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PART II – AIRCRAFT

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CONTROL CHAINS, CHAIN WHEELS AND PULLEYS

1 INTRODUCTION

1.1 The purpose of this Leaflet is to provide guidance and advice on the installation and maintenance of steel roller chains, chain wheels and pulleys used in aircraft control systems.

1.2 Chains provide strong, flexible and positive connections, and are generally used wherever it becomes necessary to change the direction of control runs in systems where considerable force is exerted, e.g. aileron and elevator controls. The change of direction is achieved by the use of chain wheels or pulleys. Chains may be found in, control column installations, aileron controls and elevator controls, and in trim control systems.

1.3 Chains may be used solely in control runs or in conjunction with cable assemblies. In either case, the incorrect assembly of the chains should be rendered impossible by the use of non-reversible chains in conjunction with the appropriate types of wheels, guards and connectors.

1.4 Subject headings are as follows:—

2 SPECIFICATIONS

2.1 Chains used for aircraft purposes are generally of the simple roller type and comply with the requirements of British Standard BS 228: 1984, entitled Specification for Short Pitch Transmission Precision Roller Chains and Chain Wheels. A complete schedule of dimensions and breaking loads for chains is given in this Standard.

NOTE: BS 228 is equivalent to ISO 606 — 1982.

2.2 Chain assemblies are produced to standards prepared by the S.B.A.C. These standards providing a range of chains built up in various combinations with standard fittings, e.g. end connectors with internal or external threads, bi-planer blocks for changing the plane of articulation of a chain through 90° (see Figure 4) and cable spools for connecting chains to cables having eye-splices. Such fittings are illustrated in Figures 1 and 4.

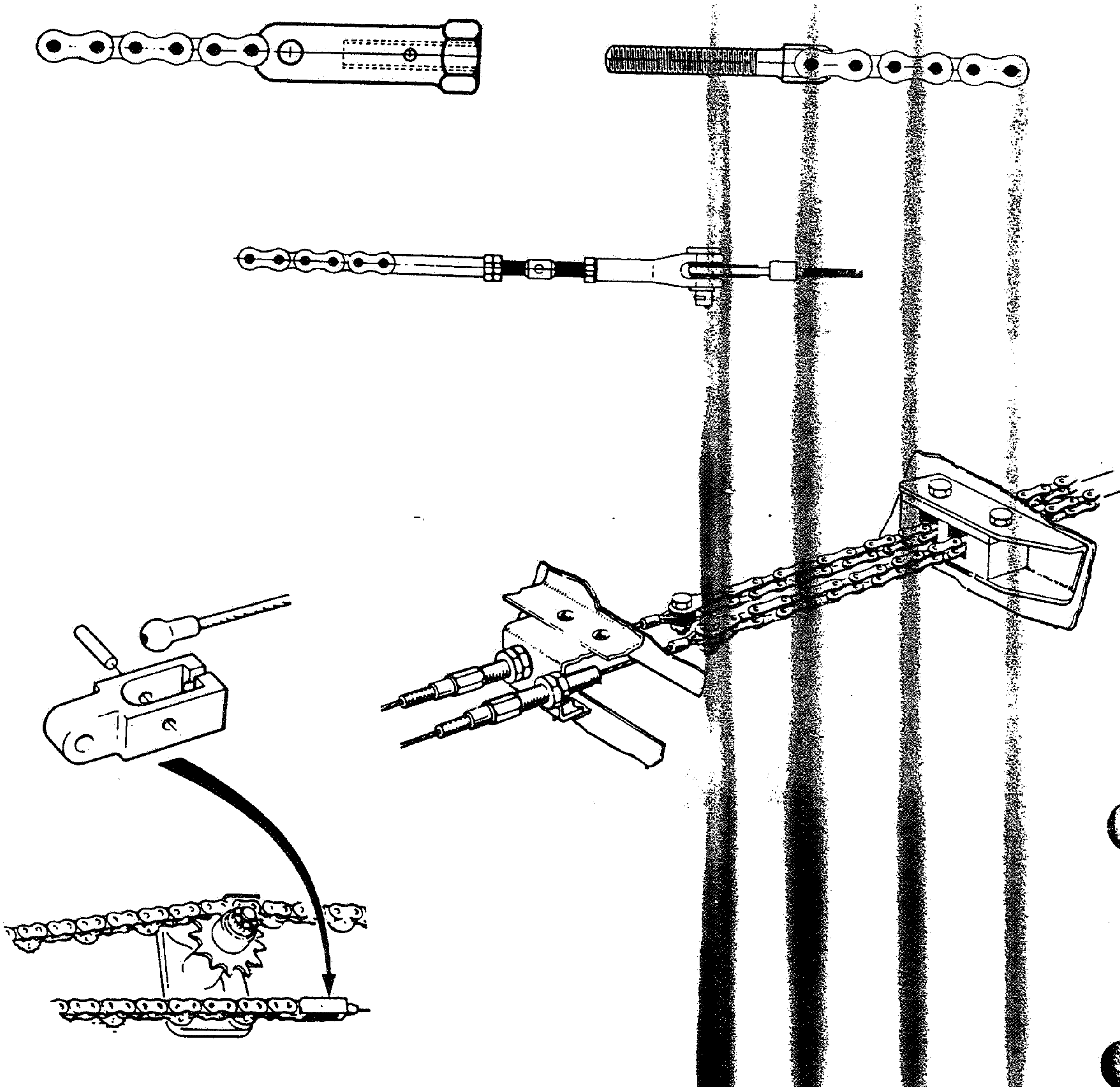


Figure 1 STANDARD CHAIN FITTINGS

3 CHAIN ASSEMBLIES

3.1 A simple roller chain consists of outer and inner plates, rollers, bearing pins and bushes; the component parts are shown in Figure 2(a). The chain has three principal dimensions (known as gearing dimensions since they are related to the size of the wheels on which the chains run), these being pitch, width between inner plates, and roller diameter. The positions at which these dimensions are measured are shown in Figure 2(b).

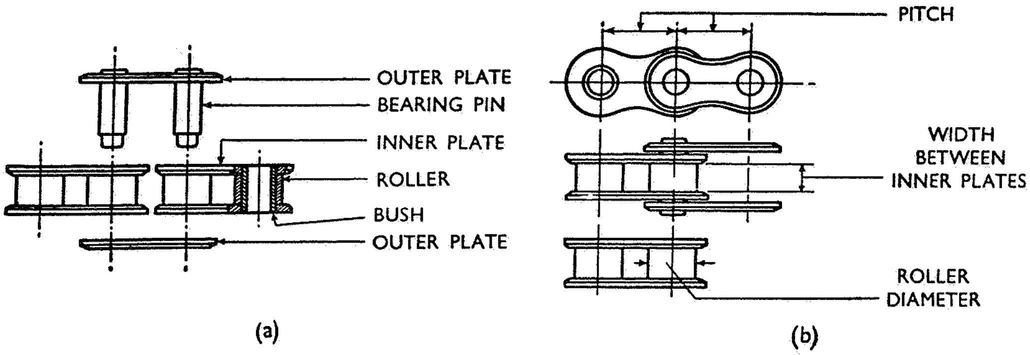


Figure 2 CHAIN DETAILS

3.2 A typical assembly for ⅜ in and ½ in chains, using a standard end connector with an internal thread, is shown in Figure 3.

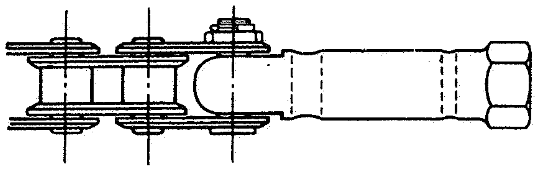


Figure 3 TYPICAL CHAIN END ASSEMBLY

3.3 The pitch of the chain is the distance between the centres of the rollers, and for aircraft purposes, four sizes of chain are standardised by the S.B.A.C., as shown in Table 1. BS 228 prescribes that the proof-load (see paragraph 6.6) for a chain should be one-third of the minimum breaking load; the relevant figures for simple chains are also given in Table 1.

TABLE 1

Chain Pitch	*BS No.*	*Minimum Breaking Load*	*Proof Load (lb)*
8 mm	1	800 lb	267
0·375 in	2	1900 lb	634
0·50 in	4	1800 lb	600
0·50 in	6	3500 lb	1166

3.4 Chain assemblies for aircraft systems should be obtained as complete, proof-loaded units from approved chain assembly manufacturers, and no attempt should be made to break and reassemble riveted links or riveted attachments. If it is necessary to disconnect the chain, this should be undertaken only at the bolted or screwed attachments. Split pins must not be re-used, and this applies also to nuts and bolts which have been peened.

NOTE: The procedure specified by S.B.A.C. standards for securing nut and bolt joints for Class 1 application is to peen the bolt end for 8 mm pitch chain and to split pin the bolts of the remaining standard chains. In all cases the nut is actually a lock nut, since the hole in the loose outer plate is also tapped.

3.5 The use of cranked links for the attachment of the chain to end fittings, etc, is not permitted, thus, when a chain is required to terminate in a similar manner at each end, the length should be an odd number of pitches. For the same reason, an endless chain should have an even number of pitches.

3.6 The use of spring clip connecting links is prohibited, and the attachment of chains to other parts of the system should be effected by positive methods such as pre-riveted or bolted joints.

4 INSTALLATION OF CHAIN ASSEMBLIES

4.1 Figure 4 illustrates typical arrangements of chain assemblies. Figure 4(a) shows the simple transfer of straight-line to rotary motion, Figure 4(b) illustrates how a change of direction of straight-line motion is obtained, whilst Figure 4(c) shows a change of direction of motion in two planes by the use of a bi-planer block.

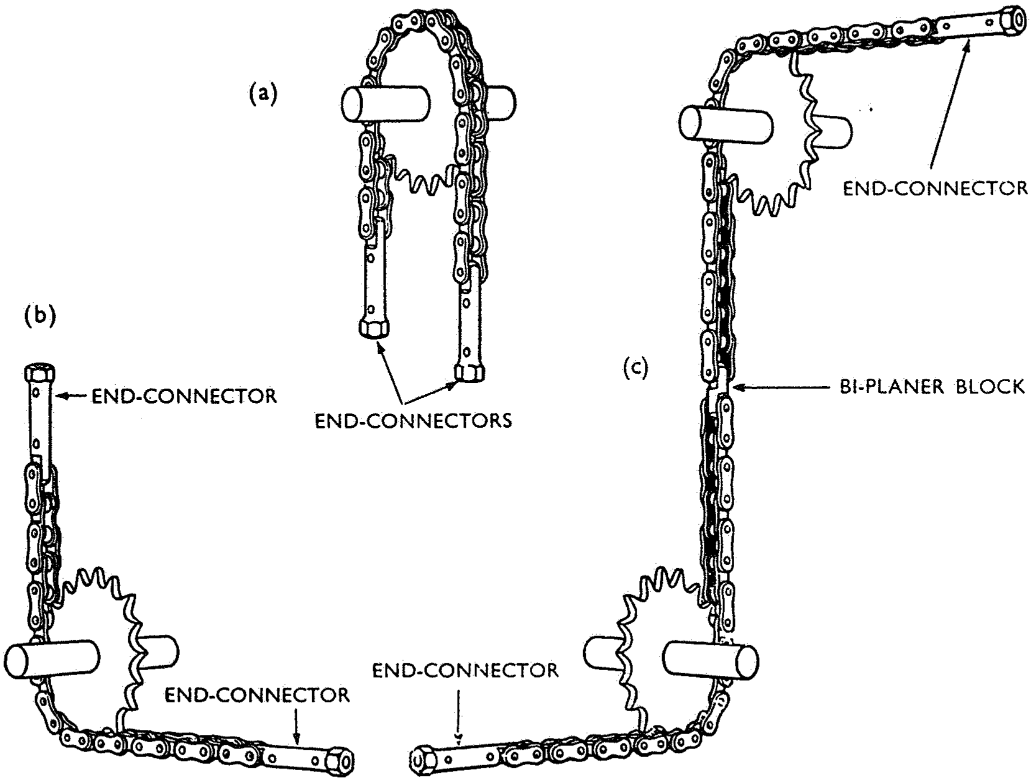


Figure 4 TYPICAL CHAIN ASSEMBLY ARRANGEMENTS

4.3.1 Non-reversible chains are similar to standard chains except that every second outer plate is extended in one direction in order to break up the symmetry of the chain. The complete system of non-reversibility involves the use of five features, i.e. the non-reversible chain, the shroud on the wheel, correct positioning of the wheel on its shaft, the chain guard, and non-interchangeable connectors. The shape of the special outer plates and the principle of non-reversible chains is shown in Figure 5.

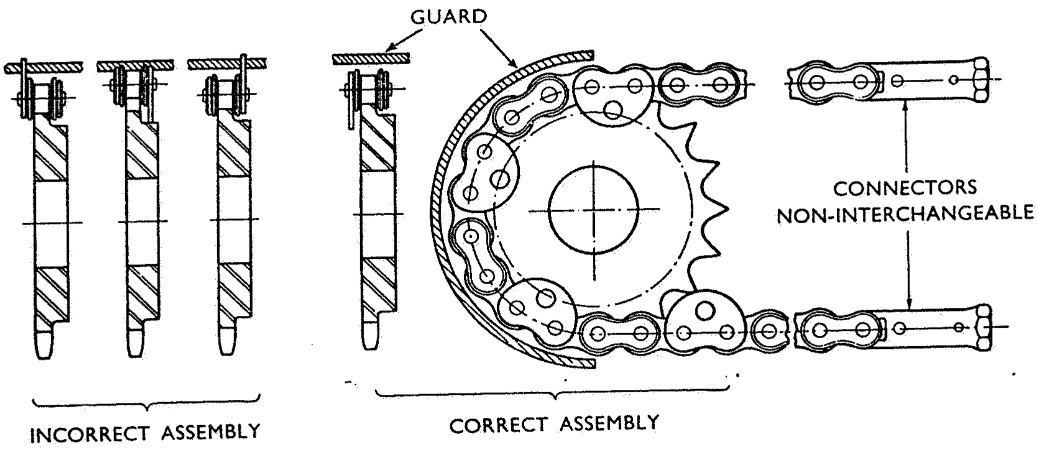


Figure 5 NON-REVERSIBLE CHAIN ASSEMBLY

4.3.2 It will be seen from Figure 5 that by providing a shroud on one side of the wheel and by making use of the chain guard, the reversing of the chain end to end on its wheel is not possible. It should be borne in mind that in practice a special feature, such as an attachment collar, a key, or a flat on the shaft in conjunction with a specially shaped hole, is incorporated in the wheel mounting to ensure that it can be assembled on its shaft in one definite position only.

4.3.3 Figure 6 illustrates an instance where the use of jockeys is necessary or where contra-rotation of the wheels is required; it will be seen that the feature of non-reversibility does not affect the ability of the chain to gear on both sides.

4.4 Inspection after Assembly

4.4.1 After installation in the aircraft, the chain should be examined for freedom from twist, particularly in instances where the attachment is made to threaded rods by means of screwed end connectors, or where a twist may inadvertently be applied to the chain during the locking of the assembly. Care should be also taken to ensure that the chain is not pulled out of line by the chain wheel; the chain should engage smoothly and evenly with the wheel teeth and there should be no tendency for the chain to ride up the teeth.

(c) The percentage extension over the nominal length should be calculated by the following formula:

$$\text{Percentage extension} = \frac{M - (X \times P)}{X \times P} \times 100$$

where

M = Measured length under load in inches.
X = Number of pitches measured.
P = Pitch of chain in inches.

6.3.2 If the extension is in excess of 2% on any section of the chain the whole run of chain should be replaced. Should localised wear be likely to occur in a chain run, additional checks should be made on such sections, and the percentage extension ascertained from the formula given in paragraph 6.3.1(c). If the extension in such sections is in

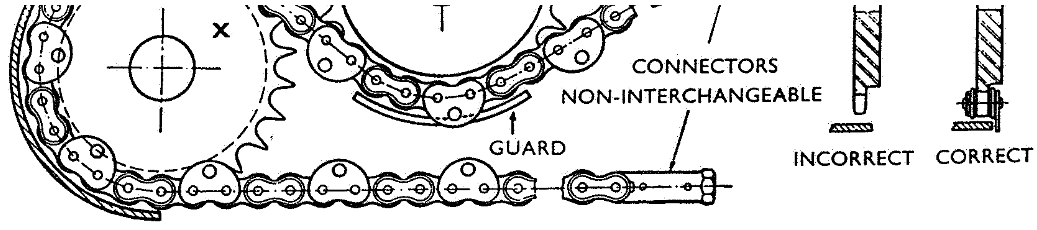


Figure 6 NON-REVERSIBLE CHAIN WITH JOCKEY PULLEY

4.4.2 The pre-tensioning of chains should not be excessive, as this will cause friction, but

6.4 **Checking Articulation.** The chain should be checked for tight joints by articulating each link through approximately 180°. The most suitable method being to draw the chain over a finger. Tight joints may be caused by foreign matter on the bearing pins or between the inner and outer plates; this may be remedied by cleaning as described in paragraph 6.3.1(a). If cleaning is not successful, the end of the bearing pin may be very gently tapped with a light hammer, but if this does not clear the joint, the chain should be rejected. Tightness may also be caused through lack of clearance between the inner and outer plates due to damage; if this is so, the chain should be rejected.

6.5 **Checking for Deterioration.** The chain should be examined for damage, cracks and wear to plates and rollers, and for evidence of corrosion and pitting.

NOTE: It is not permissible to break down or attempt to tighten a riveted link in a run of chain.

6.6 **Proof Loading.** It is not necessary to proof load a chain after removal for routine examination. However, if it is desired to replace a portion only of the assembly, proof loading of the complete assembly is necessary. The proof load (Table 1) should be evenly applied, and unless this can be assured, it is considered preferable to fit a complete new assembly.

6.7 **Protection and Storage.** After the chain has been cleaned, inspected and found to be acceptable, it should be thoroughly soaked in an appropriate oil, time being allowed for the lubricant to penetrate to the bearing surfaces. If not required for immediate use, the chain should be laid on a flat surface, carefully coiled, and wrapped in greaseproof paper, care being taken to ensure the exclusion of dirt, and the prevention of distortion, during storage.

7 INSTALLATION OF CHAIN WHEELS AND PULLEYS

7.1 During installation, chain wheels and pulleys should be checked to ensure that they are attached in the manner and method specified by the relevant drawings. The correct positioning of chain wheels is of particular importance when non-reversible chains are used (see paragraph 4.3). During maintenance, chain wheels should be checked for security and wear on the teeth. Pulleys should be checked for damage and excessive wear on the walls and on the chain guide section. The continued efficiency of ball races should also be ascertained.

Issue 1.

15*th November*, 1974.

AIRCRAFT

SYSTEMS AND EQUIPMENT

LANDING GEAR

1 INTRODUCTION This Leaflet gives general information on the different types of landing gear used on aircraft, the various components employed, and the maintenance practices normally recommended. Because of the wide variety of landing gear designs, this Leaflet should be read in conjunction with the appropriate aircraft Maintenance Manual and the approved Maintenance Schedule. The Leaflet does not deal with the specialised methods of operating on water, snow and ice.

1.1 Information on associated subjects will be found in the following Leaflets:—

BL/6-15 Manufacture of Rigid Pipes

AL/3-13 Flexible Pipes

AL/3-14 Installation of Rigid Pipes in Aircraft

AL/3-18 Tyres

AL/3-19 Wheels and Brakes

AL/4-1 Hydraulic Systems—Installation and Maintenance

2 GENERAL The functions of a landing gear are to support an aircraft during ground manoeuvres, dampen vibration, and absorb landing shocks; when required, it also performs the functions of steering and braking. These objectives are achieved by many different designs, depending on the type of aircraft to which the landing gear is fitted and the degree of sophistication required. A landing gear usually takes the form of two or more main undercarriage units in the wings or fuselage, and an auxiliary undercarriage unit at the nose or tail which carries only a small proportion of the total load and is used for steering purposes.

2.1 With slow, light aircraft, and some larger aircraft on which simplicity is of prime importance, a fixed (non-retractable) landing gear is often fitted; the reduced performance caused by the drag of the landing gear during flight is offset by the simplicity, reduced maintenance and low initial cost. With higher performance aircraft, drag becomes progressively more important, and the landing gear is retracted into the wings or fuselage during flight; there are, however, penalties of increased weight, greater complication and additional maintenance.

2.2 The landing gear of an aircraft may receive harsh treatment throughout its installed life, being subject to frequent landing shocks and in regular contact with spray, ice, dirt, and abrasive grit. Regular washing, servicing and lubrication are required, therefore, to guard against corrosion, seizure of mechanical parts and failure of electrical components.

3 FIXED LANDING GEAR There are three main types of fixed landing gear; those which have a spring steel leg, those which employ rubber cord to absorb shocks, and those which have an oleo-pneumatic strut to absorb shocks. Exceptions include aircraft with rubber in compression, spring coil, and liquid spring struts.

3.1 **Spring Steel Legs.** Spring steel legs are usually employed at the main undercarriage positions. The leg consists of a tube, or strip of tapered spring steel, the upper end being attached by bolts to the fuselage and the lower end terminating in an axle on which the wheel and brake are assembled.

3.1.1 **Maintenance.** Spring steel undercarriages should be inspected regularly for damage and corrosion. The aircraft should be jacked up periodically, so that all load is taken off the wheels, and the security of each undercarriage checked by attempting to move it against the restraint of its attachments to the airframe structure. If there are signs of looseness, the bolts should be removed for detailed inspection and the bolt holes should be checked for cracks or fretting. Axle fittings should be similarly inspected, and all nuts and bolts should be tightened to the specified torque.

3.2 **Rubber Cord.** When rubber cord is used as a shock-absorber, the undercarriage is usually in the form of tubular struts, designed and installed so that the landing force is directed against a number of turns of rubber in the form of a grommet or loop.

3.2.1 Rubber cord is colour coded to indicate the date of manufacture and the specification to which it conforms, by replacing some of the fibres in the outer cotton covering with coloured threads wound in a spiral. Details concerning the significance of the colour coding may be obtained from British Standards F16, F51, F70 or F71 as appropriate.

3.2.2 **Maintenance.** The undercarriage should be examined for damage, corrosion, wear or cracks at the pivot points, and bent pivot bolts, and should be lubricated as specified in the approved Maintenance Schedule. The rubber cord should be inspected for chafing, necking, or other deterioration, and it is advisable to replace it if it is more than five years old, regardless of its external condition.

3.3 **Oleo-pneumatic Struts.** Some fixed main undercarriages, and most fixed nose undercarriages, are fitted with an oleo-pneumatic shock-absorber strut. The design of individual struts varies considerably, and reference should be made to the appropriate Maintenance Manual for a particular type, but operation and maintenance procedures for a typical design are covered in the following paragraphs.

3.3.1 **Construction.** Figure 1 shows the construction of a simple oleo-pneumatic strut, in this instance a nose undercarriage which also includes a steering mechanism. The outer cylinder is fixed rigidly to the airframe structure by two mounting brackets, and houses an inner cylinder and a piston assembly, the interior space being partially filled with hydraulic fluid and inflated with compressed gas (air or nitrogen). The inner cylinder is free to rotate and move up and down within the outer cylinder, but these movements are limited by the torque links, which connect the inner cylinder to the steering collar. The steering collar arms are connected through spring struts to the rudder pedals, and a shimmy damper is attached to the steering collar.

3.3.2 **Operation**

(i) Under static conditions the weight of the aircraft is balanced by the strut gas pressure and the inner cylinder takes up a position approximately midway up its stroke.

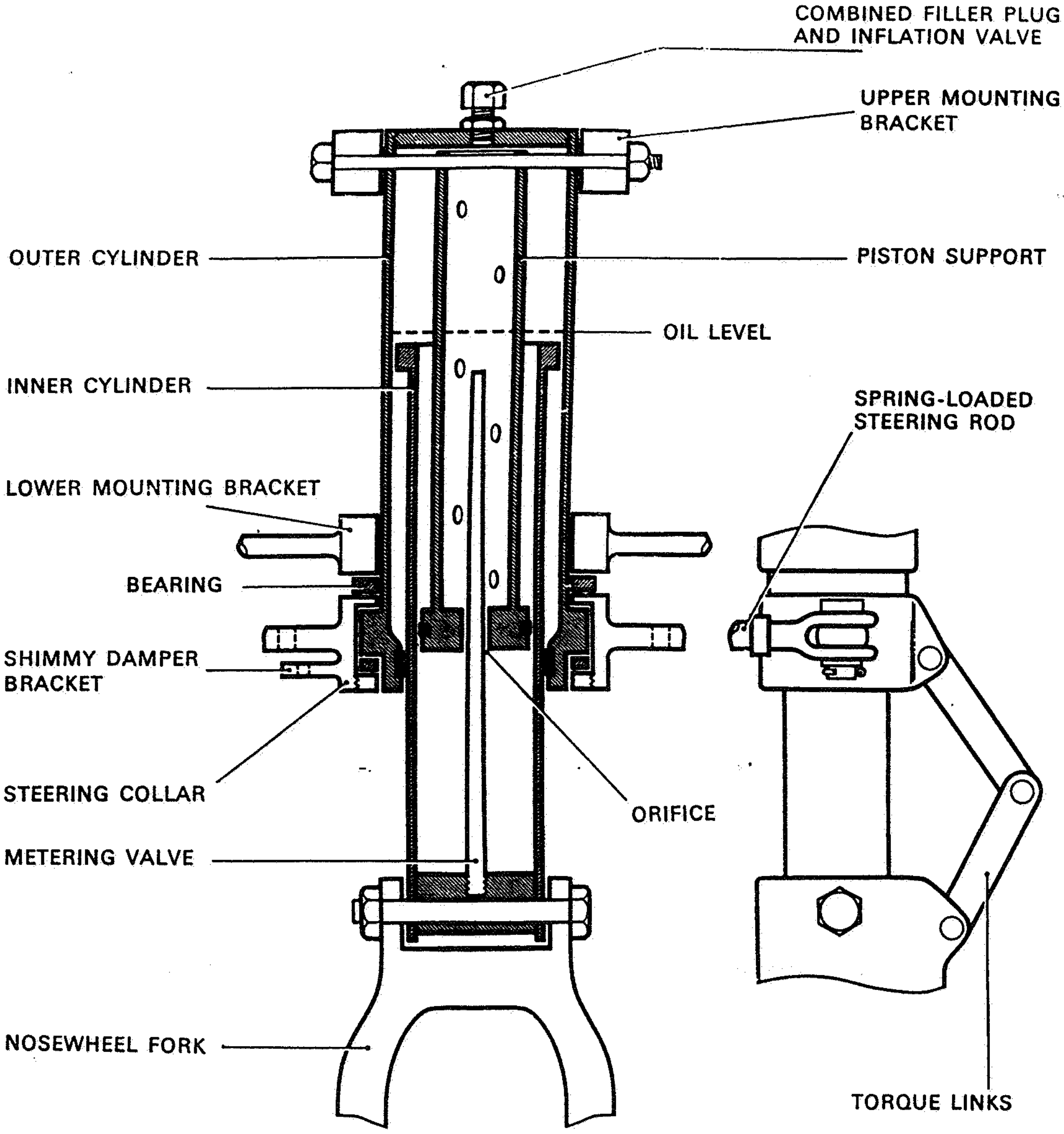


Figure 1 OLEO-PNEUMATIC STRUT

(ii) Under compression (e.g. when landing), the strut shortens and fluid is forced through the gap between the piston orifice and the metering rod, this restriction limiting the speed of upward movement of the inner cylinder.

(iii) As the internal volume of the cylinders decreases, the gas pressure rises until it balances the upward force.

(iv) As the upward force decreases, the gas pressure acts as a spring and extends the inner cylinder. The speed of extension is limited by the restricted flow of fluid through the orifice.

NOTE: On some struts an additional valve is fitted to the piston or inner cylinder, to further restrict the flow of fluid during extension, and prevent violent extension of the strut if upward force is suddenly released, such as when a bounce occurs.

(v) Normal taxying bumps are cushioned by the gas pressure and dampened by the limited flow of fluid through the orifice.

(vi) Movement of the rudder pedals turns the nose wheel to facilitate ground manoeuvres, the spring struts being provided to allow for vertical movement of the nose wheel, and prevent shocks from being transmitted through the rudder control system.

3.3.3 **Maintenance.** Oleo-pneumatic undercarriages should be subjected to inspections similar to those recommended for spring leg and rubber cord types, such as examinations for cracks or damage to mounting structure, corrosion, and wear at pivot points. In addition, the following maintenance is necessary:—

(i) Machined surfaces of the strut inner cylinder should be wiped free of aust or dirt at frequent intervals, to prevent damage to the lower cylinder seals. A lint-free cloth, soaked in the fluid used in the strut, should be used for this purpose.

(ii) The extension of the inner cylinder, i.e. the length of the visible portion of the inner cylinder, should be checked frequently against the centre of gravity/loading graphs provided in the approved Maintenance Manual.

NOTE: Because of the tightness of the sealing glands in the strut, it may be necessary to rock the aircraft to free the inner cylinder and obtain the true extension.

(iii) The strut should be inspected frequently for fluid leaks. If leaks are due to faulty glands the glands may be replaced, but if they are due to a scored inner cylinder, the strut should be changed.

(iv) Torque links, steering arms, and damper attachments should be checked for security, and for cracks, wear or any other damage.

(v) All moving parts of the undercarriage should be lubricated on assembly, and at the intervals specified in the approved Maintenance Schedule.

3.3.4 **Servicing Struts.** When it becomes necessary to check the fluid level in a strut, the following procedure should be carried out:—

(i) Jack up aircraft to take the weight off the strut.

(ii) Remove inflation valve cap and release air pressure completely.

(iii) Remove valve housing.

(iv) Compress strut and check fluid level is at bottom of filler hole; if not, top-up with the approved fluid.

(v) Extend and compress strut several times to expel any trapped air, then repeat (iv).

(vi) With strut compressed, replace valve housing and inflate strut to specified gas pressure, checking that the leg extends completely.

NOTE: It is usually recommended that a new seal is fitted when replacing the valve.

(vii) Lower aircraft and check that extension of the inner cylinder is in accordance with the tables or graphs supplied by the manufacturer, for the particular aircraft weight and centre of gravity position.

3.4 **Shimmy Dampers.** Most nose and tail wheels are fitted with shimmy dampers to prevent rapid oscillation during ground manoeuvres.

3.4.1 A simple damper consists of two friction discs, one connected to a fixed part of the undercarriage and the other connected to the oscillating part. The discs are held in contact by spring pressure and resist relative movement between the parts to which they are connected.

3.4.2 A type of damper commonly found on light aircraft is illustrated in Figure 2; the piston rod is connected to the steering collar and the cylinder attached to a fixed part of the strut. The cylinder is completely filled with fluid, and small holes in the piston allow a restricted flow of fluid when force is applied to the piston rod. Movement of the nose undercarriage is therefore slowed down, and oscillations damped.

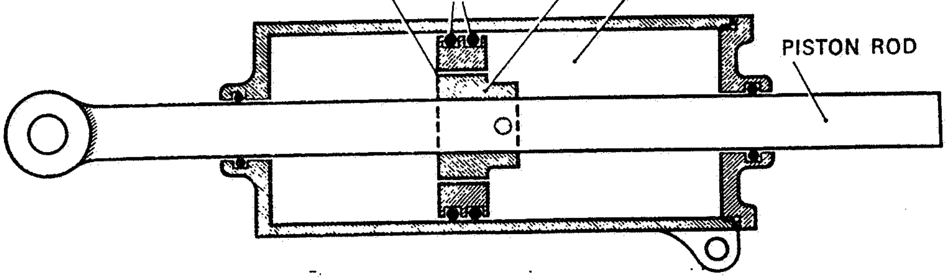


Figure 2 DAMPER STRUT

3.4.3 **Maintenance.** Friction disc dampers should be inspected for security, damage, and wear of the friction material. Piston type dampers will not operate satisfactorily if air is present in the cylinder, and should be inspected frequently for oil leaks; they should be removed at the periods specified in the approved Maintenance Schedule, and the oil level checked.

4 RETRACTABLE LANDING GEAR The majority of modern transport aircraft, and an increasing number of light aircraft, are fitted with a retractable landing gear, for the purpose of improving aircraft performance. Retraction is normally effected by a hydraulic system, but pneumatic or electrical systems are also used. In some instances power is used for retraction only, extension being effected by gravity and slipstream. Retractable landing gear is also provided with mechanical locks to ensure that each undercarriage is locked securely in the retracted and extended positions; devices to indicate to the crew the position of each undercarriage; and means by which the landing gear can be extended in the event of failure of the power source. In addition, means are provided to prevent retraction with the aircraft on the ground, and to guard against landing with the landing gear retracted. Undercarriage wells are normally sealed by doors for aerodynamic reasons, but one particular aircraft type employs inflatable rubber bags to seal the main undercarriage wells.

4.1 Retractable undercarriages normally consist of an oleo-pneumatic shock-absorber strut, similar to the one shown in Figure 1 but supported in a trunnion bearing which is fixed to a spar or strengthened box section in the wings or fuselage; the strut is braced longitudinally by drag struts, and laterally by sidestays. In some designs the drag strut or sidestay is in two parts, and hinges about the centre point to provide a means of retraction, while in others the retraction jack operates on an extension of the shock-absorber strut housing. Figure 3 shows a typical retractable undercarriage unit which is hydraulically operated in both directions and locked by means of a geometric (over-centre) lock.

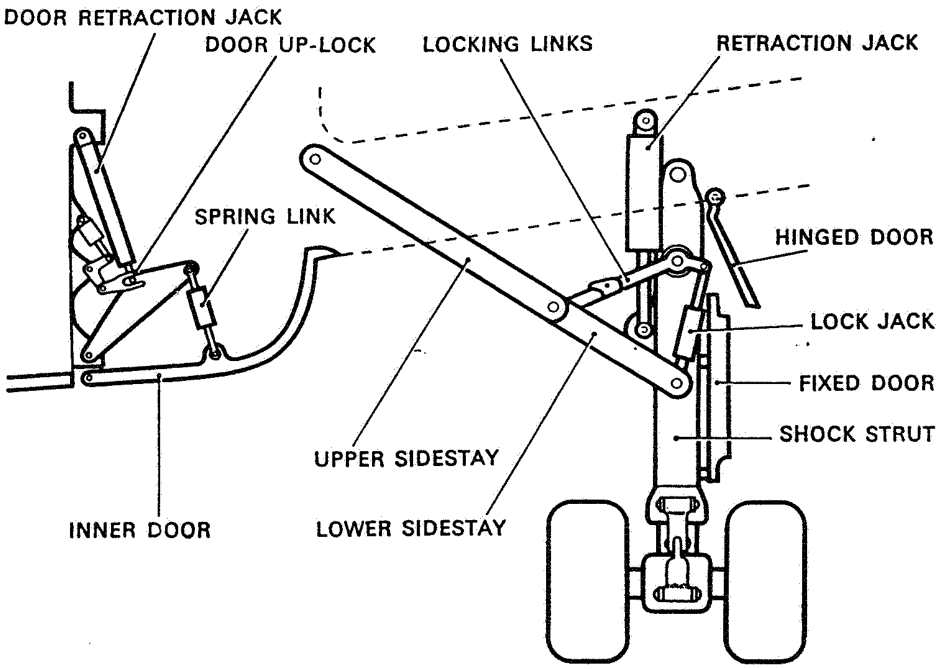


Figure 3 TYPICAL UNDERCARRIAGE UNIT

4.2 **Hydraulic Retraction System.** A hydraulic system for retracting and extending a landing gear normally takes its power from engine driven pumps, alternative systems being available in case of pump failure. On some light aircraft a self-contained 'power-pack' is used, which houses a reservoir and selector valves for the landing gear and flap systems; an electrically driven pump may also be included, or the system may be powered by engine driven pumps. This type of system normally provides for powered retraction of the landing gear, extension being by 'free-fall', with the assistance of spring struts.

