevant manuals, should be carefully followed.

1.6 Guidance on the general rigging of aeroplanes is given in Leaflet 6–5 and on the inspection of aeroplanes after heavy landings or abnormal flight loads in Leaflet 6–3.

2 General

In high performance aeroplanes the surfaces subjected to airflow are manufactured to within relatively close contour and gap limits and these limits have to be maintained if increased drag and other penalties are to be avoided. In this connection, the most critical areas of the aeroplane, where high accuracy in manufacture and the greatest care in maintenance are involved, include the leading edges of wings, tailplane and flying control surfaces, shrouds and trailing edges, engine intakes and static-vent areas. However, it should be noted that production tolerances are normally permitted and thus it should never be necessary to adjust any dimension to give an accuracy greater than that required by design solely for the purpose of maintaining performance standards.

2.1 Modern high performance aeroplanes are so manufactured that the original smoothness of contour is maintained more effectively than in previous generations of aeroplanes (e.g. by the use of machined skin panels). Nevertheless, small departures from the prescribed alignment and contours can occur during service and may be very difficult to recognise. Although such irregularities may have a negligible effect at lower speeds, changes of trim may occur as the aeroplane reaches its limiting Mach number.

NOTE: Although an aeroplane may be flying at subsonic speed, it is not unusual for the airflow over certain sections to be at transonic or supersonic speed.

2.2 Apart from changes of attitude and trim which may or may not occur due to departures from the original aerodynamic contours (e.g. malalignment of control surfaces, incorrect fitting of inspection panels, fairings and cowlings, dents or wrinkles in wing skins, protruding bolt heads, etc.), such defects will also cause an increase in drag, resulting in a deterioration in aeroplane performance and range. For long-distance flights the results could be a marked increase in fuel consumption and seriously reduced fuel reserves.

2.3 In addition to defects which may be 'built in' as described in paragraph 2.2, it should be borne in mind that fairings and other fittings which are insecurely attached, might distort in flight, with similar results.

2.4 In summing up, it can be said that anything which disturbs the normal smooth airflow over an aerodynamic surface will have an adverse effect on the handling and performance of the aeroplane. However, if such adverse effects are reported, the full range of ground-set trim adjustments should be utilised before a search is made for the less obvious profile defects.

3 Defects

For the purpose of this Leaflet, it is assumed that the more common control faults, such as mechanical stiffness, jerkiness of controls, excessive play, etc., have been dealt with and that servo motors, cable tensions, spring struts, rigging limits, etc., are satisfactory.

3.1 Engine Cowlings and Fairings

The correctness of the fit of engine cowlings and fairings is important and must be within drawing tolerances, since, for example, if excessive airflow enters inside the cowlings, considerable pressure build-up may occur and drag may result (see also paragraph 3.4.2). The gaps between the edges of cowlings and fairings should be within design limits (see Figure 1) and no overlap should be permitted unless this is the design intention. It is essential that any rubbing strips or seals onto which the cowlings or fairings bed, should be in good condition.

3.1.1 The contours of cowlings and fairings should be maintained in the design condition, since dents, bent corners or protruding attachment bolts or other securing devices will affect the flow of air over the component. It should also be ensured that the cowlings and fairings are so adjusted and locked that they cannot move or vibrate in flight as a result of aerodynamic loads.

3.1.2 The contours of turbine engine air-intake ducts are of particular importance, since dents or damage to the lips of the ducts or the skin inside will interfere with the smooth airflow to the engine, with a resultant loss in performance and an increase in fuel consumption. In some cases such defects have resulted in rough running of the engine because of uneven distribution of air to the compressor and, in other cases, in inefficient operation of the engine cooling system.

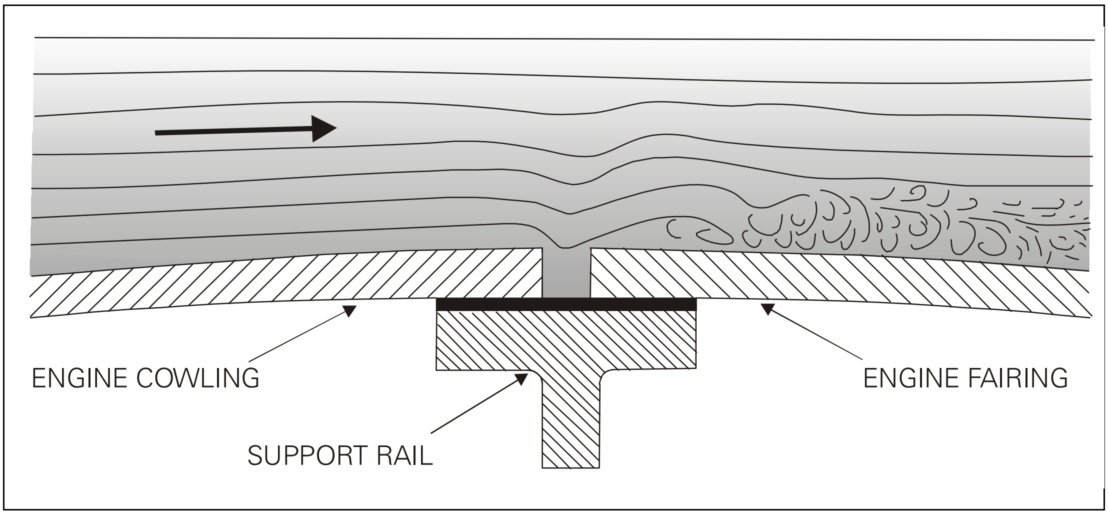

Figure 1 Drag Due to Gap in Cowlings

3.1.3 Cowlings and fairings should be stored and handled with care (see also paragraph 4.4). Attachment devices, locating dowels and fittings should be checked for looseness resulting from strain, wear, etc. Toggle fasteners should be correctly adjusted to give the required 'over-centre' loading and the associated fairings should be a good flush fit.

3.2 **Fuselage**

Cabin pressure leaks can cause a severe disturbance to the smooth flow of air along the fuselage and will create a considerable increase in drag. It should be ensured that cabin pressurisation seals at entrance doors, emergency hatches, clear-vision panels, etc., provide a complete and effective seal. The effect of such a defect is illustrated in Figure 2.

3.2.1 Entrance doors, hatches, etc., should be carefully checked for alignment with the fuselage skin, with the fuselage pressurised where appropriate, since if any wear has occurred to the latches, locks, rails or hinges, it may permit the door, hatch, etc., to protrude beyond the normal fuselage contour, creating a disturbance to the airflow.

3.2.2 It should be noted that the effect of pressurisation leaks, malalignment of aerodynamic contours, etc., is particularly detrimental towards the forward end of the fuselage and special care should therefore be given to the fit of windscreens, glazing strips, crew entrance doors, nose fairings and radomes.

3.3 **Wings**

The smoothness and contour of the wing surfaces, especially the top surfaces, is of the utmost importance if increased drag is to be avoided and the lateral trim of the aeroplane is to remain unaffected throughout the speed range.

3.3.1 It is necessary, for example, on aeroplanes fitted with fuel filler caps designed to be flush with the top surface of the wing, to ensure that the cap is fitted properly and not protruding above the wing contour; this is particularly important, for example, after fitting new sealing washers.

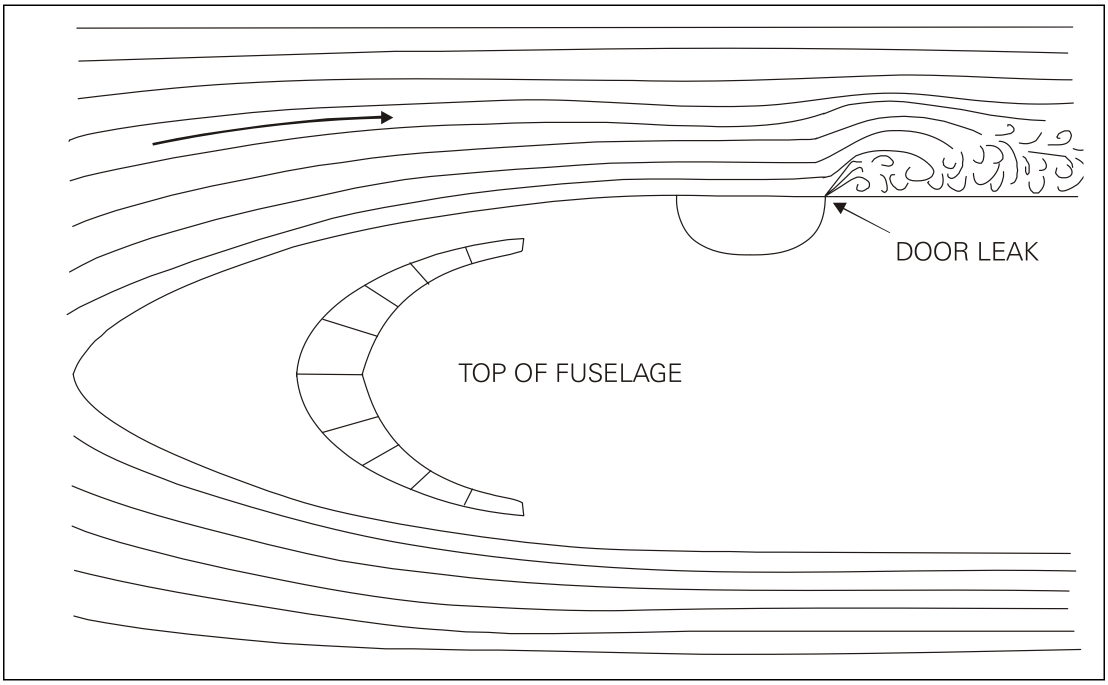

Figure 2 Pressure Leak from Fuselage

3.3.2 Even small irregularities such as those caused by protruding rivet or bolt heads, badly replaced screws in panels, stepped or gapped panel joints, convexity and concavity or ripples in the wing skin which may not be obvious during normal inspection, must not be ignored, since all can result in a break in the smoothness of the airflow over the wing.

3.3.3 An important factor from the point of view of high Mach number performance, is waviness and this is most important near the leading edges of lifting surfaces. Waviness can cause early shock-wave effects, which result in increased drag and a lower buffet boundary.

3.3.4 On aeroplanes which carry dinghies or life-rafts in wing stowages, the fit of the stowage cover is of paramount importance in maintaining the design airflow over the wing. The fit of the cover with the surrounding skin contour must be maintained within permitted tolerances. Correct fit may be obtained by adjustment of the cover retaining attachments, but can also be affected by the weather-seal around the interior of the cover.

3.3.5 The wing tip is also an important part of a wing and should be examined for surface condition. Detachable wing tips should also be examined to ensure that the chord line and rigging are satisfactory.

3.3.6 To ensure freedom from defects such as those described in 3.3.1 to 3.3.5, some manufacturers of high speed aeroplanes provide contour jigs or templates with which to check the wing surfaces, including the leading edges, shrouds and trailing edges. Such jigs should be used with considerable care and in accordance with the manufacturer's instructions; any departures from contour in excess of permitted limits should be rectified.

3.3.7 When jigs are not available, a rough check for contour defects may, in some cases, be made by running the fingers around the suspected surfaces, since this may reveal irregularities in surface finish which may not otherwise be perceptible. It is also sometimes helpful in the detection of more obvious defects, such as skin dents, malalignment of shrouds and ailerons, etc., when jigs are not available, to stretch a thin cord across the wing, from the leading edge to the trailing edge and parallel to the line of flight and to check as indicated in Figure 3.

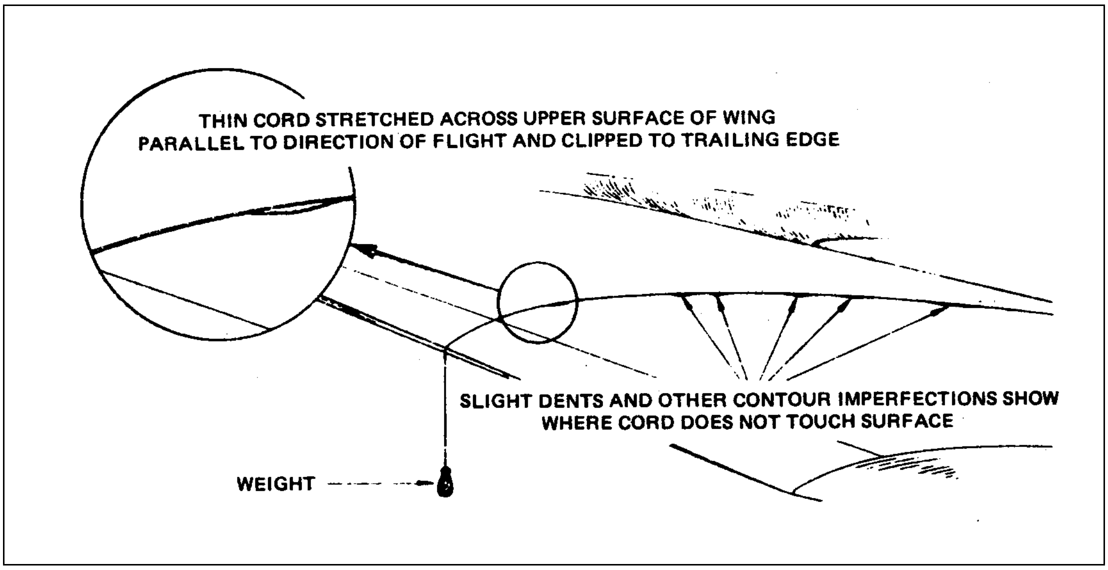

Figure 3 Checking Contours

3.3.8 It is sometimes possible to make a rough check on the more obvious types of defects by locking all the flying controls in the neutral position and then standing aft of the aircraft as shown in Figure 4. This may reveal distortion or damage to the trailing edges of the wings, flying controls and shrouds, which may sometimes be caused by accidental contact with ground equipment.

a) By slightly altering their position (up or down) the observer can make a rough check on the control surfaces and the rear of the wing surfaces. This is mainly done to check access points, tank doors, rear edges of cowlings, etc., to ensure that they blend into the natural contours of the aerofoil surfaces.