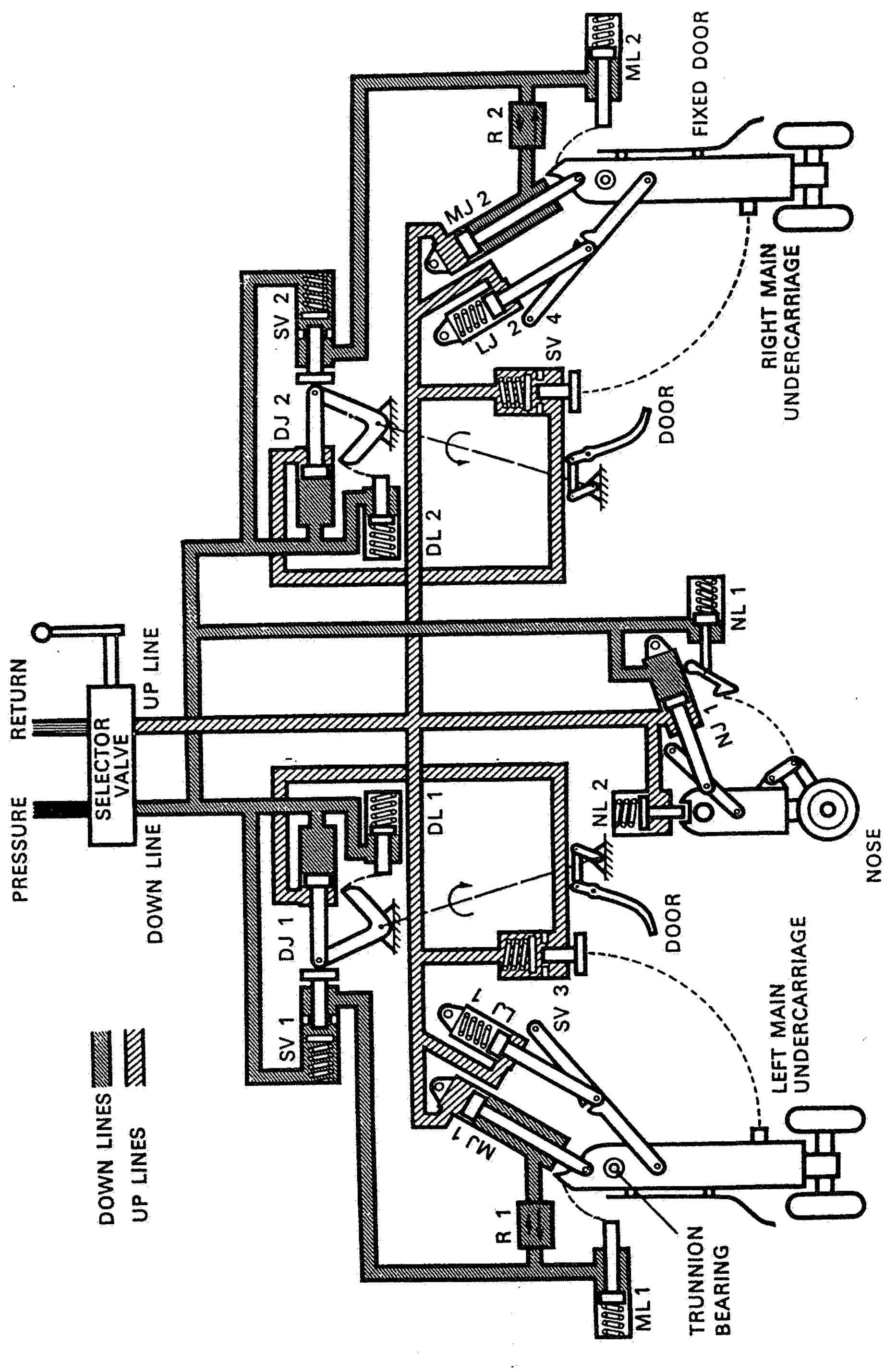


Figure 4 SIMPLE HYDRAULIC RETRACTION SYSTEM

4.2.1 Figure 4 is a schematic diagram of a simple hydraulic retraction system. The various components shown illustrate operation of this system, but are not intended to represent a typical design; actual components often operate in a different manner, but their purpose is the same.

4.2.2 Operation of the system illustrated in Figure 4 is as follows:—

(i) **Retraction.** When the landing gear selector is moved to the 'up' position, fluid under pressure is directed to the 'up' line and fluid from the 'down' line is directed back to the hydraulic reservoir. Fluid flows to the sequence valves (SV3, SV4), retraction jacks (MJ1, MJ2, NJ1), main undercarriage down-lock jacks (LJ1, LJ2), and nose undercarriage down-lock (NL2); it cannot pass the sequence valves, which are closed, but operates the retraction jacks and down locks. The locks operate first, releasing the landing gear and allowing the retraction jacks to raise each undercarriage, the nose undercarriage engaging its spring-loaded up-lock (NL1) first, because of the jack's smaller size. At the end of upward travel of the main undercarriage units, a striker on each leg contacts the plunger of its associated sequence valve (SV3, SV4), and opens the valve, allowing fluid to flow to the door jacks (DJ1, DJ2). The main undercarriage engages the up-locks (ML1, ML2) and the doors close, engaging locks DL1, DL2. Fluid in the 'down' lines returns to the reservoir, flowing unrestricted through the restrictor valves (R1, R2) and overcoming the small restriction of the spring loading of the sequence valves (SV1, SV2).

NOTE: The nose undercarriage doors are operated mechanically by linkage to the nose shock-absorber housing.

(ii) **Extension.** When the landing gear selector is moved to the 'down' position, fluid under pressure is directed to the 'down' line, and fluid from the 'up' line is directed back to the reservoir. Fluid flows to the sequence valves (SV1, SV2), door jacks (DJ1, DJ2), door locks (DL1, DL2), nose undercarriage retraction jack (NJ1) and the nose undercarriage up-lock (NL1). The sequence valves are closed, so fluid pressure releases all the door locks and the nose undercarriage up-lock, and the doors and nose undercarriage extend, the nose undercarriage engaging its down-lock (NL2) at the end of its travel. When the doors are fully open, the door jacks strike the plungers of their associated sequence valves (SV1, SV2) and open the valves, allowing fluid to flow through the restrictor valves (R1, R2) to the main undercarriage up-locks (ML1, ML2) and retraction jacks (MJ1, MJ2). These locks are released, and the retraction jacks lower the main undercarriage fully, the spring-loaded lock-jacks (LJ1, LJ2) imposing a geometric lock on the sidestays. Main undercarriage doors are held open by fluid pressure.

NOTE: Restrictor valves are normally fitted to limit the speed of lowering of the main undercarriage units, which are influenced in this direction by gravity. The nose undercarriage often lowers against the slipstream and does not need the protection of a restrictor valve.

4.3 **Pneumatic Retraction System.** Operation of a pneumatic retraction system is similar to that of a hydraulic system, except that pressure in the return lines is exhausted to atmosphere through the selector valve. Pressure is built up in a main storage cylinder by engine driven air pumps, and passes through a pressure reducing valve to the landing gear selector valve. Operation of the selector valve to the 'up' position directs pneumatic pressure through the 'up' lines to the retraction rams, and opens the down line to atmosphere. Operation of the selector valve to the 'down' position directs pneumatic pressure through a second pressure reducing valve and the down lines, to the up-lock rams and retraction rams. A simple pneumatic system is illustrated in Figure 5.

NOTE: A low pressure is used for landing gear extension, for the same reason that restrictor valves are used in hydraulic systems, which is to prevent damage occurring through too-rapid extension of the undercarriage units.

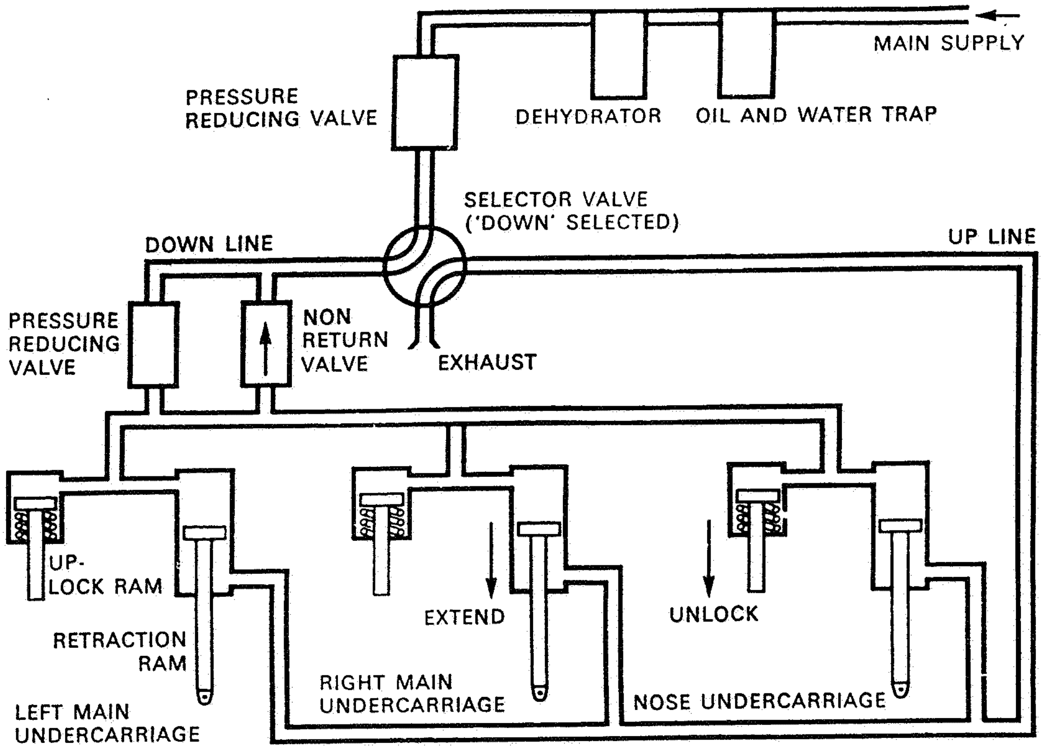


Figure 5 SIMPLE PNEUMATIC RETRACTION SYSTEM

4.3.1 Retraction rams are usually damped to prevent violent movement. The hollow piston rod is filled with oil or grease, which is forced through the annular space between the inner surface of the piston rod and a stationary damper piston whenever the ram extends or retracts, thus slowing movement.

4.3.2 Up-locks and down-locks are similar to those used with hydraulic systems, the geometric down-locks being imposed by over-centering of the drag strut at the end of retraction ram stroke, and the up-locks by spring-ram operated locks. Down-locks are released by initial movement of the retraction rams during retraction, and up-locks are released by pneumatic pressure in the spring-rams during extension.

4.3.3 Undercarriage doors are operated mechanically, by linkage on the shock-absorber housing.

4.4 **Electrical Retraction System.** An electrical retraction system is often fitted to light aircraft which do not otherwise require the use of a high pressure fluid system. The main and nose undercarriage units are similar to those used in fluid retraction systems, but push and pull forces on the retraction mechanism are obtained by an electric motor and suitable gearing. Figure 6 illustrates a typical system, in which a single reversible electric motor provides the power to retract and extend the landing gear.

4.4.1 The motor operates a screw jack, which provides angular movement to a torque tube; a push-pull rod from the torque tube acts on the drag strut of the nose undercarriage, and cables and rods from the torque tube act on the main undercarriage sidestays, rubber cord being used to assist extension of the main undercarriage units.

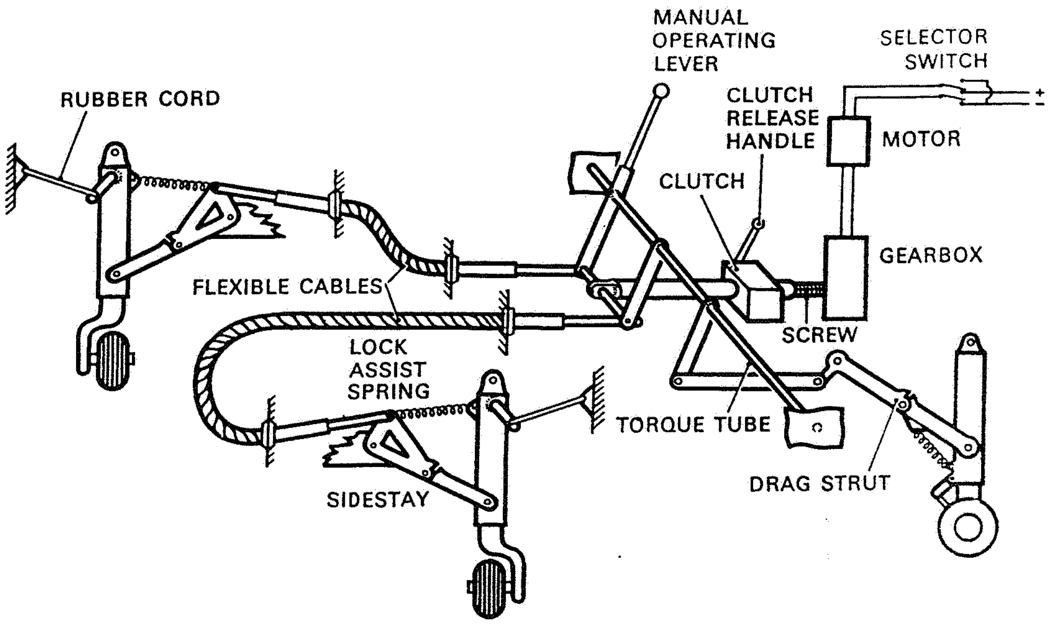


Figure 6 SIMPLE ELECTRICAL RETRACTION SYSTEM

4.4.2 Down-locks are imposed by over-centering of the drag strut and sidestays during final movement of the operating mechanism, with the assistance of springs. Limit switches on the drag strut and sidestays cut off electrical power and brake the motor when the down-locks have engaged, while a limit switch on the torque tube stops and brakes the motor when the landing gear is fully retracted.

4.4.3 Undercarriage doors are operated by linkage to the shock-absorber housings.

4.5 **Position Indication.** Although the landing gear, when selected down, may be visible from the crew compartment, it is not usually possible to be certain that each undercarriage is securely locked. An electrical indicating system is used to provide a positive indication to the crew of the operation of the locks and of the position of the landing gear. The system usually consists of microswitches on the up-locks and down-locks, which make or break when the locks operate, and which are connected to a landing gear position indicator on the instrument panel. A mechanical indicator may also be provided, to show that the landing gear is down and locked when the electrical system is inoperative. On British manufactured aircraft, the electrical undercarriage indicating system operates in such a manner that a green light is displayed when the undercarriage is locked down, a red light is displayed when the undercarriage is in transit, and no lights are visible when the undercarriage is locked up; bulbs are usually duplicated to avoid the possibility of false indications as a result of bulb failures. On other aircraft, similar indications may be obtained by the use of magnetic indicators or lights, but on some light aircraft a single green light indicates that all undercarriages are locked down, and an amber light indicates that all undercarriages are locked up.

On some transport aircraft, provision is also made for the crew to examine the locks during flight in the event of failure or incorrect operation of the indicating system. Whichever indicating system is used, it is important that the microswitches are adjusted so that operation of the lights coincides with the corresponding position of the landing gear.

4.6 **Safety Features.** Since the correct operation of the landing gear is of the utmost importance, a number of safety features are included in the retraction system to ensure its correct operation under all conditions.

4.6.1 **Nose-wheel Centering.** To avoid damage to the airframe structure, the nose wheel must always be aligned in a fore and aft direction during retraction, and a number of methods are used to ensure that this happens automatically. One method utilizes a cam and cam track between the inner and outer cylinders on the shock-absorber. The cam is fixed to the top of the inner cylinder, and the track to the bottom of the outer cylinder. As the strut extends under internal gas pressure after take-off, the cam engages the track and centres the nose undercarriage before it retracts. A second method is the use of a peg located at the top of the shock-absorber strut, which engages a track fixed to the strut housing or in the wheel bay, and this device centres the undercarriage as it retracts. Hydraulic nose wheel centering on aircraft with powered steering is discussed in paragraph 5.

4.6.2 **Selector Lock.** To prevent inadvertent retraction of the landing gear when the aircraft is resting on its wheels, a safety device is incorporated which prevents movement of the selector lever; mechanical ground locks are also provided for servicing purposes. The safety lock consists of a spring-loaded plunger which retains the selector in the down position and is released by the operation of a solenoid. Electrical power to the solenoid is controlled by a switch mounted on the shock-absorber strut; when the strut is compressed the switch is open, but as the strut extends after take-off, the switch contacts close and the electrical supply to the solenoid is completed, thus releasing the selector lever lock and allowing the landing gear to be selected up. A means of overriding the lock, such as a separate gated switch to complete the circuit, or a mechanical means of avoiding the locking plunger, is provided for emergency use and for maintenance purposes.

4.6.3 **Warning Devices.** To guard against landing with the landing gear retracted or unlocked, a warning horn is incorporated in the system and connected to a throttle-operated switch. If one or more throttle levers are less than approximately one third open, as would be the case during approach to land, the horn sounds and the red warning lamp illuminates if the landing gear is in any position other than down and locked. A horn isolation switch is often provided to allow certain flight exercises and ground servicing operations to be carried out without hindrance.

4.6.4 **Emergency Extension.** A means of extending the landing gear and locking it in the down position is provided to cater for the eventuality of main system failure. On some aircraft the up-locks are released manually or by means of an emergency pneumatic system; the landing gear 'free-falls' under its own weight and the down locks are engaged by spring jacks. On other aircraft the landing gear is extended by an emergency pressure system which often uses alternative pipelines to the jacks. Pressure for the emergency system may be supplied by a hydraulic accumulator, a hand pump, a pneumatic storage cylinder, or an electrically powered pump.

4.7 **Maintenance.** The landing gear performs an important function and every care should be taken to ensure that the instructions for its inspection and maintenance contained in the relevant Maintenance Manual and approved Maintenance Schedule are correctly carried out.

4.7.1 **General Precautions.** The following precautions are relevant to most types of landing gear, and will help ensure the safety of personnel and correct operation of the system.

(i) Ground locks should be fitted whenever the aircraft is out of service, and the appropriate circuit breakers tripped, or fuses removed, when work is carried out on the system.

(ii) Replacement or adjustment of components in the retraction system should be followed by a retraction test.

(iii) Components should never be removed while the system is under pressure, i.e. by hydraulic accumulator or pneumatic supply bottle.

(iv) When components are removed, the open pipelines should be properly blanked; rags or masking tape must not be used for this purpose.

(v) New components should be inspected for cleanliness before installation, and it is usually recommended that components containing fluid should be completely filled before installation, or primed and bled after installation.

(vi) Care should be taken to ensure that the fluids used for topping up the hydraulic system or shock-absorber strut are perfectly clean. Funnels and containers must be kept clean and should be rinsed in clean fluid before use.

(vii) Fluid bled or drained from the system, or used for flushing, must be discarded.

(viii) Care should be taken to prevent spillage of fluid, which may have a detrimental effect on paint, rubber, cable insulation, etc. Some fluids are also irritant to the skin and eyes.

(ix) Air pressure should be released slowly, particularly in confined spaces.

(x) Ground equipment used for replenishing fluids, or for providing hydraulic power or air pressure, should be kept scrupulously clean and should be serviced at stipulated intervals.

(xi) Unless otherwise specified, components should usually be installed using the appropriate lubricant or anti-seize compound on mating surfaces.

(xii) Only the recommended lubricants and fluids should be used, and any tests necessary should be carried out strictly in accordance with the relevant Maintenance Manual.

4.7.2 **Routine Servicing.** At the periods specified in the approved Maintenance Schedule, the landing gear should be lubricated and the relevant inspections carried out. The appropriate inspections detailed in paragraph 3 are also applicable to retractable landing gear, and, in addition, the retraction mechanism should be inspected for security, damage, wear of moving parts, fluid leaks and chafing of pipelines and electrical cables. Doors and wheel bays should be inspected for damage resulting from debris thrown up by the wheels, or witness marks from the tyres indicating faulty adjustment or damaged linkage. Minor damage may usually be blended out and the part re-protected as appropriate, but cracks, kinks in pipelines, or wear beyond the limits specified in the Maintenance Manual are not acceptable. Some leakage from the components of a pneumatic system is usually permissible, since the operating medium is replaceable, but serious leaks could affect operation of the system. Leakage from a hydraulic system may sometimes be corrected by cleaning and re-making a connection, but a component with a persistent leak should be replaced.

4.7.3 **Component Installation.** Whenever a new component is installed in the retraction system, it should be carefully adjusted to prevent physical damage and ensure correct operation. A common method of adjusting components and linkage after installation is to jack-up the aircraft, install ground locks on the undercarriages not being worked on, make the system electrically safe, and operate the individual retraction jack using a hand pump rig. This ensures slow, controlled operation, and allows individual adjustments to be made to the mechanism in accordance with measurements quoted in the relevant Maintenance Manual. After adjustment, the system should be reconnected and bled, and retraction tests carried out.

4.7.4 **Retraction Tests.** Retraction tests should be carried out following replacement of a faulty component, whenever incorrect operation is reported or suspected, and after a hard or overweight landing. The sequence of operations will depend on the particular installation and type of retraction system concerned, and full details should be obtained from the relevant Maintenance Manual. The following procedure is applicable to most retractable landing gears.

(i) Raise the aircraft so that the wheels are clear of the ground, and lock the lifting jacks. Ensure that no ground equipment or personnel are in the vicinity of the undercarriages and doors.

NOTE: In some aircraft the arc described by the wheels during retraction brings them nearer to the ground, and additional ground clearance must be allowed in these instances.

(ii) Connect electrical power and external hydraulic or pneumatic servicing equipment as appropriate.

(iii) Carry out several retractions and extensions, initially at low power to ensure slow operation, and using both the normal and emergency systems, and check the following:—

(a) Undercarriages for proper operation.

(b) Doors for correct operation and fit.

(c) Clearance in the wheel bays with the landing gear retracted, making due allowance for the effects of centrifugal force on tyre diameter.

(d) Linkage for correct operation and adjustment.

(e) Locks, switches, warning devices and mechanical indicators for correct operation.

(f) Freedom from fouling during retraction or extension, especially of flexible pipes.

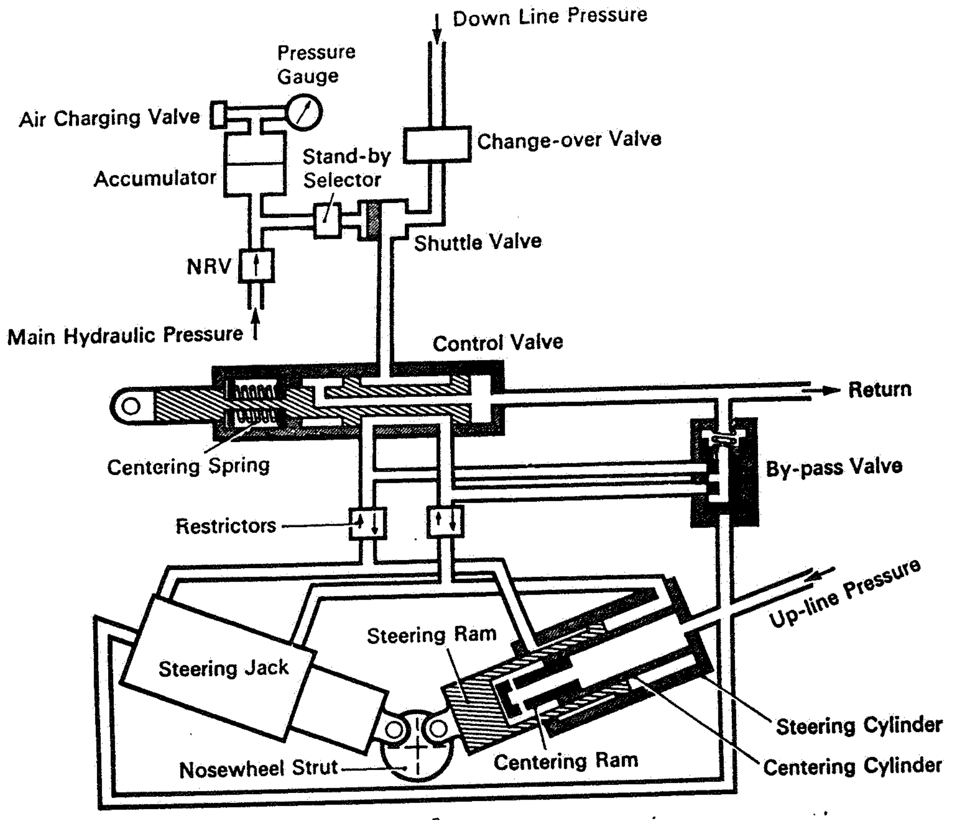
(g) General smooth operation of the mechanism.

NOTE: Retraction tests following initial assembly, replacements or significant adjustments, should be carried out with the wheel doors disconnected from their operating struts, and, if necessary, the sequence valves operated by hand; loose operating rods should be guided clear of structure. This procedure will permit direct inspection for clearance and alignment, and will also permit adjustment of mechanical stops, sequence contact points, up and down locks, and over-centre linkage.

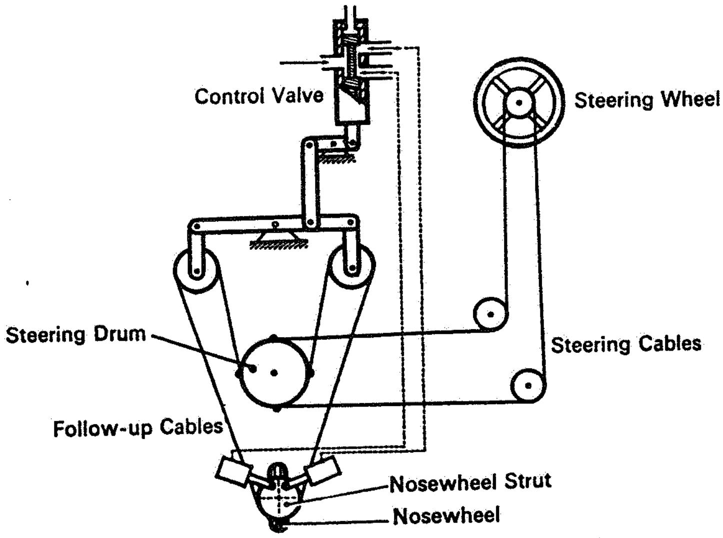
(iv) Remove servicing equipment, lower aircraft and fit ground locks.

(v) Finally tighten and lock any equipment installed immediately prior to the test.

5 POWERED STEERING Light aircraft generally employ a simple steering system, in which the nose wheel is mechanically linked to the rudder pedals. Larger aircraft require powered steering arrangements, in which the nose wheel is turned by hydraulic, pneumatic, or electrical power. A powered steering system generally includes a cockpit steering wheel or tiller, a control valve, steering cylinders to actuate the nose undercarriage, a follow-up device to hold the nose wheel at the correct angle, and a power source. A typical hydraulically operated system is described below, and illustrated in Figure 7.



HYDRAULIC SYSTEM



MECHANICAL LINKAGE (IN CASTORING POSITION)

Figure 7 POWERED STEERING SYSTEM

5.1 **Hydraulic Steering System.** Main operating pressure is derived from the undercarriage 'down' line, and a limited emergency supply is provided by a hydraulic accumulator. In the system shown in Figure 7, hydraulic pressure passes through a change-over valve, which ensures that the steering system is only in operation when the nose undercarriage is down.

5.1.1 **Steering Operation.** Pressure is directed through the control valve to the steering jacks, which retract or extend to rotate the nose shock-absorber strut within its housing. Movement of the steering wheel is transmitted through mechanical linkage to the control valve, in accordance with the amount and direction of turn required. Follow-up linkage from the nose undercarriage gradually resets the control valve as the nose wheel turns, and when the selected angle is reached a hydraulic lock is formed between the control valve and the steering jacks, preventing further movement. When the steering wheel is released, the control valve returns to neutral under the action of its centering springs, and the nose wheel is free to castor.

5.1.2 An inner cylinder in each steering jack is connected to the landing gear 'up' line and is supplied with fluid under pressure when the landing gear is selected up. The steering jacks extend equally to centralise the nose wheel before pressure is applied to the nose retraction jack, and the by-pass valve allows fluid from the steering jacks to flow to the return line.

5.1.3 **Castoring.** Whenever the control valve is in its neutral position, fluid is free to flow between the steering jacks, thus allowing the aircraft to be towed, or the nose wheel to return to the central position after a turn has been initiated with the steering wheel. Angular movement of the nose wheel during towing will be transmitted through the follow-up linkage to the steering wheel. Some form of quick-release pin is often provided to enable the steering jacks to be disconnected so that the nose wheel may be turned through large angles during ground servicing.

5.1.4 **Damping.** Restrictors in the pipelines between the control valve and the steering jacks, provide damping for the nose undercarriage.

5.2 **Maintenance.** The lubrication and inspection requirements of the steering system are broadly similar to those detailed in paragraph 4.7 for retractable landing gear. Installation and adjustment of the mechanical linkage, and functional testing of the system are described in the following paragraphs.

5.2.1 **Mechanical Linkage.** Proper adjustment of the mechanical linkage is most important, since slackness or faulty installation could lead to incorrect operation of the steering system. To facilitate installation of components, rigging pins are usually inserted through jig-drilled holes in the steering wheel, drum assembly and follow-up linkage (see Figure 7) in order to fix their positions. The nose wheel can then be centralised, and the cables and rods fitted and adjusted, accordingly. Cables should be tensioned using a tensionmeter, and rods adjusted so that the connecting pins and bolts can be easily fitted. When new pulleys or cables are fitted, it is usually recommended that they are 'bedded-in' by operating the steering wheel a number of times over its full range of travel; cables should then be re-tensioned.

5.2.2 **Functional Test.** The following test is applicable to the system illustrated in Figure 7 and contains the basic essentials for tests on similar steering systems. The hydraulic installation on a particular aircraft may necessitate additional operations, and these will be fully described in the appropriate Maintenance Manual.

(i) Ensure that the shock strut is correctly serviced.

(ii) Jack the aircraft so that the wheels are clear of the ground and ensure that no ground equipment or personnel are in the vicinity of the landing gear.

(iii) Depressurize the main hydraulic system and check that the nose wheel has freedom of movement over the full castoring range.

(iv) Connect a hydraulic test rig and ground electrical power, and set controls and switches for normal hydraulic operation.

(v) Operate the steering wheel over its full range, and check that the nose wheel follows smoothly and stops at selected positions.

(vi) Set the nose wheel a few degrees to one side and select the landing gear up, checking that the nose wheel centres before the down-lock breaks.

(vii) Lower landing gear and repeat operation (vi) with the nose wheel displaced in the opposite direction.

(viii) Carry out further retractions to check that the steering is only operative when the nose undercarriage is down.

NOTE: Operations (vi), (vii), and (viii) could lead to extensive damage if malfunction occurs, and should be performed with the test rig adjusted to give a slow rate of operation of the retraction system.

(ix) Check that the stand-by accumulator is correctly charged with air pressure and operate the test rig to pressurise the accumulator.

(x) Select stand-by steering and check that the nose wheel can be steered satisfactorily. This check may involve a specified number of turns before the accumulator is exhausted or the stand-by system low pressure warning lights illuminate.

(xi) Set the stand-by selector to off, and disconnect the test rig and external electrical power.

(xii) Lower the aircraft and finally lock any components installed prior to the test.

6 BOGIE UNDERCARRIAGES On heavy aircraft, the need to spread the weight over a large area has resulted in the use of multiple wheel undercarriages. A typical four-wheeled bogie is illustrated in Figure 8, but a larger number of wheels are used on some undercarriages.

6.1 The undercarriage unit normally consists of a shock-absorber strut, at the lower end of which a bogie beam is pivoted, and the axles are attached to each end of the beam. On some aircraft the rear pair of wheels swivels on the bogie beam, and castors when the nose wheel is turned through a large angle; on others, the upper torque link member is replaced by a pair of hydraulic jacks, which, when nose wheel steering is applied, rotates the whole bogie. Castoring or steering prevents excessive torque on the undercarriage leg and minimises tyre scrubbing during turns. For normal operation, the swivelling pair of wheels is locked in line with the fixed pair. Brake torque at each wheel is transmitted through compensating rods to the shock-absorber strut, thus preventing excessive loads on the bogie beam.

6.2 On retractable landing gear a levelling strut or 'hop damper' provides a means of positioning the bogie beam at suitable angles for retraction and landing; this strut is usually connected into the hydraulic system to prevent retraction if the bogie is not at a suitable angle, and combines the functions of hydraulic ram and damper unit.

6.3 **Maintenance.** In addition to the lubrication, testing and maintenance of landing gear described in previous paragraphs, particular care and higher standards of workmanship are necessary with bogie undercarriages. Since this type of undercarriage is fitted to heavy aircraft, the materials used are of very high strength, and great care is

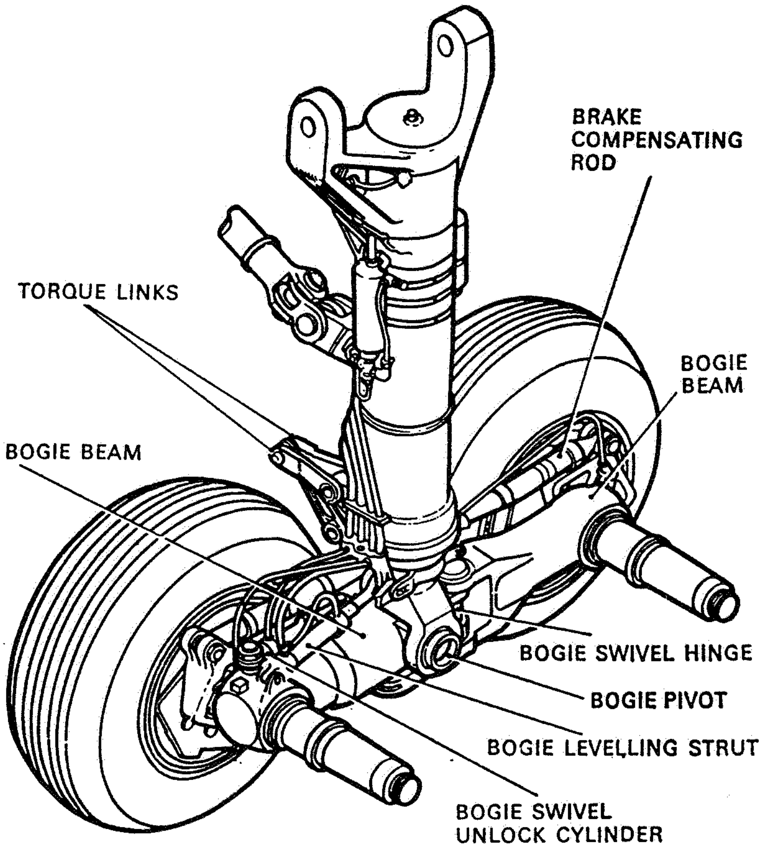


Figure 8 TYPICAL BOGIE UNDERCARRIAGE

taken in the manufacture, heat treatment and finish of the components. However, these materials are usually more susceptible to failure from scratches, indentations or corrosion, than materials of lower strength. All servicing functions should, therefore, be carried out with special care, particularly with regard to lubrication, the lack of which could result in corrosion or hydrogen embrittlement. If any surface damage is found during inspection, it should be repaired strictly in accordance with the instructions and limitations specified in the manufacturer's manuals, or, if no adequate guidance is given, in accordance with an approved repair scheme.

6.3.1 When changing wheel or brake assemblies, the axle should be fitted with a protective sleeve to prevent damage, and the surface and threads should be inspected for damage and corrosion before re-assembling the wheel or brake.

6.3.2 When carrying out retraction or steering tests, operation of the levelling strut and locking/unlocking of the swivelling wheels should be checked in accordance with the appropriate Maintenance Manual.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

CONTROL SYSTEMS

1 INTRODUCTION This Leaflet gives general guidance on the inspection procedure for control systems which are either manually operated, power assisted or power operated. The Leaflet should be read in conjunction with the relevant approved drawings and manuals for the aircraft concerned.

2 CONTROL SYSTEMS A control system is defined as a system by which the flight attitude or the propulsive force of an aircraft is changed (BCAR, Chapter A5–3).

2.1 For the purpose of duplicate inspection (see paragraph 2.2) the flight control system includes the main control surfaces, lift and drag devices and trim and feel systems, together with any flight control lock systems, and the associated operating mechanisms and controls. In the case of rotorcraft, the flight control system includes the mechanisms used by the pilot to control collective pitch, cyclic pitch and yaw. The engine control system includes the primary engine controls and related control systems (e.g. throttle controls, fuel cock controls, oil-cooler controls) and the mechanisms used by the crew to operate them.

2.2 **Duplicate Inspection.** A duplicate inspection of a control system is defined as an inspection which is first made and certified by one qualified person and subsequently made and certified by a second qualified person.

2.2.1 Components or systems subject to duplicate inspection must not be disturbed or re-adjusted between the first and second parts of the inspection, and the second part of the inspection must, as nearly as possible, follow immediately after the first part.

2.2.2 In some circumstances, due to peculiarities of assembly or accessibility, it may be necessary for both parts of the inspection to be made simultaneously.

3 INSPECTION OF CONTROL SYSTEM COMPONENTS

3.1 Control system components, the parts of which are concealed during bench assembly before installation, shall be inspected in duplicate on assembly during manufacture, overhaul or repair.

3.2 Both parts of the duplicate inspection and the results of any tests made during and after final assembly shall be certified on the Inspection Record for the part concerned.

4 DUPLICATE INSPECTION OF CONTROL SYSTEMS

4.1 A duplicate inspection of the control system in the aircraft shall be made (a) before the first flight of all aircraft after initial assembly, (b) before the first flight after the overhaul, replacement, repair, adjustment or modification of the system. The two parts of the duplicate inspection shall be the final operations, and as the purpose of the inspection is to establish the integrity of the system, all work should have been completed. If, after the duplicate inspection has been completed, the control system is disturbed in any way before the first flight, that part of the system which has been disturbed shall be inspected in duplicate (paragraph 2.2) before the aircraft flies.

4.2 In some instances it may not be possible after complete assembly of the aircraft to inspect all parts of the system because some sections of the system may get progressively 'boxed in' and sealed during assembly operations. In such cases the condition and security of any section which is liable to be sealed must be established to the satisfaction of the persons named in paragraph 5 before the section is sealed and the related Inspection Record endorsed accordingly.

NOTE: Inspection Records should be carefully prepared to ensure that any duplicate inspection required at an early stage during assembly operations is clearly indicated, thus avoiding unnecessary dismantling at later stages.

4.3 The correct functioning of control systems is at all times of vital importance to airworthiness, and it is essential that suitably licensed aircraft engineers and members of approved inspection organisations responsible for the inspection or duplicate inspection should be thoroughly conversant with the systems concerned. The inspection must be carried out systematically to ensure that each and every part of the system is correctly assembled, and is able to operate freely over the specified range of movement without risk of fouling. Also that it is correctly and adequately locked, clean and correctly lubricated, and is working in the correct sense in relation to the movement of the control by the crew.

5 PERSONS AUTHORISED TO CERTIFY DUPLICATE INSPECTIONS

5.1 Persons authorised to make the first and second parts of the duplicate inspection of control systems in accordance with Chapter A5–3 of BCAR are as follows:—

(a) Aircraft engineers appropriately licensed in Categories A, B, C and D.

(b) Members of an appropriately approved Organisation who are considered by the Chief Inspector competent to make such inspections, in accordance with Airworthiness Notice No. 3.

(c) For minor adjustments to control systems when the aircraft is away from base, the second part of the duplicate inspection may be performed by a pilot or flight engineer licensed for the type of aircraft concerned.

5.2 **Certification.** It is recommended that the certification of the duplicate inspection be in the following form:—

Duplicate Inspection performed in accordance with the requirements of BCAR, Chapter A5–3.

1st Inspection .... signature

.... authority

2nd Inspection .... signature

.... authority

Date ....

6 GENERAL

6.1 JAR 25.671(b) states that, in relation to aeroplanes, each element of each control system must be designed, or distinctly and permanently marked, to minimise the probability of incorrect assembly that could result in the malfunction of the system. The interpretive material in ACJ.671(b) states that for control systems which, if incorrectly assembled would hazard the aeroplane, the design should be such that at all reasonably possible breakdown points it is mechanically impossible to assemble elements of the system to give an out-of-phase action, reversed controls or interconnection between two systems which was not intended; only in exceptional circumstances should distinctive marking be used.

6.2 Section G of BCAR, in respect of rotorcraft, specifies that the physical features of the control system elements shall be such that it is mechanically impossible to assemble any system with reversed connections or to confuse the connections between systems.

6.3 These requirements are satisfied in practice in a number of ways, e.g. by the use of end fittings having different diameter threads for different cables, by the use of different diameter pins in correspondingly different diameter holes in end fittings, by staggering the positions of breakdown points so that cross-connecting, etc., is impossible.

6.4 The above requirements do not, however, minimise the necessity of thorough end-to-end inspection of each control run. Cases are on record of control cables being crossed and re-crossed so that the relative movements of the controls and the control surfaces were correct.

7 SCHEDULE OF INSPECTION A schedule of all inspections and functioning checks applicable should be compiled to ensure that no part of the system is overlooked. The schedule should include as a minimum sufficient instructions to enable the following to be completed:—

(a) The duplicate inspection of parts of components which will be concealed during bench assembly.

NOTE: Where such work is the subject of a sub-contract order, instructions regarding inspection and duplicate inspection should be stated on the order, and incoming release documentation should be endorsed to the effect that such inspections have been completed.

(b) The duplicate inspection of the internal locking and critical assembly features the correctness of which cannot be proved during final inspection or functioning tests with the assembly installed in the aircraft.

(c) The duplicate inspection of parts of the control system which may subsequently be obscured by the erection of further structure.

(d) The duplicate inspection, functioning and checking for correct relative movement of the complete system.

(e) The final inspection of the complete system to ensure that all covers, guards, etc., are correctly fitted.

(f) The recording of control surface movements and the serial numbers of components.

NOTE: In considering the instructions to be included in a Schedule of Inspection, it should be noted that the term "control systems" includes (for the purpose of this Leaflet) all power-operated or power-assisted controls together with their attachments and operating mechanism which in any way change the flight attitude or propulsive power of the aircraft. Only when other controls, such as an engine auto-stabiliser or an automatic control unit or parts of these units are interconnected with the control system in such a way that they cannot be instantly over-ridden by the crew in flight, are they considered as part of the control system.

8 POWERED CONTROLS

8.1 **Power-assisted Controls.** In this type of control part of the force needed to move the control surface is provided by a power system and part by the physical effort of the pilot. The pilot's 'feel' is thus provided by the control surface loads.

8.1.1 Initial movement of the pilot's controls produces (by mechanical connection) a small movement of the control surface which operates a control valve causing the control jack to follow-up, thus providing the bulk of the force to permit the movement of the control surface. As the control surface reaches the position appropriate to the position of the pilot's control, the valve is closed and the system comes to rest.

8.1.2 In the event of power failure or faults in the power system, satisfactory control can be maintained by manual means. A disconnecting mechanism is usually provided to prevent interference from the power system when it is not in use.

8.1.3 The trim control of power-assisted control systems is usually provided by conventional trailing-edge tabs, as for manually-operated flying control systems.

8.2 **Power-operated Controls.** In this type of system the whole of the force needed to operate the control surfaces is provided by power systems independent of each other but working in parallel.

8.2.1 Movement of the pilot's control operates a valve controlling an appropriate mechanism which operates the control surfaces until they reach the position appropriate to that of the pilot's control, when the valve is closed and the system comes to rest. It is not inherent in the system that the pilot's 'feel' should have any direct connection to the force on the control surface, and this, together with the self-centring of the controls, is achieved by artificial means. The two most common methods of providing feel are (a) constant load for a given control position imposed by a spring strut and (b) a variable loading related to airspeed and applied by a 'q' system, i.e. a force mathematically proportional to the square of the speed of the aircraft.

8.2.2 To provide for the event of power failure or faults in the power-operating mechanism, manual reversion might be provided, or there may be two or more systems, each with its own independent hydraulic system having additional pumps to safeguard against failure of their own pressure sources. In controls incorporating three power systems, where the servo unit is attached to the main structure and the jack rams move to control the aerofoil surface, a seizure of the unit selector valve could cause a hydraulic lock in the jack concerned. In this unlikely event the combined pressure of the two other jacks is designed to cause a safety relief valve in the defective unit to open, thus maintaining normal power control. The independent systems may operate one at a time, requiring manual changeover if a fault develops, or may be operating all the time in harmony, with a device to cut out (by manual selection or automatically) the system which fails to operate correctly.

8.2.3 Since power-operated controls are irreversible, it is not usual to make use of the conventional trailing-edge trim tab, and trim is often obtained by adjusting the zero position of the artificial feel mechanism. However, balance tabs are sometimes fitted to assist in maintaining hinge and servo loads to within the design values.

9 INSTALLATION OF FLYING CONTROLS The flying controls must be installed in accordance with the requirements prescribed in the relevant approved drawings and documents associated with the drawings, or with the requirements of the relevant manual. All parts used in the installation (e.g. electrical, hydraulic and pneumatic parts of the system) must bear evidence of prior inspection and, where applicable, duplicate inspection. It must be ensured that the highest standards of workmanship and cleanliness have been observed, and that no parts have been damaged or subjected to distortion during assembly.

9.1 **Pulleys and Sprockets.** All pulleys and sprockets must be aligned to provide a satisfactory 'run' for the cables and chains so preventing riding on the flanges of the pulleys and sprockets and chafing against the guards and covers.

9.1.1 The pulley and sprocket bearings should be examined to ensure that they are properly lubricated, rotate freely, and are free from dirt, swarf and paint spray, etc.

9.1.2 Non-metallic pulleys should be examined for freedom from embedded foreign matter and metal pulleys for freedom from roughness and sharp edges.

9.2 **Guards and Covers.** Pulleys and sprockets must be guarded to prevent jamming of cables and chains. The guards and covers must be so fitted and locked that they cannot foul the controls in any position and are held positively against rotation about the pulley or sprocket axis. Where a guard forms an integral part of a removable panel, adequate precautions must be taken to check the controls and the correct positioning of the guard after the panel has been replaced.

9.2.1 Glands, gaiters, etc., intended to prevent the escape of lubricant, ingress of foreign matter or loss of cabin pressure where controls pass through pressurised areas, must be undamaged and correctly and securely attached.

9.2.2 When longitudinally-split rubber seals are fitted at pressure bulkheads to seal the apertures through which control cables pass, care must be taken to ensure that the assembly is such that the seal will not be chafed as this could result in the seal being broken permitting the retaining rings to come off and ride along the control cable, possibly causing jamming of a pulley. Care must also be taken to ensure that the retaining rings are installed correctly into the groove in the seal to prevent a similar occurrence.

9.3 **Levers and Fairleads.** All levers and fairleads should be aligned to give the required run without chafing. After installation the levers should be checked for free and unrestricted movement.

9.4 **Chains.** Information on the assembly, testing and installation of chains is given in Leaflet **AL/3–2** and should be read in conjunction with this Leaflet.

9.5 **Cables.** Information on the assembly and testing of spliced and swaged cables is given in Leaflet **BL/6–24.**

9.5.1 Before installing a cable which has an identification tag affixed other than as shown in British Standards SP53, SP54, SP105 and SP106, the tag should be removed and, for future identification purposes, the particulars on it should be entered in the Aircraft Log Book.

9.5.2 Where applicable the protective treatment specified should be applied to the cables. However, where the cables pass through or over fairleads, any excess greasy substance should be removed to prevent these parts collecting abrasive dust which would wear the cables.

NOTE: In order to improve the wear and fatigue life of control cables, British Standards require a lubricant to be applied during spinning of the cable. It is important, therefore, when cleaning cables not to wash out the lubricant by saturating the cable with a grease solvent.

9.5.3 The cables should be free from broken wires or other defects, e.g. kinks and 'bird-caging', which would affect their strength.

9.5.4 It is important that the cables should be correctly tensioned and this can be helped by having the control surface locks in position during tensioning to support the weight of the control surfaces. During tensioning, adjustment should be made equally on all turnbuckles, otherwise circuits which incorporate a number of pulleys and fairleads and/or where the cables have to negotiate several bends may be difficult to tension evenly.

9.5.5 Where the tension is specified in the drawing or manual, this should be checked by means of a tension meter specified for the weight of cable concerned, due allowance being made for temperature. To obtain a true reading the tension meter should be placed in the position on the cable indicated in the drawing or manual. In the absence of a position being specified it should be placed away from fairleads and pulleys.

NOTE: Where long cable runs are concerned, drawings and manuals often detail the tensions required over a range of ambient temperatures.

9.5.6 Where the tension is not specified it should be ensured that the cable run is not too slack or too taut but has a satisfactory 'feel' over the whole range of travel of the controls.

9.5.7 Turnbuckles should be locked (using wire of the gauge and specification quoted in the relevant drawing or manual) using any of the methods illustrated in Figures 1 to 3. Prior to locking, it should be ensured that the end-fittings are 'in safety' (i.e. the internal fitting extends past the inspection hole in the external fitting) by attempting to pass a hardened pin probe through the inspection hole. Locking wire must not be used more than once.

NOTE: Some turnbuckles are designed so that they can be locked by special locking devices (e.g. spring locking clips to MS21256). Instructions regarding their assembly and use should be obtained from the relevant manual.

9.5.8 With the larger type of control cables (i.e. cables from 45 to 120 cwt), it has been found that tension loads tend to straighten out the helically-wound cable resulting in a torque action sufficient to break the locking wire or release lock nuts on turnbuckles or similar assemblies. To overcome this 'unlocking' action a tube fitted over the turnbuckle assembly and drilled to accommodate three bolts is often specified. This provides a positive means of preventing independent rotation of any part of the assembly.

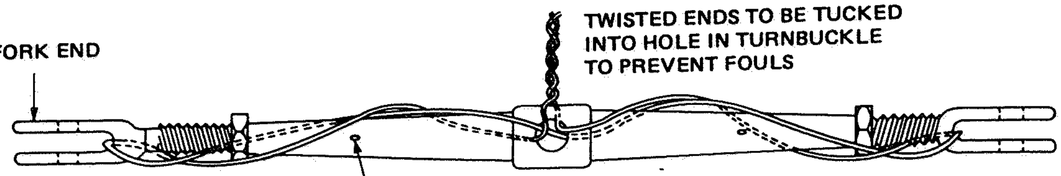

Figure 1 WIRE-LOCKING OF TURNBUCKLE WITH FORK END-FITTINGS

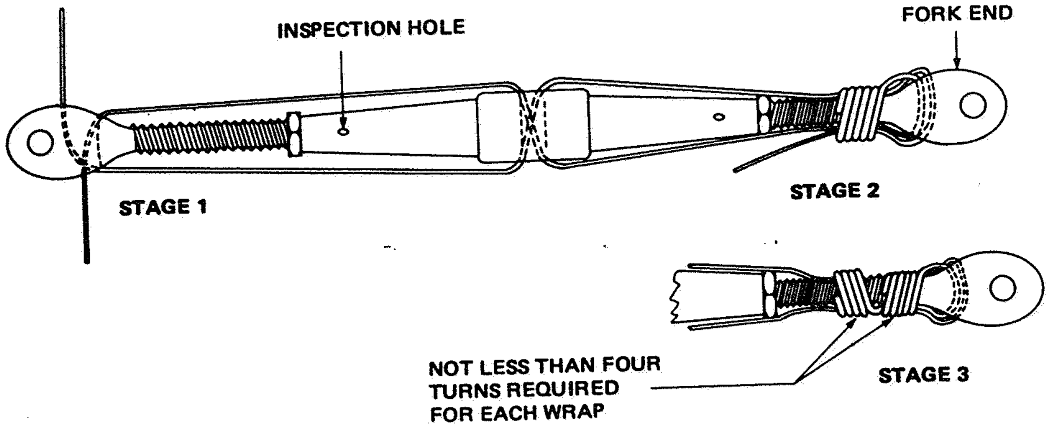

Figure 2 ALTERNATIVE METHOD OF WIRE-LOCKING TURNBUCKLE WITH FORK END-FITTINGS

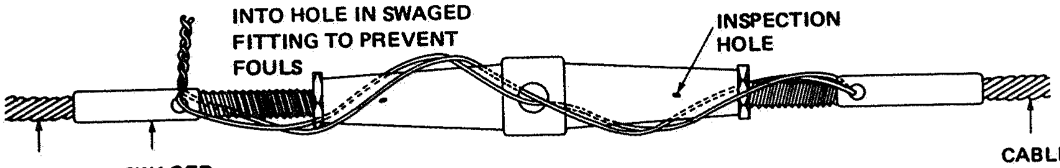

Figure 3 WIRE-LOCKING OF TURNBUCKLE WITH SWAGED END-FITTINGS

9.5.9 The adjustable end-fitting shown in Figure 4 may be attached, for example, to a swaged cable, a chain or a tension rod. The threaded end must be in safety and the locknut adequately tightened. The screwed portion (A) must not abut the fitting (B) in the fork end as this would impose an additional strain on the fitting, the joint would lack flexibility and there would be no provision for further adjustment.

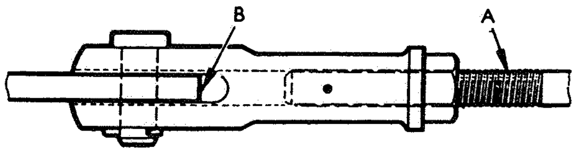

Figure 4 ADJUSTABLE FORK END-FITTING

9.6 **Control Rods.** Control rods should be perfectly straight (unless designed to be otherwise) when fitted, and bell-cranks, etc., to which they are attached, should be checked for freedom of movement before and after assembly of the control rods. The assembly as a whole should be checked for correct alignment.

9.6.1 Where self-aligning ball-races are fitted, free rotational movement of the rods must be obtained in all positions.

9.6.2 There have been cases of control rods with self-aligning bearings becoming disconnected because of failure of the peening retaining the ball-races in the rod end housings, thus allowing the rods to become detached from the ball-races. This can be obviated if the control rods are assembled so that the abutment flange of the rod end housing is interposed between the ball-race and the anchored (as opposed to the free) end of the attachment pin or bolt (see Figure 5). Alternatively, a washer having a larger diameter than the hole in the abutment flange may be required under the retaining nut on the end of the attachment pin.

9.7 **Gearboxes and Torque Tubes.** Where this type of equipment is installed in the system, it should be ensured that the gearboxes are correctly mounted, that the torque tubes are not bowed and run freely in their guides, that universal joints are correctly fitted and give the correct degree of angular transmission throughout a complete rotation of the torque tube, and that only the lubricant specified by the aircraft manufacturer is used in the gearbox.

9.8 **Control Surfaces, Tabs, etc.** The method of attachment varies with each type of aircraft, but it must be ensured that the component is assembled to the aircraft without strain and that adequate clearance exists between adjacent control

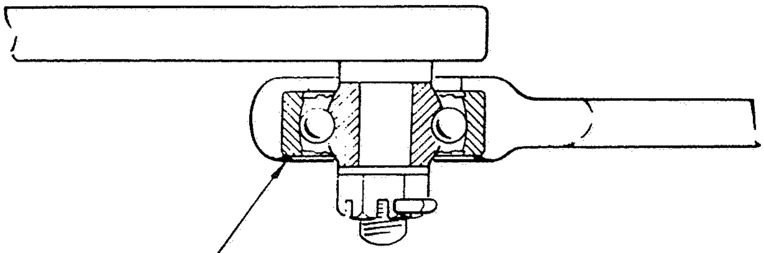

Figure 5 SELF-ALIGNING BEARING

surfaces, or between the control surface and adjacent structure and shrouds, throughout the full range of movement. There must be no slackness in linkage which may cause collective backlash and introduce control flutter.

9.9 **Rotor Blades.** Rotor blades are particularly susceptible to damage and sensitive to its effects. Particular care is necessary, therefore, when handling and assembling rotor blades to prevent them becoming dented or scored. The attachment of rotor blades must be inspected in duplicate as must the re-securing of the blades after unfolding.

9.10 **Locking.** All connections of components and parts in the control system must be positively secured and locked in accordance with drawing requirements (see Leaflet **BL/6–13**).

9.11 **Lubrication.** All moving parts should be lubricated with the specified lubricant during assembly. Proprietary bearings, such as those of the oil-retaining variety, should receive lubrication only when recommended by the manufacturer.

9.12 **Placarding.** A check should be made to ensure that all placards and notices relating to the functions, direction of movement and operational positions of controls, levers, handles, etc., are clearly and correctly applied in accordance with drawing requirements and are in their specified positions.

NOTE: It is important that all placards and labels should be maintained in a clean and legible condition.

9.13 **General.** During installation, care must be taken to avoid any possibility of the controls jamming or fouling against adjacent structure, or cables rubbing together or chafing against other fixed or moving parts throughout their range of movement. Where clearances are not stated on drawings and there is some doubt about their adequacy, the guidance of the approved Design Organisation should be sought. The system should be protected against corrosion and deterioration and should be effectively bonded (see Leaflet **EEL/1–6**).

10 CONTROL SETTINGS

10.1 **Manually operated.** The manual operation of the system should be witnessed whilst the controls are operated throughout their full range. This should be carried out in quiet conditions as some mechanical defects can be detected by an unusual noise. The primary systems should be checked for static friction, using a spring balance. The CAA recommends that the forces on the control column or wheel and rudder pedals necessary to overcome static friction should not exceed the values given in Table 1. In the case of systems incorporating cables, these conditions should be met with the cables rigged at the stipulated tensions.

TABLE 1

Maximum Weight of Aeroplane kg(lb)	Maximum Static Force on Control N(lbf)		
	Elevator	Aileron	Rudder
5700 kg (12,500 lb) or less	17·79 N (4 lbf)	8·89 N (2 lbf)	26·68 N (6 lbf)
22 680 kg (50,000 lb) or more	44·48 N (10 lbf)	35·59 N (8 lbf)	44·48 N (10 lbf)
Linear variation should be assumed between these weights.			

10.2 The full and synchronised movement of the controls should be checked to the relevant rigging diagrams, and the limit stops adjusted as necessary to the relevant rigging diagram requirements. The stops should be relocked. It is important that the pilot's controls and control surfaces contact their stops in the correct sequence.

NOTE: When checking the range of movement of the control surfaces, it is important that the controls should be operated by the pilot's controls and not by handling the control surfaces. It should be ensured that all obstructions, such as trestles, are out of the way of control surfaces.

10.3 During the checking of settings it should be ensured that collective backlash in the system does not exceed permitted limits and, when controls are in the 'full-travel' position and against their respective stops, that chains, cables, etc., have not reached the limit of their travel. Where dual control facilities are provided, it should be ensured that they are correctly synchronised and function satisfactorily when operated from both positions.

10.4 Where components or control systems are interconnected it should be ensured that they are correctly co-ordinated in accordance with drawing requirements.

10.5 Where friction devices are employed it should be ensured that the selected degree of friction is applied to the controls throughout the range of movement.

10.6 Trim tabs and other tabs should be checked in a similar manner to the main control surfaces, it being ensured that any devices for indicating the position of the tabs function correctly. When screw jacks are employed to actuate the tab, care must be taken to ensure that they are not out of safety when in the fully extended position.

10.7 Where spring devices are fitted in the control system, these should be checked for correct tension, cleanliness and adequate lubrication.

10.8 Guidance on control functioning checks for aeroplanes and rotorcraft is given in paragraph 11.

10.9 **Powered Controls.** The rigging of powered controls varies with each type of aircraft, therefore, it is impracticable to attempt in this Leaflet to define a procedure; it is essential to follow the manufacturer's requirements in this respect. However, reference can be made to the nature of the precautions which should be taken when rigging such systems.

10.10 It is of the utmost importance that each system should be correctly adjusted and all means of adjustment correctly locked. Where cables are used in powered control systems, it is essential that they are correctly tensioned to prevent malfunctioning of the actuating units. The tensioning requirements, the type of tension meter to be used, and the positions where readings are to be taken will be prescribed in the relevant manual for the aircraft concerned. To compensate for structural flexing and changes in temperature, cable-tension compensator-units are sometimes incorporated in the control circuit; these compensators should be pre-set and the system adjusted as prescribed in the relevant manual. To simplify the adjustment, compensator units may be provided with scales or datum holes to indicate when the adjustment is correct.

10.11 It is important during initial setting that jacks do not bottom, unless the relevant manual so specifies, as this may result in over-stressing of parts of the unit which could lead to failure in service.

10.12 Pins, usually 'rigging' pins (which must have a red warning flag permanently attached), are sometimes required to simplify the setting of such parts as pulleys, levers, hydraulic control units, etc., in their neutral positions by inserting the pins in the alignment holes provided. This arrangement also simplifies the correct alignment and tensioning of the various control systems. When rigging pins are not provided, the neutral positions may be checked by means of alignment marks, by the use of special templates or by taking linear measurements; these procedures will be clearly defined in the relevant manuals.

NOTE: To prevent damage to the control system, if by error rigging pins were left in position, some rigging pins are designed to have a maximum shear value and only those designed for the system concerned should be used, but in general, the accuracy of diameter and correct fitting are the important considerations. Ground locking devices should never be used in lieu of rigging pins.

10.13 If the final alignment and adjustment of the system is correct it should be possible to withdraw the rigging pins easily. Any undue tightness of the pins in the rigging holes indicates incorrect tensioning or malalignment of the system.

NOTE: All rigging pins or centralising devices must be removed immediately after the rigging operation is completed and before operating the power systems, otherwise damage may result. This precaution must be made part of the control system clearance procedure. Similarly, precautions should be taken to ensure that all obstructions, such as trestles, are out of the way of control surfaces.

10.14 When static friction tests are prescribed for the control circuits, these should be done with a spring balance or suitable test rig in the manner prescribed and must not exceed the limiting values permitted. In some power-assisted systems, excessive friction could upset the feel of the system to the detriment of the handling qualities of the aircraft.

NOTE: In some instances it may be necessary to disconnect the 'feel' spring struts in order that the true friction value can be obtained. It may also be necessary to check spring-strut break-out forces following the static check.

10.15 Since the hydraulic systems are independent of each other, a check should be made to ensure that the routeing of all pipelines and electrical cables does give the necessary isolation. In addition, pipelines and electrical cables should be checked for signs of chafing while the systems are functioning.

10.16 It is essential that all control functioning checks and tests are carried out strictly in accordance with the manufacturers' publications complying with Chapter **A6–2** of BCAR.

NOTE: It must be ensured that test rigs contain the correct fluid and are provided with the same standard of filtration as is provided on the aircraft.

10.17 The correct engagement and disengagement of control locks should be checked at the same time as a check on the correct functioning of the associated warning devices.

10.18 The range of movement of the controls and control surfaces should be checked in both directions from the neutral position. If the range does not meet the rigging tolerances, the necessary adjustments should be made and the duplicate inspection completed.

10.19 Where components in control systems are interconnected their operation should be correctly co-ordinated in accordance with drawing requirements. Where friction devices are employed, it should be ensured that the selected degree of friction is applied to the controls throughout the range of movement.

10.20 When testing the system all hydraulic equipment and pipe-lines should be checked for leaks. The appropriate filters should be checked for cleanliness and freedom from damage, and particular care should be taken to follow the instructions given in the relevant manual, as a broken or disintegrated filter may cause a valve to jam. Where 'tell-tale' indicators are incorporated in filters these should be checked at the periods specified. After checking for cleanliness, all air should be expelled from the systems.

10.21 **Engine Ground Run Test.** As some parts of the hydraulic systems are not tested with the hydraulic test rig the controls should be operated during a convenient ground test run to ensure that all engine pumps operate satisfactorily over the speed range of the pumps. Where part of a hydraulic system has been disconnected, e.g. to change an engine or pump, precautions should be taken to expel any air which may have entered the system and the operation of the system should be rechecked.

11 CONTROL FUNCTIONING The final functioning checks on control systems is of the greatest importance and it is essential that they should be completed systematically. The checks should be carried out after thorough cleaning and only when all other work on the system has been completed.

11.1 **Aeroplanes**

11.1.1 The functioning checks must include verification that full, free and correct movement of the controls is obtained throughout the system relative to the movement of the crew controls.

11.1.2 A list of all controls and the salient checking points should be drawn up in a suitable sequence and in duplicate.

11.1.3 A person competent to certify a duplicate inspection should operate the controls in the cockpit, maintaining the sequence specified in the checking list. Another person competent to certify the duplicate inspection should check on the control movements in the same sequence. For the second part of the inspection the two persons should exchange positions and repeat the checks in identical sequence.

11.1.4 The relative movements of the control surfaces in relation to the pilot's controls should be carefully checked to the manufacturer's instructions.

NOTE: Where 'free operating control surfaces' are installed the relative movements of controls are affected. For example, if the control column is moved back, the elevator does not move at all, but the tab of the elevator moves downwards causing the elevator to move upwards in flight. This type of control system requires a special checking technique and the manufacturer's instructions must be closely followed.

11.1.5 The movement of wing-flaps and slats should be checked for synchronisation and a check should be made to ensure that the relevant surface position indicator accurately registers the position of the surfaces throughout their range of movement.

(a) A check should be made (where applicable) to ensure that the wing-flap or slat asymmetric control device is functioning correctly.

(b) Where wing-flaps are interconnected with leading-edge flaps or slats, the installation should be checked for correct operation during extension and retraction of the wing-flaps.

11.1.6 Where spoilers/speed brakes are interconnected with the aileron control system, their correct operation in relation to the ailerons should be checked.

11.1.7 Where an aerodynamic feel simulator is connected into the main control systems, its correct operation should be checked with the aid of a suitable pitot system test rig.

11.1.8 It should be ensured that when operational time limits are specified for certain controls, e.g., flaps, spoilers or speed brakes, these are within permitted limits.

11.2 **Rotorcraft**

11.2.1 A list of all controls affected, and the salient checking points, should be drawn up in a suitable sequence and used as indicated in the relevant parts of paragraph 7.

11.2.2 The nature of the functioning checks necessary will vary with the system concerned, but where applicable the following should be checked:—

(a) That the direction of movement of the main and tail rotor blades or other related controls in relation to the movement of the pilot's controls is correct.

(b) That the operation of interconnected control systems (e.g. engine-throttle and collective-pitch controls) are co-ordinated in accordance with drawing requirements.

(c) That the range of movement and neutral positions of the pilot's controls (i.e. cyclic-pitch control columns, collective-pitch levers and yaw pedals) are as specified in the relevant drawings.

(d) That the maximum and minimum pitch angles of the main rotor blades, in both fore-and-aft and lateral cyclic-pitch, are within drawing requirements.

(e) That the maximum and minimum pitch angles of the main rotor blades in collective pitch are within drawing requirements.

(f) That, in the case of multi-rotor aircraft, the rigging and the movement of the blades of the rotor are in correct synchronisation.

(g) That the tracking of the main rotor blades is satisfactory.

(h) That, when tabs are provided on main rotor blades, these are correctly set.

(j) That the neutral, maximum and minimum pitch angles and coning angles of the tail rotor blades are in accordance with drawing requirements.

(k) That, when dual controls are provided, these function correctly and in synchronisation when operated from both positions.

(l) That, to comply with Chapter **G4–2** of BCAR, the static operating loads of the system are not excessive and, when specified, do not exceed drawing requirements.

11.2.3 **Tracking Checks.** When the main rotors do not 'cone' by the same amount during rotation, they are said to be 'out of track', and this may result in excessive vibration at the control column. Tracking checks should be carried out at the prescribed engine operating conditions, if possible in still air. Where it is not possible to obtain still-air conditions, the rotorcraft should be faced into a wind not exceeding 10 knots and it should be free from gusts.

11.2.4 **Tab Setting.** The setting of the tabs on main rotor blades (if provided) should be checked to eliminate out-of-balance moments which will apply torque to the rotor blades. The tab setting should be checked for correctness by running the rotor at the prescribed speed and ensuring that the cyclic-pitch control column remains stationary. Out-of-balance moments impart a stirring motion to the column.

11.2.5 **Checking Blade Angles.** Before checking blade angles it must be ensured that the rotorcraft and, where applicable, the rotorhead, is set up in the correct lateral and longitudinal position. The blades must be set in the specified position for the check. The blade angle should be checked on each blade in turn and, when specified, the angles of the subsidiary blades on the main rotor must agree with those of the master blade within the prescribed limits. When it is necessary to adjust the initial blade rigging in order to obtain correct tracking or acceptable flight characteristics, the rigging should be re-checked after test flying has been completed to ensure that it is within permitted limits.

11.3 **Control Locks.** A check should be made on internal ground control-locking systems to ensure they are positive in action, engage fully in the 'locked' position and have adequate clearance in accordance with drawing requirements in the 'unlocked' position. There should be no possibility of interference between the locks and the controls over the full range of movement of the latter.

11.4 **Inspection after Functioning.** When the functioning checks have been completed, all checking equipment should be removed from the aircraft and a final inspection made to ensure that the systems are free from all foreign matter which might cause jamming (e.g. nuts, bolts and small tools). All access panels should be replaced, care being taken to make sure that securing screws are the correct length not to foul the controls and that chains and cables retaining the access panels are correctly fitted.

12 AUTOMATIC-PILOT INSTALLATIONS The information in this paragraph does not apply to any particular type of installation of automatic-pilot but gives general guidance on essential points which relate to the flying control system. Any moving parts of the automatic-pilot that constitute integral parts of the normal control system, whether the automatic-pilot is 'in' or 'out', should be regarded as part of the flying control system and should be inspected in accordance with the procedure given in this Leaflet.

12.1 When the automatic controls are disengaged, the normal controls should function satisfactorily, e.g. the resistance offered by the automatic-pilot motors, where applicable, should not affect the control of the aircraft.

12.2 A check should be made on the means provided for disconnecting the automatic-pilot from the normal controls to ensure it is possible to do so at all positions of the controls and that the manual override of the automatic-pilot is satisfactory.

12.3 The interconnecting mechanism between the automatic-pilot and the normal controls should give the required range of travel and should be correctly aligned and smooth and positive in operation. The clearance should be in accordance with drawing requirements.

12.4 Operating cables, where applicable, should be checked for tension in the manner applicable to the particular installation.

13 GROUND TEST—AFTER OVERHAUL OR MAJOR DISMANTLING

13.1 All rigging pins or retaining devices should have been removed from the controls. Where control locks are not provided, it may be necessary to support the control surfaces until the system is functioning. The control surfaces should be checked for freedom from obstruction and the automatic-pilot should be disengaged.

13.2 If any one of the independent systems has been disturbed, a complete series of checks required to test that system should be made. Where any rectification affects more than one system or where there is any possibility of the functioning of all systems being affected, then the complete series of checks to test all systems should be made.

14 PERIODIC INSPECTIONS Periodic inspections on the complete flying control systems should be carried out in accordance with the requirements of the Maintenance Schedule or constructor's Manual.

AL/3-8

Issue 2.

December, 1979.

AIRCRAFT

SYSTEMS AND EQUIPMENT

FIRE—GENERAL PRECAUTIONS

1 INTRODUCTION This Leaflet deals with fire precautions during maintenance and engine running, and indicates some of the maintenance and inspection procedures concerned with fire prevention. Some general information on the causes of aircraft fires is also included. The Leaflet should be read in conjunction with the relevant manuals for the aircraft concerned, the Factories Act and any local regulations concerning the prevention of fire.

1.1 Guidance on the installation and maintenance of airborne fire detection and extinguishing equipment is given separately in Leaflets **AL/3-9** and **AL/3-10**.

1.2 Leaflet **BL/10-2** gives guidance on the methods of testing aircraft furnishing materials in order to ensure compliance with BCAR, Chapter **D4-3**.

1.3 CAP 74* gives guidance on the fire prevention measures which should be taken when fuelling and de-fuelling aircraft.

2 PREVENTION OF FIRE ON THE GROUND Personnel engaged in the maintenance, overhaul and repair of aircraft, should be fully conversant with the operation of fire protection equipment provided and the action to be taken in the event of discovering a fire. Supervisors should satisfy themselves that all reasonable safety precautions are taken and that all apparatus is completely serviceable. Personnel should not wear footwear with exposed iron or steel studs, nails or tips in hangars, fuelling and de-fuelling areas, and aircraft movement areas, and it is recommended that matches or other means of ignition should not be carried.

2.1 **Fuelling Operations.** Personnel concerned with fuelling should be fully conversant with the guidance material in CAP 74, with local aerodrome instructions and with the safety precautions detailed in the relevant aircraft Maintenance Manual. Fuelling should only be carried out at a site approved by the aerodrome authority, and the precautions outlined in paragraphs 2.1.1 to 2.1.7 should be observed.

2.1.1 **Fuelling Zones.** Fuelling zones should be established before fuelling commences. These zones should be regarded as extending at least 6 m (20 ft) radially from the filling and venting points on the aircraft and fuelling equipment. Within this zone, smoking, the use of naked lights and the operation of switches which are not of an approved pattern should be forbidden.

(a) Unless fuelling takes place in a designated no smoking area, "No Smoking" signs should be displayed not less than 15 m (50 ft) from the fuelling equipment and aircraft tank vents.

*CAP 74 is available from Printing and Publication Services, Greville House, 37 Gratton Road, Cheltenham, Glos., GL50 2BN.

(b) Auxiliary Power Units (APUs) which have an exhaust discharging into the zone should, if required to be in operation during fuelling, be started before filler caps are removed or fuelling connections made. If an APU is stopped for any reason during a fuelling operation it should not be started again until fuelling has ceased and there is no danger of igniting fuel vapours.