3.3.9 A check similar to that outlined in paragraph 3.3.8 can be made from a position forward of the wing, in order to check the contour of the wings and tailplane, with special emphasis on the leading edges, since defects in these areas are particularly critical.

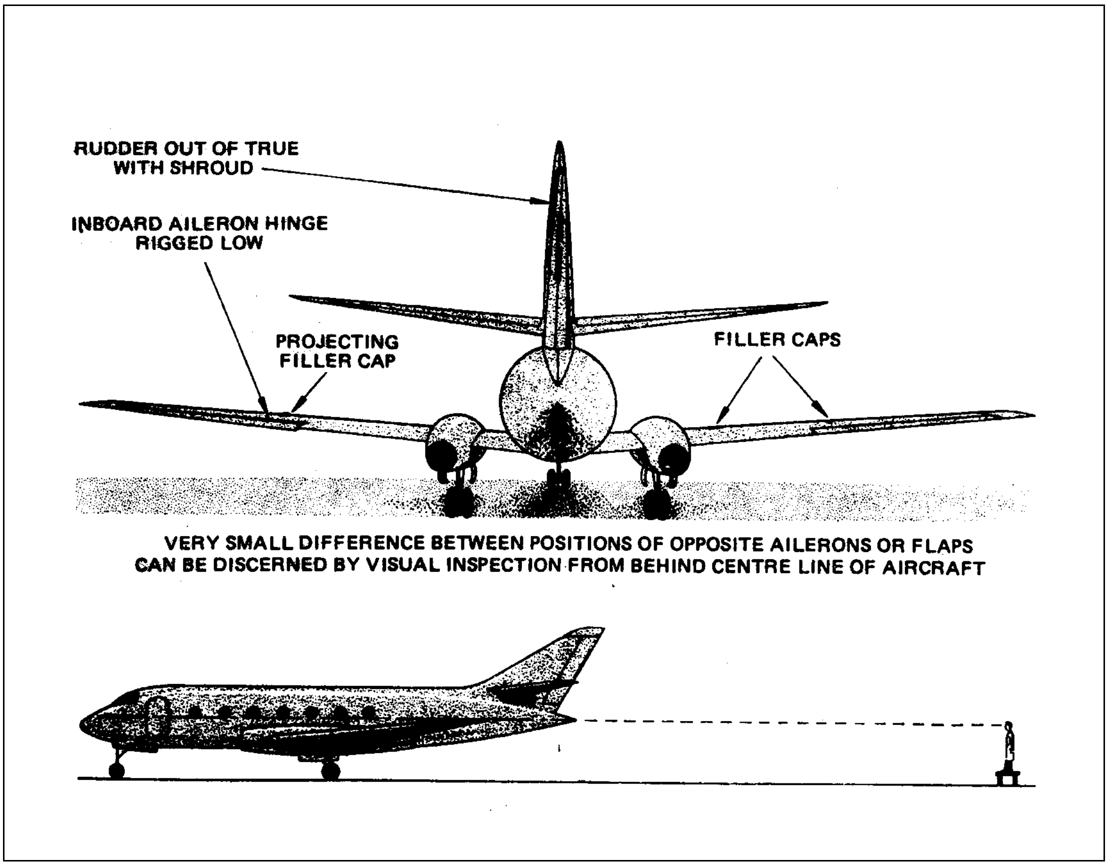

Figure 4 Checking by Observation

3.4 **Landing Gear Doors and Fairings**

Landing gear doors and fairings are often the cause of considerable drag and should, therefore, be carefully inspected in the retracted position for fit, contour and sealing. In addition, such components may be subjected to high aerodynamic loads and the possibility exists that badly fitting or ineffectively secured panels could become detached from the aeroplane, with serious results. Where such components are subjected to high aerodynamic loads the rigging procedures normally incorporate a degree of pre-loading to counter the effect of air loading.

3.4.1 In some cases it may be found necessary to simulate aerodynamic loads by loading the doors with weights or by use of a spring balance. This practice would indicate any excessive play or backlash in the mechanical linkage. In mechanically-actuated door operating systems, this check would be sufficient to ensure against sag in flight, but when the door operating system is completely or partially hydraulically operated, subsequent sag in flight may depend on the efficiency of the hydraulic system. In the latter case every effort should be made to ensure that the relevant part of the hydraulic system is free from both internal and external leaks.

3.4.2 A landing gear door, fairing or seal which is in any way badly fitting when the door is closed may allow air to enter the landing gear bay and eventually escape at the aft end of the door or fairing, creating considerable drag. In this case drag is caused by the fact that the air leaking into the cavity loses speed and then has to be speeded up again as it leaks out at the other side. Figure 5 illustrates the more serious case of flow breakaway as a result of leakage, but even if this does not occur, the drag penalty may still be quite high.

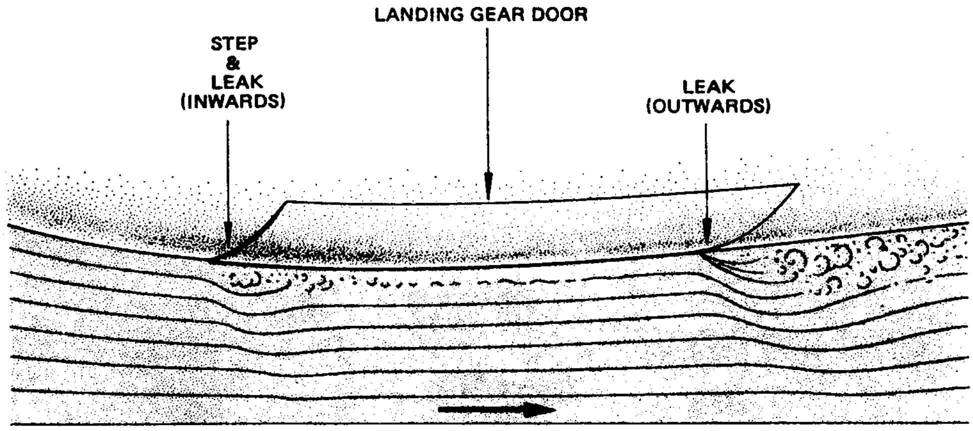

Figure 5 Leaks at Landing Gear Door

3.5 **Flaps**

The undersurface of the flaps should be examined for damage caused by debris thrown up during take-off and landing and flap shrouds should be checked for security, damage and distortion. The flaps should also be checked for sagging when in the 'up' position. In the case of flaps which employ slots for improved efficiency it should be ensured that the correct gaps are maintained.

3.6 **Aileron Shrouds**

The clearances between ailerons and aileron shrouds are very critical and must be checked carefully. The shrouds should be rigid and free of any form of damage on both bottom and top surfaces and care must be taken to ensure that no distortion of the shroud, or the wing skin immediately in front of the shroud has occurred, since this could upset the airflow over the aileron in a manner similar to that illustrated in Figure 6.

3.7 **Movable Leading Edge Devices**

Movable leading edge devices should be checked in the retracted position to ensure that they conform to the contour of the main wing, particularly on the upper surface. The condition of any seals in the leading edge should also be checked, to ensure that there is no air leakage from the lower to the upper surface. The leading edge devices should also be checked in the extended position to ensure that the correct gap is maintained between the devices and the wing.

3.8 **Airbrakes/Spoilers**

Airbrakes and spoilers should be checked to ensure that they are a flush fit when retracted. Where spoilers are used for lateral control, they should be checked to ensure that the 'dwell' before spoiler extension with control displacement is correct.

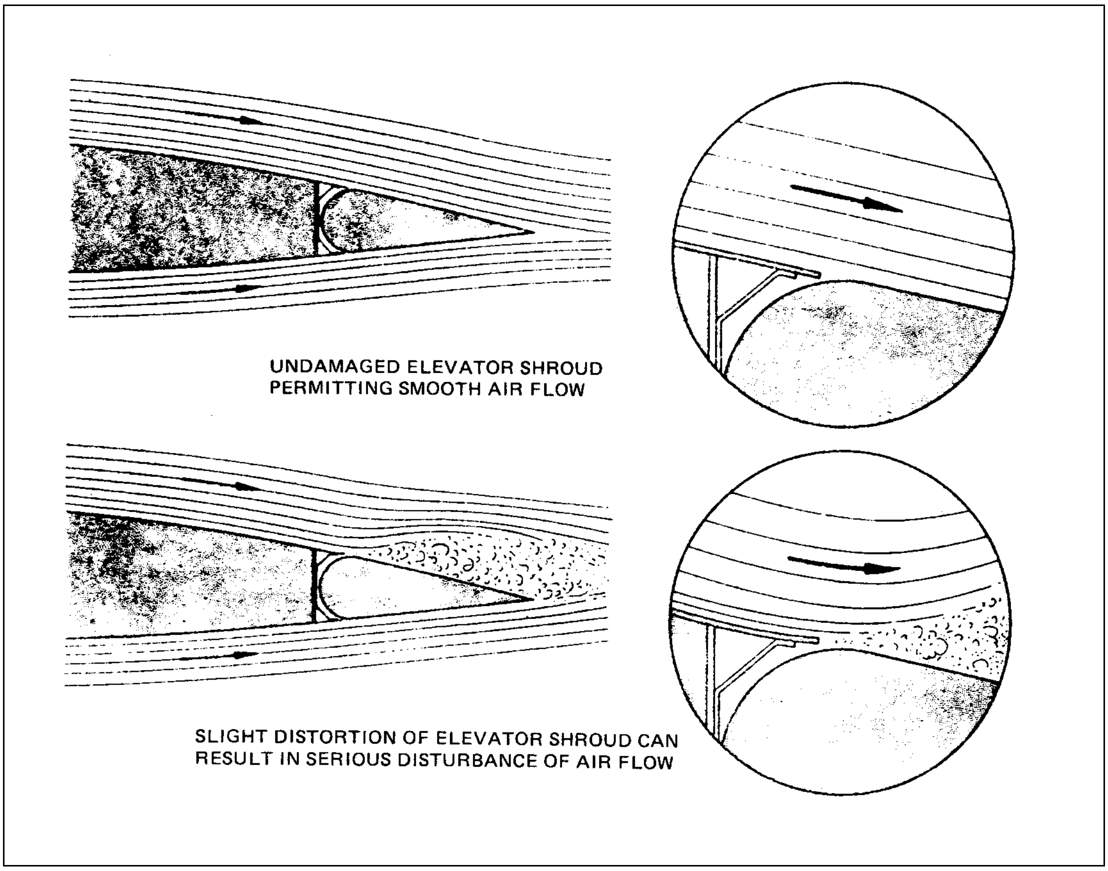

Figure 6 Airflow Over Elevator

3.9 **Vortex Generators**

A check should be made to ensure that vortex generators are not bent or distorted and that none is missing.

3.10 **Wing Fences**

Wing fences should be checked for alignment and, in addition, the condition of any seals between the fence and the wing should be carefully checked.

3.11 **Tail Unit**

Care should be taken to ensure that any fillets between the tailplane and fin and the fin and fuselage, are in good condition and free from dents and other damage.

a) The leading edges and surfaces of the tailplane and elevators should be checked for damage caused by debris thrown up during engine run, take-off and landing.

b) Particular care should be paid to the alignment and clearance of rudder and elevator shrouds, since these can become very critical at speeds approaching Mach 1. Slight distortion of tailplane shrouds or excessive clearances can create a breakaway of the airflow over the elevator surfaces at high speeds which can result in little or no response to elevator control inputs. As these conditions would generally occur only at speeds approaching the limiting Mach number for the aeroplane concerned, it should be assumed that the lack of elevator response might occur in a dive when a dangerous condition could result. The airflow which occurs over the elevators is illustrated in Figure 6.

4 Precautions During Maintenance

To ensure as far as possible against damage to aeroplane surfaces during maintenance, the precautions outlined in the following paragraphs are recommended as the minimum necessary.

4.1 When working on the top surfaces of aeroplanes, precautions should be taken to avoid damage to the surface by scratching, etc. and suitable mats or protective coverings, as detailed in the appropriate manual, should always be placed in position before work is commenced.

4.2 Ladders or trestles should never be rested against any part of the aeroplane and fuelling hoses should not be dragged over flying control surfaces, wing leading or trailing edges, etc.