(c) Ground Power Units (GPUs) should be located as far as practical from aircraft fuelling points and vents, and should not be connected or disconnected while fuelling is in progress.

(d) Fire extinguishers should be located so as to be readily accessible.

2.1.2 **Precautions Prior to Fuelling.** Before the transfer of fuel commences, the following procedure should be carried out:—

(a) The aircraft should be connected to an effective earthing point and to the fuelling equipment.

(b) When overwing fuelling, the nozzle of the hose should be bonded to the aircraft structure before removing the tank filler cap. When fuelling from hand-operated equipment, including pumping from cans or drums, similar precautions should be taken to bond the pumping equipment, hose nozzle and containers. If funnels are used they too should be bonded to the nozzle or can and to the aircraft. If a chamois leather filter is used, the funnel, and all metal parts securing the leather, should be included in the bonding circuit.

(c) When pressure fuelling, the fuel tank pressure relief valves should, if possible, be checked for correct operation, and the bonding lead on the fuelling hose should be connected to the receptacle, located adjacent to the fuelling point, before connecting the nozzle.

2.1.3 **Precautions During Fuel Transfer**

(a) When overwing fuelling, the amount of fuel required should be determined and the quantity of fuel delivered should be regulated so that no overflow occurs. Fuel should not be splashed nor allowed to run into the aircraft structure.

(b) When pressure fuelling, any fuel levelling devices between tanks should be operated as necessary. The correct sequence of operations is essential to avoid damage to tanks and subsequent leakage of fuel or vapour.

2.1.4 **Precautions After Fuelling.** When the transfer of fuel is completed, the bonding wires should not be removed until the filler caps have been refitted or the pressure fuelling hose disconnected, as appropriate.

NOTE: Any cables, clips and plugs used for bonding or earthing, should be maintained in good condition and should be regularly tested for continuity.

2.1.5 **Work on Aircraft During Fuelling.** Whilst fuelling is in progress, servicing, maintenance, test and repair activities within the fuelling zone should be closely controlled.

(a) All ground equipment such as trestles, jacks, steps, etc., should be moved clear of the aircraft, to prevent damage to the aircraft as it settles because of the weight of fuel being uplifted.

(b) The main aircraft engines should not be operated.

(c) Only those electrical circuits essential to the fuelling operation should be switched on, except that some operators may permit certain specified maintenance work to be carried out during kerosene fuelling. The maintenance permitted is usually restricted to the replacement of complete unit assemblies. Testing and functioning of defined systems and equipment may be continued unless fuel spillage occurs or fuelling equipment becomes defective. No maintenance work may be permitted on aircraft using fuels which present a higher degree of fire hazard.

(d) Strobe lighting should not be operated.

(e) The engines of vehicles normally employed for servicing aircraft, including those on electrically powered vehicles, should not be run within the fuelling zone unless they have been designed for the purpose. All vehicles, their engines and equipment, should be subjected to regular inspection and maintenance to preserve their safety characteristics.

(f) All connections between ground equipment and an aircraft should be made before fuelling equipment is connected, and should not be broken until fuelling has been completed.

(g) Battery trolleys may be used within the fuelling zone provided that connection is made to the aircraft before fuelling equipment is connected. The circuit should remain unbroken until fuelling has ceased.

(h) Vehicles operating in the fuelling zone should not pass under or park beneath an aircraft unless specifically required to do so for maintenance or fuelling purposes. A clear exit path should be maintained.

(j) Aircraft combustion heaters should not be used.

(k) Maintenance work which may create a source of ignition should not be carried out in the vicinity of tanks or fuelling equipment.

(l) All hand torches and inspection lamps, and their cable connections, used within the fuelling zone, should be of certified 'flameproof' or 'intrinsically safe' type.

(m) Only authorised persons and vehicles should be permitted within the fuelling zone and the numbers should be kept to a minimum.

2.1.6 **Special Hazards**

(a) Aircraft should not be fuelled within 30 m (100 ft) of radar equipment under test, or in use in aircraft or ground installations.

(b) When any part of an aircraft landing gear, i.e. the wheels, tyres and brakes, appears overheated, the Aerodrome Fire Service should be called and fuelling should not take place until the heat has dissipated (see also Leaflet **AL/3-19**).

(c) Extreme caution should be exercised when fuelling during electrical storms. Fuelling should be suspended during severe electrical disturbances in the vicinity of the aerodrome.

(d) The use of photographic flash bulbs and electronic flash equipment within 6 m (20 ft) of the filling or venting points of aircraft or fuelling equipment, should not be permitted.

2.1.7 **Spillage of Fuel.** The actions to be taken in the event of a spillage of fuel will depend on the size and location of the spillage, the type of fuel involved, and prevailing weather conditions.

(a) If, despite care, fuel is inadvertently spilled in the aircraft structure, it should be cleared before the main aircraft engines are started. Lowering the flaps may accelerate drainage in some cases. Flight should be delayed to permit the evaporation of spillage, and air blowers should be utilised as necessary.

(b) In the case of a minor spillage of fuel on the ground, all liquid should be mopped up and the area allowed to dry out before starting any aircraft or vehicle engines in the vicinity.

(c) In the case of a major spillage of fuel (i.e. covering an area greater than 5 m^2 (55 ft^2)), action should immediately be taken to stop the flow of fuel, to evacuate all persons from the area and to notify the Aerodrome Fire Service.

(d) Fuel should not be washed into drains or culverts, but if such contamination does occur, large-scale water flushing should be carried out and the local water authority notified. Absorbent cleaning agents or emulsion compounds should be used to absorb spilled fuel, the contaminated absorbents being placed in suitable containers and removed to a safe location for disposal. The selection of tools and equipment to be used in removing spilled fuel and disposing of contaminated materials should have regard to minimising the risk of ignition.

2.2 **Work in Hangars.** Before commencing any inspection, overhaul or repair work involving the use of possible ignition sources in the vicinity of the fuel tanks, all tanks should be drained. De-fuelling should be carried out in the open air, by means of a fuel tanker utilising the pressure fuelling/de-fuelling connections on the aircraft, or by draining the tanks into suitable containers. In either case, adequate bonding preacutions should be taken, the tanker or containers being bonded to the aircraft and the ground before draining commences. Care should be taken to avoid spilling fuel onto the ground, and containers should be sealed immediately after filling. To avoid danger from sparking between containers and ground contacts, the aircraft should normally be moved from the site first.

NOTE: If fuel tests (e.g. calibrations, flows, etc.) or draining become necessary inside hangars, then additional precautions are required. Adequate notices should be displayed and fire-fighting personnel should be in attendance. It should be noted that for calibration checks aircraft are usually on jacks to maintain a known datum and could not, therefore, be towed away in the event of a fire.

2.2.1 The draining of fuel tanks does not render them free from fire risk, as they will contain fuel vapour. It is therefore necessary to purge tanks of vapour before subjecting them to inspection or repair involving the use of heat, electrical equipment or other sources of ignition. The safety precautions applicable to the inspection and repair of tanks are included in Leaflet **AL/3-15**.

2.2.2 Special care is necessary during fuel flow testing, and foam or CO_2 type extinguishers should always be available whilst this work is in progress. The use of an enclosed flow test rig, similar to that described in Leaflet **AL/3-17**, is recommended (see paragraph 2.2 NOTE).

2.2.3 Electrical equipment used during maintenance work, e.g. portable lighting equipment, electric drills, soldering irons, etc., should be maintained in good condition to avoid generating sparks, and in any case this equipment should not be used when flammable vapours are present in the atmosphere. For work in areas where heavy fumes are present, e.g. inside fuel tanks, flameproof torches must be used. Care should be taken that no flammable fluid is splashed on naked bulbs or other hot surfaces as spontaneous ignition may follow. Low voltage electrical supplies for inspection lamps, etc., are advantageous.

2.2.4 As far as possible only non-flammable cleaning fluids and paint strippers should be used, but if the use of solvents giving off flammable vapours is unavoidable, they should be handled with care and if spilt, should be wiped up immediately. During the use of such fluids the aircraft electrical system should be made inoperative with, for preference, the aircraft batteries removed.

2.2.5 In certain aircraft, special battery lead stowages are embodied. These should be utilised in accordance with the appropriate instructions contained in the Maintenance Manual.

2.2.6 The spraying of large surfaces with dope or paint should be carried out in a properly constructed and equipped spray shop. When touching up small areas, all electrical apparatus worked from a mains supply should be switched off or removed from the vicinity.

2.2.7 Open containers of dirty oil, fuel, dope or solvents should not be stored in aircraft hangars and should be removed from the vicinity of aircraft as soon as possible, otherwise accumulations of flammable vapour may result.

2.2.8 Magnesium and titanium swarf should be completely removed after drilling or machining operations. Special dry powder extinguishants, which are usually known by a trade name, should be used on fires of these combustible metals; water must not be used. The extinguishants form a crust or skin over the burning metal and thus exclude air.

2.2.9 Before permitting the refitting of floor panels or inspection covers, inspectors should ensure that the bays are clean and free from all foreign matter, that all drains are unobstructed, and all applications of primers, sealing compounds, etc., in the boxed up area are dry. In addition, all electrical connections, fuse box covers, etc., should be checked, and the systems functioned, and if the bay houses part of the flying control system duplicate inspection of the flying controls should be carried out before fitting the covers or panels.

NOTE: Fire precautions specified in the Factories Act, and in other governmental or local regulations for industrial premises, should always be strictly observed.

3 MAINTENANCE AND FIRE PREVENTION The following recommendations give guidance on maintenance practices which will reduce the risk of fires occurring in flight or when ground running engines.

3.1 **Power-Plant.** Faulty assembly or mechanical failure of engines or power-plant components can cause fire, and careful inspection is therefore essential to ensure that fractures, cracks or leaks are detected and rectified.

3.1.1 Attention should be given to main engine and APU starter systems, and, in particular, to ignition harnesses and to high energy igniter plugs and leads in turbine engines. Maintenance instructions must be carefully carried out in accordance with the engine Maintenance Manual.

3.1.2 Pipes carrying flammable fluids are routed by design as far from exhaust systems and electrical apparatus as the installation permits, and, if disturbed, should be re-installed so that the original distances from such sources of ignition are not reduced. Great care must always be exercised to ensure that pipes are in good condition, are appropriately colour coded, are adequately clipped and bonded, and that unions are correctly secured so that leaks cannot occur, and that drains are clear. Guidance on the inspection of flexible and rigid pipes is given in Leaflets **AL/3-13** and **AL/3-14**, respectively (see also paragraph 3.1.12).

3.1.3 It is most important to trace the source of any flammable fluid leakage and to rectify it immediately. Kerosene, lubricating oil, gasolene and most hydraulic fluids will ignite spontaneously if in contact with hot surfaces, such as exhaust pipes, combustion chambers, jet pipes and overheated brakes. Gasolene at ambient temperatures and kerosene at elevated temperatures will vapourise and form a combustible mixture with air, which may be ignited by sparks from electrical equipment or accumulations of static electricity. Fuel and oil drains should be checked for blockage and the routeing of the pipes must be clear of cowlings and brake systems. Cowlings should be kept clean to obviate accumulations of flammable fluids, greases and dirt.

3.1.4 The flame traps or shutters of air intake systems must always be in good condition. Flame traps will burn if combustible sludge is allowed to accumulate on the gauze.

3.1.5 Grommets or flash plates used to seal openings in firewalls must always be refitted carefully and renewed if damaged. Gaps through or around a firewall are not permitted. Seals must be securely fixed in position, approved sealants should be renewed as necessary, and distorted or damaged cowlings must be repaired or renewed.

3.1.6 The power plant bonding system is an important safeguard against fire and all bonding connections should be inspected frequently according to the recommendations of Leaflet **EEL/1-6.**

3.1.7 A major failure, such as the fracture of a cylinder or induction manifold on a piston engine (particularly a supercharged engine) is a serious matter, as air/fuel vapour mixture may be discharged and contact a hot surface in the power plant area, where ignition could occur. Careful visual examination may reveal minor defects before the danger of a complete breakdown arises.

3.1.8 Shortage of coolant in liquid-cooled piston engines will result in over-heating with a grave risk of mechanical failure of the engine causing a fire. It follows that careful maintenance of cooling systems is an aid to fire prevention.

3.1.9 Cracked exhaust manifolds, pipes, ejectors, or turbine-engine combustion chambers may allow hot gases or torching flame to impinge on vulnerable parts of the power plant installation, either causing fire directly or giving rise to mechanical failure which may start a fire. Exhaust systems and combustion chambers should therefore receive very careful examination.

3.1.10 Engine vibration is generally an indication of a serious defect and can also result in the cracking of pipes or leaking of high pressure hoses and loosening of pipe connections.

3.1.11 It is most important that all the appropriate fire precautions are taken during the operation of auxiliary power units whilst the aircraft is on the ground. Intakes and exhausts must be free from obstruction. Temperature and warning indicators should be observed and action taken accordingly.

3.1.12 A contributory cause of fires in engine bays is the saturation of flexible-pipe lagging by flammable liquids. This can occur when the outer covering (e.g. sleeving of neoprene or rubber) has been damaged or has deteriorated, allowing seepage into the lagging. This condition can be detected by blistering or a soggy feel, as distinct from the hard feel of unsaturated pipes. If pipes are in a saturated condition they should be renewed.

3.2 **Airframes.** Leakage of fuel, hydraulic, de-icing or lubricating fluids, can be a source of fire in aircraft, and this should be noted when inspecting aircraft systems. Minute pressure leaks of these fluids may be dangerous, as they could quickly produce an ignitable mixture.

3.2.1 Fuel tank installations should always be carefully examined for signs of external leaks. With integral fuel tanks, the external evidence of a leak may occur at some distance from where the fuel is actually escaping, particularly with kerosene which has particular penetrating properties.

3.2.2 Hydraulic fluids are generally flammable and should not be allowed to accumulate in the structure. Lagging and sound-proofing materials may be rendered highly flammable if soaked with oil of any kind and should be renewed.

3.2.3 All oxygen system equipment must be kept absolutely free from traces of oil, grease or flux, as these substances will ignite spontaneously in contact with pressurised oxygen. Oxygen servicing cylinders should be clearly marked so that they cannot be mistaken for cylinders containing Air, CO_2 or Nitrogen, as explosions and fatal accidents have resulted from these errors during maintenance operations.

NOTE: When a form of lubricant is necessary (e.g. because of a binding thread) the approved or recommended lubricant must be used. Lubricant should be used sparingly to ensure that it does not enter the oxygen system.

3.2.4 Any spillage or leakage of flammable fluid in the vicinity of combustion heaters is a serious fire risk, particularly if any vapour is drawn into the heater and passed over the hot combustion chamber. All safety devices, such as NO-HEAT or OVER-HEAT switches should be inspected at the intervals prescribed in the relevant Maintenance Schedule.

3.2.5 Hot air de-icing and other heating systems should be carefully inspected, particularly on turbine-engined aircraft, where high initial air temperatures exist, to ensure that the ducting and lagging are free from defects.

3.2.6 Pyrotechnical equipment such as signal cartridges, should be renewed if defective in any way. Stowages should not be located in high temperature zones.

3.3 **Smoking Compartments.** In these compartments, furnishing materials must be flame-resisting, and must be approved in accordance with CAA Specification No. 8 (see Leaflet **BL/10-2**). It is important that any gaps or crevices in the flooring and at the free edges of panelling should be sealed and this should be checked at regular intervals. Furnishing materials should also be inspected for grease or oil stains which may tend to propagate a fire, and loose covers which have been laundered or dry-cleaned should be re-proofed as necessary. Ash trays must be fitted and a hand-held fire extinguisher of an approved type must be installed (see Leaflet **AL/3-10**).

NOTE: The use of highly toxic extinguishants such as methyl bromide or carbon tetrachloride is prohibited in either crew or passenger compartments. However, in the case of a fire occurring during servicing or maintenance, the toxicity of the extinguishant may be less important, particularly if it is possible to direct the extinguisher through an open door or window into the fuselage.

3.4 **Electrical Equipment.** As faulty electrical equipment can provide a source of ignition by generating sparks or becoming over-heated, attention should be given to the following points:—

(a) Overheating and eventual destruction of cables can be caused by over-loading a circuit. To prevent this, particular care should be taken when installing new fuses or cables to ensure that the design standards as shown on the relevant drawings or manuals are maintained.

(b) Overheating of equipment can be caused by poor ventilation. Gauzes may become choked and cooling ducts damaged or disconnected.

(c) Electrical sparks from bad commutation in generators or motors, and arcing at relays and loose connections, are particularly dangerous. Terminal ends and cover bands must be torque loaded in accordance with the Maintenance Manual and securely locked.

NOTE: There have been cases of short-circuits at terminal positions and special care is necessary to prevent inter-action between circuits at these positions, particularly after any re-orientation of cables and looms. Care is also necessary to prevent arcing and tracking across terminal blocks through the ingress of moisture.

3.4.1 Deterioration of cable insulation can be caused by exposure to fluids such as fuel, hydraulic fluid, oil, etc., or their vapours. Heat and sunlight also have deleterious effects and if exposure is severe or continuous the insulation may eventually break down. Faulty insulation on cables may be the cause of arcing, particularly on heavy duty cables which are attached to movable components or parts, e.g. adjustable lamps, portable apparatus and leads to control columns. Particular care should be taken to ensure that these cables are correctly installed and tested for insulation resistance and freedom from chafing at the prescribed intervals, in accordance with the relevant Maintenance Manual.

3.4.2 Bearing failure in engine-driven rotating equipment may result in friction that could generate sufficient heat to destroy the component and create a serious fire risk.

4 ENGINE RUNNING PRECAUTIONS Fires during engine starting and running can be avoided by observing the correct drill given in the relevant Manuals for the aircraft and engine concerned. General guidance on some important points is given in the following paragraphs:—

(a) Whilst engines are being started and ground run, fire extinguishing apparatus, preferably of the CO_2 trolley type with extending applicator and under the control of trained and experienced personnel, should be positioned near the aircraft. Additionally, a good communication system should be arranged between the cockpit and ground.

(b) Persons in control of engine ground running should be familiar with the approved ground running instructions in the appropriate Manuals and with the correct fire drill procedure.

4.1 Piston Engines

4.1.1 Care should be exercised when priming piston engines preparatory to starting, particularly when an electrical priming pump is used or when priming is carried out by pumping the throttle (to operate the carburettor accelerator pump). Overpriming can cause an excess of fuel in the engine, and could result in an intake fire.

4.1.2 When excess-fuel conditions exist and an engine fails to start (a common occurrence when engines are hot), the fuel cock should be turned OFF (or the fuel cut-out closed) and the throttle should be fully opened. After ensuring that all ignition switches including booster coil switches are OFF, the engine should be turned. Most types of engines can be turned in the running direction by the propeller or starter, but when this has been done, precautions should be taken to dispel any accumulations of fuel in the exhaust system. On some small engines the propeller can be used to turn the engine in the reverse direction of rotation to expel the over-rich fuel-air mixture through the air intake.

4.1.3 If an air intake fire occurs before the engine picks up, a previously agreed signal should be made to the person at the controls, who should immediately turn off the appropriate engine fuel cock; it is often recommended to continue to motor the engine on the starter so that the burning fuel is drawn into the engine. If the engine picks up and runs, an air intake fire will probably cease without further action, in which case the fuel may be turned on again. Consideration should then be given to any damage which may have been caused to the intake filters by the intake fire.

4.1.4 If an intake fire persists or appears to be serious, a ground CO_2 type fire extinguisher should be discharged into the air intake. Outside action will also be necessary if burning fuel runs from the intake or exhaust on to the ground.

NOTES: (1) The ideal fire extinguishants to use are CO_2 or BCF which will cause no harm to the engine. If CO_2 or BCF have been drawn into an engine no harm should result provided the engine is run or turned over adequately within the next few hours. However, if an extinguishant such as methyl bromide is allowed to remain in the engine, particularly at temperatures below 4°C when it is in a liquid state, it will be necessary to strip the engine to ensure that corrosion has not occurred. If foam has been drawn into an engine the danger of corrosion can be greater. Mechanical foams can leave deposits which may be cleared by hot engine running. Chemical foams can leave deposits which require engine stripping.

(2) Mechanical foam is an extinguishant formed by mixing air, water and foam-making liquid.

4.1.5 Should an engine fire occur whilst ground running, the drill given in the appropriate Manual should be followed. To help the person in charge of the ground fire-fighting equipment, any other operating engines should be shut down.

4.1.6 Any practice which promotes accumulation of flammable fluid or vapour inside engine cowlings should be avoided. Exhaust systems must give complete sealing; flanges, gaskets and air intake sealing must be regularly examined and maintained. In shutting-down, engines should first be cooled by running at low power for a short period, and fuel cut-outs (if fitted) should be used strictly in accordance with the engine manufacturer's operating instructions.

4.2 **Gas Turbine Engines.** The most frequent cause of fire during starting is the accumulation of fuel in the engine and jet pipe following an earlier 'wet start' (i.e. an unsuccessful attempt to start in which the fuel has failed to ignite and has been distributed throughout the engine and jet pipe and drained into the lower combustion chambers and drain system). It is necessary to ensure that the drain system operates correctly, and to drain the vent tank (which has a limited capacity), as advised by the manufacturer. It is normal practice to carry out a 'dry run' (i.e. motor the engine through the starting cycle with the fuel and ignition turned off) after a wet start, before making another attempt to start an engine.

4.2.1 As kerosene spreads readily and does not evaporate quickly, a very slight leak is significant and must be remedied. Fuel which may have collected in cavities, cowlings, etc., should be wiped up after maintenance operations before any attempt is made to start the engines.

4.2.2 If there is any indication of an internal engine fire when an engine is not running, the fuel cocks should immediately be turned OFF and every attempt made to localise the fire. An outside assistant should discharge a CO_2 or BCF extinguisher into the intake or jet pipe if necessary.

4.2.3 When starting and running gas turbines, particular note should be taken of the jet pipe temperature. If this exceeds the manufacturer's limitations, a serious risk of mechanical failure followed by fire may result.

4.2.4 The recommendations of paragraph 4.1.5 apply equally to gas turbine engines.

4.3 **Engine Nacelle Fire Extinguisher Doors.** These engine nacelle doors (British Standard C.6), when fitted, should be maintained strictly in accordance with the aircraft Maintenance Manual. It is important that the doors operate freely inwards, and that the beads or lips on the doors will not restrict the removal of the extinguisher nozzle.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

FIRE DETECTION EQUIPMENT

1 INTRODUCTION This Leaflet gives guidance on the installation and maintenance of fire, overheat and smoke detection systems. Detection systems in current use are designed to give indication of fire, smoke or hydraulic mist at various locations in an aircraft by the illumination of warning lamps and, in the case of fire, by audible warning devices. Guidance on the maintenance and testing of the associated electrical system is given in the relevant paragraphs of Leaflet **EEL/2-1.**

1.1 This Leaflet should be read in conjunction with the manufacturers' data sheets for the equipment concerned and with the Maintenance Manuals and Schedules for the aircraft in which the equipment is installed.

1.2 Information on general fire precautions is given in Leaflet **AL/3-8** and on extinguishing equipment in Leaflet **AL/3-10.**

NOTE: This Leaflet incorporates the relevant information previously published in Leaflet ML/2-2, issue 2, dated 1st November 1964.

2 REQUIREMENTS REGARDING THE PROVISION OF FIRE AND OVERHEAT DETECTION EQUIPMENT Chapters D5—8 and K5—8 of British Civil Airworthiness Requirements prescribe the conditions under which fire and overheat detection equipment should be fitted to aircraft. Fire detectors must be fitted in the Designated Fire Zones of all power plants except those of low-powered piston engined aircraft with a maximum authorised weight of 12 500 lb or less.

NOTE: A Designated Fire Zone is a region where a potential fire risk may exist following failure or leakage of any component, equipment or part of the power plant.

2.1 Detection systems must be capable of providing rapid detection of a localised fire or overheat condition and indication of the area in which some corrective action is required. Detectors must not automatically operate main power unit extinguishers although they may, in certain circumstances, be used to shut down an auxiliary power unit.

2.2 The construction and installation of fire detectors and the design of the system must be such that:—

(i) Indication of fire is given immediately it occurs and continues for the duration of the fire; it is recommended that indication that the fire has been extinguished should also be given with the minimum of delay.

(ii) So far as is practicable, the failure of any component is more likely to render the system inoperative than to cause it to function spontaneously.

(iii) The functioning of any associated electrical circuit may be checked by the flight crew.

2.3 The main power plant fire detection system should contain an audible warning device to supplement the visual indications. The audible warning may be isolated during critical flight conditions, but if a manual cancelling facility is also provided, this should reset automatically when the warning signal has ceased.

3 DETECTION SYSTEMS On most civil transport aircraft the engine compartments are divided into two or more fire zones. The actual engine, where the likelihood of fire is most probable, is protected by fire warning and extinguishing systems, while other zones, such as around the jet pipes, may be fitted with overheat warning systems but not necessarily fire extinguishing systems. Overheat warnings result from the leakage of hot gases which, although they may not result in fire, may cause other damage to the engine bay or airframe structure.

3.1 In addition to warnings originating in the main engine compartments, potentially dangerous overheat or fire situations in other parts of the aircraft may be notified to crew members by separate warning systems.

3.1.1 The presence of smoke or hydraulic mist in equipment bays or baggage compartments is sometimes indicated by special detectors, particularly when these compartments are not accessible in flight. To permit visual inspection of these compartments, louvres are sometimes mounted in the roof, through which a periscope may be inserted.

3.1.2 Structure adjacent to high pressure hot air ducting such as is normally used on turbine powered aircraft for supplying air for cabin pressurisation, de-icing and air conditioning systems, is normally protected by excess temperature detectors placed at strategic positions near the ducts, normally close to pipe joints.

3.1.3 Auxiliary power units (A.P.U.s) are used on many large aircraft and these are protected by a system similar to that applied to the main engines. In this case, however, the warning system may also operate the normal shut-down system to stop the A.P.U. automatically in the event of a fire or overheat condition on the ground.

3.2 Signals received from any of these detectors are used to illuminate appropriate warning lamps on the flight deck. The control units of main engine fire detection circuits are also sometimes used to operate a 'trend indicator', which continuously indicates temperature conditions in the engine bay, and may also be used to operate, at the warning temperature, an alarm bell or other audible warning device.

3.3 Test facilities, which will completely test the continuity and operation of the circuit, are normally provided in all detection systems. Alternatively, some circuits may be fitted with warning lamps which incorporate a press-to-test facility.

4 TYPES OF DETECTORS Both 'unit' and 'continuous' type detectors are in use, the 'unit' type being situated at the points most likely to be affected by fire, whilst the 'continuous' type are routed to provide maximum coverage in the fire zone. Detectors of either type may be used separately, or together in a combined fire warning and engine overheat system. Detectors or control units of any one type may have alternative temperature settings and the part number marked on the case is the only positive means of identification of the warning temperature.

4.1 **Unit Type Detectors.** These include the following types, although some are now fitted only on older types of aircraft and are not considered further in this Leaflet.

4.1.1 **Melting-link Switches.** These switches consist of a pair of contacts held apart by a mechanism which is released when a fusible compound melts. At a predetermined temperature the compound melts, allowing the contacts to come together and complete the circuit to a warning lamp.

4.1.2 **Thermo-couple Detectors.** These units are used to operate a sensitive relay or electronic circuit when a predetermined temperature is exceeded.

4.1.3 **Differential Expansion Switch.** This type of unit detector is often used in engine installations and combustion heater zones. The switches operate on the principle of the difference in the coefficients of expansion of dissimilar metals, and reset automatically when the ambient temperature is reduced below the warning level.

4.2 **Continuous Type Detectors.** To ensure efficient detection of fire a considerable number of unit detectors may be necessary in some installations, and in such cases continuous type detectors are normally used.

4.2.1 **Continuous Wire Type Detectors.** These detectors operate on either of two principles, the mode of operation depending on the type of control unit fitted to the system. Detector elements are manufactured in various lengths and may be joined together to form a continuous detector loop which is routed round the installation as required. An element consists of a stainless steel or inconel tube, with one or two centre electrodes insulated from the tube by a temperature sensitive material. In certain circumstances elements are enclosed in a perforated armoured sheath which gives protection from random damage.

(i) **Resistance Type.** The resistance of the insulating material decreases with an increase in temperature until, at the warning temperature, sufficient current passes to operate a warning circuit. The element is fed with a current which is passed through a control box for operation of the warning system.

(ii) **Capacitance Type.** The element forms a capacitor, the capacitance of which increases with increased temperature. The central electrode is fed with half wave alternating current which it stores and returns to a control unit during the second half of the cycle. The stored charge increases with the temperature and, when the warning temperature is reached, the back current is sufficient to operate a relay in the warning circuit. The main advantage of the capacitance system is that a short circuit grounding the element or wiring does not result in a false fire warning.

4.2.2 **Liquid Type Detector.** This detector consists of a tube and expansion chamber filled with liquid. If a short length of the tube undergoes a sudden rise in temperature, the liquid expands and builds up a pressure differential across an orifice leading to the expansion chamber. A Bourdon tube is thereby deflected to close a pair of electrical contacts.

4.2.3 **Pyrotechnic Flame Switch.** This consists of a metal capillary housing a pyrotechnic cord which will ignite if sufficient heat or flame touches any part of the capillary length. If this occurs pressure is generated within the capillary and operates a switch mechanism.

4.3 **Smoke Detectors.** Freight holds, baggage compartments and equipment bays in the fuselage are often fitted with smoke detectors. Air from the compartments is arranged to flow through a smoke detector either by mounting a detector in the roof of each compartment or by passing air from all compartments through a single detector. In the latter case cabin differential pressure is used to circulate air through the detector and a separate visual indicator shows which compartment is affected. Alternatively, when only a visual indicator is fitted, air may be drawn through the system by means of an external venturi. It should be noted that this type of system may not continuously monitor the compartments concerned and frequent checks may need to be carried out during flight by switching on the indicator lamp.

4.3.1 **Photo-electric Cells.** There are two types of detectors which use photo-electric cells to give warning of the presence of smoke.

(i) In the single cell detector a divergent beam of light is directed towards a photo-electric cell but direct illumination is prevented by an opaque screen. When smoke is present the light is scattered round the screen and falls on the cell, increasing the cell's electrical conductance. Cell output is amplified to operate the warning relay.

(ii) In the double cell detector, detecting and balancing cells, located in separate compartments but affected by a single projector lamp, are connected in a bridge circuit which is adjusted to pass no current under normal conditions. When smoke is introduced in the detection cell chamber, the smoke causes increased light scatter and a current flows in the bridge circuit. This causes operation of a sensitive relay which in turn energises a power relay and results in illumination of the warning lamps.

4.3.2 **Alpha Particle Detector.** A third type of detector is used on some aircraft and depends on the absorption, by smoke, of alpha particles. It consists of a small d.c. operated unit embodying a double balanced ionisation chamber containing radium coated strips, and a special cold cathode tube. One chamber is protected from sudden atmospheric changes by partial enclosure and the other is open to cabin air. When smoke enters the open chamber the alpha particles are absorbed with a consequent decrease in ionisation current. This initiates discharge of the cold cathode tube and so operates the alarm. A part from periodic checks for security and damage no maintenance is required with this type of detector. A test switch on the signal panel verifies the correct sensitivity and functioning of the equipment.

4.3.3 **Visual Smoke Indicators.** Although visual smoke indicators provide the only means of smoke detection on a few aircraft, they are usually installed to verify that warnings given by an automatic detector are genuine, or as a means of locating the smoke source. Smoke present in any particular compartment will be drawn past the appropriate indicator window and will be rendered visible when automatic operation of the smoke detector results in illumination of a lamp in the indicator. A switch is provided to illuminate the lamp for test purposes and a pilot window in the indicator is available to check lamp serviceability. A device is also provided in the indicator to show that air is flowing through it, even though no smoke is present.

4.3.4 **Carbon Monoxide Detectors.** Certain aircraft of American manufacture are equipped with systems for detecting concentrations of carbon monoxide (CO). Although primarily intended to indicate contamination of cabin air (samples of which, taken from air flowing from the engine blowers, and cabin heaters, are automatically analysed by a cyclic device) a warning of excess CO would probably be associated with a fault involving increased fire risk.

5 INSTALLATION AND MAINTENANCE The efficiency of any detection system depends on the suitable positioning of the detectors and on the proper maintenance of all components within the system. For details of particular installations reference should be made to the relevant manuals for the aircraft concerned but the following paragraphs discuss the servicing requirements of the most common aircraft fire detection systems and indicate the faults which may be found.

5.1 **General.** Fire detection equipment is located around and adjacent to the engines where maintenance operations are comparatively frequent, and is therefore susceptible to damage from actions unconcerned with the maintenance or testing of the fire detection system. The detectors, whether unit or continuous, and the associated wiring, are attached to the engine or cowlings and are affected by engine vibration and by leakage or spillage of fluids used in the engine. When work is being carried out in an area fitted with fire detection equipment extreme care is necessary to prevent damage or contamination of the system since a spurious fire indication or failure to detect an actual fire could result.

5.2 **False Fire Warnings.** Investigations into the incidence of false fire warnings have emphasised the need for correct installation and proper maintenance. Some of the probable causes of false warnings or failure to operate on test are:—

(i) **Ingress of Moisture.**

(a) Incorrect assembly of sealing washers or glands on detectors or associated wiring accessories.

(b) Premature removal of transit caps or seals when fitting new items.

(c) Inadequate tightening of connectors (a torque loading is usually specified).

(d) Failure to fit new crushed metal sealing washers (if fitted) when fitting a replacement unit.

(e) Cracked or chafed elements.

(ii) **Faulty Installation.**

(a) Detection elements too close to heat shields or other surfaces which may attain a temperature high enough to operate the detector.

(b) Short circuiting of electrical wiring by chafing against structure.

(c) Damage to detection components through carelessness during routine maintenance of adjacent unrelated equipment.

(d) Inadequate support, more particularly of continuous element detectors, with consequent damage from chafing or fracture through vibration.

(e) Clip bushes of a material unsuitable for the environment, resulting in damage to a continuous element at clipping positions.

(f) Incorrect racking of printed circuit cards in fire detection modules, possibly resulting in spurious warnings.

(iii) **Lack of Cleanliness.**

(a) Dirt, swarf or other foreign matter in electrical connections causing short or open circuit.

(b) Oil or other fluids penetrating connections, either prior to tightening or through incorrect torque loading, and resulting in failure of the insulation.

5.3 **Continuous Element Detector Systems.** Except for the types which are enclosed within an armoured sheath, continuous elements are vulnerable to rough handling and it is essential that every precaution is taken to maintain the integrity of the system and to check its function at frequent intervals. A typical system is shown in Figure 1.

5.3.1 **Installation.**

(i) There are several types of element, each type being manufactured in a variety of lengths and suitable for either fire detection or overheat warning. Before fitting a new element the part number should be checked, the element inspected for cleanliness or damage, and an electrical check carried out to ensure that continuity and insulation resistance are within the limits quoted in the relevant Maintenance Manual. Testing should be carried out at normal room temperature since an elevated temperature would result in different readings being obtained.

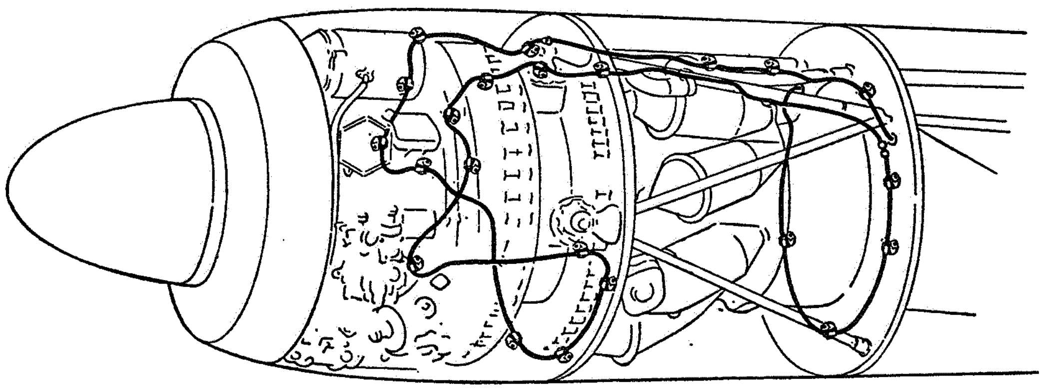

Figure 1 TYPICAL CONTINUOUS ELEMENT INSTALLATION

(ii) The manner in which the element is attached to the structure is most important. It is clipped 4 inches from end fittings and at approximately 6 inch intervals along its length, and the clips, which are often of the quick-release type, must be positioned so that no damage can be caused to the element by rubbing or vibration. Installation details are normally shown pictorially in the relevant Maintenance Manual.

(iii) Care is also necessary when bending the element and curves should be kept smooth and not less than the minimum radius quoted by the manufacturer. Clip bushes should be correctly positioned at each clip and care taken to eliminate strain on the element. Excessive bending could result in work-hardening of the capillary, so that kinks or bends which are within the specified limits should be left and not straightened. Elements vary slightly in length and any excess should be spread throughout the run.

(iv) The end fittings of each element, and of the other components in the system, are protected by caps during storage. These caps should only be removed for testing purposes or immediately before coupling up. New sealing washers must be fitted whenever a connection is broken and all parts must be perfectly clean and dry. Coupling nuts should be torque tightened to the appropriate values, using two spanners to prevent twisting the capillary.

(v) Different types of control unit are often identical in appearance and care must be taken to ensure that the correct types are fitted. Electrical connections to the units may be by terminal posts, plugs and sockets, edge connectors or contact buttons, and whichever type is used care must be taken to ensure that the contacts are clean. Where electrical connection (between the control unit and its mounting base) is by spring-loaded contact buttons, operation of the buttons should also be checked.

(vi) When installation has been completed, operation of the system should be checked by use of the appropriate test switch. If this test proves satisfactory all nuts which have been re-connected should be wire locked.

5.3.2 **Inspection**

(i) **Acceptance Checks.** All components should be examined externally for damage which may have occurred in transit, and sealing caps should be removed to ensure that the threads are clean and internal parts of connections are undamaged. Control units can be bench-checked by means of a special test set, all other components being tested for continuity and insulation resistance. Procedures for the electrical checks vary between installations and reference should be made to the relevant Maintenance Manual for details of the test for a particular component.

(ii) **Function Test.** Test circuits are usually arranged to simulate fault conditions by either grounding the centre electrode of the element (resistance type), or introducing additional capacitance into the circuit (capacitance type). By this means the system is completely checked; provided the visual and audible warnings function when the test switch is operated and cease to function when it is released, the system may be considered serviceable. It should be noted that on some aircraft the engine fire warning lamps are held on by a magnetic relay and are extinguished by moving the test switch to the 're-set' position. On other aircraft, operation of the audible warning may be dependent on throttle or flap position, or aircraft altitude. These variations will be fully described in the appropriate Maintenance Manual.

(iii) **Periodic Checks**

(a) At the intervals prescribed in the approved Maintanence Schedule all components should be examined, in situ, for security, damage, corrosion or deterioration. Any damage found on elements should be compared with the limits laid down in the manufacturer's manual and components replaced as necessary. Parts with acceptable physical damage should be given an electrical check to ensure that insulation resistance remains satisfactory. The dressing of dents, gouges, kinks, etc., is not permitted.

(b) When required by the Maintenance Schedule, the detector elements should be removed from the aircraft so that all components can be properly cleaned and inspected. Particular attention should be paid to the centre pin and ceramic insulation of connections and to those parts of the element which were not accessible for visual examination in the aircraft. Control units should be given a thorough electrical check in accordance with the relevant manual, a special test set normally being used for this purpose. When the components are re-installed, new sealing washers must be fitted and every precaution taken to keep connections clean and dry.

NOTE: The time interval between these checks varies considerably and is based on experience gained with each particular aircraft installation. On some aircraft, detector elements are only removed when they become unserviceable.

5.3.3 **Cleaning.** Cleanliness of all components in the system is essential. Dry foreign matter in end fittings and couplings should be removed with a camel hair brush, but if oil or other liquids are present they should be removed by brushing with a small quantity of approved cleaning fluid. The part should then be allowed to dry for at least 10 minutes or blown out with dry bottled air or nitrogen to remove all traces of liquid. Normal compressed air supplies are unsuitable for this purpose since they normally contain moisture or oil.

5.4 **Unit Detector Systems.** These are normally simple d.c. circuits in which a number of unit detectors are connected in parallel so that actuation of any one detector will complete the circuit through a warning lamp. In some circuits the detectors are connected between two wiring loops, either of which may be supplied through a magnetic circuit breaker. A short circuit in the energised loop results in operation of the magnetic circuit breaker and the supply is then routed to the second loop, thus preventing a spurious indication of fire. A typical installation is shown in Figure 2.

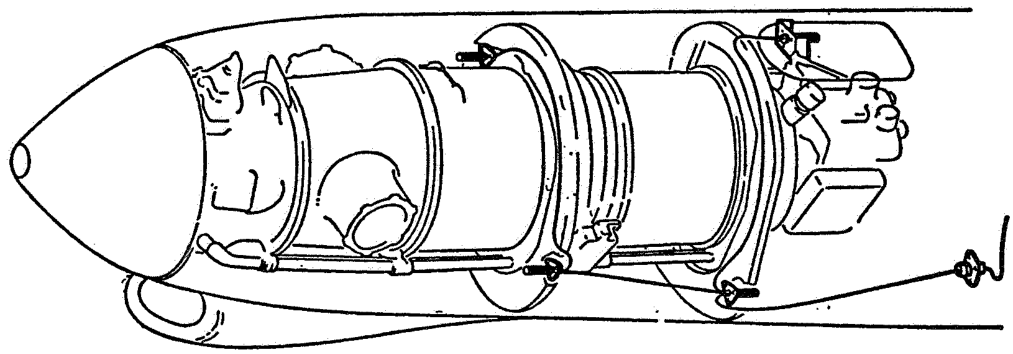

Figure 2 TYPICAL UNIT DETECTOR INSTALLATION

5.4.1 **Installation.** The operating temperature of any particular unit detector depends on its position in the engine bay and care is necessary to ensure that the correct type is fitted at each position. Details of temperature settings are contained in the relevant Maintenance Manual and the setting of a particular detector is sometimes included in its part number.

(i) The detector units are rigidly mounted in position and are of comparatively robust design, although severe blows could upset the temperature setting. Installation of the electrical wiring, however, requires considerable care, since if not adequately supported and clipped it may chafe on the surrounding structure and eventually cause a system failure. Contact with excessive heat, moisture, oil or grease could also cause deterioration of the insulation, and cables should be routed to avoid any form of contamination.

5.4.2 **Inspection**

(i) **Function Test.** Operation of this type of detection system is checked by use of a test switch which simulates operation of a detector. This completes the warning circuit and, if the warning lamp lights, proves the continuity of the associated wiring.

(ii) **Periodic Inspection.** At the intervals prescribed in the relevant Maintenance Schedule all parts of the system should be examined for security or damage, particular attention being paid to the condition of the electrical cables and their connection to each detector. Continuity of the cables, and insulation resistance between the shell and leads of each detector, should be checked with suitable test equipment.

(iii) **Detectors.** Thermo-couple type detectors should normally be removed and subjected to a bench test whenever it is necessary to verify their operation. This is not always necessary with thermal expansion type detectors however and apparatus is often recommended which enables testing to be accomplished in situ. With this equipment a heating probe is attached to the detector, and the temperature obtained by the detector is recorded on an associated temperature gauge. The temperatures at which the detector operates and resets must be within the limits laid down by the manufacturer.

5.5 **Smoke Detector Systems.** These systems vary considerably due to the differences in layout between various aircraft. Most transport aircraft are fitted with a photo-electric detector and visual indicator system through which air flows under cabin differential pressure. On some aircraft photo-electric detectors are fitted in each compartment, while in others only a visual indicator may be used and airflow induced by an externally mounted venturi. A typical system is shown in Figure 3 and described below.

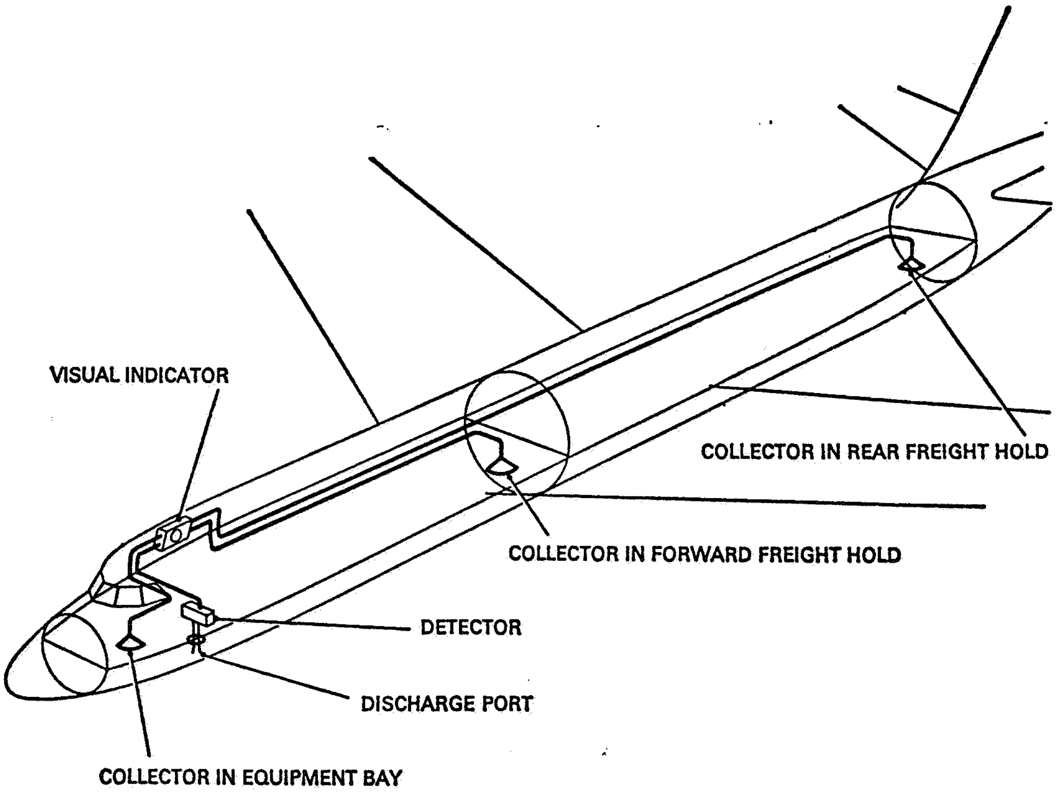

Figure 3 TYPICAL SMOKE DETECTION SYSTEM

5.5.1 **System Function Check.** Operation of the test/re-set switch on the flight deck illuminates a test lamp in the photo-electric detector, thus causing light to fall on the detector cell. This results in operation of a sensitive relay and illumination of the smoke warning lamp. At the same time a lamp in the visual smoke indicator is illuminated and becomes visible as a green light in the pilot window and a red light in each of the indicator windows. The red lights are not visible when air is flowing through the indicator (i.e. in flight). Once the test/re-set switch has been moved to the 'test' position the sensitive relay in the detector is held on by a small magnet; by moving the switch to the 're-set' position a coil in the relay is energised to overcome the magnet and break the circuit to the warning lamps. An additional test/re-set switch is fitted to some detector units and operation of this switch should be checked during servicing operations.

5.5.2 **Inspection.** The complete system should be inspected periodically for security and signs of damage. Particular attention should be paid to electric cables, pipe-lines and detector units, especially when these are located in freight compartments and liable to damage from loading and unloading operations. Air outlets from the monitored compartments must not be obstructed by furnishings, insulation, etc., and there must be a free flow of air through the louvres in the detector unit casings. Individual components should be checked for satisfactory operation as follows:—

(i) Detectors having two cells in a bridge circuit (para. 4.3.1 (ii)) are provided with a number of switches and adjusters for use during servicing. A test/re-set switch is used as described in para. 5.5.1; a 'zero' switch cuts out a resistor in the circuit to the projection lamp, thus increasing voltage to that produced with engines running; an adjusting screw alters the position of a shutter over the balancing cell, and a pointer is fitted to the sensitive relay to measure current flowing in the bridge circuit. The pointer should register zero under normal conditions, and this is set, with the 'zero' switch held on, by turning the shutter adjusting screw. If, during this check, excessive adjustment is required to zero the pointer (i.e. more than two turns per indicated micro-amp), a defective cell is indicated and the unit should be changed.

(ii) Detectors having a single cell (para. 4.3.1 (i)) are fitted with a label showing the obscuration at which that particular detector should operate its warning signal. This may be checked with a suitable meter attached to test sockets in the detector case. With the test/re-set switch set to 'test' the calibrate volts (i.e. the difference between the amplifier output volts and the signalling volts) are measured, and the figure compared with the marking on the label. The result gives the percentage obscuration at which the warning signal is actually given and this should be within the range prescribed in the relevant Maintenance Manual.

(iii) **Visual Indicator.** This component requires little attention apart from replacing an unserviceable lamp. However, since air is passing through the unit whenever the aircraft is operating, dust or dirt may obscure the viewing windows and obstruct internal passages, particularly when oil mist or moisture are present. Indicators should be removed for overhaul and cleaning at the prescribed intervals and whenever contamination becomes apparent during a routine functional test.

(iv) **Pipelines.** Operation of a smoke detection system in which the detector or indicator is connected to all the monitored compartments, is dependent on the free flow of air from those compartments through the detector and/or indicator to atmosphere. It is necessary, therefore, to ensure that pipelines are free from obstruction or leaks, and checks are specified at regular intervals in the relevant approved Maintenance Schedule. The application of either pressure or suction may be recommended.

(a) **Flow and Pressure Test.** Each pipe run should be disconnected at the ends, and air pressure applied to one end by means of an air test set. When free air flow from the opposite end is evident, that end should be blanked off and air pressure allowed to increase to the recommended test pressure (normally about 10 lb/in^2). With the air supply turned off the test pressure should be maintained for one minute. If leaks are apparent a non-corrosive leak-detecting fluid should be applied to all connections in the pipe run, while air pressure is maintained at test pressure. Leaks should be rectified when found and a further test carried out. Leak detection fluid must be washed off and the components thoroughly dried before re-connection and locking.

(b) **Flow and Suction Test.** This test is similar to the flow and pressure test except that the pipe run is required to withstand a negative pressure (usually 1 lb/in^2) for one minute, and this is applied by means of a suction rig. The flow check and application of leak detecting fluid should still be carried out with positive pressure applied to the pipe.

5.6 **Hot Air Ducting.** Air ducted from combustion heaters and engine compressors for use in the cabin air conditioning system may be of sufficiently high temperature to cause structural damage. To prevent damage caused by hot air leaks, thermal expansion type unit detectors are often placed adjacent to hot air ducts and coupled to a warning lamp in the flight compartment. A press-to-test facility incorporated in the lamps ensures that the circuit continuity can be checked, while functioning of the system can be verified during servicing operations by shorting the detector leads and ensuring that the appropriate warning lamp lights. Whenever it becomes necessary to change a detector, it is important that the replacement has the correct temperature setting, since warnings are required at different temperatures from different locations.

6 STORAGE With the exception of certain types of control units, all components in fire and smoke detection systems may be stored indefinitely provided that adequate precautions are taken to prevent the ingress of moisture. Sealing caps must be fitted to the end connections of all detector elements, and all equipment should be wrapped in greaseproof paper and packed inside suitably padded cartons. Heat sealed polythene bags should be added in tropical climates. Smoke detectors should preferably be retained in the packaging supplied by the manufacturers so that the photo-electric cells are not subjected to light during the storage period. A label should be attached to each component showing details of type, serial number, date of last overhaul, hours flown, reason for removal, etc. as applicable in each case.

6.1 **Storage Conditions.** Components should be stored on shelves which allow free circulation of air, shielded from direct sunlight and protected from moisture or corrosive fumes.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

FIRE EXTINGUISHING EQUIPMENT

1 INTRODUCTION This Leaflet gives brief details of operating principles and guidance on the installation and maintenance of the equipment embodied in typical aircraft fire extinguishing systems. The information is of a general nature and should be read in conjunction with the Maintenance Manuals for the equipment concerned and the aircraft in which it is installed. Reference should also be made to approved Maintenance Schedules, drawings, test schedules and to the following Leaflets which contain information closely associated with that covered by this Leaflet:

AL/3-8 Fire—General Precautions
AL/3-9 Fire Detection Equipment
EEL/1-6 Bonding and Circuit Testing
EEL/1-7 Fire Detection and Extinguishing Systems—Electrical Tests on Systems.

1.1 The conditions under which extinguishing systems should be fitted to aircraft are prescribed in Chapters **D5-8** and **K5-8** of British Civil Airworthiness Requirements.

2 TYPES OF SYSTEMS The extinguishing systems in general use are the fixed system, the portable system and the mixed system. The term 'fixed' refers to a permanently installed system of extinguishant containers, distribution pipes and controls provided for the protection of power plants and, where applicable, auxiliary power units. In some types of aircraft, fixed systems may also be provided for the protection of landing gear wheel bays and baggage compartments.

2.1 A portable system refers to the several hand-operated fire extinguishers provided to combat any outbreaks of fire in flight crew compartments and passenger cabins.

NOTE: The performance requirements for hand-operated fire extinguishers, methods of installation and markings which should appear on them, are specified in British Standard M 29.

2.2 A mixed system is one used in some aircraft for the protection of baggage and service compartments. The distribution pipeline and spray system is fixed in the appropriate compartment and is coupled to adaptor points to which a hand-operated extinguisher may be plugged in.

3 TYPES OF EXTINGUISHANT The extinguishants in general use are described in the following paragraphs.

3.1 **Methyl Bromide (M.B.).** This extinguishant boils at 4·6°C and is commonly used in fixed systems, particularly for the protection of power plants. Because of its toxicity, Methyl Bromide should not be used in confined spaces, flight crew compartments or passenger cabins. The effects of breathing the vapours may not be immediately apparent, but serious or even fatal after-effects may be sustained at a later stage.

3.2 **Bromochlorodifluoromethane (B.C.F.).** This semi-toxic extinguishant is particularly effective against electrical and flammable liquid fires. It is used in power plant systems, and for the protection of auxiliary power units in some aircraft; it is also used in certain types of portable extinguisher. It becomes gaseous at normal temperatures and condenses to liquid at -4°C (25°F), and can be stored and discharged at moderate pressures. It has little or no corrosive effect, although halogen acids will be formed if its products which have been decomposed by fire come into contact with water, e.g. condensation caused by fire. In contact with fire, B.C.F. volatilises instantly, giving rapid flame extinction with little or no deleterious effect on metallic, wooden, plastic or fabric materials.

3.3 **Carbon Dioxide (CO_2).** This gas extinguishant is also effective against electrical and flammable liquid fires and is used principally in portable fire extinguishers. It is non-corrosive and if the concentration needed to extinguish a fire is excessive it can have appreciable toxic effects. When discharged in a confined space, the vapour cloud can reduce visibility temporarily.

3.4 **Water.** In many aircraft, certain of the portable fire extinguishers in passenger cabins are of the water type, designed for combating fires involving ordinary combustible material such as paper, fabric, etc., where the quenching and cooling effects of water are of prime importance. These extinguishers are not suitable against electrical fires. An anti-freezing agent is normally included to permit operation at temperatures as low as -20°C. Typical examples are the water/glycol extinguisher with 38 per cent of inhibited ethylene glycol, and the 'wet-water' extinguisher with glycol, wetting agents to reduce surface tension, and inhibitors to impart anti-corrosive characteristics.

3.5 **Bromotrifluoromethane (B.T.M.).** This semi-toxic extinguishant is used in fixed systems for the protection of power plant and auxiliary power units. It is also widely used in cargo compartment fire-suppression systems of some types of aircraft.

3.6 **Dry Chemical.** Dry chemical extinguishant takes the form of a non-toxic powder, e.g. potassium bicarbonate, and is used in portable fire extinguishers fitted in certain types of aircraft. It is very effective against fires involving flammable liquids and free-burning material such as wood, fabrics and paper. Use of the extinguishant against fires in electrical equipment is not recommended, since it could render contactors and switches unserviceable which may otherwise be functioning correctly in adjacent equipment. It does not have a quenching effect and thereby the dangers of distortion or explosion when used on hot surfaces, such as overheated wheel brakes, are minimised. Some dry chemical powders have a corrosive effect on some metals (including aluminium) which may require special attention when cleaning-up after the discharge of an extinguisher. Dry chemical extinguishers should not be used in flight crew compartments or passenger cabins where visibility would be seriously affected both during the discharge of powder and also as a result of its deposition on transparencies and instruments.

4 TYPICAL FIXED SYSTEMS In the types of aircraft for which fixed fire extinguisher systems are specified, it is usual for the extinguishant to be stored in the containers under pressure and to be discharged by electrically firing cartridge units within the extinguisher discharge heads. The firing circuits are controlled by switches or fire control handles in the flight crew compartment; in some types of aircraft, control may also be automatic in the event of a crash landing. The layout of a system and the number of components required, depend largely on the type of aircraft and number of power plants, and also on whether fire protection is required for auxiliary power units, landing gear wheel bays and baggage compartments. Figure 1 diagrammatically illustrates a typical arrangement for

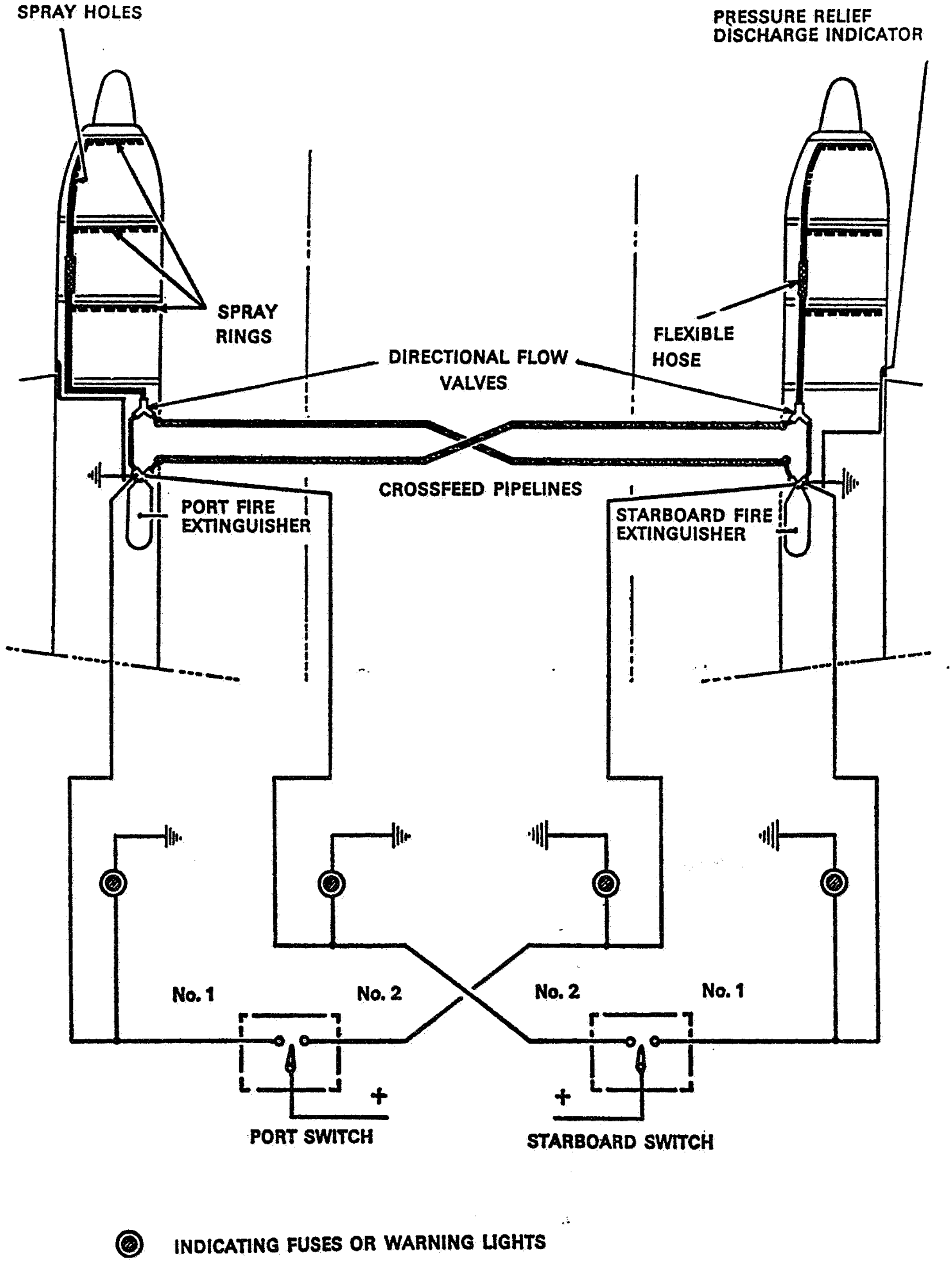

Figure 1 TYPICAL FIXED EXTINGUISHER SYSTEM power plant protection and indicates the components which, in general, form part of any fixed system. It also indicates the discharge control method normally adopted for multi-engine fire protection and known generally as the 'two-shot system'. In this system the fire extinguishers for each power plant are interconnected, so permitting two separate discharges of extinguishant into any one power plant. In some aircraft incorporating crash switches (see Leaflet EEL/1-7 paragraph 3.3), the system may be so arranged that operation of the switches will cause an adequate and simultaneous discharge of extinguishant to each power plant. Brief descriptions of the principal components of a fixed fire extinguishing system are given in the following paragraphs. For precise technical details reference must be made to the manuals for the relevant aircraft and components.

4.1 **Extinguishers.** Extinguishers vary in construction but are normally comprised of two main components: (i) the steel or copper container and (ii) the discharge or operating head. A sectioned view of an extinguisher widely used in a two-shot system is shown in Figure 2. The container is in the form of a steel cylinder and has an externally threaded neck to which the discharge head is screwed and soldered. The discharge head contains two annular machined diaphragms, each bearing an externally-threaded spigot on which a hollow charge plug is screwed to form an annulus between its inner end and its respective diaphragm. Each annulus is connected by a 'flash' hole to a port containing the appropriate cartridge unit. Below, and concentric with each diaphragm and charge plug, is a radially adjustable light-alloy hollow junction box fitted with a union to which an extinguisher discharge pipe is connected. The lower end of the junction box is closed by a cap which embodies a discharge indicator pin. (See paragraph 4.3.1). A banjo coupling is fitted in the main body of the operating head and serves as a connection for a pressure discharge indicator. (See paragraph 4.3.1 (i)).

4.1.1 When either of the cartridge units is fired, sufficient pressure is created in the adjacent annulus to rupture the associated diaphragm. The spigot and charge plug assembly is thereby detached and forced down the hollow junction box beyond the outlet union and discharge pipe through which the extinguishant then flows to the spray pipes or rings.

4.2 **Directional Flow Valves.** These valves are a special form of non-return valve designed for use in two-shot systems to allow the contents of one or several extinguishers to be directed into any one power plant. The methods of connection may vary between different aircraft systems, but the one shown in Figure 1 is typical and also serves to illustrate the two-shot operating sequence generally adopted. The extinguishers are controlled by individual firing switches each having three positions; No. 1, OFF and No. 2. When the port extinguisher switch is selected to the No. 1 position, the relevant cartridge unit in the port extinguisher is fired and the extinguisher is discharged to the port power plant. If the fire has not been extinguished, selection of the No. 2 position then causes the starboard extinguisher to be discharged also into the port power plant via the crossfeed line and port directional flow valve, the latter preventing extinguishant from entering the empty extinguisher of the port system. In order to extinguish a fire in the starboard engine, the starboard extinguisher switch is selected to its No. 1 position, and the relevant cartridge unit is fired so that extinguishant is discharged to the starboard power plant. If selection of the No. 2 position of the starboard extinguisher switch becomes necessary, then the port extinguisher will also be discharged into the starboard power plant via the appropriate crossfeed line and the starboard directional flow valve, which prevents charging the empty starboard extinguisher.

NOTE: In some types of aircraft, the cross connecting of selected extinguishers between engines is accomplished by means of transfer switches which are additional to the normal firing switches.

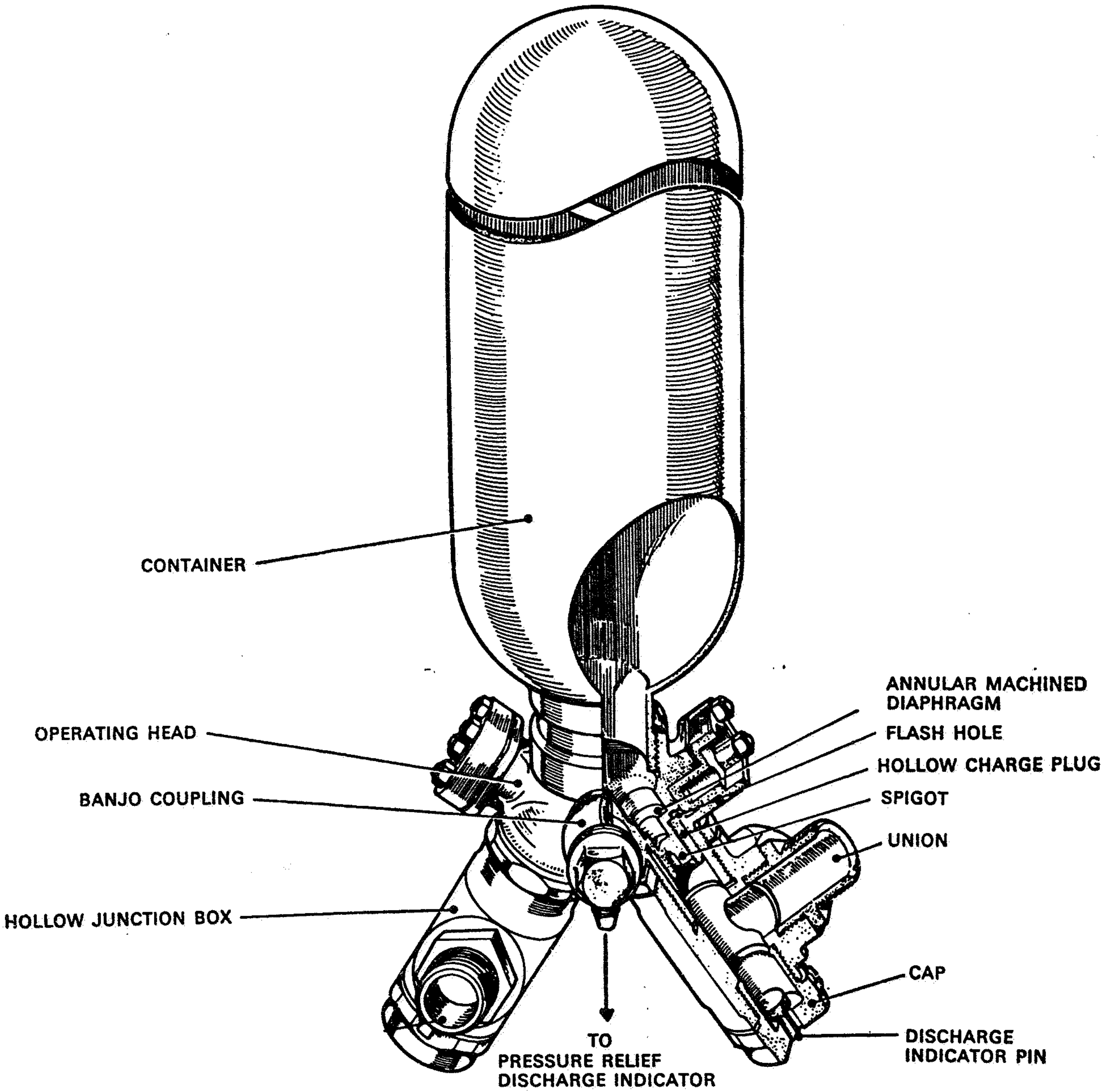

Figure 2 FIXED TYPE OF EXTINGUISHER

4.3 **Discharge Indicators.** In fire extinguisher systems of the fixed type, provision is made for positive indication of extinguisher discharge as a result of either (a) intentional firing, or (b) inadvertent loss of contents, i.e. pressure relief overboard or leakage. The methods adopted are generally mechanical and electrical in operation.

4.3.1 **Mechanical Indicators.** Mechanical indicators are, in many instances, fitted in the operating heads of extinguishers (see Figure 2) and take the form of a pin which under normal conditions is flush with the cap of the hollow junction box. When an extinguisher has been fired, and after the charge plug has been forced down the hollow junction box, the spigot of the plug strikes the indicator pin causing it to protrude from the cap, thereby providing a visual indication of extinguishant discharge. In the extinguishers employed in some types of aircraft, mechanical type pressure gauges are embodied in the containers and these serve to indicate extinguishant discharge in terms of pressure changes and, in addition, serve as a maintenance check on leakage.

(i) Protection against bursting of a fire extinguisher as a result of build-up of internal pressure under high ambient temperature conditions, is provided by a disc which fuses at a specific temperature, or a disc which bursts when subjected to bottle over-pressure. The disc is located in the operating head and when operated, the extinguishant discharges overboard through a separate pressure relief line. In order to indicate that discharge has taken place, a disposable plastic, or metal, disc is blown out from a discharge indicator connected to the end of the relief line exposing the red interior of the indicator. Discs are generally coloured red, but in certain types of indicator, green discs are employed. Discharge indicators are mounted in a structural panel, e.g. a nacelle cowling, and in a position which facilitates inspection from outside the aircraft.

NOTE: In some aircraft, indicators of similar construction but incorporating a yellow disc, are provided to indicate discharge by normal firing.

4.3.2 **Electrical Indicators.** Electrical indicators are used in several types of aircraft and consist of indicating fuses (see Leaflet **EEL/1-7**), magnetic indicators and warning lights. These are connected in the electrical circuits of each extinguisher so that when the circuits are energised, they provide a positive indication that the appropriate cartridge units have been fired. In some aircraft, pressure switches are mounted on the extinguishers and are connected to indicator lights which come on when the extinguisher pressure reduces to a predetermined value. Pressure switches may also be connected in the discharge lines to indicate actual discharge as opposed to discharge initiation at the extinguishers.

4.4 **Pipelines.** Extinguishants are discharged through a pipeline system which, in general, is comprised of light-alloy pipes outside firezones and stainless steel rings inside firezones, which are perforated to provide a spray of extinguishant in the relevant zones. In some cases, extinguishant may be discharged through nozzles instead of spray rings. Flexible fireproof hoses are also used, e.g. between a nacelle firewall and spray rings secured to an engine.

5 PORTABLE EXTINGUISHERS The portable extinguishers in common use are of the CO_2 type and the water type. Extinguishers containing extinguishant B.C.F. (see paragraph 3.2) are also used in some aircraft. The type of extinguisher installed in a particular location is chosen to be appropriate to the nature of the possible fires in the compartment in which it is installed. Extinguishers are located in accessible positions and installed in suitable attachment brackets with quick-release metal straps. Brief descriptions of their construction and operation are given in the following paragraphs for general guidance.