4.3 When removing inspection covers, panels, cowlings, fairings, etc., they should never be levered off, since this may damage and distort them. Leverage should not be applied when securing or unlocking fasteners, since this may strain the fasteners to such an extent that the associated panel could become loose.

4.4 Cowlings, fairings, etc., should never be placed directly onto concrete floors. It is recommended that suitable racks should be provided onto which the cowlings can be placed immediately after removal from the aeroplane.

4.5 When a panel, fairing, etc., is removed, it should be checked to ensure that the condition of any rubber moulding or sealing strip is satisfactory.

4.6 In certain wet take-off conditions followed by freezing, the landing gear door seals may sustain damage as a result of icing and these should be checked for any such damage.

4.7 On aeroplanes having painted surfaces, it is essential that the thickness of the paint coating, particularly at leading edges, should be carefully controlled, since the amount of paint on the top side of a leading edge can easily influence the trim of an aircraft. This is particularly important where fillers are used to restore leading edge contours and the finished work should always be checked with a contour jig.

4.8 All surfaces should be kept clean, since dirt, oil or mud will always adversely affect the performance of the aeroplane.

4.9 When changing control surfaces or other aerofoil components, care should be taken to ensure that the new components fitted are in correct aerodynamic alignment with the surrounding structure, since the slight differences which can occur in nominally similar components, as a result of manufacturing tolerances, could affect the trim or performance of the aeroplane.

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Leaflet 6-7 Assembly and Maintenance of Critical Bolted Joints

1 Introduction

1.1 This Leaflet gives guidance on the recommended assembly procedure for critical bolted joints and on the extent to which inspection can verify that design requirements have been met. Guidance is also given on the inspections necessary during maintenance and overhaul to ensure the continued effectiveness of the joint.

1.2 In the context of this Leaflet the term 'critical bolted joint' is used to describe any bolted joint or attachment where stress levels are high and where inadequate assembly techniques could result in fatigue failure. Examples of critical bolted joints are spar joints, tailplane attachments, wing attachments and engine mounting structure.

1.3 Where specialised procedures or techniques are specified for the preparation or assembly of a critical bolted joint, the manufacturer’s published procedures should be referred to and their recommendations observed.

1.4 Related CAAIP Leaflets:

2–11 Torque Loadings

4–7 Magnetic Flaw Detection

1.5 The subject headings are as follows:

2 Assembly Procedure

2.1 During the initial assembly of a joint, checks should be made to ensure that the component parts are protected against corrosion, that the edges of holes are de-burred, chamfered or radiused as appropriate and that mating surfaces are free from swarf or other foreign matter.

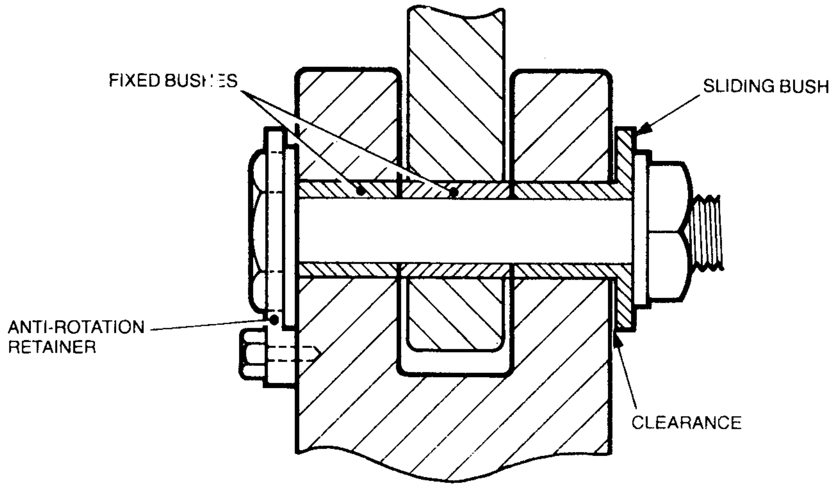

Figure 1 Fork Fitting with Sliding Bush and Anti-Rotation Retainer when Applicable

2.2 Before bolts are inserted it must be ensured that parts are correctly assembled and that no mis-alignment is present. Where one component is a fork-type fitting, a sliding bush may be fitted in one arm of the fork; provided that a clearance is maintained between the head of the bush and the fork during tightening of the assembly bolt (Figure 1), stressing of the fork fitting will be avoided. In other cases a good fit is obtained by selective assembly or by fitting shims or washers; if play is present in this type of joint the tightening of attachment bolts will induce a stress and weaken the fork fitting.

2.3 In some instances assembly instructions may require good bearing contact between the mating surfaces of the various components and also on the pressure faces of bolt heads and nuts. Tapered bolt holes should be checked by applying engineers blue to the hole and lightly rotating the bolt, while flat surfaces should be checked on a surface table, or by the use of engineers blue or feeler gauges during a trial assembly. Poor bearing surfaces should then be corrected by light lapping. Each hole should be checked using its own assembly bolt.

2.4 In some instances the surfaces of bolt holes in critical locations are stressed to prevent crack propagation and fatigue failure. Plastic deformation of the material surrounding the holes is produced by some form of broaching, such as the use of an interference fit mandrel, before the assembly bolt is fitted. In the case of tapered bolts in aluminium alloy components the hole is reamed until the bolt stands proud of the surface by a specified amount then, during final tightening, the tapered bolt expands the hole and induces compressive stress in the hole surface.

2.5 When performing operations such as drilling, reaming, lapping, etc., prior to final assembly of a joint, it is essential that the assembly is trued and held securely in position by clamps, slave bolts etc. This will prevent the ingress of swarf between faying surfaces and ensure that the joint is retained in this position when the joint bolts are finally inserted. Greater joint accuracy will be ensured if the joint bolts are inserted in sequence on each side of the joint immediately after each bolt fitting operation.

2.6 Parallel holes which have been opened to full size during assembly may be checked for size by means of plug gauges, but in certain instances, particularly when interference fits are required, the use of more specialised measuring equipment such as a pneumatic bore gauge may be necessary.

2.7 Careless fitting or assembly can considerably reduce the fatigue life of a joint. A burr on a bolt, or a piece of swarf left in a hole can scratch the surface of the hole and result in the concentration of stresses. To prevent the scoring of bolts and holes thorough cleanliness must be maintained and if shouldered bolts are used a 'bullet' should be fitted to protect the thread and provide a lead-in for the bolt shank. Lubrication of the bolts is usually recommended and the lubricant (or sealant) should be kept in a sealed container to prevent contamination when not in use. (See paragraph 3).

2.8 It will be appreciated that many highly stressed joints will require no hand fitting. The components may be jig built to very fine tolerances which obviate most of the fitting precautions outlined in the preceding paragraphs. However, a high standard of cleanliness and care in handling the components is still necessary if design strength is to be maintained.

2.9 Where joints or fittings have more than one bolt, progressive tightening should be carried out in order to prevent stresses being induced. In some cases the final tightening sequence will be stipulated on the appropriate drawing. Nuts should be fitted finger-tight then progressively tightened to the appropriate pre-load value, but new parts may require bedding-in by first tightening to half the pre-load, slackening, then finally tightening in accordance with the manufacturer’s recommendations.

3 Jointing Compound

3.1 There are a number of different compounds in use which are selected according to the type of joint, the probable frequency of disassembly, the material involved, the method of assembly, the protective treatments applied and the conditions of operation.

3.2 Pigmented varnish jointing compound to DTD 369, or other compounds covered by specification DTD 900, are frequently used to prevent scuffing and corrosion in joints and cold-setting polysulphide synthetic rubber materials are often used for joint sealing. Other materials may be specified for use in particular locations and reference should be made to the appropriate aircraft manual for instructions regarding their use.

3.3 In joints where hard-setting compounds are specified, precautions should be taken to ensure that the joint is tightened whilst the compounds are still wet, otherwise dimensional tolerances may be seriously affected if the compounds become dry before the joint is tightened.

3.4 Care should be taken to ensure that only the specified jointing compound is used, since, for example, that complying with DTD 369 is not suitable where temperatures in the vicinity of the joint may exceed 200°C, whilst hard-setting compounds are unsuitable in areas where vibration may occur.

3.5 Jointing compounds will give unsatisfactory results if kept in open containers which allow them to become semi-dry before application and to ensure consistent results from occasional use are often supplied in squeeze-tubes.

3.6 Sealants are usually supplied in twin-pack form and mixing instructions should be followed carefully. Once mixed the sealant starts to harden and final assembly of a joint should be completed within a specified application time. Sealant which is not used within its application time must be discarded.

4 Tightening of Bolts

4.1 The tension (pre-load) applied to a bolt during tightening should be greater than the highest stress likely to be encountered in service. The most efficient joint would be obtained by tightening each bolt to its yield point but, due to manufacturing tolerances and other variables, the practice would be dangerous to apply; in addition, each bolt could only be used once. A number of other ways of preloading bolts have been devised and although these may result in a less-than-optimum tension, have proved satisfactory in service.

4.2 Under-tightening of bolts in highly stressed joints may, when load is applied, result in lack of contact or rigidity between the separate parts of the assembly. Where alternating or fluctuating loads are applied to such joints early fatigue failure may occur. Conversely, over-tightening is likely to cause immediate failure of the bolts or distortion of one or more parts of the assembly.

4.3 The general problem of applying a specified pre-load to a bolt is also affected by the need to line up split-pin holes. Unless the bolt pre-drilling suits the joint and nut dimensions, or the bolt is drilled after tightening, the applied pre-load will be inaccurate to the extent of the nut adjustment. In some applications this inaccuracy may be acceptable, but in others the selection of alternative nuts or washers may be recommended.

NOTE: For some installations the bolt head is indexed and must be maintained in the required position by an anti-rotation retainer (see Figure 1).

4.4 Torque Loading

The most common method of pre-loading is by applying a specified torque to the nut during tightening. Laboratory tests are carried out to ascertain an appropriate torque loading for any particular application, taking into account the type of thread, bolt and nut materials, manufacturing tolerances, type of anti-corrosive treatment and type of lubricant. This loading is applied by means of a torque wrench and results in a reasonably consistent pre-load being applied to the bolt. The use of torque wrenches is covered in Leaflet 2–11.

4.5 Pre-load Indicating Washers

The value of the pre-load applied to a fastener by means of a torque wrench may vary considerably and, because of this, specified torque loadings are usually low compared with the actual strength of the fastener. In certain critical bolted joints the manufacturer may consider that more accurate clamping is required and specify the use of pre-load indicating (PLI) washers.

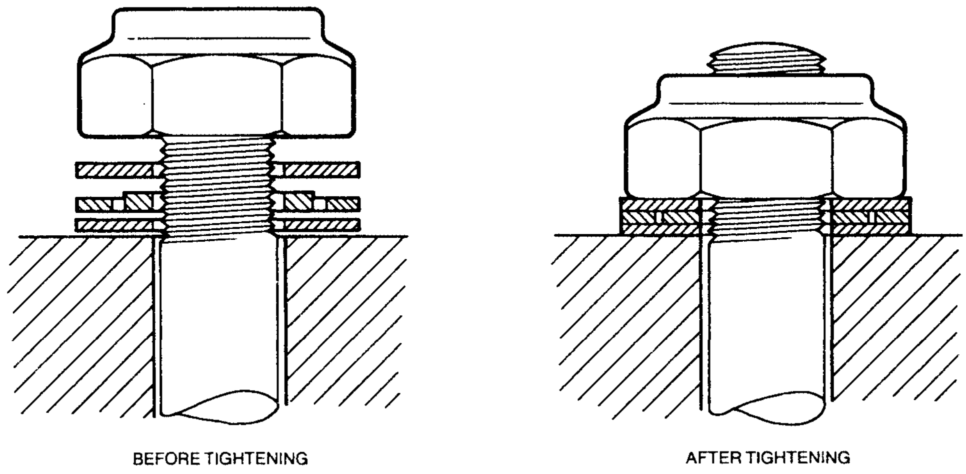

Figure 2 Pre-load Indicating Washers

4.5.1 PLI washers consist of concentric inner and outer rings and two high-strength steel washers as shown in Figure 2. The outer ring is thinner than the inner ring and has a series of radial holes drilled through it.

4.5.2 A stiff wire tool is inserted in holes in the outer ring and used to check whether the ring is free to rotate (Figure 3). As the nut is tightened the inner ring is compressed until, at a predetermined pre-load, the outer ring is nipped between the washers; at this point the outer ring can no longer be rotated and tightening is complete.

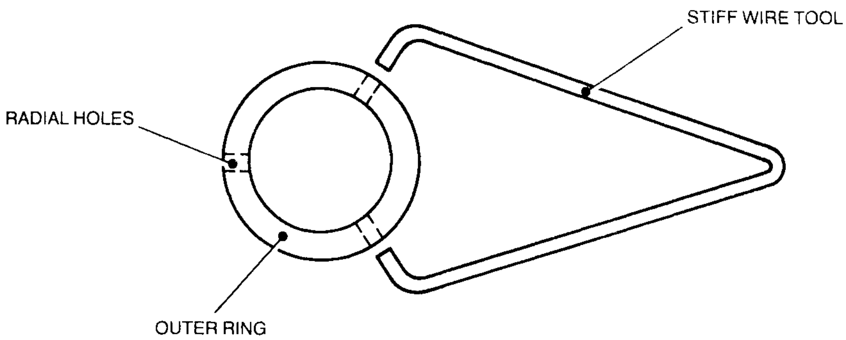

Figure 3 Checking PLI Washer for Rotation

4.5.3 PLI washers are unaffected by thread or nut friction, or by lubrication and provide a means of pre-loading a bolt which is more consistent than torque loading. The pre-load applied to the particular size of bolt can be varied to suit its application by changes in the material or dimensions of the inner ring. However, since the inner ring is compressed during tightening it can only be used once and if slackened must be replaced.