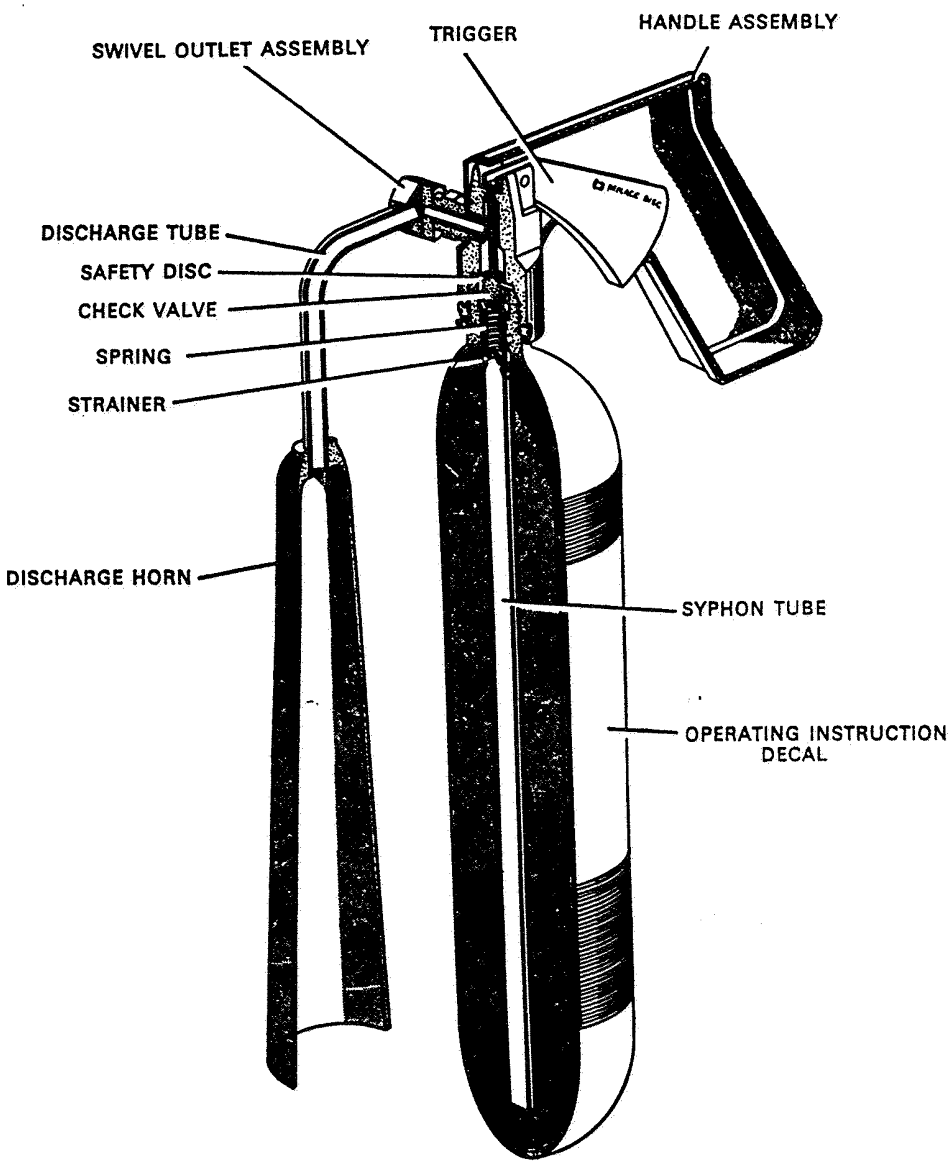

Figure 3 TYPICAL PORTABLE CO_2 EXTINGUISHER

5.1 **CO_2 Extinguishers.** A typical extinguisher (see Figure 3) comprises a steel cylinder and an operating head incorporating a pistol-type firing mechanism, check valve assembly and discharge horn which characterises CO_2 extinguishers generally. When the trigger is pressed, a lockwire and seal are broken and the spindle of the check valve assembly is forced downward, thereby removing the valve from its seat. This allows the extinguishant to flow up the siphon tube, through the centre of a safety disc, to discharge from the discharge horn. Releasing of the trigger allows the valve to reseat and seal off the flow. The purpose of the safety disc is to permit the release of extinguishant in the event of excessive internal pressures. When a safety disc bursts, the trigger of the firing mechanism springs downward and exposes the instruction 'REPLACE DISC' engraved on the side of the trigger.

5.2 **Water Extinguishers.** A typical extinguisher incorporating an anti-freeze agent is shown in Figure 4. It comprises a cylinder and a valve body which houses a lever-operated check valve assembly and a nozzle. A cartridge holder containing a cartridge of CO_2 is secured to the valve body, and, in addition to its main operating function, serves as a hand-grip. When the cartridge holder is twisted the cartridge is punctured causing the CO_2 to be released into the cylinder, thereby pressurising it. Depression of the check valve assembly lever moves the valve from its seating at the top of a syphon tube, allowing the extinguishant to be forced up the tube and to discharge through the nozzle. When the lever is released, the valve is returned to its seating under the action of a spring, and the flow of extinguishant is sealed off.

5.2.1 Some water extinguishers have a plastic head which contains an operating trigger and plunger mechanism, and screws into a threaded boss on the metallic container. The complete assembly is sealed by a rubber sealing ring. When the trigger is squeezed, the plunger mechanism breaks a seal within the operating head and thereby releases the extinguishant. The discharge is subsequently controlled by maintaining or releasing pressure on the trigger. In some cases, the containers are expendable and scrapped after discharge, and only the operating heads are subject to inspection and overhaul procedures.

6 INSTALLATION AND MAINTENANCE The methods of installing the principal components of fire extinguishing systems, and carrying out relevant maintenance procedures vary between types of aircraft. Certain aspects are, however, of a common nature and the information given in the following paragraphs is intended only as a general guide. For precise details of particular installations, reference must be made to the approved manuals and schedules for the aircraft concerned. Reference should also be made to Leaflets **AL/3-13** and **AL/3-14** which deal with the installation of flexible and rigid pipes in aircraft, and to Leaflet **EEL/1-7** for guidance on the testing of the electrical control circuits of fire extinguishers.

6.1 **Fixed Systems**

6.1.1 **Extinguishers**

(i) Before installation, the following checks and inspections should be carried out:—

(a) Containers should be inspected for signs of leakage, dents, corrosion, scoring and chafing. If one or more of these faults exist, or there is any other condition indicating weakness of a container, the extinguisher must not be installed.

(b) Weight check and, where appropriate, a pressure check (see paragraph 6.3) to determine whether any loss of extinguishant has occurred.

(c) Pin-type discharge indicators should be checked to ensure that they are flush with the cap of the operating head junction box.

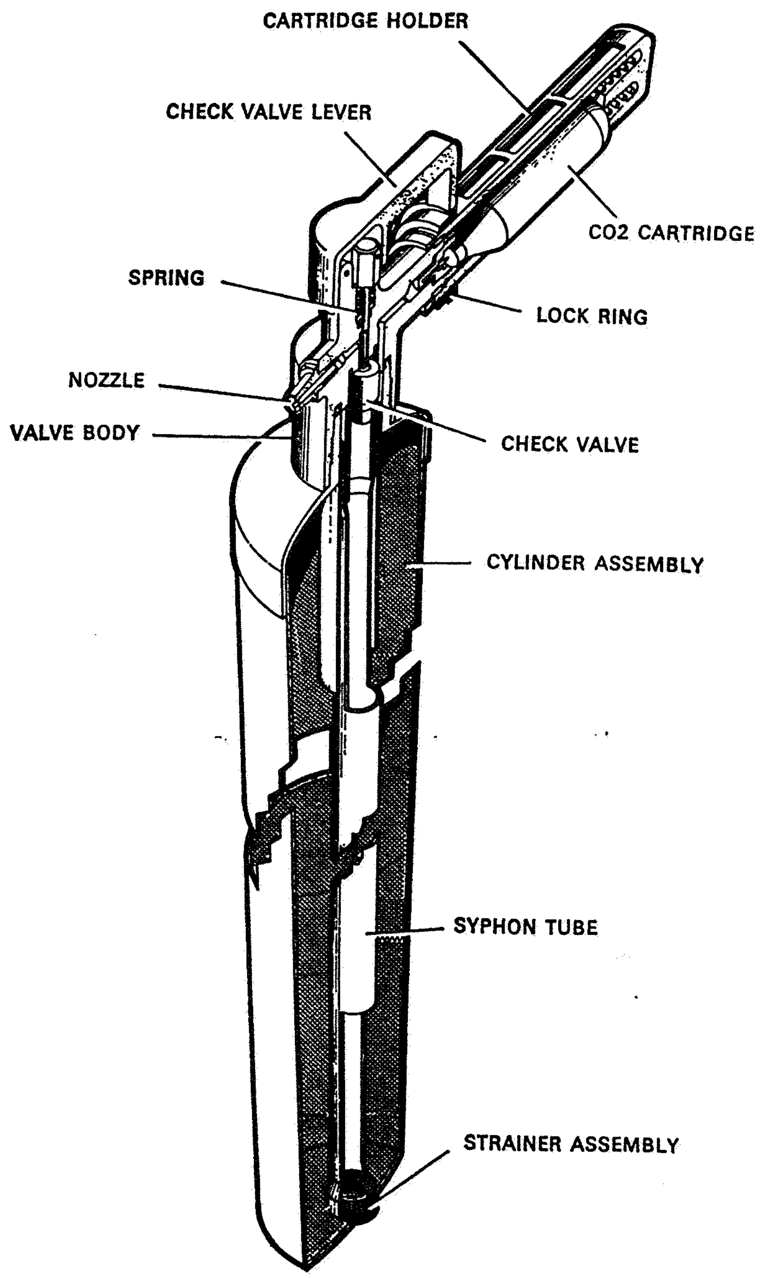

Figure 4 TYPICAL WATER EXTINGUISHER

(d) The threads of all unions and studs should be inspected for damage. Where specified, operating head junction boxes should be removed and the threads lightly smeared with an approved lubricant, e.g. Barium Chromate grease to specification DTD 369. The junction boxes should be refitted leaving the locknuts finger-tight until after an extinguisher has been installed and all connections finally made.

NOTE: In certain types of extinguishers, removal of the operating or discharge head exposes the main discharge diaphragm. To prevent damage to this diaphragm and injury to personnel, protective caps must always be fitted to the extinguisher container outlet.

(e) Before securing cartridge units to extinguishers, they should be inspected for signs of distortion, corrosion, chafing or other damage. The date of manufacture stamped on a unit should be checked to ensure that the cartridge life has not exceeded that specified in the appropriate Maintenance Manual. Checks on the insulation resistance, continuity and resistance of the fuse element should also be carried out (see Leaflet EEL/1-7).

NOTE: Cartridge units contain gunpowder and should, therefore, be handled with extreme care at all times to prevent inadvertent operation. In some cases, conductive rubber plugs known as shunts are provided, and these must be fitted to the electrical connectors when the appropriate cartridge unit is detached from its extinguisher, or the system supply cable is disconnected.

(ii) When installing extinguishers, it must be ensured that they are properly positioned in their support brackets and secured by straps or mounting bolts as appropriate to the type of extinguisher. Where locking pins are necessary, e.g. on securing straps, a check must be made to ensure that they are in a serviceable condition and correctly assembled to the straps.

NOTE: Extinguishers should be handled carefully during installation, and bumping against adjacent parts of the aircraft structure should be avoided. Accidental discharge of an extinguisher may cause injury to personnel.

(a) Operating head junction boxes and discharge outlet unions must be correctly aligned with their respective pipelines and the appropriate connections secured in the manner specified in the relevant manuals.

(b) Before connecting power supply cables to cartridge units, the discharge circuits should be tested for correct functioning (see Leaflet EEL/1-7). On satisfactory completion of the functional tests, the circuit breakers of the relevant extinguishing system should be tripped, and the cables connected and secured to the cartridge units appropriate to the type of unit. The system circuit breakers should be re-set after ensuring that the extinguisher operating switches are in the off position.

6.1.2 **Pipe Systems.** Before installation, the bore of pipes and spray rings should be checked for freedom from obstruction, by blowing through with clean, dry compressed air or with nitrogen. A check should also be made on pipes and spray rings to ensure freedom from corrosion, cracks, dents and other deformation. The mating surfaces and connections must also be clean and free from damage.

NOTE: To prevent enlargement or deformation of spray holes and jets, they should be cleaned out only by the methods specified in the relevant manuals.

(i) Metal pipes must be properly secured to the airframe structure at the specified attachment points, and there must be adequate clearance between all pipes and structural parts to avoid chafing during flight.

(ii) The minimum bend radii of pipes should comply with the dimensions specified in relevant manuals and installation drawings.

(iii) End connections should be tightened to appropriate torque values. When tightening flexible pipe connections, care must be taken to ensure that pipes do not become twisted.

(iv) After installation of a section of pipe, a pressure test of the system should be carried out. Precise details of pressure test procedures are given in relevant Maintenance Manuals and test schedules, and reference must be made to these documents. In general, however, a test requires that the pipeline from the extinguisher outlet to the spray rings should be disconnected at both ends. One end should then be blanked, and compressed air applied at the other end to check whether the pipeline will retain a given pressure over a given period.

(v) When pipes are removed from an aircraft, blanks should be fitted to the end connections and all other exposed connections in the system. Support clamps should be returned to their original positions as soon as a pipe has been removed to ensure their correct re-location.

6.1.3 **Valves.** The following points should be observed when installing and maintaining valves:—

(i) They should be inspected for cleanliness, signs of damage and freedom of movement.

(ii) Care should be taken to ensure their correct location with respect to the required flow of extinguishant.

(iii) Attachment to their respective mountings should be securely made.

(iv) Where appropriate, new sealing rings should be fitted between valve and pipe end connections.

6.1.4 **Discharge Indicators.** The fittings of disc-type discharge indicators are normally permanently fixed to the appropriate parts of the aircraft structure and it is, therefore, only necessary to check that the discs are in position and that discharge pipe connections are securely made. In certain types of indicator it is also necessary to check that a sealing plug is in position within the discharge outlet.

6.2 **Portable Extinguishers.** The pre-installation checks, installation procedures and inspections of portable extinguishers may vary between types but, in general, the following points are common to all:—

6.2.1 Before installing extinguishers in their appropriate stowage brackets, they should be inspected for general condition and signs of fluid leakage, and their weight should be checked against that specified for the type. (See paragraph 6.3).

6.2.2 The expiry dates of extinguishers should be checked against the date of manufacture to ensure that they are within the specified service life. Extinguishers having expendable containers should be fitted with new containers at the time expired date. Other extinguishers should be removed for re-charging and replaced by serviceable units.

(i) Dates of manufacture are given on some types of extinguishers in the form of a code. For example, months are represented by letters A to M (excluding I), years are indicated by the last figure of the year number, and weeks are given by figures 1–5 beneath the month and year codes. Thus $\frac{\text{E-3}}{2}$ marked on an extinguisher would indicate that it was manufactured in the second week of May 1973 and, assuming a life of five years, the expiry date of the extinguisher would be May 1978.

6.2.3 In certain types of water extinguishers, safety pins are provided to lock the triggers when the extinguishers are in transit. Such pins must be removed before installation of the extinguishers.

6.2.4 Lockwire and seals should be checked to ensure that they are intact. If the wire and seal of an extinguisher have been broken it must be withdrawn from service for a weight check.

(i) In the case of water extinguishers employing a CO_2 cartridge, a broken seal wire could indicate that the cartridge has been fired. The cartridge should therefore be removed and its weight checked. If the cartridge has been fired the extinguisher is in a pressurised condition and it should be withdrawn and replaced by a serviceable unit. If the cartridge is serviceable, and the extinguisher weight is in accordance with that specified, the cartridge should be refitted and a new seal wire attached.

6.2.5 Where a dust cap is provided on the discharge nozzle of an extinguisher, a check should be made to ensure that the cap is free to be forced off should the extinguisher be used. If necessary, the nozzle should be smeared with a light application of silicone grease.

6.3 **Weight and Pressure Checks.** The fully charged weight of an extinguisher should be checked at the periods specified in the approved Maintenance Schedule, and before installation, to verify that no loss of extinguishant has occurred. The weight, including blanking caps and washers, but excluding cartridge units, is normally indicated on the container or operating head. For an extinguisher embodying a discharge indicator switch, the weight of the switch cable assembly is also excluded.

NOTE: The provision of discharge indicators in fixed extinguisher systems does not alter the requirement for periodic weighing which is normally related to calendar time.

6.3.1 The date of weighing and the weight should, where specified, be recorded on record cards made out for each type of extinguisher, and also on labels for attachment to extinguishers. If the weight of an extinguisher is below the indicated value the extinguisher must be withdrawn from service for recharging.

6.3.2 For extinguishers fitted with pressure gauges, checks must be made to ensure that indicated pressures are within the permissible tolerances relevant to the temperature of the extinguishers. The relationship between pressures and temperatures is normally presented in the form of a graph contained within the appropriate aircraft Maintenance Manuals.

6.3.3 In certain types of portable extinguishers, a check on the contents is facilitated by means of a disc type pressure indicator in the base of the container. If the charge pressure is below the specified value, the disc can be pushed in by normal thumb pressure.

7 STORAGE Extinguishers should be shielded from direct sunlight, stored in an atmosphere free from moisture and corrosive fumes and be located on shelves which allow free circulation of air. Transit caps, sealing plates and transit pins, where appropriate, must remain fitted during storage.

7.1 The weights of extinguishers should be checked annually during storage, which, in general, is limited to five years from the date of manufacture or last overhaul. At the end of this period, extinguishers must be withdrawn for overhaul.

NOTE: The storage limiting period may vary between types of extinguishers. Reference must, therefore, always be made to the relevant manuals.

7.2 Cartridge units must be stored in sealed polythene bags in a moisture-free atmosphere and kept away from sources of heat. A label quoting the life expiry date which, in general, is five years from the date of manufacture of last overhaul, should be attached to each bag. If a cartridge unit is removed from its bag, the life expiry date is two years from the date of removal, provided the expiry is within the normal five year period.

7.2.1 Defective or time-expired cartridge units must be disposed of in accordance with regulations relating to the handling of gunpowder.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

LIFEJACKETS

1 INTRODUCTION This Leaflet gives guidance on the inspection and maintenance of lifejackets, which are required to be carried in certain aircraft operating under conditions specified in the Air Navigation Order. Owing to the wide variety in detail of lifejackets, the information is of a general nature and does not apply to any particular make or type of lifejacket. The maintenance and servicing of the less common types of survival equipment are very similar to the single inflation chamber type covered by this Leaflet.

NOTE: The Requirements for the design and manufacture of lifejackets are covered in CAA (Airworthiness Division) Specification No. 5.

2 GENERAL Lifejackets are designed as lightweight items of equipment and as such should be treated with care. Lifejackets are normally packed in specially made fabric valises or containers for ease of handling, and these also protect the lifejacket; they also help to keep the lifejacket correctly folded, to facilitate donning. However, care should be taken not to drop a packed lifejacket or to place loads upon it. Manufacturers often recommend that a lifejacket which has been subjected to such abuse or has been immersed in sea water, should be rejected for further operational use.

2.1 The necessary instructions for fitting lifejackets are displayed in the aircraft and, in many instances, these instructions are repeated in safety pamphlets for distribution to individual passengers. Similar information may also be given on the lifejacket by means of special adhesive labels or stencilling on the surface of the jacket.

2.2 Normally, lifejackets are stowed under passengers' seats and in easily accessible positions for crew members. Stowages should be kept clean and dry, and the stowage retaining device should be checked periodically for security and ease of release.

2.3 Lifejackets which have been used for demonstration by crew members should be returned for inspection as if they were time expired. To ensure that this is always done, the demonstration lifejackets should be kept out of the normal stowage and a suitable warning label should be attached.

3 LIFEJACKETS—GENERAL DESCRIPTION There are several types of lifejackets in use, and all are basically similar. Buoyancy is obtained by inflating the jacket with carbon dioxide (CO_2) gas, which is stored under pressure in a small cylinder and released by means of a manually operated mechanism. A standby mouth inflation valve is also provided in case the CO_2 system is inoperative, or if it is necessary to 'top-up' the pressure after a long period of immersion. To assist rescue operations, lifejackets are

equipped with an identification light and battery, and a whistle is also provided. Certain types of lifejackets may also carry additional equipment such as fluorescent sea marker dye, shark repellent products and special signalling devices.

NOTE: Care should be taken to avoid unintentional operation of the inflation mechanism. The mechanism cannot be used to stop the gas flow, which will inflate the lifejacket in a few seconds. However, if the lifejacket is inadvertently inflated, means are provided for deflation. This can be effected on some lifejackets by depressing the non-return valve in the mouthpiece, by means of a deflation key stowed next to the mouth inflation valve and secured to the lifejacket by an attachment cord, or by inserting the extension piece moulded on to the side of the valve protection cap.

3.1 Most lifejackets are of the single inflation chamber type as illustrated in Figure 1, but there are others which have more than one inflation chamber, gas cylinder and mouth inflation facility; some aircraft may also carry baby flotation survival cots.

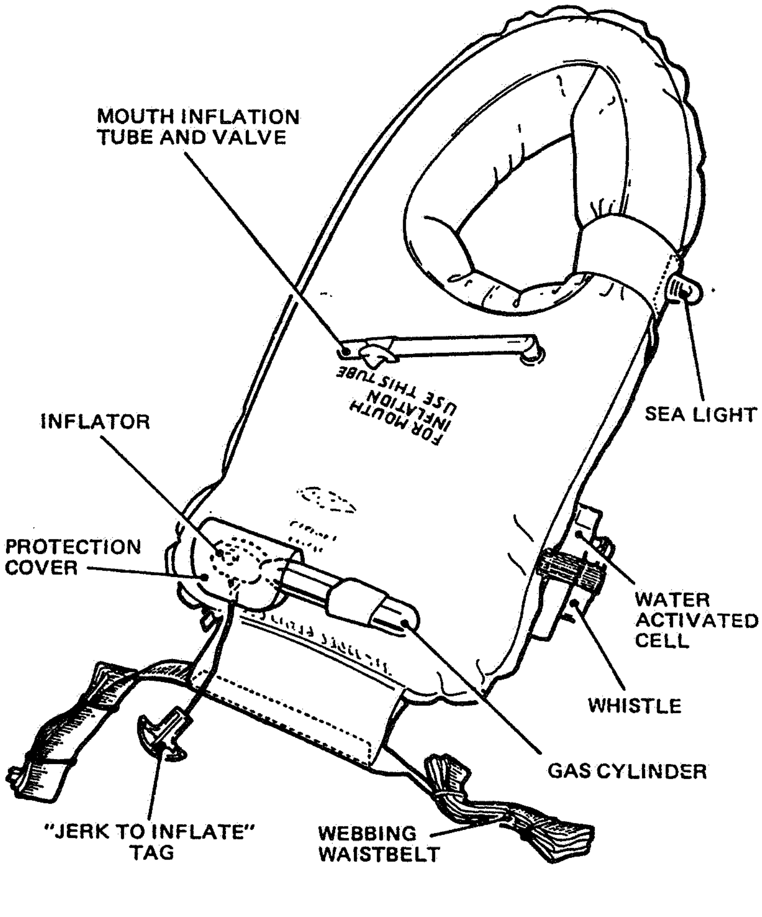

Figure 1 TYPICAL LIFEJACKET

3.2 The material used for fabricating lifejackets is generally either rubberised cotton or polyurethane coated nylon (coated on either one or both sides), the panels being joined by the use of an adhesive or by welding.

3.3 A light unit is attached to a lifejacket in such a way as to ensure that, when the lifejacket is in use, the lamp assembly will be in a prominent position. The bulb is connected by means of a plastic covered lead to a battery, which is usually water activated and located below the water line. Operation of the battery is achieved by the ingress of water into the cell.

3.4 The operating mechanism into which the CO_2 cylinder is fitted consists of a housing containing a piercing pin which, when pushed forward by a cam-type operating lever, pierces a sealing disc in the neck of the cylinder, allowing gas to flow past a non-return valve into the lifejacket. The piercing pin is actuated by pulling a red knob or tag, which is attached by a cord or chain to the operating lever.

4 MAINTENANCE REQUIREMENTS The appropriate manufacturer's publication will stipulate the periods at which inspections and related tests are required and will also give full details of the inspection and test operations involved. It may stipulate inspection after every six months of service life, with a more comprehensive inspection after every 18 months, or it may stipulate a yearly inspection only. Similar information will also be given regarding accessories, such as CO_2 mechanisms, identification lights, inflation valves, etc. The lifejacket and some of the accessories (e.g. CO_2 cylinder), will also have a maximum service or storage life, stipulated in years, which must not be exceeded. All work should be carried out in accordance with the relevant publications and the lifejacket and inflation equipment manufacturers' Service Bulletins, etc. All details of a particular lifejacket, including modifications and inspections, and the Inspector's stamp or signature, should be recorded on an Inspection Record kept at the maintenance base.

4.1 Inspections and tests should be carried out in clean premises kept at stable room temperature. To avoid damage through puncture or abrasion, the inspection tables should have smooth, well finished surfaces free from any wood splinters or sharp corners, and the working surfaces should be kept thoroughly clean. Precautions should be taken to avoid any contact with oil, grease or acid.

4.1.2 A rack should be provided from which lifejackets under inflation test can be suspended, and a method of referencing should be adopted to relate each lifejacket with the time of inflation and the duration of the test period. The rack should be kept away from direct sunlight or radiated heat.

NOTE: All inflation tests must be carried out under stable temperature conditions.

4.1.3 To trace leaks in lifejackets which have failed to maintain the required test pressure, an immersion tank containing clean water is often used. In other instances, the suspected area is smeared with an acid-free soap solution, all traces of which should be thoroughly removed by rinsing with lukewarm water immediately after test.

4.1.4 Laboratory type scales having an accuracy of 0·1 gramme should be available for cylinder gas-charge checks.

5 INSPECTIONS AND TESTS

5.1 **Lifejacket.** The lifejacket should be withdrawn from its valise, unfolded, and such equipment as the CO_2 cylinder, identification light assembly and whistle removed. A check of the serial number marked on the lifejacket and that on the related Inspection Record should be made. All instructions stencilled or labelled on the lifejacket should be examined for legibility. Such information as date of manufacture, modifications embodied, etc., must agree with the Inspection Record.

NOTE: In some instances it may be necessary to clean the lifejacket before inspection. This should be done with lukewarm water and the cleaning agent recommended by the manufacturer.

5.1.1 **Inspection.** The proofed fabric should be inspected for slits, tears, holes, adhesion of seams and general deterioration. Deterioration is seldom immediately apparent and can easily be overlooked. It is vitally important, therefore, that a careful inspection for any of the following signs should be made:

(a) Discoloured areas (not due to surface dirt which can be washed off).

(b) Sticky areas.

(c) Hard or stiff areas.

(d) Shiny areas.

(e) Wrinkled or crazed areas.

5.1.2 Webbings, elastics and cordages should be inspected for discoloration, deterioration and security of attachment (e.g. condition of stitching and security of knots).

5.1.3 Metal and plastics components should be inspected for cleanliness, damage or deterioration and security (e.g. adhesion of components to fabric where applicable).

5.1.4 **Inflation Tests.** Inflation tests are required to check a lifejacket for leaks and may be carried out after repairs have been made, to check the buoyancy chamber, or after the gas cylinder has been inspected and reassembled, to check the complete jacket. The lifejacket is inflated using a test rig, which may be connected either to the mouth inflation valve or to the operating head (with the gas cylinder removed), depending on the reason for the test.

NOTE: Before tests are commenced the test equipment should be checked for leaks, especially at the connections.

5.1.5 The initial test consists of inflating the lifejacket to a given pressure and allowing the pressure to stabilise with the air supply disconnected. After a given time, the pressure is checked to ensure that it has not dropped below a specified figure.

NOTE: The lifejacket should not be touched whilst on test as the pressure reading may be affected.

5.1.6 If the initial test is satisfactory, the lifejacket is re-inflated and allowed to stand for a longer test period, after which the pressure should not have dropped below a second stipulated figure.

5.1.7 Whilst the lifejacket is inflated a visual examination should be made for any signs of distortion or damage not revealed before inflation.

5.1.8 If any stage of the test proves unsatisfactory, leakage may be traced by either of the methods outlined in paragraph 4.1.3, when air bubbles will indicate the position of the leaks. Local repairs may often be carried out, but where damage exceeds limits specified in the relevant manual, the lifejacket should be returned to the manufacturer (see paragraph 6).

5.1.9 The mouth inflation valve will also require pressure testing for leaks, either by placing a small amount of water in the mouthpiece or by immersing the valve unit in water and checking for the presence of bubbles. A valve functioning test may be specified; this is done by applying air pressure to the mouthpiece, and ensuring that the valve opens at a specified pressure below the working pressure of the lifejacket. If the valve should leak, or if it fails to open at the functioning pressure specified, the following actions should be taken depending on the type of valve:

(a) With the type of valve which can be disassembled, this should be done and the valve should be cleaned and its seat checked for deterioration or dirt, and then lubricated with a silicone grease specified by the manufacturer. After re-test, if the valve still leaks it should be replaced by a new assembly and again tested.

(b) With the type of valve which cannot be disassembled, it should be renewed in accordance with the instructions contained in the relevant Overhaul Manual.

5.2 **Light Unit.** The life of the light unit is often indefinite, provided that periodic inspections and tests prove satisfactory.

5.2.1 **Inspection.** The battery should be inspected for any signs of damage or deterioration, or for signs of chemical reaction indicated by the presence of a white powdery deposit or bulging of the battery case.

5.2.2 It is also important to ensure that no activation has taken place due to the ingress of moisture. Depending on the design of the battery it is often possible to check for activation visually. With some types this may be done by holding a source of light at the base of the battery case and looking through the water holes at the top. It should be possible to see clearly through the holes but if any activation has taken place the holes will be obstructed.

5.2.3 When fitting water-activated batteries into stowages on the lifejackets, care is necessary to ensure that the instructions regarding the removal of the water sealing plugs or other sealing devices are carefully followed, as they will vary with the type of battery used.

5.2.4 **Electrical Tests.** Electrical tests for the water-activated type of battery are usually prescribed. They often consist of testing with a standard aircraft insulation resistance tester connected across the battery terminals to obtain a specified reading in megohms (e.g. 1 megohm minimum). A milli-voltmeter test is also often acceptable; with the milli-voltmeter across the battery terminals, no voltage should be registered.

NOTE: When testing with a milli-voltmeter, an initial test should be made at a higher scale reading to obviate damage to the meter should the battery be active.

5.2.5 The electrical circuit and the bulb should be checked for electrical continuity and functioning using a slave battery of the correct voltage.

5.3 **Gas Cylinders.** The CO_2 cylinders should be carefully inspected for any signs of damage such as dents, scores or corrosion, which would weaken the cylinder and render it unserviceable and possibly dangerous. The cylinder threads should also be checked for obvious signs of damage.

5.3.1 With the operating mechanism removed, the CO_2 cylinder should be checked for correct gas charge by weighing. Some cylinders are marked with the empty weight and the weight of the gas charge is given in the appropriate publication; later cylinders are marked with the total (charged) weight, e.g. TW. 146. Should the cylinder be found to be outside the weight limitations it should be replaced by a fully charged one.

5.3.2 All CO_2 cylinders are 'lifed' and should be returned to the manufacturer for inspection and test when their life has expired. A code representing the date of manufacture, or the actual date of manufacture of a cylinder, is stamped on its base, and this should be checked during inspection.

5.4 **Operating Mechanism.** With the CO_2 cylinder removed, the inspection instructions usually stipulate a functioning check to ensure the correct travel of the piercing pin, and in some cases the mechanism is disassembled and all parts cleaned and inspected at specified intervals. Damaged or corroded metal parts and seals or rubber washers showing any signs of deterioration should be renewed if permitted by the manufacturer.

5.4.1 On some lifejackets the operating mechanism is mounted on a rubber base and the unit is bonded to the lifejacket; no attempt should be made to separate this bond. Care is therefore necessary to avoid damage to the attached lifejacket when work is carried out on the operating mechanism.

5.4.2 After reassembly of the operating mechanism a final check should be made to ensure that the operating lever is in the correct position (i.e. cocked) and that the safety retaining device (e.g. break thread or spring clip) has been properly fitted.

5.4.3 In the event of the mechanism having been immersed in sea water, it should be disassembled, checked for corrosion and then thoroughly cleaned to remove all traces of salt deposit.

6 REPAIRS The parts of a lifejacket which are made from proofed fabric are liable to suffer from damage or deterioration, and repair schemes and instructions are often contained in the relevant Overhaul Manual. In the case of lifejackets which are joined by an adhesive, extensive repairs are often permissible within limits specified by the manufacturer, but in the case of lifejackets which are joined by welding, only minor patch repairs are usually permitted. This is because the machine settings have to be predetermined for each tool and type of weld and it is unlikely that a lifejacket servicing facility other than the manufacturer could carry out satisfactory welded repairs.

6.1 **General.** Repairs are carried out by patching with a material identical to or compatible with that used in the original lifejacket, using a self-vulcanising solution as the adhesive. Repairs may usually be carried out within the following limitations:

(a) Minor damage (i.e. cuts, tears, abrasions and deterioration extending to less than 100 mm (4 in) in length or diameter), provided it is not within 25 mm (1 in) of a seam, can be repaired by applying an external patch.

(b) Minor damage within 25 mm (1 in) of a seam but not affecting the internal seam reinforcing strip can be repaired by applying internal and external patches.

(c) Minor damage affecting the reinforcing strip can be repaired by applying internal and external patches and renewing the damaged portion of reinforcing strip.

(d) Damage exceeding 100 mm (4 in) in length or diameter can be repaired by renewing a complete panel or part of a panel.

(e) If damage is sustained to a panel which already has two repair patches, the panel should be renewed.

NOTE: The damage limits of (d) and (e) would only be applicable to lifejackets joined by an adhesive.

6.1.1 Patches should be circular, or rectangular with rounded corners, and should overlap any damage by at least 25 mm (1 in). Reinforcing strip should overlap the existing strip by at least 25 mm (1 in) and exterior tape should overlap by 50 mm (2 in).

6.1.2 The repair solution is supplied as a kit, and contains a number of ingredients which must be mixed strictly in accordance with the manufacturer's instructions. Once mixed the solution must be used within a few hours, as it soon becomes unstable.

6.1.3 All tools and utensils used when carrying out repairs, e.g. roller, brushes and spatula, should be kept scrupulously clean and free from abrasions.

6.1.4 In some cases it may be recommended that a test piece should be prepared using the fabric and adhesive used for the repair, in order to check the progress of vulcanisation. At the end of the vulcanising period (2 to 4 days) a portion of the test piece should be peeled apart and a few drops of an appropriate solvent applied to the surface. If vulcanisation is complete the liquid will spread quickly and be absorbed, but if not it will be absorbed slowly and the surface will be tacky.

6.2 **Repair Procedure.** Because of the different methods of manufacture of lifejackets, damage could be caused by using inappropriate repair procedures. As an example, some fabrics are proofed on the outside only, whilst others are proofed on the inside only; abrading the former is an essential part of the repair procedure, whereas abrading the latter would weaken the fabric and cause further damage. It is essential, therefore, that the manufacturer's instructions concerning the repair of a particular lifejacket are carefully followed and any related safety precautions are observed.

6.2.1 After repairs have been carried out the lifejacket should be tested as outlined in the Overhaul Manual.

7 FINAL ASSEMBLY After all the inspections, repairs and tests have been satisfactorily completed and before the lifejacket is folded, a careful check should be made to ensure that all the related equipment has been correctly assembled and fitted to the lifejacket in accordance with the instructions for the type concerned.

7.1 **Folding.** The folding instructions will vary in detail with different types of lifejacket, or in some instances with similar types fitted with different equipment. Care is necessary to ensure that all air has been expelled from the lifejacket before folding.

NOTE: On some lifejackets a deflation key is fitted to the mouth inflation valve to ensure that all air is expelled; this key must be removed before the lifejacket is folded.

7.1.1 After inspecting the valise or container for cleanliness and damage, the lifejacket should be inserted and the closure secured.

7.1.2 A tie-on label giving the serial number of the lifejacket and the date of the next inspection due should be attached, or when a pocket is provided in the valise, a card giving similar information should be inserted.

NOTE: When a tie-on label is used, the quality of the label and the attaching cord should be such that they cannot be damaged or become detached whilst the lifejacket is in service. Some instances have arisen where lifejackets have been transferred from one aircraft to another and the label(s) have become detached. This has necessitated unpacking and checking against the base Inspection Record to ensure that the inspection date had not expired.

8 STORAGE Leaflet **BL/1-7,** Storage Conditions for Aeronautical Supplies, gives guidance on acceptable conditions for the storage of lifejackets.

Issue 2.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

HOSE AND HOSE ASSEMBLIES

1 INTRODUCTION This Leaflet gives guidance on the installation and maintenance of hose and hose assemblies in aircraft, and should be read in conjunction with the relevant manuals for the aircraft concerned.

NOTE: In this Leaflet the term "hose" is used to describe a flexible tube which may be used on its own in some locations, and the term "hose assembly" is used to describe the hose complete with end fittings. Some manufacturers use the terms "flexible pipe" and "flexible pipe assembly" to describe the same parts.

1.1 Factors which affect the service life and reliability of hose and hose assemblies include the conditions prevailing in the area in which they are installed, the care with which they are installed and maintained, and the pressures, temperatures and externally applied loads to which they are subjected in service. The need for scrupulous cleanliness at all stages during the lives of the hoses and hose assemblies cannot be over-emphasised.

1.2 Paragraphs 2 to 9 of this Leaflet deal with rubber and synthetic material hose assemblies. Metallic hose assemblies differ considerably with regard to manufacture, installation and maintenance, and are dealt with separately in paragraph 10.

1.3 Guidance on the manufacture of rigid pipes is given in Leaflet **BL/6-15**, and on the installation of rigid pipes in Leaflet **AL/3-14.**

2 GENERAL Hose assemblies for use in high-pressure fluid systems are usually supplied by the manufacturers complete with end fittings which, in most cases, cannot be dismantled or altered in any way. However, there are some types of hose assemblies on which the end fittings may be changed, if necessary, and these are dealt with in paragraph 9.