4.5.4 Due to the method of tightening, PLI washers can only be used with self-locking nuts.

4.6 **Shear Type Fasteners**

A number of proprietary fasteners are available which permit a reasonably accurate pre-load to be applied to a bolt without the use of torque wrenches. The nut normally used has an upper hexagonal wrenching portion, separated from the main nut by a deep groove. The hexagon portion shears off during tightening when a predetermined clamping force is reached.

4.7 **Bolt Extension**

An accurate method of pre-loading which, unfortunately, cannot often be used in airframe applications for reasons of inaccessibility, is the measurement of bolt extension. The bolts are tightened until a specified extension has taken place, as measured by means of a micrometer or similar instrument.

4.8 **Dished Washers**

These washers are sometimes used on dynamically loaded structures. The washers consist of circular discs of constant thickness and have an initial 'dish' raising the centre, so that when nipped they act as a spring of very high rating and will accommodate a certain amount of stretch in the bolt shank, or bedding-in of the head. By variation of the thickness, outer diameter and height, a wide variety of load deflection characteristics can be obtained, but unlike pre-load indicating washers, there is no reliable way of ensuring when optimum tightness has been reached.

4.9 **Standard Spanners**

The use of standard spanners is seldom recommended as the only method of tightening a critical bolted joint. British Standard 192 gives the lengths of spanners to be used with the different sizes of nuts and this leverage is usually adequate for general engineering work. It would, however, be impossible for even a skilled operator to apply a consistent amount of pre-load to a variety of bolt sizes. A reasonably accurate torque loading could be applied, in emergency, by using, for example, a double ended ring spanner and a spring balance, with the direction of pull at 90° to the spanner. The balance reading multiplied by the spanner length would give the torque loading applied.

NOTE: In certain installations the material of the component dictates use of special tools or protection from contact with standard tools.

5 Inspection of Bolted Joints

5.1 Unless bolts are extracted, visual examination is unlikely to reveal the faults which are usually associated with the beginning of cracks, fretting, corrosion etc. However, visual inspection is important as a means of checking that there are no indications of movement in the joint and that the external protective treatment is in good condition.

5.2 At the periods specified in the approved Maintenance Schedule, bolts should be extracted to enable a detailed examination to be made. Although this can be done most conveniently if the joint is broken down during major overhaul, on some aircraft one or more bolts may be required to be removed from critical joints at more frequent intervals. Whenever bolts are to be removed from these joints it will be necessary to support the surrounding structure in such a way as to remove the loads normally taken by the joint. The supports should be adjusted so that no residual loads are present in the joint when the bolts are removed and this may often be checked by fine adjustments to the supports until the bolts rotate easily. Bolts may often be removed by means of a suitable extractor but, if the bolts are tight or stuck because of the presence of corrosion products or jointing compound, it may be preferable to punch them out with a drift. Extreme care is necessary to avoid damaging the bolt threads as this could result in damage to the hole and induce stress failure; it is also advisable to support the structure round the head of a bolt using a hollow dolly.

5.3 **Examination of Bolts**

When bolts are removed they should be examined for signs of steps, cracks, fretting or corrosion. An appropriate type of non-destructive testing must be used when checking for cracks, the electromagnetic process being suitable for most steel bolts. See Leaflet 4–7.

5.3.1 Where applicable, the protective coating should be examined for condition and, if the plating is scored or partially rubbed away, the bolt should either be replated or discarded.

5.3.2 The threads should be thoroughly cleaned and examined to ensure freedom from damage. Failure to do this may result in excessive friction between the bolt and nut and lead to incorrect preloading if a torque wrench is used.

5.3.3 If, after examination, a doubt exists regarding the serviceability of the bolts, they should be rejected.

5.4 **Examination of Bolt Holes**

The bolt holes should be examined for signs of scoring, fretting, corrosion and cracks. A preliminary examination should be made before the hole is cleaned, since this is the most suitable time for detecting corrosion deposits, but it may be found that jointing compound obscures much of the hole surface.

5.4.1 The hole should be cleaned out with a suitable solvent, such as trichloroethylene and then reinspected.

5.4.2 The inspection of bolt holes can sometimes be difficult, but an optical aid such as a endoscope is often used and eddy current methods are also frequently recommended.

5.5 **Fretting**

Examples of aircraft components which have failed through fatigue originating in areas of fretting, have shown that fractures do not necessarily pass through adjacent bolt holes.

5.5.1 Fretting at major joints is often revealed, by black or grey dust or paste in aluminium structures and brown rust stains in steel parts, at the periphery of faying surfaces. Cracks may develop from the outer edge of a fretted area and extend across the component. An examination of a component showing signs of fretting should, therefore, include the flat surfaces as well as the bolt holes.

5.5.2 An inspection of this nature would entail disassembly and examination by means of penetrant dye, eddy current or ultrasonic (surface wave) methods.

5.6 **Reassembly of the Joint**

When reassembling the joint the assembly recommendations given in the preceding paragraphs should be taken into consideration.

6 Locking

Locking devices must be sufficiently effective to prevent loosening or turning of the threaded parts and they should be fitted as specified in the relevant drawing or manual. Most locking devices may only be used once, but those which can be re-used should be checked for effectiveness before being refitted.

Leaflet 6-8 Glass Windscreen Assemblies

1 Introduction

This Leaflet gives guidance on the installation and maintenance of aircraft glass windscreen assemblies of both the simple and complex electrically heated type. As the assemblies fitted to different aircraft vary considerably, the information given in this Leaflet should be read in conjunction with the Maintenance Manuals and the approved Maintenance Schedule for the type of aircraft concerned. The CAA Requirements regarding tests on pressure panels are given in Chapter D3–7 and ACJ 25.775(d) of British Civil Airworthiness Requirements.

2 Glass

Glass is a hard, brittle material having the outstanding quality of transparency. To overcome brittleness but to leave transparency unimpaired is the main object of the manufacture of safety glass as used for aircraft windscreens. Examples of specifications which meet the requirements are DTD 218 Laminated Safety Glass, DTD 869 Laminated Safety Glass, High Light Transmission, DTD 761 Safety Glass Windscreen, Gyro Sight Quality and DTD 5576A Electrically Heated Laminated Safety Glass.

2.1 Characteristics of Glass

Glass, unlike metals, is non-crystalline. When heated or cooled it shows no sharp change in physical properties and has no definite melting point, but at about 600°C plate and sheet glass begin to flow under their own weight.

2.1.1 Glass may be broken by loading in various ways, e.g. impact, tension, twist, compression or shear and fracture will occur under any type of loading when deformation has produced the necessary tensile stress.

2.1.2 The breaking strength of glass is greatly influenced by five factors:

a) Heat treatment (paragraph 2.2).

b) Length of time of loading (paragraph 2.3).

c) The rate of application of a load (paragraph 2.4).

d) The condition of the surfaces and edges (paragraph 5).

e) Method of installation (paragraph 3.2).

2.2 Heat Treatment

2.2.1 Annealing

After manufacture glass is cooled very slowly so that stress set up during the forming of the sheet may dissipate. If this were not the case, built-in tensile stress would weaken the glass to such an extent that it could break spontaneously. When glass of greater strength than annealed glass is required, a tempered glass is used.

2.2.2 Tempered Glass

The glass is heated to some point within the range in which it becomes soft and then the surfaces are quickly cooled by blasts of compressed air. This chills and hardens the outer surfaces whilst the inside is still hot and contracting, thus putting the outer 'skins' of the glass in a state of compression, resulting in a considerable increase in strength.

a) The main drawback of tempering is that the glass will break up into tiny particles when fractured (the greater the degree of tempering the smaller will be the particle size) thus seriously obstructing vision.

b) In the United Kingdom, glass which has been tempered to give maximum strength is termed 'toughened glass' (e.g. Type 1 of DTD 5576A). The term 'strengthened glass' (e.g. Type 2 of DTD 5576A) is used to indicate glass which has been tempered to a lesser degree than toughened glass. Although less strong than toughened glass it has the advantage of larger particle size should fracture occur.

c) Because of the physical nature of tempered glass it cannot be filed, drilled or trimmed in any way, therefore any adjustments required during fitting must, of necessity, be done on the mounting frame. Great care is necessary when fitting the glass to prevent damage, for example chipping. Scratches, chips, flaws and other surface defects weaken glass very considerably and on this score alone every effort must be made to avoid such defects, particularly at the edges of the glass (see paragraph 5).

2.3 **Fatigue**

Cyclic fatigue of toughened glass at commonly used stress level, is effectively non-existent.

2.4 **Safety Factors**

The safety factors required on glass components are very much higher than for other materials used in aircraft manufacture, because of the loss of strength with duration of load, scatter in strength inherent in glass, thickness tolerances and high notch sensitivity.

3 Windscreen Design

The design of windscreens varies considerably according to the type of aircraft to which they are fitted, the extent of de-misting and impact strength required and also on whether an electrical method of anti-icing is to be used. The details given in the following paragraphs are of a general nature, outlining some design features of typical windscreen assemblies.

3.1 Windscreens are of laminated manufacture and in general can be considered as belonging to one of two categories,

a) the simple windscreen, usually fitted to non-pressurised aircraft having limited performance, and

b) the electrically-heated panel windscreen fitted to pressurised aircraft with all-weather capability.

3.1.1 **Simple Windscreens**

A panel is usually made up of two pre-formed and pre-tempered glass layers or plies, each of which is bonded to a sandwiched sheet or ply of reinforcing material termed the 'interlayer'. The suitability of a material for use as an interlayer depends on a number of factors, the most important of which are its ability to withstand impact, to prevent breakage into dangerous fragments and to prevent detachment of such fragments from the inner surface of a panel. The material normally used for the interlayer is polyvinyl butyral (plasticised with dibutyl sebacate or triethylene glycol de-hexoate), generally referred to as vinyl.

a) The vinyl and glass layers are bonded by the application of pressure and heat, the temperature being considerably less than that required for tempering the glass and below the temperature at which vinyl would flow. The bond is achieved without the use of a cement as vinyl, after laminating, has a natural affinity for glass.

3.1.2 **Electrically Heated Windscreens**

These windscreens are used on pressurised aircraft to prevent the formation of ice and mist on the panels and to improve the impact resistance of the windscreen panel at low temperatures (see Appendix 2 of Chapter D4–2 of British Civil Airworthiness Requirements or ACJ 25.775(d)). The physical properties of vinyl vary considerably with changes in temperature. Considering a range of ambient temperatures normally encountered under flight operating conditions, the vinyl would be brittle in the lower part of the range and plastic in the upper part. Since the desired impact resistance characteristics of a windscreen depend to a large degree on the plasticity of the vinyl interlayer, it follows that impact resistance is dependent on interlayer temperature.

a) The panels are of special laminated manufacture containing a resistance type heating element in the form of a film deposited on the inner surface of the outer glass layer. The heating element is supplied with power from the aircraft electrical system via terminals on the panel frame and by busbars 'fired' onto a glass layer at the top and bottom edges of the element. The temperature of the panel is controlled by a temperature-sensing element laminated into the panel and connected to an automatic control unit.

b) The windscreens in certain of the larger types of aircraft consist of up to seven transparent layers made up of glass, vinyl, acrylic plastic and polyester material. In a typical assembly, three thin vinyl interlayers are employed and they sandwich two layers of thick stretched acrylic plastic. Together the acrylic layers provide most of the windshield structural integrity. The outer layer of the windscreen is a thin, chemically toughened and abrasive-resistant glass layer and its inner face is covered with the heating element which is supplied with power from busbars at the top and bottom of the windscreen. Two sensing elements for automatic temperature control and an overheat sensing element are laminated into the panel. Only one of the control elements is used; the other serves as a spare. The inner layer of the windscreen assembly is made of an abrasion-resistant polyester material.

c) There are two types of heating elements in general use; namely, tin oxide and gold film, the latter complying with specifications DTD 5576A. These panels are briefly described in the following paragraphs.

   i) **Tin Oxide Film Panels**. In this type of panel, the heating element is produced by spraying with a flame gun a coating (0·000002 inch thick) of tin oxide at 1000°C on the inner surface of the outer glass layer which is then bonded to the vinyl interlayer.

   ii) **Gold Film Panels**. In these panels a combined film of gold and metal oxide is used as the heating element. The film is electrically-deposited on the surface of the glass in a vacuum chamber.