2.1 **Hose Assemblies.** Modern high-pressure, metal-reinforced rubber or synthetic material hose assemblies are designed for the widest possible application in aircraft and engine construction. The tube or lining of the hose is manufactured from material such as synthetic rubber, which is specially compounded to withstand the deleterious effects of high pressures, high temperatures, oils, solvents, fuels and other fluids. The hose is considerably strengthened by the incorporation of high tensile steel wire braiding or spiral lay, which provides maximum resistance to bursting, together with minimum dimensional alterations when the hose assembly is subjected to high internal pressure. Hose assemblies are generally designed either for specific functions or for a limited range of functions only, and it is essential to ensure that only the hose specified on the appropriate drawing or in the approved parts catalogue is fitted in any particular system and location.

2.1.1 One material which is widely used for the manufacture of hose for engine and hydraulic systems is polytetrafluoroethylene (PTFE). This material is chemically inert, is unaffected by the synthetic oils and fluids used in aircraft systems, operates satisfactorily at high fluid and ambient temperatures, and normally has an unlimited shelf life. PTFE hose is, however, more susceptible to damage from careless handling than rubber hose, and great care is required during removal, installation and inspection.

2.1.2 The operating conditions under which a hose assembly may have to function vary considerably. Fluids may have to be conveyed at very high pressures at altitude where the ambient temperature may be in the region of −55°C; on the other hand high ambient temperatures in the region of jet engines may affect the same hose assembly. Hose assemblies required to function in designated fire zones or adjacent to fireproof bulkheads must possess fire-resistant properties, and are usually fitted with a protective sleeve; these sleeves are usually made from woven asbestos, are covered with asbestos-impregnated synthetic or silicone rubber, and may be secured to the hose assembly by clips.

2.1.3 In addition to the pressures and temperatures to which hose assemblies are subjected, vibration, and in some cases appreciable angles of flexing, may have to be accommodated. It is, therefore, essential that the lives specified for these assemblies in the approved Maintenance Schedule should not be exceeded.

2.2 **Construction of High-pressure Hose Assemblies.** A typical high pressure hose assembly (Figure 1) consists of an inner tube or lining covered by one or two closely-woven wire braids, either moulded or sandwiched between the synthetic rubber of the tube, or woven on the surface of the tube. The whole may be enclosed by an outer cover, the purpose of which is to provide protection for the other parts of the hose, to resist abrasion and the effects of weather and environmental fluids and chemicals, and, in some cases, to provide a degree of fire resistance. In some cases cotton braid is introduced between the wire braids and the rubber inner and outer tubes, and a thin rubber layer may be interposed between layers of wire braid.

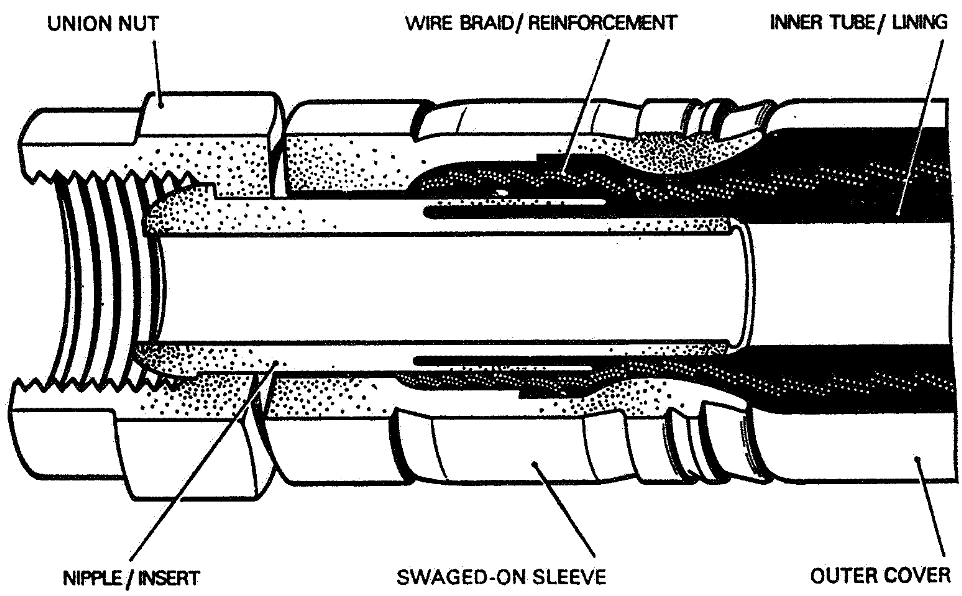


Figure 1 HIGH PRESSURE HOSE ASSEMBLY

2.2.1 The end fittings on a hose assembly are made of steel or light alloy, depending on the application, and they are designed to exert a grip on both the tubes and wire braids so as to resist high pressure, twisting and vibrating loads, and to provide an electrical bond throughout the assembly.

2.3 **Measurement of Length.** The length of hose assemblies with straight end fittings is taken as the distance between the extremities of the two nipples. In the case of elbowed end fittings the length is taken from the centre of the bore (see Figure 2).

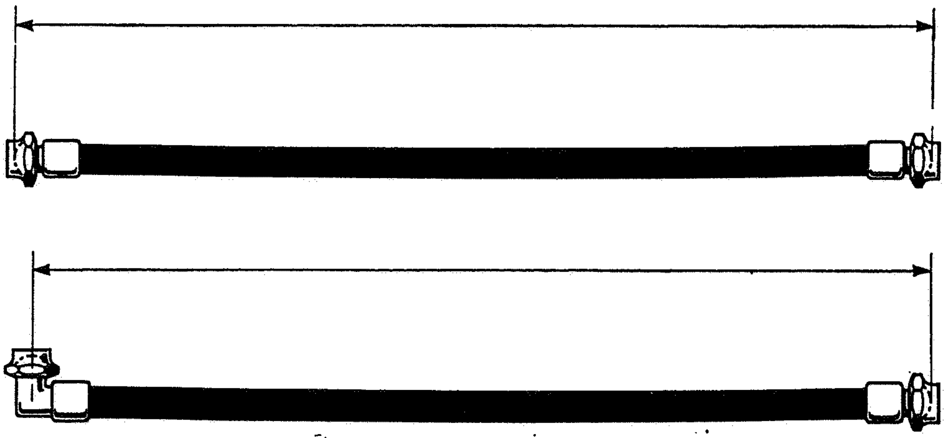


Figure 2 MEASURING HOSE ASSEMBLIES

2.4 **Low-pressure Hose.** There are many types of low-pressure hose used on aircraft, e.g., the thin-walled textile-reinforced type used for instrument lines (especially for instruments mounted on panels equipped with vibration isolators) and the rubber or canvas spirally-corrugated hose having a spiral of spring steel embedded in the corrugations, which is often used for systems where there are negative pressures.

2.4.1 With low-pressure hose it is important to ensure that bends are not too acute, since this may result in kinking of the hose or flattening of the cross-sectional area at the bend. Where sharp bends cannot be avoided an internal support coil may be included in the design.

3 STORAGE OF HOSE AND HOSE ASSEMBLIES PTFE hose does not normally have a specified storage life, but rubber or synthetic rubber hose normally has a storage life, depending on the formulation of the material, of between three and five years. The storage details relevant to a particular hose or hose assembly should be obtained from the appropriate Maintenance Manual or manufacturer's manual, and any instructions relating to the inspection and testing of hose or hose assemblies while in storage or prior to installation should be carefully observed. The storage life of hose supplied in bulk is calculated from the cure date, and the storage life of hose assemblies is calculated from the date of manufacture or assembly.

3.1 **Storage Conditions.** Bulk supplies of hose are generally stored in coils of large diameter, but hose assemblies should be stored flat and relieved of stress. Hose and hose assemblies should be stored away from strong light and running electric motors, and air should be permitted to circulate freely about the parts unless they are contained in plastics envelopes. The temperature should be controlled between 10°C and 26°C.

3.1.1 Preformed hose assemblies and PTFE hose assemblies which are being stored after removal from an aircraft system must be stored in such a way that the required or assumed shape is maintained; no attempt should be made to straighten or bend these hoses. A length of locking wire may be attached between the end fittings to prevent the hose from straightening.

3.2 **Sealing Blanks.** During storage, the correct sealing blanks should be fitted. Plugs and caps conforming to appropriate AGS and AS Specifications are usually suitable, but in instances where the standard blanks cannot be used, blanks should be so designed that they cannot enter the end fitting or be left in position when the assembly is connected. It is also important to ensure that the material used for blanking will not "pick-up" or otherwise tend to leave small particles inside the end fitting after long periods of storage. Tape or rag must not be used for blanking purposes.

3.3 **Rotation of Stock.** Strict rotation of issue from stores must be observed to ensure that older stock is issued first.

3.4 **Bore Protection.** In some special cases, to prevent deterioration of the bore or inner lining of the hose, it may have to be stored filled with the liquid which it is intended to contain in service; special instructions concerning such assemblies will normally be attached by the manufacturer. If a hose assembly is issued in an airtight plastics envelope, this should not be removed until the part is fitted. Should the envelope become damaged during handling, any desiccant contained within should be checked for condition and the envelope should be re-sealed or renewed.

4 MARKINGS ON HOSE AND HOSE ASSEMBLIES There are many ways in which the date of manufacture is marked on hoses and hose assemblies, varying according to the type and construction of the item. The date may be stencilled on the external surface, or impressed on a tab or band secured to the hose; in instances where the external surface is of cotton braid some of the 'strands' are woven in black and some are coloured to indicate the month and year of manufacture.

4.1 In addition to the date of manufacture, hose assemblies are marked with the drawing number or part number, inspection stamp, 'test' stamp and name of manufacturer.

4.2 Most hose assemblies are marked along their length with one or more continuous thin lines to indicate any twist which may occur on installation. Some manufacturers use these lines also for construction identification (see Figure 4), e.g. a hose having a single high-tensile wire braid would be indicated by a single line, while a hose having a double wire braid would be indicated by a double line.

5 PRE-INSTALLATION CHECKS Before a hose assembly is fitted to an aircraft it should be examined for damage and corrosion, and for cleanliness. The part number, date of manufacture and date of last test should also be ascertained. Where specified by the manufacturer, hose assemblies should be pressure tested before installation (see paragraph 8).

5.1 Where possible, every hose assembly should be examined internally to ensure that the bore is free from obstruction or damage. Straight hose assemblies may be examined by looking through them with a light positioned at the opposite end, but preformed hose should be checked by means of a ball test (paragraph 9.4.2 (a)).

5.2 If the end fittings have been welded, brazed or silver soldered, they should be examined for any corrosion which may have developed during manufacture. An Introscope or similar inspection instrument should be used in cases where direct viewing is impractical.

5.3 The hose bore should be examined for cleanliness, blown through with clean, dry compressed air as necessary and, when recommended by the manufacturer, flushed with clean fluid of the type used in the system to which the hose assembly is to be fitted.

6 INSTALLATION When installing a hose assembly, it should be ensured that there is adequate clearance between the hose and other parts of the aircraft structure, so as to prevent chafing or electrolytic corrosion. It must be borne in mind that hose may flex when internal pressure is applied, and considerable 'whip' may occur under surge conditions; the force exerted when a hose 'whips' may be sufficient to cause damage to the hose assembly and to surrounding components.

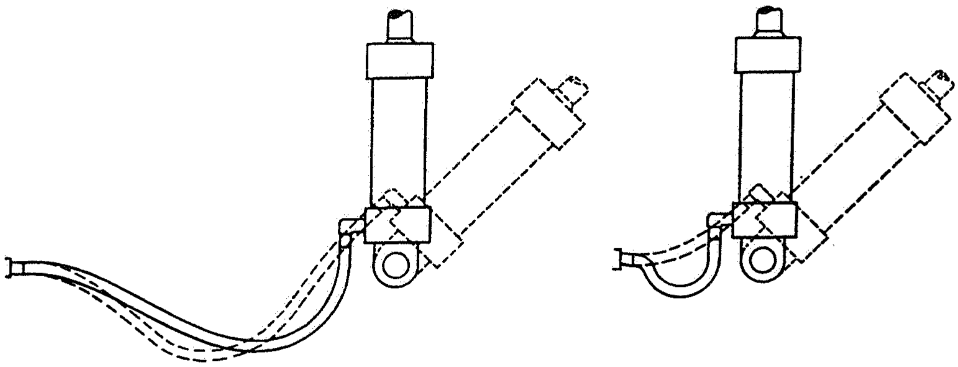
6.1 The serviceability and life of a hose assembly is considerably affected by the degree of bending of the hose. There may be some variation in the connecting angle and distance between fittings for a particular hose assembly in similar installations, and a check should be carried out to ensure that the bend radius is not less than the minimum specified by the manufacturer.

6.1.1 There are two classes of minimum bend radii recommended by hose manufacturers for each hose diameter. The minimum bend radii recommended for hose in locations where there is no relative movement, are smaller than those recommended for hose in locations where there is relative movement between end fittings, e.g. a hose assembly connected to a flap actuator would have a larger radius bend than a hose assembly connecting two rigid couplings at different angles. The flexing radius should, in general, be twice the bend radius of a static installation. It should also be noted that the recommended minimum bend radii for PTFE hose may vary from those recommended for rubber hose.

6.1.2 It is important to ensure that the bend radius of hose fitted to moving parts is never less than the recommended minimum, throughout the range of movement of the parts. Correct and incorrect methods of installation are shown in Figure 3, where the different alignment of the hose assemblies resulting from movement of the attached parts is illustrated.

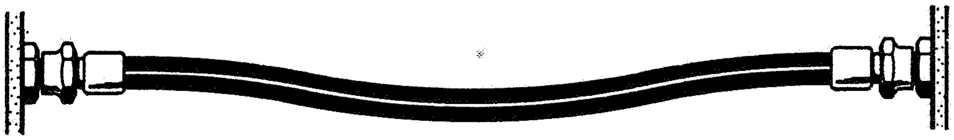
6.2 To allow for shrinkage, vibration, movement of parts and 'whip', all straight hose assemblies should be at least 3 per cent longer than the maximum distance between the fittings to which they are connected. In no circumstances may a hose assembly be under any form of tension (see Figure 4 (B)).

6.3 Sharp bends in a hose adjacent to an end fitting must be avoided, as this can cause considerable local strain and rapid failure of the hose (see Figure 4 (D)). When fitting hose assemblies with different types of end fittings, the correct method of installation should be observed.

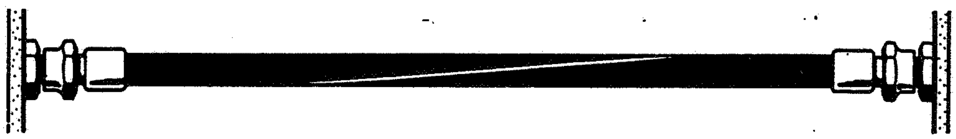


(A) CORRECT (B) INCORRECT

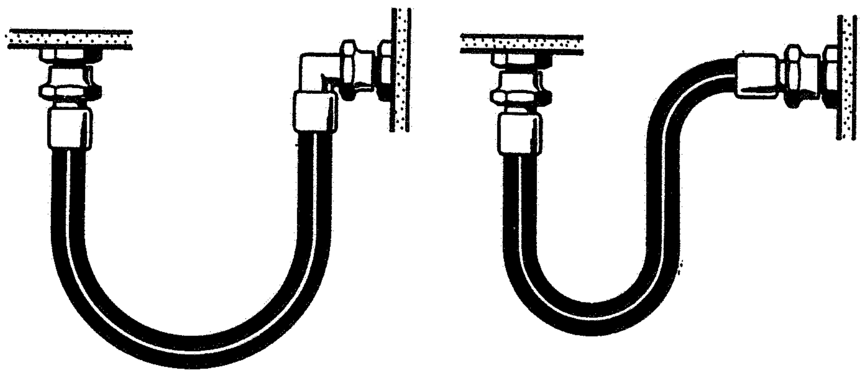
Figure 3 CORRECT AND INCORRECT INSTALLATIONS



(A) CORRECT—MINIMUM LENGTH 3 PER CENT GREATER THAN MAXIMUM DISTANCE BETWEEN END FITTINGS



(B) INCORRECT—HOSE TWISTED AND UNDER TENSION



(C) CORRECT (D) INCORRECT

Figure 4 CORRECT AND INCORRECT INSTALLATIONS

6.4 **Lubrication of Couplings.** If the lubrication of coupling threads is specified to avoid 'picking up', it is essential to use the lubricant specified by the manufacturer, and to ensure that it does not enter the bore of the hose assembly; this can be done by applying lubricant to the external threads only. For connections in oxygen systems, where the presence of oil or grease is very dangerous, only specified lubricants may be used. Because of the sensitivity of oxygen to many substances, it is essential that the instructions given in the relevant manual are followed when applying these lubricants.

6.5 **Tightening of Couplings.** When fitting a hose assembly, it is most important to prevent it from twisting when the connections are tightened. The union nuts at each end should be fitted finger-tight and then, while holding the hose portion firmly as near to the coupling as possible, the union nuts should be tightened with a spanner. On some hose end fittings, flats are provided for holding the hose with a second spanner while tightening the union nuts.

6.5.1 The continuous coloured line which some hose assemblies have on their outer cover will assist in detecting any twist in an installed hose (see Figure 4(B)). In the case of hose with a metal braided outer cover, twist may be detected by distortion of the braid pattern in a helical direction, but careful tightening or loosening of the union nuts is the only safe way of avoiding twist and strain in the hose assembly.

6.5.2 Care must be taken when tightening union nuts or banjo bolts, to avoid damage to the nuts, bolts or threads. Spanners should be of the correct size and in good condition, and the bolts and nuts should be tightened to the appropriate torque as specified in the relevant manual.

6.6 **Support Guides.** In many installations, a hose is supported or retained by large 'U' fittings or guides fitted to the adjacent structure to guide the movement of the hose in a particular plane, and to prevent it fouling or catching other moving parts of the aircraft installation. These support guides are usually encased in synthetic rubber to prevent damage to the hose. It is important to check the positioning of these support guides in relation to the angular movement of the hose to ensure that the hose movement is not restricted at extreme angles.

6.6.1 **Clipping.** In some installations, where there is no relative movement of the hose assembly, the hose is clipped to give support and minimise vibration. It must be ensured that, where clips are fitted, the hose is not distorted by overtightening or poor positioning of the clip.

6.6.2 **Taping.** Where taping of a hose is considered necessary as a protection against fouling, this should be reduced to a minimum, since, apart from restricting the hose flexibility, deterioration of the hose under the tape often occurs. On no account should leather be used for this purpose, since acid from the leather will corrode any metal parts with which it comes into contact.

6.6.3 **Movement of Hose Assemblies.** Where a hose assembly is connected to a moving part, it is important to ensure that the hose can only move in the plane or planes intended in the design.

(a) In the case of a hose assembly having movement in more than one plane, torsional loads will be imposed on the hose at the end fittings. If such movement is the design intention, a hose which has no metal braid or wire spiral in its construction is generally used, otherwise the torsional effect would result in early deterioration. In such instances special attention should be given to the locking of end fittings.

(b) Each moving hose should be observed during the functioning tests of the component to which it is connected so that it can be checked throughout its travel for evidence of chafing, binding, tight bends and other deleterious effects. An important application of these checks is to brake hose assemblies, which may appear to be of adequate length when the aircraft is resting on its wheels, but may be too short when the undercarriage strut is fully extended. It should be borne in mind, however, that an excessively large loop in the hose may be hazardous during retraction of the undercarriage.

6.6.4 **Tests after Installation.** After installation of a hose assembly, the associated system should be tested for flow, pressure and bonding as specified on the appropriate drawing or in the relevant aircraft manuals. During tests, freedom from leaks and excessive movement under pressure should be verified.

NOTE: In positions where the hoses cannot be seen with the system in operation, every possible precaution must be taken to ensure safety in the known most adverse condition of operation.

7 MAINTENANCE The life of a hose assembly varies largely according to environmental and operating conditions, but may also be affected by storage conditions and the care taken during its installation. The life is assessed from experience with a particular installation, and it may be specified in a number of ways. Some hose assemblies are given a definite life after which they are scrapped regardless of their apparent condition, some are given an overhaul life which usually coincides with the aircraft overhaul periods, and some are renewed only "on condition"; the life applicable to a particular hose assembly will be specified in the approved Maintenance Schedule. Apart from the replacement of time-expired or unserviceable hose assemblies little maintenance is possible, except in some cases, the replacement of end fittings and protective sleeves, but regular inspections of the condition of the assembly should be carried out, and care should be exercised during its service life to prevent deterioration through abuse.

7.1 **Inspection.** The inspection of hose assemblies should normally be carried out in situ, at the intervals specified in the approved Maintenance Schedule. During each inspection the date of manufacture of hose should be checked to ensure that its prescribed life will be valid until the next inspection, and the assembly should be examined for defects as outlined in paragraphs 7.1.1 to 7.1.9.

7.1.1 **General Condition.** General deterioration of a hose may be recognised by discoloration, flaking, hardening, circumferential cracking or crazing of the outer cover (Figure 5). These defects do not render the hose unserviceable unless the cracks penetrate to the braid.

7.1.2 **Installation.** The installation of a hose assembly should be checked to ensure that it is not twisted, stressed, or bent through too sharp an angle, and that any clips or supports are correctly fitted and not chafing or imposing stress on the hose.

7.1.3 **Chafing and Cuts.** Light chafing and cuts in the outer cover are generally acceptable if the braiding is not exposed, but the reasons for the damage should be ascertained and corrected. In the case of hose assemblies which have no outer covering over the braid, any damage to the braid will normally entail rejection, but some manufacturers permit the acceptance of isolated broken strands. Chafing which occurs under clips may entail changing both the hose and the clips.

7.1.4 **Kinks.** This defect is usually caused by incorrect installation or by mishandling. It shows up as a sharp increase in radius at one point in a bent hose, and is usually easy to detect visually unless the hose has a protective cover; finger pressure should be used to check this type of hose. Any kinked hose must be considered to be permanently damaged and must be scrapped.

Figure 5 AGEING CRACKS

7.1.5 **Corrosion.** Hose assemblies with corroded wire braid, or end fittings which are corroded (other than very lightly and locally) must be scrapped.

7.1.6 **Contamination.** Contamination of a hose with an outer rubber cover will show up as swelling, sponginess, hardening or disintegration of the surface, and is not acceptable. Hose which is contaminated should be rejected and renewed.

7.1.7 **Overheating.** The overheating of rubber covered hose is apparent as scaling, crazing, or discoloration of the surface. Hose with an outer wire braid may assume an overall golden brown colour when exposed to normally high temperature, and this is acceptable; patches of discoloration caused by overheating are not acceptable.

7.1.8 **Blisters.** Blisters may form on the outer synthetic rubber cover of hoses, but these do not necessarily affect the serviceability of the hoses provided they are able to withstand the applicable test described in (a) or (b). Certain factors must be taken into consideration, however, e.g. if the hose is exposed to spray from the tyres, puncturing of the outer cover may allow corrosive elements to attack the wire braiding.

(a) **Hose Assemblies in Pneumatic Systems**

(i) Remove the hose assembly from the aircraft and puncture the blister with a needle having a chisel point. The needle should be inserted parallel with the outer cover of the hose so that it penetrates the outer cover only. The blister should then collapse.

(ii) Pressurise the hose at 1½ times working pressure under water.

(iii) When the hose is pressurised, the air supply should be turned off. Bubbles will appear from air trapped beneath the outer cover but eventually disappear, and if no further bubbles appear, the hose is serviceable.

(iv) A constant flow of air bubbles indicates a leak and can be observed as a pressure drop on the pressure gauge. A leaking hose must be scrapped.

(b) **Hose Assemblies in Hydraulic Systems.** Remove the hose from the aircraft and puncture the blister as outlined in (a). If fluid emerges from the pin hole the hose must be scrapped; if air only emerges the hose should be pressurised with fluid at 1½ times its maximum working pressure for a period of two minutes and, if no fluid leakage occurs, it can be regarded as serviceable.

7.1.9 **Leaks.** A hose assembly should be checked for leakage with pressure in the associated system. A leak may be detected by the presence of fluid on the hose, end fittings or adjacent structure, or by the appearance of blisters on the hose (paragraph 7.1.8). When a protective sleeve is fitted, stains may appear on the sleeve or fluid may emerge from the ends of the sleeve, but if the leak is small and no fluid is visible, the presence of fluid may sometimes be detected by squeezing the sleeve. Hose assemblies in pneumatic systems may be checked by applying, externally, a non-corrosive soapy water solution, by the use of special test equipment, or by carrying out a leak rate check (Leaflet **AL/3-22**). If there is any doubt the hose assembly should be removed from the aircraft and subjected to a pressure test (paragraph 8). A leaking hose must be scrapped.

8 PRESSURE TESTS When specified in the approved Maintenance Manual or Schedule, or whenever the serviceability of a hose assembly is in doubt, a pressure test should be carried out.

8.1 **Test Equipment.** Before pressure testing a hose assembly the following points should be verified: (a) that the test equipment available is adequate for the proposed tests, and located in such a position as to preclude cross-contamination with dissimilar fluids, (b) that the test medium is clean and suitably protected against the ingress of dirt, (c) that the test equipment and instruments are checked at regular intervals, and a record kept of these checks, and (d) that before any tests are made, either in the aircraft or on separate components, the test figures are ascertained from the appropriate drawings or manual.

8.1.1 To prevent injury to personnel in the event of a hose failure during the pressure testing of a hose removed from an aircraft, the hose should be located behind a heavy plastics screen. For tests using air as the test medium the hose should also be submerged in water.

8.2 **Test Medium.** Pressure tests are usually made with a fluid similar to that which the hose will carry in service. However, there are some exceptions, for example, paraffin is usually recommended for testing petrol hoses as it is safer and more searching. Pneumatic and oxygen hoses are usually tested with water then thoroughly dried out with a warm air blast. This is followed by a further test with clean, dry air, in which pressure is limited to maximum system pressure.

8.2.1 Oxygen pipes must not be contaminated with oil, and should not be connected to a compressor for test purposes.

8.3 **Hose Flexing.** When under test, the hose should be restrained to approximately the shape it assumes in service.

8.3.1 If the hose is non-flexing in service it should be flexed approximately 15° from its normal shape several times each way and the pressure should be maintained for at least two minutes. Low pressure non-flexing hoses used in regions of high ambient temperature should be regarded as exceptions and should not be subjected to flexing during pressure testing, since such hoses, having been subjected to extremes of heat during service, will automatically be rendered unserviceable if treated in this manner.

8.3.2 Hoses which are subject to flexing in service should be tested in a similar manner but, in addition, should be flexed through their normal flexing angle plus 15° each way.

8.3.3 No leakage or malfunction should occur during any of these tests.

8.4 **Test Pressures.** Unless otherwise stated on the appropriate drawing or in the relevant manual, hoses should be pressure tested to 1½ times their maximum working pressure.

8.4.1 In some instances hose assemblies are tested in situ, in which case one end should be connected to a universal type of inflation adapter gauge and the other shut off or blanked as required. For information on the universal type of adapter and gauge see Leaflet **AL/3-14**.

9 RE-USABLE END FITTINGS The purpose of re-usable end fittings on hose assemblies is to save the cost of renewing a complete assembly when only the hose portion is unserviceable. An end fitting consists basically of two or more components; a socket fits tightly over the hose, and a tapered nipple (or insert), when screwed into the hose bore, expands the hose and clamps it firmly against the socket. This is the most common method and is known as a 'compression seal' (Figure 6 (A) and (B)), but a somewhat different method of attachment, known as a 'lip seal' (Figure 6 (C)), is used by some manufacturers; the nipple in this case has a cutting spur or separate collar which separates the inner hose from the braid during the assembly operation. The re-use of end fittings is satisfactory if precautions are taken to ensure that no damage is caused to the hose bore during the assembly operation and the manufacturer's instructions are followed with regard to both assembly and testing. A brief description of a typical assembly technique is given in the following paragraphs and illustrated in Figures 6, 7 and 8, but reference should always be made to the aircraft or hose manufacturer's manuals for specific instructions on measurement, assembly, lubricants, tools, etc.

9.1 **Hose.** The new hose must first be carefully measured and cut to length with a fine-tooth hacksaw or specialised cutting equipment, ensuring that the cut-ends are square and smooth. It should then be thoroughly cleaned and blown out with dry compressed air.

9.1.1 To minimise fraying when cutting off hose which has a cloth or metal sheath, it is advisable to wrap the hose with masking tape and saw through the tape.

9.1.2 High pressure hose usually has a metal braid sheath and, when this has a protective rubber cover, the cover must often be removed to enable the hose to enter the socket. Using a sharp knife, the cover should be cut off to the depth of the socket and the exposed braid carefully cleaned with a wire brush. Care must be taken to avoid damage or displacement of reinforcement wires.

9.2 **Fitting Sockets.** Sockets usually have a form of coarse left-hand internal thread to grip the outside of the hose, and threads at the outer end of the bore which mate with threads on the nipple.

9.2.1 To prevent the ingress of moisture on hoses which have a metal braid sheath, it is sometimes recommended that a sealant is applied to the braid and socket bore before assembly.

9.2.2 Large bore hoses are quite rigid and, to facilitate entry of the nipple, it is often recommended that the hose is slightly flared and its bore carefully chamfered before assembly into the socket. Except where a sealant is specified, lubrication of the outer surface of large diameter hose will also ease its assembly into the socket.

9.2.3 Actual assembly of the hose and socket is carried out by holding the socket firmly in a vice and screwing the hose into the socket until it bottoms.

NOTE: Some manufacturers recommend that, after screwing the hose fully into the socket, it should be unscrewed a quarter turn to allow for expansion when the nipple is inserted.

9.2.4 After assembly of the hose to the socket it is recommended that the hose is marked with a grease pencil, paint or tape, at the point where it enters the socket, in order to provide a means of checking that the hose is not forced out of the socket during subsequent insertion of the nipple.

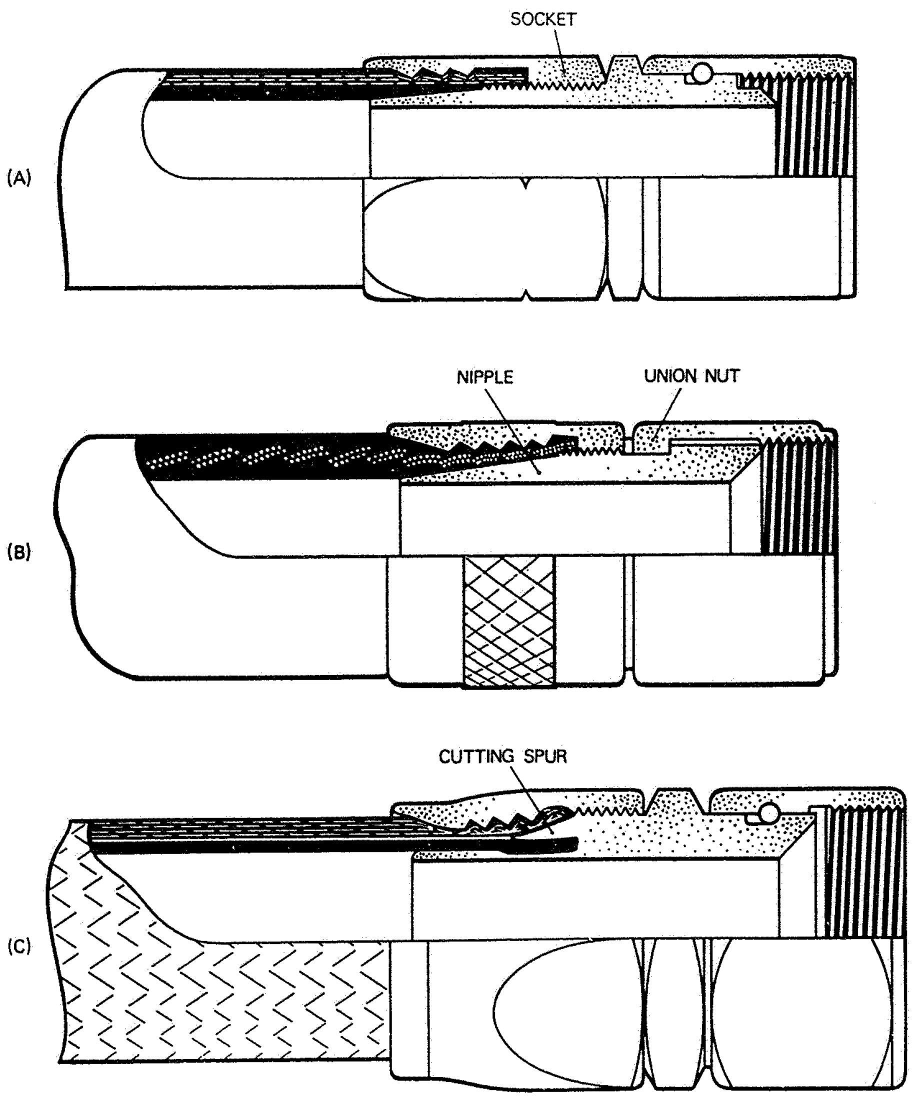


Figure 6 TYPICAL RE-USABLE END FITTINGS

9.3 **Fitting Nipples.** To complete the hose assembly, nipples must be screwed into the previously assembled hose and socket. This operation must be carried out with extreme care, as misalignment of the nipple could easily result in its tapered end cutting into the hose wall; slices of rubber dislodged in this way have been known to cause malfunction of associated components.

9.3.1 Nipples are usually tapered over approximately half their length and are often provided with a plain pilot extension to guide the nipples accurately into the hose (Figure 7). When the nipple does not have a pilot extension, an assembly mandrel should be used and should extend at least 6 mm (¼ in) beyond the end of the nipple. The assembly mandrel also acts as a means of turning a nipple which does not have an integral hexagon or flats.

NOTE: Because of their design, lip seal fittings do not require the use of an assembly mandrel.

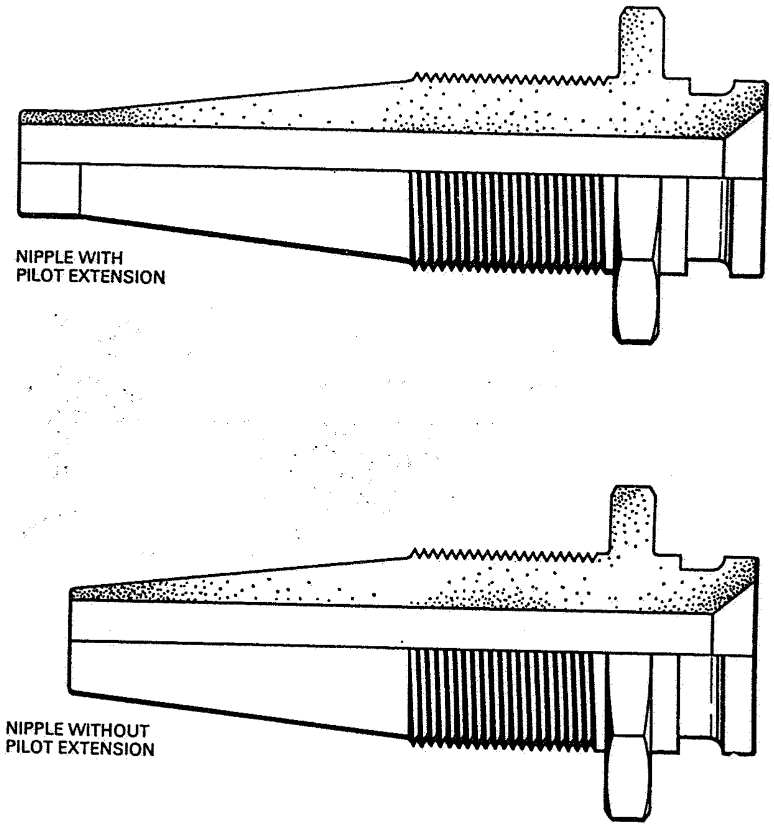


Figure 7 NIPPLE CHARACTERISTICS

9.3.2 Angled nipples are always provided with a pilot extension because an assembly mandrel cannot be used, but some manufacturers recommend that a straight nipple should be partially inserted first, to ensure that a concentric thread is started in the hose bore.

9.3.3 To assemble a nipple, the hose and socket should be held in a vice and, where appropriate, the nipple screwed onto a mandrel of the correct size (Figure 8). The hose bore and nipple should then be liberally lubricated with the recommended lubricant and the nipple screwed carefully by hand into the hose and socket until the threads on the nipple engage with those in the socket. The nipple should then be screwed fully home by use of a spanner or tommy bar as appropriate. With the lip seal type of fitting the hose should be pressed firmly into the socket during this operation and particular care taken when engaging the socket threads.