3.2 **Windscreen Attachment Methods**

There are several methods of attaching windscreen assemblies dependent on the type employed. The method frequently adopted for simple type windscreens is the one generally referred to as 'Friction Mounting'; it is illustrated in Figure 1. The periphery of the panel is clamped between metal glazing strips and the fuselage frame by a series of bolts. To avoid damaging the glass and to ensure that the joint will be watertight, a suitable lining, usually in the form of a special rubber strip or moulding, is fitted or bonded to the structure.

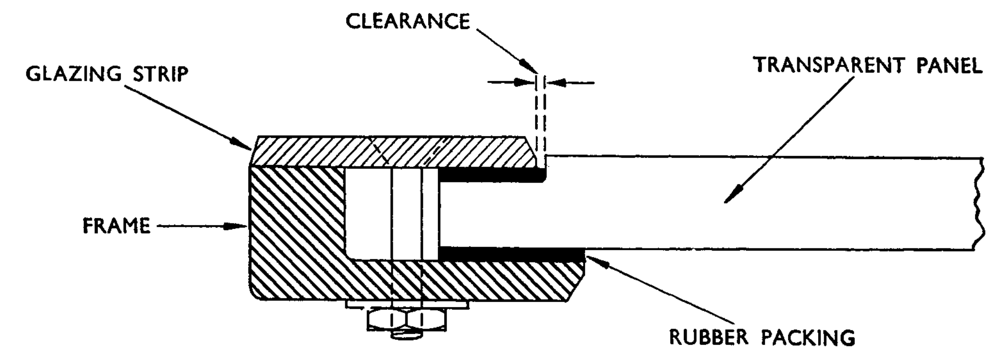

Figure 1 Friction Mounting

3.2.1 The impact strength of a laminated panel is based on the ability of the interlayer to stretch and deform and thus absorb the shock load, assuming that the impact is great enough to shatter the glass layers. Under such conditions it is essential that the vinyl interlayer be held securely around the edges of the panel. It is for this reason therefore, that panels designed to resist high impact loads and in particular electrically heated panels, are secured to the windshield frames by bolts passing through the edges of the panels rather than relying on the clamping action shown in Figure 1.

a) The vinyl interlayer of this type of windscreen is generally thicker than that used in ordinary laminated windscreens and it is extended beyond the periphery of the glass layers. In windscreens employing layers of acrylic plastic this applies to these layers also. A further refinement in the design is an aluminium alloy reinforcing strip, which is in the form of a frame and is embedded in the vinyl. This strip, together with aluminium alloy inserts in each of the bolt holes, assists in preventing the vinyl from deforming at the edges under pressurisation loads and also when tightening bolts during installation. A typical assembly is shown in Figure 2.

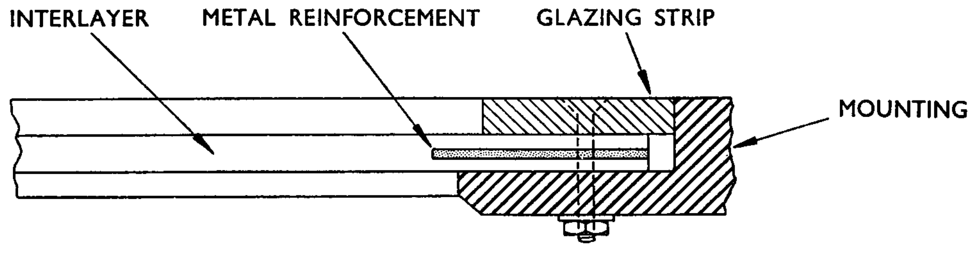

Figure 2 Extended Interlayer Method

4 Installation

The installation of windscreen panels must be in accordance with the procedure specified in the relevant aircraft Maintenance Manual. The information given in the following paragraphs is of a general nature and is intended as a guide.

4.1 Before installation, panels should be carefully checked for any sign of damage such as scratches and chips (see paragraph 5.1.2 and 5.1.3). The frames must be clean and seals, where fitted, must be undamaged. Frame mounting faces should be inspected for flatness and freedom from distortion.

NOTE: Cleaning agents must be of the type specified in the relevant aircraft Maintenance Manual and should not be applied indiscriminately to windscreens and surrounding structure. Incorrect cleaning agents may attack the interlayer and cause delamination.

4.2 Where specified, clearances between panels and fuselage structure must be checked to ensure that they are within limits. In some instances, particularly for simple type windscreens, the edges of panels are rebated (see Figure 1) to accommodate the glazing strips and specified clearances between strips and raised portions of panels must be maintained.

4.3 The condition of pressure and weather seals should be examined before installation of a panel and, where necessary, replaced or repaired in the manner specified for the particular type of aircraft.

4.4 In installations requiring a fluid plastic compound for sealing purposes, the compound must be applied in a uniform layer and of the correct thickness to form a gasket between windscreen and fuselage frames, the required thickness being obtained by bolting a windscreen to its respective frame. In some cases a bedding-down template is provided for this purpose.

NOTE: The compound must be left to cure for the relevant time period before finally tightening the attachment bolts.

4.5 A silicone grease (sometimes referred to as a release agent) of the type specified in the appropriate aircraft Maintenance Manual, should be applied to the mating surfaces of windscreen frames to form a silicone film which is non-adhesive to pressure and weather seals and facilitates subsequent removal of panels.

NOTE: In some types of aircraft, a preformed strip or gasket may also be fitted to serve this purpose.

4.6 On electrically heated windscreen panels fitted to certain types of aircraft, a code number is etched in the corner of the glass near the busbar terminals to indicate the heating element resistance. As it is possible for the number to be covered when the panel is installed, details should be noted before installation to ensure correct heating circuit connections.

4.7 In aircraft in which a standby magnetic compass is located on a structural support between two windscreen panels, care must be taken to ensure that the panel attachment bolts in the vicinity of the compass position are of non-magnetic material. After installation, a check compass swing must be carried out to prove the accuracy of the standby compass, with current to the windscreens switched both 'on' and 'off'.

4.8 Attachment bolts and nuts should be coated with a compound to provide a seal at each of the bolt holes. Where compounds are specified, details of types and methods of use are contained in the relevant aircraft Maintenance Manual.

4.9 During the initial stages of fitting attachment bolts, the panel should always be adequately supported to prevent it resting on the bolts thus preventing the countersunk heads from seating correctly. Locating keys are provided for this purpose in some types of aircraft and they should be used in the manner specified. When installing windscreens of the extended interlayer type, it is important to ensure that the specified clearance exists between fixing holes and bolts.

4.10 Attachment bolts should be tightened evenly and in a staggered sequence ensuring that the panel is not distorted and that bolt torque loadings are as specified.

4.11 Cable terminals on electrically heated windscreen panels should be suitably protected against damage. After installation the anti-icing system cables should be connected to their respective terminals, identified in accordance with the relevant wiring diagram and the heating system checked for correct functioning.

4.12 After installation of a windscreen panel in a pressurised cabin type aircraft and elapse of the requisite curing time for sealing compounds, a cabin pressurisation and leak rate test should be carried out if prescribed in the relevant aircraft Maintenance Manual.

5 Inspection and Maintenance

The information given in the following paragraph is of a general nature and should be read in conjunction with the Maintenance Manuals and approved Maintenance Schedules for the aircraft concerned.

5.1 **Damage**

Panels should be inspected for defects and any signs of damage such as delamination, chipping and cracking of glass layers. The following brief descriptive details are intended as a guide to this type of damage and other defects which may occur.

5.1.1 **Delamination**

This is a defect which can occur in laminated windscreens characterised by the separation of a glass layer from the vinyl interlayer. Delamination should not be confused with deliberate stress-relieving edge separation of panels which is sometimes employed. In such cases a parting medium is used, introducing a separation penetrating the edges of the panel assembly to a distance of 6 mm to 25 mm (0·25 inch to 1 inch) and giving a yellowish or brownish appearance at the edges.

a) Defective delamination has characteristics that tend to divide it into the following main types and resulting from different types of stress at the glass/vinyl interface.

   i) **Clear (or cloudy)**. Of the two types, delamination is apt to be clear. However cloudy delamination will result if moisture penetrates the delaminated area. In doubtful cases delamination can be confirmed by carrying out a reflection test by means of a flaw detector using a light beam. The beam is directed onto the surface of the windscreen and produces two sharply defined lines on a ground-glass screen representing the top and bottom surfaces of the windscreen. Any delamination present will produce an additional line and its proximity to either of the other lines is helpful in deciding which of the layers has separated.

   ii) **Rough-edge**. This is characterised by its irregular, sharp or jagged boundary. It may develop long finger-like projections if, during the course of delamination the parting between vinyl and glass is not uniform.

iii) **Smooth-edge**. Smooth-edge delamination advances with a smooth boundary. It does not have rough or jagged areas within it, nor indications of internal cracks or chips.

b) A small amount of delamination is permitted on most aircraft but details of the permissible extent and any limits concerned with aircraft flight operations, e.g. flights under pressurised conditions, should be obtained from the relevant aircraft Maintenance Manual and Flight Manual.

5.1.2 **Scratches**

Scratches are defects in the surface of a panel and every effort must be made to avoid them. They are normally more prevalent on the outer surface where windshield wipers are indirectly the primary cause. Any dust or grit trapped by a wiper blade can immediately become an extremely effective cutting device as soon as the wiper is set in motion. Wiper blades must therefore be maintained in a clean condition and should only be operated when the windscreens are wet.

a) On the basis of severity, scratches may be classified as hairline, light and heavy.

i) **Hairline Scratches**. A hairline scratch can be seen but is difficult to feel with a fingernail. It can be caused by wiping the glass with a dry cloth. To avoid hairline scratches, the glass should be cleaned with a mild detergent and water, using a soft brush or clean, soft cotton cloth, followed by drying with a clean, soft cotton cloth.

ii) **Light Scratches**. A light scratch is less than 0·254 mm (0·010 inch) deep and can be felt with a fingernail. This type of scratch ordinarily has few edge chips.

iii) **Heavy Scratches**. A heavy scratch is 0·254 mm (0·010 inch) or more in depth and can be readily felt with a fingernail. This type of scratch is apt to show extensive edge chipping.

b) If the integrity of a panel is not suspected and provided visibility is not seriously affected, scratches are permissible within limits detailed in the relevant aircraft Maintenance Manual.

c) Scratches can be removed by polishing, but due to an uneconomic time factor, possible optical distortion and problems of assessing optical standards acceptable in the ultimate operational situations, it is recommended that a panel assembly be returned to the manufacturer and replaced by a serviceable assembly.

5.1.3 **Chipping**

Chips are flakes or layers of glass broken from the surface which can occur if the exterior surfaces of a panel are struck by a sharp object. The inner surfaces of a lamination of the panel may also chip in unheated areas, as a result of high internal stresses. There are two types of chips: conchoidal and V-shaped. Conchoidal chips are usually circular or curved in shape with many fine striations that follow the outline of the outer edge. V-shaped chips are sharp and narrow, the 'V' appearing to propagate toward the interior of the glass. Visibility through chipped areas of a windscreen panel is usually poor.

a) Chips occurring at the inner surfaces of glass panels are critical because the existing condition may result in cracking or shattering of a pane, or in the case of an electrically heated windscreen, destruction of the resistance heating film. These chips are usually associated with rough-edge delamination (see paragraph 5.1.1).

5.1.4 **Cracks**

These are serious defects which, depending on the type of glass and the formation and propagation of the cracks, may result in considerable strength reduction of the windscreen and effects on visibility varying from slightly impaired to complete obscurity. In annealed glass the damage may take the form of single cracks, or cracks forming an irregular criss-cross pattern. The more usual result of damage to strengthened glass is the formation of cracks spreading radially from the point of damage and in these cases, vision is impaired but not completely obscured. Cracks in a toughened glass form a pattern defined as shattering, a defect resulting in considerable reduction in strength and loss of vision. A windscreen having such a defect should be removed and replaced by a serviceable assembly.

a) The extent to which cracks are permitted, limitations on aircraft operation and the action to be taken in order to rectify the defects, may vary between aircraft types. Details are given in the relevant aircraft Maintenance Manual and Flight Manual and reference must therefore always be made to these documents.

5.1.5 **Vinyl Rupture**

Vinyl rupture consists of a failure across the section of vinyl at the inner edge of the metal insert (Figure 2) and necessitates changing the panel.

5.1.6 **Vinyl 'Bubbling'**

Small bubbles occurring within the vinyl interlayer of electrically heated windscreens are not a delamination nor are they structurally dangerous. They are usually due to overheating conditions, being formed by a glass liberated by the vinyl. They need not be a cause for windscreen replacement unless vision is seriously impaired. Their presence, however, may indicate a defective window heat control system which should be rendered inoperative pending rectification.

5.1.7 **Discolouration**

Electrically heated windscreens are transparent to direct light but they normally have a distinctive colour when viewed by reflected light. This apparent discolouration is due to the resistance heating film and it may vary slightly between windscreens. Only black or brown discolouration, when viewed normal to the surface, should be regarded as a possible defect necessitating removal of the windscreen and replacement by a serviceable one. The cause of such discolouration may be a burnout of the heating film or a carbon deposit between a busbar and the heating film due to overheating.

5.2 **Sealants**

Weather sealants provided around the periphery of windscreens must be inspected for evidence of erosion, lack of adhesion, separation or holes. The obvious purpose of maintaining an effective weather sealant is to protect the windscreens against moisture entry and the delamination or electrical problems associated with moisture penetration. When new sealant is required, the damaged material should be removed, the area cleaned and new material applied in the manner prescribed in the relevant aircraft Maintenance Manual.

NOTE: Damaged material should always be removed with a plastic tool that will fit, without binding, in the gap between windscreen and frame. The use of a metal tool is inadvisable, as this could damage the glass or vinyl interlayer.

5.3 **Cleaning of Windscreens**

Windscreens should be washed regularly with warm water and mild detergent, using a clean, soft cloth or cotton wool pad; after washing the panels should be rinsed and dried with a clean, soft cotton cloth. Scratching of the glass must be avoided.

5.3.1 Some aircraft manufacturers recommend the use of a proprietary detergent which is also suitable for the surrounding aircraft structure and therefore to some extent simplifies cleaning operations; it is important that only the detergent specified is used and that the prescribed proportion of detergent to water is observed.

5.3.2 Grit, dirt, etc., should be removed at regular intervals from recesses, for example, where the panel joins the frame, to prevent it being picked up by the cleaning cloths and causing scratching. The accumulation of cleaning and polishing materials in recesses must be avoided.

6 Storage

Extreme care is necessary during transportation, storage and handling of windscreens to prevent damage. It is recommended that panels should be packed with both faces covered with adhesive polythene; they should then be wrapped in acid-free paper and cellulose wadding and put into reinforced cartons, these being covered with waxed paper and secured with adhesive tape.

6.1 The panel should be stored in their cartons on suitable racks, away from sunlight or strong artificial light, at a controlled temperature of between 10°C to 21°C (50°F to 70°F) in well ventilated conditions.

6.2 It is important to ensure that during handling or storage the thicker glass ply of a laminated panel is kept uppermost to prevent delamination (see paragraph 5.1) and that the polythene film is not removed until the panel is fitted to the aircraft.

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Leaflet 6-9 Inspection of Composite Structures

1 Introduction

This leaflet provides general guidance for the inspection of composite aircraft structure (including repaired structure) for which no, or incomplete, manufacturer instruction exists.

The term 'composite structure' generally refers to structure manufactured from a very broad band of material types when used in aerospace applications, e.g. metal alloys, metallic honeycomb sandwich structure, fibre reinforced non-metallic matrix systems etc. For the purposes of this leaflet the term 'composite structure' refers to both monolithic and sandwich structures manufactured from fibre reinforced non-metallic matrix systems, e.g. Glass Fibre Reinforced Plastic (GFRP or GRP), Carbon Fibre Reinforced Plastic (CFRP) etc. Inspection guidance for metallic composite structure may be considered to have been given in part by CAP 562, Leaflet 6-2.

2 General

The use of composite materials has increased significantly during recent years, developing from simple minor structural applications, e.g. wing tip fairings (e.g. Cessna C172), to use in significant sections of Primary Structure, e.g. fuselage and wings (e.g. Europa and many gliders) to complete airframes (e.g. T67 and Grob 115). Therefore, inspector familiarity with these materials, and the significance and nature of any damage, has become increasingly important.

Composite materials comprise of more than one constituent material (inhomogeneous), and exhibit net properties that differ from those of any one of the constituent materials. Such a composition tends to provide properties that vary with direction (anisotropic). These properties, when correctly engineered, provide for the often quoted benefits of composite materials, e.g. high stiffness to weight and strength to weight ratios etc. However, these properties also provide for the possibility of more types of damage than would be found in metallic structure, and each type of damage may carry a particular significance to the structure. Therefore, it becomes necessary for the inspector to be aware of these damage types, although composite structure is usually designed such that the same level of predominately visual inspection required for metallic structure will also be required for composite structure to ensure that safety is maintained, i.e. any damage that may remain undetected visually will not propagate between inspections to threaten ultimate load capability and fatigue life.

Structural deterioration may arise from various causes, e.g. wear and tear, load, environment etc, and can affect various parts of the structure according to the design of the aircraft and the use to which it is put. Therefore, this leaflet should be read in conjunction with the appropriate manufacturer's publications and Maintenance Schedule for the aircraft concerned.

Although considerable guidance may be given in the appropriate publications as to suitable opportunities for inspecting normally inaccessible structures, experience should indicate to the operator further opportunities for such inspections which can be included in the Maintenance Schedule, e.g. when the wing tip is removed permitting access to the adjacent wing structure etc.

Furthermore, whenever unscheduled access has been gained to a part of the structure which is normally inaccessible, then advantage should also be taken of this dismantling to inspect all parts of the structure exposed. The need to exploit such opportunities for inspection will be more prevalent to composite structures, than to metallic structure, due to the possibilities of significant Barely Visible Damage (BVD) and externally Non-Visible Damage (NVD). Apart from the airworthiness aspects, these combined inspections could often be to the operators advantage, since they may obviate the need for future dismantling. Furthermore, damage may be detected at an earlier stage of development requiring a smaller, and less costly, repair.

3 Cleanliness

The propensity for composites to suffer BVD and NVD requires the use of effective cleaning processes prior to inspection. A clean paint surface could make the difference between locating BVD and not, i.e. NVD, e.g. when non-penetrating impact occurs. Subtle changes in light reflection can be the determining factor.

Composite materials, and the associated protective treatments, e.g. paint, gel coats, etc., may react in significantly different ways from one material system to the next when exposed to various cleaning agents and techniques. These reactions may also differ from those more frequently experienced by operators familiar with metallic structure and any of the associated surface treatments. Therefore, it is important that manufacturer's guidance is obtained regarding cleaning materials and methods prior to the start of the cleaning process. However, a generic cleaning procedure applicable to common composite material structure may comprise of:

3.1 **Gaining access** (see also CAP 562, Leaflet 6-2): This includes removal of all acoustic liners, thermal blankets etc., such that all surfaces can be made visible in adequate lighting, either directly or with the aid of suitable inspection devices, such as mirrors or boroscopes. Note that particular care is required when handling and accessing composite structures, e.g. removing panels, placing body weight on surfaces, tool handling etc., because this type of structure is vulnerable to damage resulting from such activity, particularly the control surfaces and trailing edges. Protective equipment such as mats and crawling boards should always be used when, and in accordance with, instructions specified by the aircraft manufacturer.

3.2 **Removal of obvious debris, loose paint, dirt etc.:** Loose paint should be removed with care to avoid damage to the composite surface. This may be achieved by hand sanding, e.g. using Grade 320 paper. Note that a primer paint of contrasting colour may have been used to mark the surface of the structural laminate. Any sanding beyond the primer layer will damage the fibres and matrix. The manufacturer should be consulted for guidance if large areas of paint are to be stripped. Blasting, e.g. Plastic Media Blasting etc, or chemical stripping methods should be considered to be unacceptable unless specifically permitted by the manufacturer. Most blasting media will damage the composite outer fibre and matrix layer, whilst the constituent materials in paint stripper, e.g. Methylene Chloride, can be particularly damaging to the matrix.

3.3 **Initial visual inspection:** There should be a preliminary inspection of all surfaces, edges, and joints and is intended to provide an approximate indication of the nature and extent of any damage. Typical defects which may be detected at this stage include cracks, holes, gouges, dents, edge delaminations, fastener hole damage, severe burns, and sealant damage. A careful initial inspection may allow for an earlier, and therefore less costly, 'scrap' decision to be made without wasting time and effort completing any further work.

3.4 **Cleaning:** Cleaning may be achieved simply by wiping the surface using a cloth moistened with a suitable degreasing agent, e.g. Methyl Ethyl Keytone (MEK), Isopropyl Alcohol (IPA) etc. A clean cloth should be used for each application of agent and for each removal of excess fluid and dirt respectively. Should a more thorough clean be required, e.g. using a mild detergent and water, then masking will be necessary to prevent further damage from cleaning agent ingress at the damage site. Masking should be completed using a compatible tape. The cleaning agent should be applied with a sponge, cloth, or similar non-metallic means of application, i.e. that which will not damage the surface. The structure may be rinsed using clean water. High pressure hot water jets, or steam, should not be used. The structure may be dried using a clean dry cloth. Drying can be accelerated using a clean dry compressed airflow. Typically this may be at temperatures up to 50°C for most materials that have been cured at elevated temperature. However, materials cured at room temperature (without elevated temperature post cure) should be treated with caution at lower temperatures, e.g. 30°C maximum.

All drain paths and drainage holes should be checked to ensure that they are clear of debris once cleaning has been completed.

3.5 **Visual inspection**: see Section 4.

The sequence above may form the preliminary stage of a repair action should defects be found.

4 Inspection Methods

Approximately 90% of all aviation inspections of composite structure are visual, often being complemented by a Tap Test. Many other inspection techniques are used by the aviation industry, e.g. Dye Penetrants, Bond Testers, Ultrasonic Inspection, Radiography, Mechanical Impedance, and Thermography. However, these methods tend to be used more by manufacturing industry and public transport operators, than by small aircraft operators, due to the relatively high cost of installation and operation. These techniques are often only used following the visual location of damage, or suspected damage. Details regarding these methods are available in many texts, and will only be briefly mentioned (Appendix 1) because they generally fall outside the scope of this Leaflet. Furthermore, Non-Destructive Inspection and Testing (NDI and NDT) are the subject of extensive research activity and consequently the material in this Leaflet does not attempt to be a comprehensive coverage of NDI and NDT.

All inspections must be completed by suitably qualified personnel, e.g. see CAP 747 Mandatory Requirements for Airworthiness Generic Requirement (GR) No. 23.

4.1 **Visual Inspection:** Some composite damage can be located by visual inspection, whilst some may not. Inspection may be complicated by the material surface finish. The material may remain in its natural finished state, it may have been finished with a dye, it may have a gel coat (possibly coloured), or it may have been painted. Paint colour may be significant to damage detectability. These conditions should be allowed for when completing inspection. Furthermore, knowledge of the surface material type, e.g. the type of weave etc, will help identify the existence of damage. Note that it is common for a manufacturer to use a sacrificial protective woven outer layer to protect the structural plies, particularly unidirectional plies. This may give a false impression of the structural build. Manufacturer's data, e.g. repair manuals, drawings etc, should be consulted to establish this point. If in doubt, then treat the outer ply as a structural ply.

Visual inspection may allow for the detection of many defect types, e.g. some impacts, delaminations, disbonds, cracks, some heat damage, 2·54mm (0·1in.) depth, scratches of 1·27mm (0·05in.) length etc. Lesser dimensions may be located in favourable conditions. The nature and extent of damage that may be detected may vary significantly, being a function of many variables, e.g. cleanliness, lighting, inspector skill and experience, surface finish, colour etc.

All visual inspections should be completed in adequate lighting, and at such a distance, that an inspector may be confident of locating damage as identified in Section 5. Manufacturer’s instruction should be followed regarding the distance from the structure that an inspection should be completed because the nature and extent of inspectable damage should be a function of the design. Typically, a visual inspection should be completed at a distance no greater than 1·52m (5ft.) from the structure, whilst a detailed visual inspection should be completed at whatever lesser distance, e.g. typically 0·2-0·3m (8-12ins), allows confirmation of the existence, nature, and extent of any damage. This may be complemented using a 10X magnifying glass. Obviously, any suspicion of damage, or previous experience of damage at any given location, requires a detailed visual inspection and may require further disassembly. Particular attention should be paid to previous repair locations. Extensive disassembly may require aircraft jacking. Jacking should be completed in accordance with manufacturer’s instruction.

The inspections may be completed with suitable inspection devices, such as mirrors, light probes and boroscopes, ref. CAP 562, Leaflets 6-2 Section 8 and Leaflet 4-9.

Once located, the significance of the damage should be assessed, e.g. as being cosmetic or structural damage, see Section 5.

Note that visual inspection will not be adequate to allow detection of some damage types i.e. NVD, e.g. some delaminations, impacts, and heat damage etc. The design should allow for this, or further actions should be called in the manufacturer’s data to deal with potential problems. Furthermore, note that some damaged structure may relax, e.g. impact damage, to the extent that 60%, or more, of the original profile may be recovered. Therefore, the time between a damage event and inspection may be significant to detectability.

4.2 **Light Test:** Delamination in GFRP components that do not have rigid foam, or any similar obstructions inside, can often be detected by pointing a bright light at the surface whilst looking at the other side. Damage may be evident as a dark area. Care must be taken in positioning the light source so as not to let the composite get hot, as this can cause damage. CFRP does not allow for such inspection. This is an inspection method widely used and recommended by manufacturers such as Grob and Slingsby.

4.3 **Tap Test:** In its crudest form the Tap Test is the simple tapping of the structure with a coin, or similar small hard blunt object, such that a sound is generated. A damaged structure usually produces a 'duller' sound than an undamaged structure. Although crude, the Tap Test can be a useful complimentary tool for a visual inspection, particularly when confirming the presence and approximate dimensions of disbonds and delaminations. It may be possible to detect such defects down to 12·7-25·7mm (0·5-1in.) diameter in typical composite manufactures. A structure should be explored in 6-13mm (0·25 – 0·5in.) steps to locate such damage. Note that the minimum detectable dimension increases with material thickness. The usefulness of the Tap Test for sandwich structure is limited to damage detection at the presented face, e.g.

inter-ply delamination or core to skin disbond. Significant honeycomb cell fluid content may sometimes be detected. Unfortunately, the sound will also change due to factors other than damage, e.g. changes of thickness, hidden attached structure, potting material, the presence of repairs etc. Therefore, knowledge of the composite structure, and the surrounding structure, is necessary to gain the most useful information from the Tap Test. Furthermore, a Tap Test is difficult to use reliably over large areas because an inspector may experience problems maintaining concentration during such a repetitive task.

Note that automated electronic Tap Test equipment is available which measures impact signal transmission duration or frequency.

5 Damage

The significance of composite damage is dependent upon the function of the structure and the type and extent of damage. The most likely cause of damage, approximately 80%, is impact, often the result of ground handling. This may produce one, or more, of the damage types identified below. The most significant damage types are delamination, disbond and material penetration. The significance of the extent of damage is a function of the design. Reference should be made to manufacturer's data regarding this issue.

5.1 **Structural Function:** The function of the structure depends upon the design. However, it is common for structure to be categorised as Primary Structure or lesser structure, e.g. Secondary Structure. Primary Structure is that which, if damaged, could threaten the structural integrity of the aircraft, e.g. wing spars, skins, ribs, ailerons, etc, or fuselage skins, stringers, etc, or tail structure, elevators, rudders, etc. Secondary Structure is that which may pose a significantly lower safety risk and/or be associated with an economic cost, e.g. wing/body fairings, nacelles etc. The categorisation may not always be clear, e.g. a fairing may initially appear to be Secondary Structure, but could, upon separation, threaten the safety of the aircraft by impact with Primary Structure. If in doubt, such structure should be treated as Primary Structure. Furthermore, the categorisation may be extended to distinguish between sections of any individual component, e.g. a flap may be 'zoned' such that structure adjacent to hinge attachments is considered to be more critical than the field areas, thus requiring more stringent allowable damage limits to be applied to the former. The inspector should use manufacturer's guidance to clarify the function of the structure. This is particularly important for smaller aircraft designs because they tend to use a wider range of configurations than larger public transport aircraft.

5.2 **Types of Damage:** The type of structural damage, be it to Primary or lesser structure, may be categorised as **cosmetic** or **structural**.

5.2.1 **Cosmetic Damage:** Cosmetic damage is that which is of no immediate structural concern. However, cosmetic damage that could allow fluid ingress should be repaired, i.e. dried and sealed, to prevent it from progressing to become structural damage.

Wrinkling and Dimpling: Minor skin wrinkles and dimpling (sandwich panel skin wrinkling that adapts to the shape of the honeycomb cells, which should not be present if the part has been correctly designed with small honeycomb cells), Figures 1 and 2, may have been present since manufacture. Defects present from manufacture may be distinguished from damage by careful inspection for other evidence of degradation, e.g. surface crazing, fibre breakout, loose resin material, delamination etc. However, if in doubt, such structure should be Tap Tested for delamination to ensure that any apparent 'wrinkling and dimpling' is not the result of skin buckling, i.e. damage which is of structural interest.

Resin Rich and Resin Starved Areas: Porosity in resin rich areas, or exposed fibre in resin starved areas, Figures 3 and 4, should be obvious and must be dried and sealed to prevent long term degradation due to fluid ingress.

Surface Damage: Many structures use a sacrificial outer ply layer, e.g. a woven glass ply, to resist 'wear and tear' or to help prevent unidirectional fibre break out. The manufacturer's drawings should be referenced to avoid the incorrect determination of the significance of any surface ply damage. If any doubt exists regarding the function of the outer ply, then it should be treated as a structural ply and repaired accordingly. Damage to a sacrificial layer, although of no immediate concern, may allow fluid access to the main structure. Again, such damage should be dried and sealed.

5.2.2 **Structural Damage:** Structural damage is that which threatens the function of the structure, whether it be damage to Primary or lesser structure.

Composite structural damage may be further categorised as being **penetration damage**, damage between plies (**inter-ply damage**), or damage to the constituent materials (**intra-ply damage**), e.g. matrix or fibre damage. Sandwich structure adds further possibilities, e.g. honeycomb damage or core to skin interface damage.

5.2.2.1 **Penetration Damage:** Any laminate penetration, e.g. holes resulting from impact damage etc, is a concern because it represents damage to both fibre and matrix material. Such damage is often self evident, although smaller holes may be missed and could allow long term moisture ingress to occur. This is particularly true for sandwich structure. Any penetrations should be repaired.

5.2.2.2 **Structural Inter-Ply Damage:** Damage between plies.

Delamination: Delamination, Figure 5, is the separation between plies in a laminate, i.e. in the plane of the laminate. It may run across the whole laminate, or it may run to the laminate edges, and/or it may occur between many plies in any single laminate.

Composite structure is often compression critical. Delamination may further reduce the compressive strength, both at the local fibre level and at the component buckling level. Furthermore, delamination is often BVD, or NVD, on the external face of the structure. Therefore, thorough inspection of clean structure and access to the internal face of the structure is essential if the chances of detecting potentially significant damage are to be maximised.

Delamination may sometimes be visible as cracking parallel to the fibres at the laminate edges. Any cracked paint and debris at laminate edges should be removed, using non-metallic scrappers etc, prior to inspection of the edge.

Delamination that is not visible may sometimes also be located by using a Tap Test, see above. The chances of finding hidden delamination are greatly increased by knowledge of an event, e.g. an impact, or by the presence of other damage. Any fibre break-out on the internal face of the structure is likely to be associated with delamination. Any clues that indicate the presence of delamination, e.g. dents, paint damage, deformations, should by followed by a Tap Test.

Inspection for delamination should include all laminate edges, cutouts, and any opened fastener holes. Delamination resulting from poor fastener hole fit, wear and tear, poor drilling, or excessive fastener pull-up load is common.

Disbond: Disbond is the separation between laminates, e.g. a bonded joint, or the separation of a laminate skin from honeycomb core material, see 'Sandwich Structure Damage' paragraph 5.2.2.4.

Early detection of disbond is important because it may provide an indication of imminent joint failure. Obviously, this may be critical for any bonded Primary Structural joints that do not have secondary fastening. It should be noted that the progression from the initial areas of disbond to catastrophic failure may be very rapid. The progression may be accelerated by moisture ingress or fatigue loading at the joint.

Disbond may be evident as a gap in the adhesive line at the joint section edge, Figure 6, if accessible, or as ply peeling and/or paint damage along the joint edge when viewed perpendicular to the presented face. Disbond may sometimes be detected by using a Tap Test. Again, as with delamination, a 'duller' sound will be produced at the damage site than in the surrounding structure. However, interpretation may be difficult due to changes in section at the joint, varied back-up structure, and the presence of other joints.

Inspection of the disbond initiation surface, if visible, may help determine the potential severity of a problem. Correctly designed, the joint should fail in the adherend, i.e. the materials being joined together, because the joint should be stronger than the parent material. Such a failure, i.e. 'cohesive failure', will be evident as fractured matrix material and exposed and/or damaged fibres extending beyond the adhesive line into the adherend material. Such a failure is an indication of an overload. A more thorough inspection of the aircraft structure should be initiated, e.g. a 'heavy landing' inspection, unless the damage is the result of a known local event.

The disbond may be the result of a failure in the adhesive material, i.e. 'adhesive failure'. Fractured adhesive material may appear, probably without exposed fibres, to be paler in colour than the undamaged adhesive. Such a failure is an indication of an under strength adhesive.

The disbond may be the result of poor bonding between the adhesive and the adherend. This may appear as smooth unbroken adhesive and adherend surfaces without fibre exposure. Such a failure is potentially catastrophic because it may be the result of the adherend joint surfaces being contaminated. Such a contamination is very likely to have effected most, if not all, of a joint. Unlike an overload of a fully bonded joint, the material that has not already disbonded at the time of a finding is very likely to be poorly bonded. Such a finding must be followed by repair action that will recover full strength to the whole of the joint unless it can be shown that the remaining joint is at full strength, e.g. a small disbonded area is the result of a known local contamination.

5.2.2.3 **Structural Intra-Ply Damage:** Damage to the constituent materials.

Fibre Damage: Composite material fibres carry the laminate load via shear transfer from the matrix material. Therefore, the failure of any fibres may be significant to the strength of the part, particularly when tensile loads are parallel to the major fibre direction.

Fibre failure may be visibly evident as fibre breakout, Figure 7. The form of the fibre breakout will depend upon the fibre arrangement in the material, e.g. unidirectional, woven etc, and the strength of the fibre-matrix bond. Unidirectional material may often produce long fibre filament breakout, whilst woven materials, e.g. aramids, often result in fibre tufts standing proud of the surface. Such breakout may be evident across the material surface, along the structure edges, at cut-outs, or in fastener holes. Those composite systems with weak fibre-matrix bonding, e.g. aramids, tend to produce more loose fibre and tufts, when damaged, than may be evident in a system with a strong fibre matrix bond. The latter may result in a cleaner brittle failure. Such damage may be associated with extensive delamination. Fibre breakout is often the result of impact damage, poor handling, or poor drilling, and is more likely to be evident on the back face of the structure. Any fibre damage, particularly that to primary structure, must be repaired immediately.

Matrix Damage: Matrix material allows the transfer of load to and between fibres. Therefore, matrix material damage is potentially very serious. The failure of the matrix material may be particularly significant to the shear and compressive strengths, and stiffness, of a structure.

The matrix may be damaged by direct overload or by exposure to the environment, e.g. heat, moisture etc. The properties may be altered at the time of exposure to the environment and/or altered when exposed for a period of time. The alteration may be reversible or irreversible.

Heat Damage: Heat may soften the matrix such that shear and compressive strengths and stiffness are significantly reduced. If the heat is excessive, i.e. the glass transition temperature range (the temperature range over which a reversible change from brittle to rubbery state occurs) is exceeded, then irreversible damage may occur as the matrix breaks down (typically at a temperature above the cure temperature).

Heat damage may be evident as obviously burned and discoloured matrix material. However, other clues should also be used as indicators of heat damage because exposure to lesser heat may not discolour the matrix. Such clues include knowledge of any events, e.g. exposure to engine heat, blistered and discoloured paint, or gel coat damage etc.

Lightning Strike Damage: Lightning strike damage is a particularly severe form of heat damage which may be evident, assuming that total destruction has not occurred, as distinct 'pin-hole' burns at the lightning contact points, extensive damage (any and all types) remote from the contact point, e.g. delamination, and severe burns at junctions with metallic structure. Further clues may include damage to any attached conductive paths, e.g. aluminium 'window frames', or missing static wicks. The extremities of an aircraft are particularly vulnerable to lightning damage, e.g. wing tips, fins, control surfaces etc.

It should be noted that discoloration may not define the full extent of the matrix damage. It may be necessary to trim an additional margin from the cut-out area, e.g. 25-55mm (1-2 in.), to clear damaged matrix material that has exceeded the glass transition temperature, but which has not visibly burned. Alternatively, it may be possible to define the damage boundary by careful grinding of the trimmed cut-out edges until a change in texture is experienced. This process requires skill and judgement.

Any inspection for lightning damage should include a check of all electrical paths and contacts, including static discharge wicks, aluminium flame sprayed surfaces etc. It is essential that the integrity of the protection systems are maintained. Manufacturers tend to recommend the use of bond testers to check that the resistance of the system remains in limits.

Fluid Ingress: Fluid ingress may refer to both the uptake of fluid by the matrix or the uptake of free standing fluid, the latter being a particular problem with sandwich structure, see paragraph 5.2.2.4. Fluid ingress may degrade the matrix material resulting in strength reduction which, again, can be particularly significant for structure subject to shear and compressive loads. The extent of degradation will vary from one fluid to the next. Fluid, if not removed from the part, may make repair impossible due to part destruction if the repair cure temperature exceeds the fluid boiling point.

Fluid ingress may not be very obvious. However, any evidence of protective layer damage, e.g. to the paint, should raise suspicions and require that any subsequent repair action be preceded by drying action, see Section 3.4.

Heat and moisture combined may further enhance the degradation of the properties of a composite. Compressive and shear properties are lowest in the 'hot and wet' condition, e.g. a carbon epoxy system, 0·6% moisture content, may show 10-15% compressive strength reductions between room temperature and 50C. Tensile properties are lowest in the cold and dry condition, e.g. a carbon epoxy system may show 5-10% tensile strength reduction between room temperature and -56C.

Matrix Cracking: Matrix cracking may often be the first visible indication of potentially significant damage, e.g. it may be associated with delamination and may be evident at the laminate edge as regularly pitched cracks transverse to the major load direction. It may also be evident as surface crazing over the plan surface areas. The latter is more common to woven materials.

Porosity: Porosity, Figure 8, may allow fluid ingress and result in material degradation. It may be evident as local surface pitting. Severe internal porosity may sometimes be located using a Tap Test. The existence of porosity may also indicate that the local structure has excess resin or that a local repair exists. Porosity should be dried and sealed. However, severe porosity requires a more substantial repair.

Fibre-Matrix Disbond: A laminate manufactured from predominately unidirectional plies in many orientations may split parallel to fibres in some of the plies as the fibre disbonds from the matrix. This is typical of unidirectional CFRP and may not be too significant if the splitting occurs in a small number of plies laying perpendicular to the load direction. However, splitting may have a significant effect upon the stiffness and compressive strength in some designs, particularly those subject to bi-axial loading.

Such damage may be evident as cracking in the damaged plies at the laminate edge or as fibre breakout from the presented face. However, it should be noted that many designs avoid the use of unidirectional materials in the outer plies, thus reducing the opportunity of detecting such damage.

5.2.2.4 **Sandwich Structure Damage:** Sandwich structure comprises of a honeycomb, or foam, core sandwiched between skins.

The skins are thin laminates which have a similar function to that of an 'I-Beam' cap, i.e. resists bending. The core has a function similar to that of an 'I-Beam' web, i.e. resists shear, and also crushing loads. Therefore, the effects of damage can be considered accordingly.

Skin Damage: The laminate skins may suffer similar damage to that already described, e.g. delamination and disbond. However, the limited thickness, e.g. typical 3 or 5 plies, of the skins increases the likelihood of, and therefore importance of, detecting skin penetration because these damages allow access for free standing fluid to the cell structure of the core. Similarly, skin-core disbond at sandwich structure edges, Figure 9, may allow fluid ingress. A considerable amount of fluid may accumulate, Figure 10, creating weight and balance problems for control surfaces. Furthermore, the accumulated fluid may freeze, expand, and further damage the part. Any attempt to repair the part without drying will also be futile if the cure temperature is greater than the boiling point of the fluid. Total destruction of the part is likely.

Fluid ingress may sometimes be detected using a Tap Test, if the mass of free standing fluid is adequate to alter the sound transmission qualities of the structure. A

Tap Test may also be used to detect near side skin-core disbond away from the edges of the structure.

Core Damage: Core damage is often obvious, e.g. Core Depression, Lateral Core Crushing, Figure 11, Skin Bulging, Dents etc. However, the skin may disbond from the crushed core and recover the original structural profile. Therefore, any suspicion of impact on a sandwich structure, e.g. missing paint, scratches, etc, should be followed by a Tap Test. Any damage should be dried and repaired.

5.2.2.5 **Structural Damage Causes:**

The above text identifies the majority of the basic damage types that may be experienced by composite structure. However, such damages may appear in many permutations depending upon the cause. Some causes have particular characteristics which are identified below, (other than impact which has already been mentioned).

Overload: This occurs if any of the primary failure strengths e.g. tensile, compressive, shear etc., are exceeded. Failure may also occur without exceeding any one of the primary strengths due to the interaction of stresses. The nature of the damage, e.g. fibre failure, delamination, matrix cracking etc, will depend upon the strength(s) exceeded. When failure occurs without exceeding any one of the primary strengths, damage may be evident as delamination because the stress interactions often result in out of plane stresses which exceed the out of plane strength (not normally considered a primary strength in many designs).

Fatigue: Contrary to popular belief, composite materials may suffer fatigue damage, particularly when damaged and exposed to the environment. Damage may also be evident as many permutations of the damage types identified in this leaflet. Fatigue damage is often evident throughout the life of the structure. Typically, damage may progress from initial transverse fibre-matrix disbond through intra-ply matrix cracking, inter-ply matrix cracking, delamination, and fibre failure. Engineering properties, e.g. stiffness and strength, reduce during this progression. This contrasts with metallic structure, which typically only shows evidence of fatigue damage during the final 5% of its life. Fastener locations in composite structure are particularly vulnerable to fatigue damage. Loose fasteners result in delamination, hole deformation, and sometimes heat damage. Note that composite structure failed in fatigue tends to show significantly more damage than a structure failed by comparable pseudo-static overload, e.g. typically up to ten times the number of damage sites. Knowledge of the existence of a fatigue environment and the above damage sequence should draw the inspector’s attention to the damage types identified and help the determination of damage significance. Again, any damage that is not obviously cosmetic requires immediate repair.

Lightning Strike Damage: Composite materials do not tend to be good conductors and consequently the energy from a lightning strike may be dissipated via complete, or partial, destruction of the part. Any combination of damage types identified above may be evident, but typically include obvious burns, various permutations of heat damage, and extensive delamination, see Section 5.2.2.3 above.

Wear and Tear: 'Wear and Tear' refers to general degradation such as fastener hole bearing damage, often the result of repeated panel removals, erosion of leading edges, minor ground handling damage, including abrasions, gouges, nicks and scratches etc. The significance of the damage must be assessed on a case by case basis and repaired accordingly. Such damage are usually self evident on a cleaned surface.

Ultra-Violet (UV) Radiation: Although not usually directly visible, UV damage may be evident through other damage types, e.g. matrix surface crazing, gel coat crazing etc. (note that some gel coats are partly intended to protect the composite from UV). UV damage reduces the engineering properties of the matrix material and makes it more vulnerable to load, the environment etc. Many of the older matrix systems are vulnerable to UV damage as are Arimid fibres. The damage severity increases with time exposure and altitude flown. Again, such damage should be repaired. Note that more recent matrix systems are more resistant to UV damage.

Abrasions, Gouges, Nicks, and Scratches: These may be of structural concern if fibres have been broken, particularly those parallel to the major load direction, or if a path for fluid ingress has been provided.

Existing Repairs: Repairs are structural discontinuities and will tend to provide unsymmetrical and unbalanced structure, thus making them a likely source of problems, e.g. repair ply peeling and delamination. Repairs tend to be more porous than the surrounding original structure.

Repair locations are usually obvious on unpainted structure, whilst the location of repairs on painted structure may be possible by careful visual inspection at a shallow angle to the clean surface. The identification of repairs may be eased by consulting the manufacturer’s repair documentation which should provide some clues as to typical repair shapes, e.g. square, circular, etc, and typical repair styles, e.g. flush, scab doublers etc.

Obvious initial indications of degraded repairs include lifted paint and peeled repair doubler edges. Note that particular attention should be paid to recent repairs because a poor bond may well result in ply peeling, or possibly repair separation, within a short number of cycles.

A Tap Test may help to confirm the presence of a repair. Laminate repairs tend to have overlapped joint areas, additional plies, e.g. doublers etc, and increased porosity. Repaired sandwich structure tends to have extensive potting material around the repair boundary. These factors will alter the sonic response of the structure.

6 Repairs

Composite aircraft manufacturers may classify areas of the aircraft, usually Primary Structure, as non-repairable or no repairs permitted areas. These areas are usually detailed in the Maintenance Manual and/or the Flight Manual. If damage is located in these areas the manufacturer must be consulted immediately for advice. For areas where repairs are permitted the repair should be carried out strictly in accordance with the manufacturer’s instructions and using approved data. Allowable repairs should be carried out only in a suitably clean environment where temperature and humidity controls can be maintained and using only the material specified in the approved data. Personnel carrying out repairs should be suitably qualified in composite repair techniques and be aware of the health hazards associated with working with resins, hardeners, solvents and composite material dust. Consideration should be given to the effect that the repair may have on aircraft Centre of Gravity limits. Repairs to composite flight control surfaces may require control surface balancing which should be accomplished strictly in accordance with the manufacturer’s instructions.

Note that repairs may interfere with lightning protection systems. Ensure that any damaged or displaced systems are corrected in accordance with manufacturer’s data.

7 Paint Finish

Manufacturers often specify colours and types of paint finish because composite materials, particularly older materials, are sensitive to heat and UV radiation damage. Any change to aircraft paint scheme must be strictly in accordance with the manufacturer's instructions. Further information regarding paint schemes may be found in CAP 747, GR No. 10.

APPENDIX 1

Further NDT Techniques

NDT inspection must be completed by suitably qualified personnel, CAA CAP 747 GR No. 23 provides some guidance in this matter.

Penetrants: Red dye-penetrant may be of limited use for surface damage detection in composite structure. Its use should be considered to be part of a destructive exploration of the part because the penetrant will be difficult, if not impossible, to remove and may contaminate and degrade the material. Furthermore, poorly finished surfaces may give rise to many false indications.

Bond Testers: Bond testers use ultrasonic signals to detect shifts in the through-thickness resonant frequency of a bonded joint to locate disbonds or poor cohesion. A coupling fluid is required.

Low frequency bond testers (<100kHz) operate by measuring the phase and amplitude of the signal returned from energy transmitted in a plate wave mode to determine the integrity, or otherwise, of the material. A coupling fluid is not required.

High frequency testers (25-500kHz) operate by passing narrow bandwidth standing ultrasonic wave signals into the material. Deviations in the measured resonant frequency indicate the presence of a defect. A coupling fluid is required. Materials may be inspected to a thickness of 0·5 in. Delaminations may be located down to 0·5in. diameter.

Ultrasonic Inspection: Ultrasonic inspection involves the detection of ultrasonic waves passed through the structure. The receiver may be on the opposite side of the structure to the transmitter, i.e. Through Transmission (TTU), or on the same side of the structure as the transmitter, i.e. Pulse Echo (PE).

TTU allows disbond, delamination, and crack detection in monolithic and sandwich structure. However, good access to both sides is required.

PE allows detection of similar damage in monolithic structure, but from one side of the structure. However, damage detection will be limited to the near face skins in sandwich structure. This technique is available in a portable form.

Ultrasonic inspection may be developed into a map of the part and its defects, i.e. C-Scan. The use of sophisticated processing and focused transceivers allows the development of the C-Scan into a three dimensional representation.

Radiography: Radiography is the passing of X-rays through a structure and the recording of the shadow from that structure onto film. The shadow is a function of part thickness, density, manufacture, and X-ray voltage.

Radiography may be useful for the detection of transverse cracking and fluid ingress (in sandwich structure).

Composites require low voltages due to the low material densities. The low difference in densities between constituent materials makes the contrast between materials, and contrast between material and damage, difficult. Penetrants may be used, but these tend to be unpleasant materials, e.g. Zinc Iodide, which cannot be removed from the composite. Furthermore, the structure may require working to get the penetrant to fully penetrate the damage. Other disadvantages include safety considerations, limited equipment access, cost, and the need for skilled interpretation.

Mechanical Impedance: This method uses changes in structural stiffness to detect damage, particularly disbond and delamination. The stiffness is a function of thickness, geometry, elastic variables and densities. The phase and amplitude of a transmitted sonic signal are measured. This method may provide accurate determination of the extent of damage. Inaccuracies may result from incorrect receiver alignment, resonance, and noise from other equipment.

Thermography: This method relies upon the detection of thermal gradients, i.e. using IR radiation, to locate defects. The factors affecting the inspection include surface temperature, surface emittance, surface reflectance, background temperature, and the energy differential.

Thermography may be very useful for the detection of moisture ingress, particularly in sandwich structure. Unfortunately, an energy source is required to create the thermal gradient, e.g. the part may need to be removed from the aircraft and heated in an oven, or an engine run may be necessary, or immediate access to an aircraft upon return from a high altitude flight may be required. Furthermore, the equipment is expensive, knowledge of the structure is required, and interpretative skills are necessary.

Moisture Meters: These devices may be used to detect moisture in GRP and arimid material. They use the radio frequency dielectric power loss attributed to an increase in the conductivity of the composite, due to moisture absorption, to measure moisture content. This method of moisture detection cannot be used with conductive fibres, e.g. carbon, and cannot be used local to metallic structure, e.g. embedded conductive lightning protection grids may give false indications.

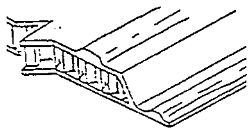

FIG.1 WRINKLED MATERIAL

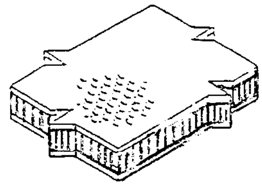

FIG.2 DIMPLING

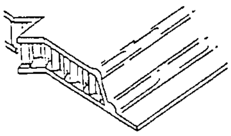

FIG.3 RESIN RICH MATERIAL

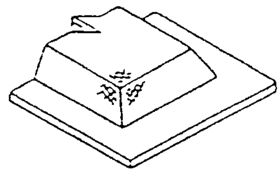

FIG.4 RESIN STARVED MATERIAL

FIG.5 DELAMINATION

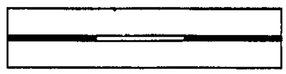

FIG.6 EDGE DELAMINATION

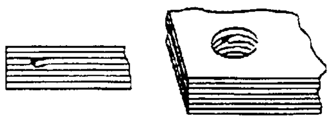

Fig.7 FIBRE BREAKOUT

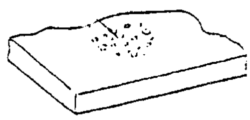

FIG.8 POROSITY

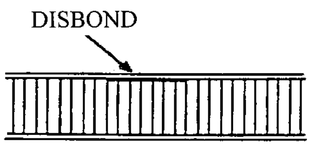

FIG.9 SKIN-CORE DISBOND

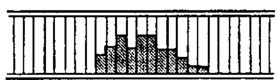

FIG.10 FLUID INGRESS

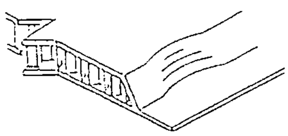

FIG.11 LATERAL CORE DENTING

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