9.3.4 Check by reference to the mark applied to the hose (paragraph 9.2.4) that the hose has not been pushed out of the socket during insertion of the nipple.

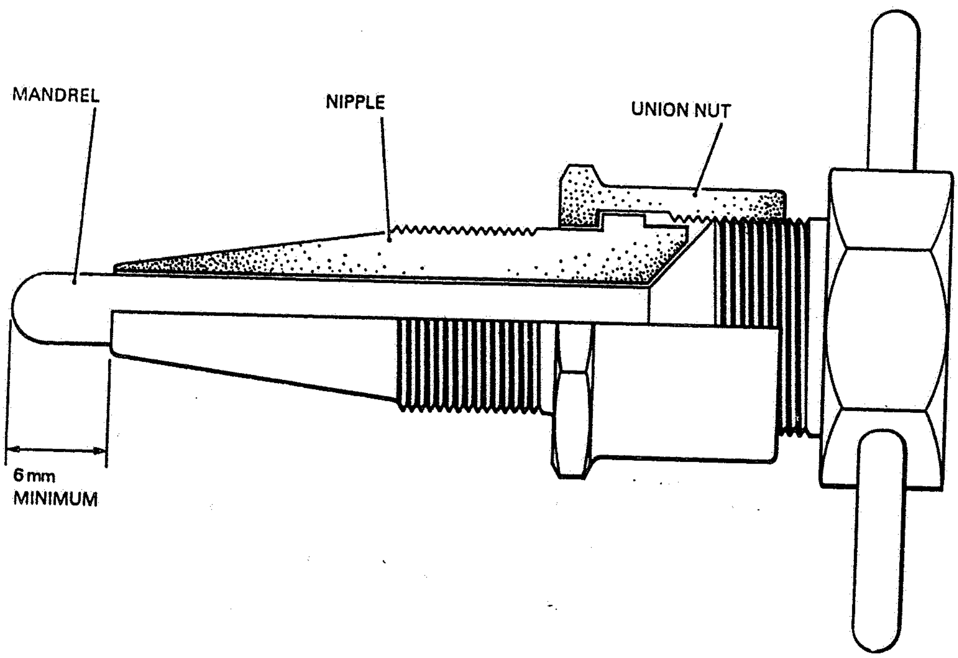


Figure 8 ASSEMBLY MANDREL

9.4 **Inspection.** Sockets and nipples which have been removed from an unserviceable hose should be inspected for damage and corrosion, and any traces of hose adhering to the threads must be removed. Before re-using a lip-seal type of nipple all traces of rubber should be removed from under the lip and, subject to limitations laid down by the hose manufacturer, the lip should be restored to its original profile. After the hose assembly has been made up it should be thoroughly cleaned and dried, examined and pressure tested to 1½ times maximum system pressure, to ensure that it will withstand the pressure existing in the system with which it is to be used.

9.4.1 **External Inspection**

(a) Check all metal parts for signs of damage, particularly of the union nuts and cone faces.

(b) Check that the union nuts turn freely.

(c) Check that the gap between the socket and union nut (or integral hexagon) is within limits.

(d) Check the hose for damage at its point of entry into the socket.

9.4.2 **Internal Inspection.** Internal bulges and flaps can often be detected by looking through the hose with a light held at the opposite end, but a more satisfactory examination can be made using normal inspection equipment (e.g. an Introscope). Hoses which have straight nipples may be readily examined, and hoses which have one angled nipple may be examined from the opposite end. Hoses which have an angled nipple at both ends, however, present difficulties, and although radiological examination would show if the nipple had been assembled eccentrically it might not reveal damage to the hose bore, and would in any case defeat the object of using re-usable fittings. In these cases either a ball test or a flow test is recommended.

(a) **Ball Test**

(i) With the hose assembly suspended from one end, a ball should pass freely through the assembly under its own weight and without lubrication. The check should be repeated from the opposite end, and if the ball fails to pass through the hose in either direction the hose must be rejected as unserviceable.

NOTE: Precautions must be taken to ensure that a hose in which a ball has become lodged is not introduced into service; the hose should be cut immediately and the ball extracted.

(ii) The diameter and material of the ball are specified by the hose manufacturer and vary with the design of the hose, but a steel ball having a diameter of approximately 90% of the bore of the end fittings is generally used.

NOTE: It is sometimes recommended that a rod should be used on small diameter hoses.

(b) **Flow Test.** In some instances a ball test may be considered to be inadequate and it may be required to be demonstrated that the assembly is capable of passing a given quantity of fluid in the time and under the conditions specified.

9.4.3 **Pressure Test.** Hose assemblies with re-usable end fittings should be given pressure tests identical to those described in paragraph 8 for normal hose assemblies.

9.4.4 **Bonding Test.** Where hose assemblies have metal wire braid reinforcing or embody any form of metal in their construction (such as a wire spiral) a bonding test will be specified. An approved type of bonding tester should be used, and the resistance recorded should not exceed 0·050 ohm or 0·025 ohm per foot length, whichever is the greater.

10 FLEXIBLE METALLIC HOSE ASSEMBLIES This type of flexible hose is made entirely of metal, mainly stainless steel, and must, therefore, be treated separately from the synthetic rubber and metal composite flexible hoses dealt with in the previous paragraphs.

10.1 **Construction.** Flexible metallic hose is constructed from an annular or spirally convoluted, seamless, flexible inner tube, reinforced by an exterior covering of one or more layers of stainless wire braid.

10.1.1 **Reinforcing Overbraid.** Unless restrained by some means, the effect of internal pressure on the convoluted tube would cause elongation, and the convolutions would tend to flatten out. Such elongation is prevented by means of a layer, or layers, of wire braid, which is braided upon, or slipped over the inner tube and securely anchored at the end fittings. Special attention is given during the manufacture of the hose to braid tension, pitch angle and final diameter to ensure that change of length of the assembly under pressure is kept to a minimum. This practice obviates the possibility of premature fatigue failure induced by excessive 'panting' and, in addition, 'fretting' on the convolution crests is avoided.

10.1.2 **Function.** The wire overbraid counteracts any tendency of the inner tube to elongate under pressure by containing the end loads thus produced between the fittings. The overbraid also performs other important functions, such as providing protection against damage for the inner tube, and by the exertion of a considerable damping influence on the inner tube when the assembly is under the effects of vibration and pressure impulse.

10.2 **End Fittings.** Various types of steel end fittings are available and are designed to effect a pressure-tight seal at the end of the hose. The seal is achieved by mechanical means or by brazing, silver soldering or welding the fitting to the tube. The end fitting also provides an anchorage for the wire braid to take the end loads caused by internal pressure.

10.3 **Storage.** Assemblies which are to be stored should preferably be left in the boxes in which they are received, but in any case they should have their sealed plastics envelopes intact. Under these conditions, the assemblies have no life limitations, provided that normal steps have been taken to prevent corrosion due to atmospheric conditions, physical damage, etc. It is also important in the event of the plastics envelope having been removed or damaged, to fit approved blanks; adhesive tape or rag should not be used.

10.4 **Identification.** Each assembly has a tag, brass band or adhesive label attached to it on which appears the part number of the assembly, the date of manufacture, the manufacturer's name and inspector's stamp.

10.5 **Pre-installation Check.** Before a hose assembly is fitted, the following checks should be made:—

(a) Verify the part number is correct to the drawing or the appropriate manual.

(b) Remove the blanking plugs or caps and ensure that the end fittings are undamaged and free from corrosion. Special attention should be given to the seating faces.

(c) As far as possible, examine the bore for corrosion.

(d) Carry out the pre-installation pressure test, according to the instructions given on the drawing or in the manual.

NOTE: Prior to fitting, cleanliness of the assembly is imperative.

10.6 **Installation.** When 'offering-up' the hose assembly, particularly if considerable manipulation is required to fit it within a confined space, care must be taken to ensure that the minimum bend radius is not less than that specified. Flexible metallic assemblies comprise thin-section, highly-stressed metal components and it is imperative that they are not stressed beyond their elastic limits.

10.6.1 Union nuts at the end fittings should be hand-tightened at both ends and the hose should lie in a natural manner before the union nuts are finally tightened. Due to its construction, metallic hose will always tend to lie in its natural manner, but care is required to ensure that no twist is applied to the hose during final tightening.

(a) Where provision is made for the use of two spanners, one on the end fitting and one on the union nut, a spanner should always be used on the end fitting to steady the assembly and prevent twisting of the hose on final tightening.

(b) Where no provision is made for the use of a spanner on the end fitting, the hose should be firmly gripped by hand as near the end fitting as possible while the union nut is finally tightened.

(c) After tightening of the union nuts, a hose assembly should always be checked to ensure freedom from twist and tension. It must also be ensured that the end fittings are relieved of the weight of the hose and its contents by suitable supports.

(d) Thread lubricants should only be used if specified on the appropriate drawing or in the relevant manual (see paragraph 6.4).

10.6.2 **Flanges.** In the case of assemblies incorporating 'Vee' band flanges, the correct type of 'O' ring should be carefully positioned in the flange groove, and the inner flange brought into alignment before placing the clamping device in position. This type of flange is produced both with and without means of positive lateral positioning —in the former case care must be exercised in engaging the spigot portion provided for the purpose.

10.6.3 **Supports.** Support clips, which may be either of the close-fitting type and support the hose positively, or of the loose guide type which will allow movement of the hose while containing it in a specific space, must be placed as prescribed on the appropriate drawing.

NOTE: Wire locking of union nuts should be made in the approved manner as described in Leaflet BL/6-13.

10.6.4 **Bonding.** After installation, a bonding check should be made between the assembly end fittings and between the end fittings and the components to which they are connected. The resistance should not exceed 0·050 ohm.

10.7 **Inspection.** When carrying out a visual inspection of flexible metallic hose assemblies installed on an aircraft, any of the following would be cause for rejection:—

(a) Signs of distortion or damage of the wire braiding, or of the braiding being pulled away from end fittings.

(b) Leakage around end fittings.

NOTE: The hose should also be examined for signs of leakage at the lowest points in its run.

(c) Abrasion of the hose caused by contact with adjacent components.

(d) Signs of twisting of the assembly, generally visible as a distortion of the regular pattern of the overbraid in a helical direction.

(e) Corrosion of the external surfaces of the hose end fittings.

(f) Visible cracks or other damage pertaining to the end fittings.

NOTE: When hose assemblies are adjacent to the power plant, a careful examination should be made for any discoloration caused by hot gas leaks which may occur at the shroud ring, exhaust cone or other parts of the engine.

10.7.1 Assemblies should be removed for detailed examination at the periods stated in the Maintenance Schedule or at any time the hose assembly becomes suspect. They should be immersed in a clean non-chlorinated solvent and thoroughly agitated to loosen any oils or deposits on internal and external surfaces and to assist in flushing any deposits clear of the convoluted bore and other parts such as elbow fittings, etc. After cleaning, the assemblies should be inspected as indicated in (a) to (f).

NOTE: It is important not to use any form of internal brushing such as the type used for rifle or tube bore cleaning, as this may cause damage to the inner diameter of the convolutions when the rod or brush is pushed into the bore.

(a) Examine the end fittings for corrosion and damage.

(b) Examine all welded or brazed joints for damage, cracks or corrosion.

(c) Examine all threads for wear.

(d) Check that all mating surfaces (nipple faces) are undamaged.

(e) Examine the wire braid for chafing, dents, and for looseness at end fittings.

(f) Examine the hose for corrosion and discolouration due to overheating.

10.7.2 **Testing.** Assemblies which are considered satisfactory after examination as above should be pressure tested at room temperature using the following procedure:—

(a) Lay the assembly in a free position on a bench, and couple it to a controlled pressure supply of a suitable test fluid, as defined by either manufacturer's requirements or hose usage. After washing through thoroughly, blank off the open end of the assembly. Unless otherwise stated on the appropriate drawing or in the relevant manual, it is usual to pressurise to $1\frac{1}{2}$ times the system maximum working pressure. When the correct pressure has been reached, the pressure supply should be cut off, and there should be no indication of a drop on the pressure gauge after a period of five minutes.

(b) If the hose assembly is part of a pneumatic or air conditioning system, it should be connected to a suitably controlled pressure supply of clean dry air, and immersed in clean water or other suitable liquid at a temperature of about 26°C. Air pressure should be applied slowly up to $1\frac{1}{2}$ times the maximum working pressure of the system in which the assembly is used. The pressure should be maintained for five minutes and the assembly checked for any signs of bubbles indicating a leak.

NOTES: (1) Water at this temperature assists in the dispersion of any air bubbles trapped under the wire braiding, but the assembly should also be agitated.

(2) In the case of hose assemblies with mechanically-attached end fittings, no attempt must be made to seal off a leak by further tightening of the fitting.

(c) **Pressure Test Observations.** During operation (a) and (b) above, the assembly should be checked for the following:—

(i) Signs of leakage.

(ii) Tube distortion under pressure.

(iii) Movement of the wire braiding adjacent to its attachment to the end fittings.

(d) After the assembly has been uncoupled from the test rig and allowed to remain unconfined for at least one hour, a length check should be made with reference to the length tolerances given on the appropriate drawing or in the relevant manual. There may be a slight elongation, but if this is beyond acceptable limits, the assembly should be rejected and returned for investigation to the manufacturing organisation concerned.

(e) **Ball Test.** A ball test should be carried out as detailed in paragraph 9.4.2 (a), but where this is not possible a flow test should be made in accordance with the design requirements for the particular hose.

(f) **Drying.** To avoid corrosion, assemblies which have undergone the tests mentioned in this paragraph (10.7.2) must be thoroughly dried by placing them in a forced-draught, hot-air oven for 30 minutes with the air temperature controlled at 100°C to 105°C, and the longitudinal axes of the hoses in line with the air flow. However, if paraffin was used as the pressure testing medium, it is sufficient to vibrate and drain the hoses until dry.

(g) **Test Identification.** Upon completion of testing, a further identification band or tag should be affixed to the assembly bearing the date of test and the inspection stamp. It is also recommended that an appropriate reference be made in the log book or other records.

Issue 1.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

INSTALLATION AND MAINTENANCE OF RIGID PIPES

1 INTRODUCTION This Leaflet gives guidance on the installation and maintenance of rigid pipes in aircraft, and should be read in conjunction with the relevant manuals and the installation drawings for the aircraft concerned.

1.1 Guidance on the manufacture of rigid pipes is given in Leaflet **BL/6–15**, and on the installation and maintenance of hose and hose assemblies in **AL/3–13**. Additional information on hydraulic systems, pneumatic systems, pitot-static systems, thermal de-icing systems and fuel systems, is given in Leaflets **AL/3–21**, **AL/3–22**, **AL/10–1**, **AL/11–2** and **AL/3–17** respectively.

1.2 Information on the identification marking of system pipes is given in British Standard M23, entitled "Identification Scheme for Aircraft Pipe Lines".

NOTE: This Leaflet incorporates the relevant information previously published in Leaflet ML/3-2, Issue 2, dated 15th February, 1961.

2 GENERAL Certain requirements are general to the installation of all types of fluid systems, e.g. the need to avoid 'U' bends, the relief of pressure which may increase as the result of a temperature rise, the isolation of fuel pipes in certain areas and the need to reduce the possibility of incorrect assembly. All these factors are taken into consideration in the design of a fluid system, but maintenance personnel should also be thoroughly acquainted with the system on which they are working and aware of the problems associated with rigid pipes and their connections, so that any necessary inspection, maintenance or repair, can be carried out in a satisfactory manner.

2.1 Since fluid systems vary widely in purpose and design, it is essential that any work on a particular system is carried out strictly in accordance with the relevant Maintenance Manual.

3 INSTALLATION OF RIGID PIPES

3.1 **Pre-installation Checks.** Before a pipe assembly is fitted into an aircraft, it should be checked to establish that it is of the specified type and that there is evidence of prior inspection and testing. The inspector's stamp should normally appear adjacent to the part number.

3.1.1 A pipe should be inspected for damage to the pipe itself, the end fittings and the protective treatment, for correct forming of the flared ends (or correct preset on flareless couplings), and for signs of external corrosion. If damage or deformation is suspected the pipe should be pressure tested or the roundness of the bore checked (as applicable) as outlined in Leaflet **BL/6–15**. Such checks are extremely important, since dented or otherwise damaged pipes may cause a restriction to fluid flow which could have serious consequences. Where permitted in the Maintenance Manual, light external corrosion may be blended out and the protective treatment re-applied. Internal or deep corrosion would be causes of rejection of the assembly.

3.1.2 Dirt, swarf, dust, etc., introduced by fitting pipes which have not been adequately cleaned, may not only affect the various services of which the pipe system forms a part, but may increase the wear of the various components in the system and thus cause a malfunction. It is of the utmost importance, therefore, that adequate precautions are taken at all times to ensure the scrupulous cleanliness of individual pipes and the complete pipe system. Prior to assembly, all pipes should be blown out with clean, dry air and, where applicable, flushed with clean, filtered fluid of the type to be used in the particular system in which the pipes are to be installed. For pipes used in oxygen systems an additional approved degreasing process should also be used, since oil or grease in contact with oxygen under pressure may cause an explosion.

3.1.3 If a pipe is not to be installed immediately, its ends should be blanked following pre-installation inspection and tests, using the blanks fitted during storage or suitable alternatives. Plugs and blanks to standard specification are generally suitable for this purpose, but in instances where standard blanks cannot be fitted it must be ensured that the blank used is so made that it cannot be left in position when the pipe is installed. Rag, tape or paper should not be used for blanking purposes.

3.2 **Installation.** When transporting or carrying pipe assemblies, or moving them into position on the aircraft, care should be taken, particularly with long pipes of small diameter, not to damage them and to support them adequately so as to prevent distortion and kinking. Pipes should be loosely fitted into position in the supporting clamps (paragraph 3.2.1) and adjusted so that the connections meet correctly (paragraph 3.2.2). The connections should be completed, the clamps tightened and bonding attached as specified.

3.2.1 **Pipe Supports**

(a) Multiple pipe clamps are used to support groups of pipes running adjacent to one another. These clamps are often made of red fibre, aluminium alloy, moulded rubber, nylon or other materials. The two halves of the clamps are usually joined together by bolts, which also serve to secure them to the aircraft structure. It is important to ensure that the semi-circular recesses in each half of a clamp mate correctly, do not have sharp edges and are of the correct size for the pipes they support.

(b) In instances where packing is required between the pipes and clamps, the material used should be that specified in the relevant manual or drawing. Typical packing materials are cork sheet, tinned copper or stainless steel gauze and various types of tape or low-friction liners, but leather should not be used since it may cause corrosion of the pipes.

(c) To ensure electrical continuity, some pipe clamps are self-bonding, but in other cases the use of metal gauze between the pipes and clamp may be specified. Bonding strips which bridge pipe connections are often used and should be assembled as specified in the relevant manual or drawing.

(d) Where individual pipes require support, standard clips are usually specified and usually have a moulded rubber lining which obviates the need for packing. Where individual pipes run close together a double type of 'P' clip is often used to avoid contact between the pipes and to provide support.

(e) A minimum clearance of 6 mm (0·25 in) from fixed structure, of 18 mm (0·75 in) from control ro [illegible] moving parts, and of 25 mm (1·0 in) from control cables, must b [illegible] ovement may cause chafing. Particu [illegible] te clearance is maintained between [illegible] carried out to ensure that clearance [illegible] of movement of the associated part. [illegible] cts which it may not be possible to s [illegible] r due to centrifugal force, or in width due to ageing.

3.2.2 Connection of Pipes

(a) When connecting pipes with standard brazed, flared or flareless couplings the following points should be verified:—

(i) That union nuts rotate freely, and can be withdrawn from the pipe end without being impeded by bends or other obstructions.

(ii) That all loose parts such as nipples, non-metallic glands, washers, etc., which form part of the coupling, are of the correct type and are correctly located.

(iii) That the pipe ends align correctly with their mating parts. Pipes should never be forced into position, since this may introduce considerable stress into the connection, and result in subsequent leakage or fatigue damage.

(iv) That the pipes are not drawn into position by their union nuts, since this would impose a strain on the flare of a flared coupling or the sleeve of a flareless coupling, and cause deformation of the pipe.

(b) With pipes which have the compressed rubber gland type of coupling, the pipe end must be hard against the shoulder of the recess in the union adaptor before any attempt is made to tighten the union nut.

(c) Where flexible hose is used to connect rigid pipes, it is essential that the correct type of hose is used, since some may not be compatible with the system fluid.

(i) It should be ensured that all sharp edges have been removed from the pipe ends, and that, where specified, the pipe ends have been protected against corrosion.

(ii) A gap of 6 to 12 mm (0·25 to 0·5 in) should exist between the pipes to prevent contact when flexing occurs.

(iii) Hose clips should be of the correct size and type, and should provide an adequate degree of adjustment for subsequent tightening. Care should be taken to ensure that clips are fitted on the side of the beading remote from the pipe ends, and are accessible when all other systems have been installed.

(iv) If a hose proves difficult to assemble, it may usually be lubricated by system fluid. Care must be taken to ensure that pieces of hose are not cut or broken off during assembly and left in the pipe bore.

(d) Two spanners should always be used when tightening (or disconnecting) a pipe coupling; one to hold the sleeve or adaptor and one to turn the union nut. Overtightening should be avoided since many standard pipe couplings are made of aluminium alloy, which can easily be strained. Any special tightening techniques or tightening torque values specified in the relevant publication should be carefully observed.

(e) If lubrication of threads is specified to avoid 'pick-up', it is essential that the correct lubricant is used and that it does not enter the bore of the pipe. This is particularly important with couplings used in oxygen systems, where dry film lubricants requiring special application procedures are usually specified.

4 TESTS AFTER INSTALLATION All pipes will have been pressure tested following manufacture, but it is usually necessary to carry out pressure and flow tests after installation of a pipe, to ensure that there are no leaks from the pipe and its connections and that, where essential to the correct operation of the associated system, the required flow rate is obtained.

4.1 Power for carrying out the tests may be provided by the aircraft engine-driven pumps or by an external test rig suitable for the system concerned. The tests should be carried out strictly in accordance with the relevant Maintenance Manual. Guidance on typical procedures is also given in the appropriate CAIP Leaflets. Special note should also be taken of any precautions specified for the safety of personnel or the prevention of damage to the aircraft or its systems.

4.2 While the associated system is pressurised, and while the services are being operated, the pipelines should be inspected for flexing or displacement to ensure that the required clearances are maintained. The pipe supports should also be checked for security of attachment and the pipes for local distortion at the clamping points.

4.3 Leakage from pipes in liquid systems (e.g. hydraulic systems) can usually be detected by careful visual inspection, and leakage from gas systems (e.g. pneumatic systems) can usually be detected aurally or, after painting the pipes and connections with a solution of water and acid-free soap, be detected by the appearance of bubbles. If the soap solution is used it should be washed off immediately after the test.

4.4 If leakage from a connection is apparent, the connection may be tightened, but should not be over-tightened in an attempt to cure the leak. Leaks are often caused by solid particles at the mating faces of a joint, by misalignment of a nipple, or by damage to one of the components in the joint. Loosening and re-tightening of a coupling will often cure a leak but if it does not do so, the coupling should be disconnected and the cause of the leakage ascertained.

4.5 After all tests have been completed satisfactorily, it is important to ensure that any liquid which may have leaked or been spilled on the airframe structure or components, is removed. In addition to any fire hazard, aircraft liquids may also have deleterious effects on some of the alloys and compounds with which they come into contact.

4.6 When the work of installing and testing a pipe is complete, the connections should, where applicable, be locked in the appropriate manner (see Leaflet **BL/6-13**).

5 MAINTENANCE OF RIGID PIPES The maintenance of these components should be in accordance with the relevant Maintenance Manual, but the factors outlined in paragraphs 5.1 to 5.5 should be taken into account.

5.1 General

5.1.1 Pipes which are attached to the structure of an airframe may often be in a shielded position and will not normally be subject to accidental damage, but other pipes are located in exposed positions where they may be highly susceptible to damage or corrosion. Pipes located in a wheel bay, or attached to an undercarriage leg, could easily be damaged by stones, mud or detached rubber thrown up from the tyres or corroded by regular contact with water. In other positions pipes may be subject to abuse from carelessly performed, unrelated servicing activities. Special care must, therefore, be taken when inspecting pipes in exposed locations.

5.1.2 Chafing may occur under pipe clamps and clips, particularly where vibration is present. Pipes which have sharp bends and which are subject to high pressure pulsations tend to develop an oval section at the bend, which may eventually develop into a crack. The possibility of damage from both these causes should be considered when inspecting pipes in any location.

5.2 **Leaks.** The presence of a leak from a pipe connection in a liquid system will often be shown by the presence of liquid or an accumulation of dust or dirt on the outside of the pipe or connection. Leakage from a gas system may only be detected by the loss of system pressure, but the position of the leak may usually be detected as outlined in paragraph 4.3. The actions described in paragraph 4.4 should be taken to cure a leak, but if these are not effective the pipe assembly should be renewed.

5.3 **Damage.** Reference should be made to the relevant Maintenance Manual when assessing damage, since the acceptability may vary with particular materials and particular systems.

5.4 **Corrosion.** Corrosion may affect pipes of any material, particularly in exposed locations and in the areas of clips and supports, where moisture may be trapped. Corrosion products should be removed and the depth of any pits should be checked (see Leaflet BL/4-2). Pipes which have corroded areas which cannot be blended out within the limits specified in the relevant Maintenance Manual should be renewed. If the corrosion can be removed satisfactorily, protective treatment should be re-applied to the affected areas.

5.5 **Rubber Hose Couplings.** Rubber hose couplings can be affected by expansion, contraction, vibration and heat, and should be inspected regularly for deterioration and freedom from oil and grease. When couplings are removed from pipe ends it is essential that damage to the pipe be avoided; if the hose is stuck to the pipe it should be carefully cut axially with a sharp knife and peeled off.

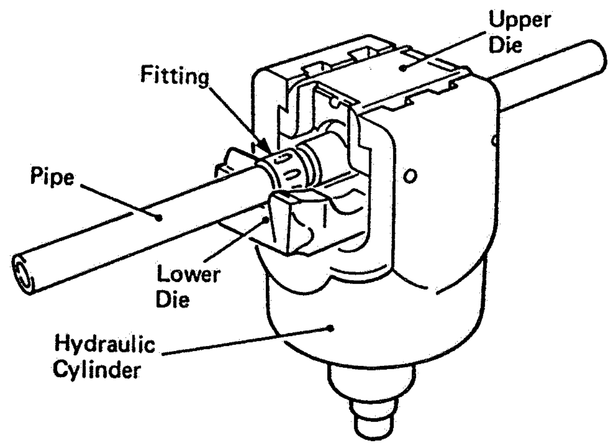
5.5.1 Hose clips have a tendency to loosen subsequent to initial installation, due to compression of the rubber, and may need to be re-tightened when they have been in service for a short period.

6 REPAIR OF RIGID PIPES Damage to rigid pipes which is outside the specified limits for acceptable damage, will usually necessitate the removal of the affected pipe and the fitting of a new or reconditioned item. However, in some cases repairs may be permitted, either by the insertion of a new portion of pipe or by the insertion of a coupling, depending on the extent of the damage. After repairs, the inspections and tests detailed in paragraph 4 should be carried out.

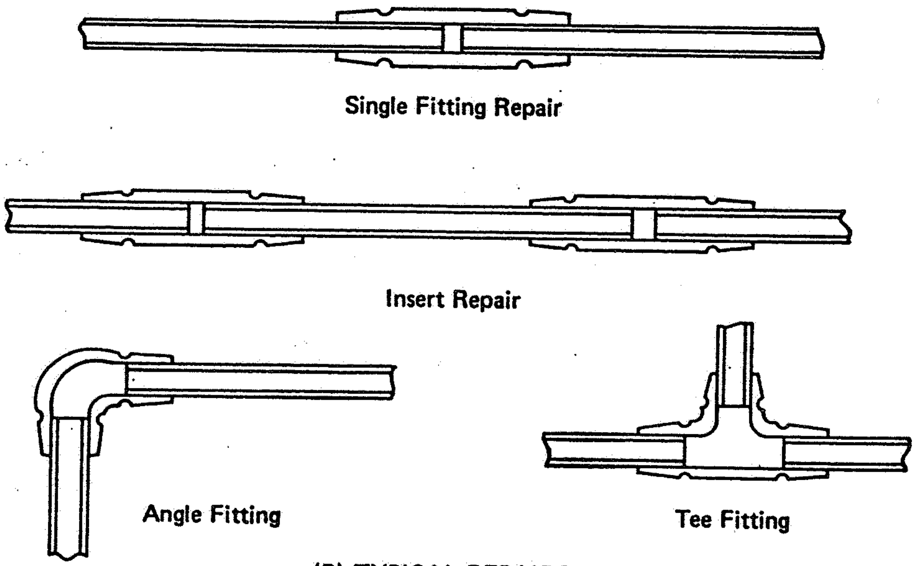
6.1 **Repairs using Standard Couplings.** These repairs will normally involve removal of the damaged pipe, since the pipe ends will have to be flared or flareless couplings fitted, and will usually be applied only to straight sections of pipe. However, the addition of a pipe coupling could change the resonant frequency of that portion of pipe, and this could lead to vibration and fatigue; these repairs should thus only be used when specified in the relevant Maintenance Manual.

6.1.1 A circumferential crack or deep score may be repaired by cutting out the small damaged section of pipe and inserting a union body and two connections. Care should be taken to ensure that the final length of pipe is correct and that the couplings will not foul parts of the structure when installed. The pipes should be thoroughly cleaned after preparation of the ends, and pressure tested before re-installation.

6.1.2 If the damage is in excess of that which could be repaired as outlined in paragraph 6.1.1, the damaged portion of pipe should be cut out and a new section inserted, using two new union bodies and connections, or, if the damaged portion includes one existing end fitting, by replacing that fitting and joining the new section to the old with a union body and two connections. The precautions outlined in paragraph 6.1.1 should also be observed.



(A) HYDRAULICALLY-OPERATED SWAGING TOOL



(B) TYPICAL REPAIRS

Figure 1 TOOLS AND TYPICAL REPAIRS FOR EXTERNAL SWAGING PROCESS

6.2 **Repairs Using Swaged Fittings.** Some manufacturers specify the use of swaged fittings for carrying out in situ repairs to pipelines. Full details of the processes and of the type of swaged fittings to be used in a particular case are given in the relevant Maintenance Manual, and all repairs should be carried out strictly in accordance with those instructions.

6.2.1 **External Swaging Process.** The damage which can be repaired by this process is broadly as outlined in paragraphs 6.1.1 and 6.1.2, and the repair consists of a tubular fitting which is swaged over a pipe joint. The gap between the pipe ends can be up to 8 mm (0·3 in), thus permitting a degree of latitude when replacing a damaged portion of pipe. Typical repairs are illustrated in Figure 1.

(a) The equipment necessary for carrying out externally swaged repairs is available in three kits, each covering a range of pipe diameters and comprising a hydraulically operated swaging tool with pairs of dies to cover the range of pipe diameters, a ratchet pipe cutter and a deburring tool. Various marking gauges are also provided to enable fittings to be correctly positioned, and GO/NO GO gauges enable checking of the swaging operation to be carried out.

(b) The method of operation of the process is briefly as follows:—

(i) Release pipe supports sufficiently to enable the repair to be carried out.

(ii) Select the repair kit appropriate to the pipe diameter.

(iii) Fit and operate the ratchet cutter to remove the damaged portion of pipe.

(iv) Using the deburring tool (which incorporates a rubber plug to prevent swarf being trapped in the pipe), remove the burrs and chamfer the pipe ends.

(v) Clean the pipe ends, then, using the appropriate gauge, mark the pipe so that the swage fitting can be correctly located.

(vi) Select and fit the appropriate fitting and position it over the ends of the pipes being joined.

(vii) Select the appropriate dies, fit them to the swaging tool, position the tool over the fitting and operate the tool in accordance with the manufacturer's instructions to complete the swaging operation.

(viii) Remove the swaging tool and dies, and visually inspect the fitting for cracks. Check that the swaging operation is satisfactory by use of the GO/NO GO checking gauge provided.

6.2.2 **Internal Swaging Process.** The components used in this process are a male externally threaded fitting and a female fitting with either a separate or an attached union nut. This process can be used for repairing the type of damage outlined in paragraphs 6.1.1 and 6.1.2, or for repairing leaking or damaged couplings, using a special repair fitting with an extended barrel. The tools used, and some typical repairs, are illustrated in Figure 2.

(a) Swaging equipment is provided for each pipe diameter and wall thickness, and consists of an expander, a die set, a holding collar and a set ring for checking the expander setting.

(b) The method of operation of the process is briefly as follows:—

(i) Release the pipe supports sufficiently to enable the repair to be carried out.

(ii) Remove the damaged portion of the pipe using a chipless cutter, then deburr the pipe ends using the tool provided. Clean the pipe ends.

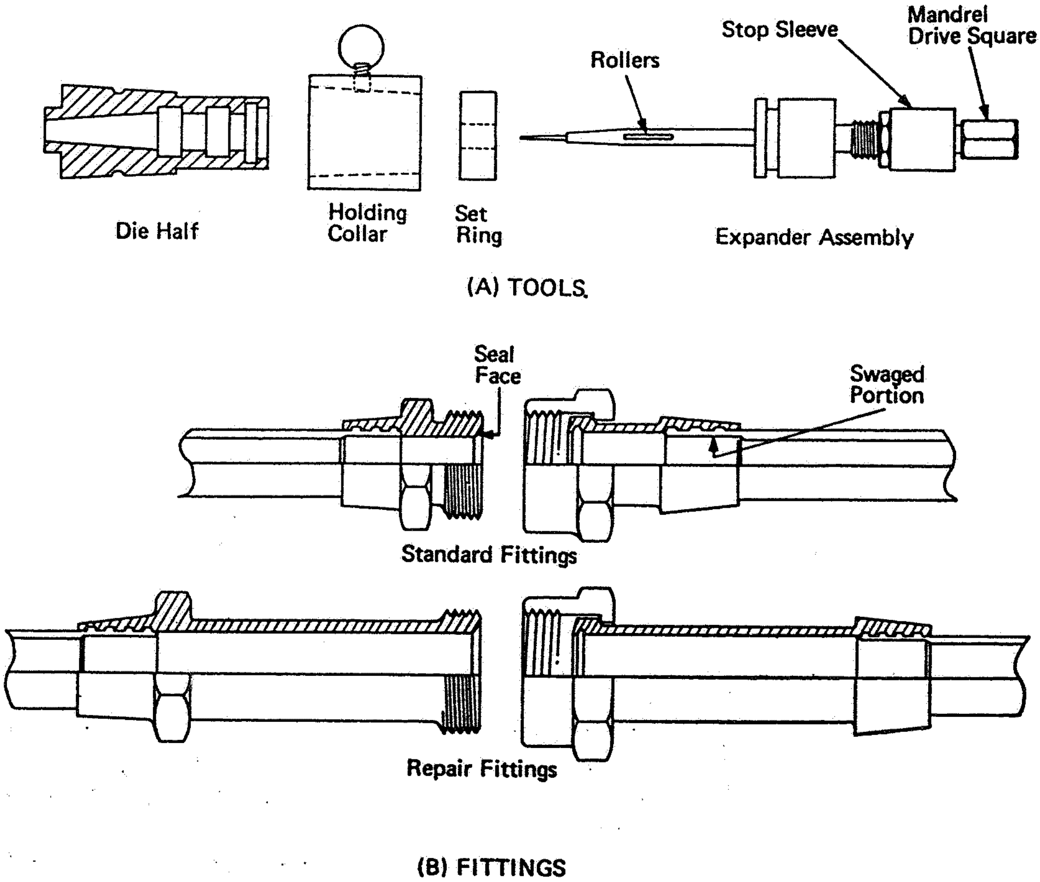


Figure 2 TOOLS AND TYPICAL REPAIRS FOR INTERNAL SWAGING PROCESS

(iii) Select the appropriate tools, check the fit of the holding collar and die set, and check the setting of the expander with the associated set ring.

(iv) Position the pipe in the fitting and ensure that it butts against the fitting shoulder. Mark the pipe at the end of the fitting for future reference (see 6.2.2 (b) (ix)).

(v) Insert the expander into the pipe with the mandrel retracted and place the assembly in one die half. Push in the mandrel until it stops, then rotate it until finger tight.

(vi) Fit the other die half and secure with the holding collar.

(vii) Rotate the mandrel with a wrench or rotary tool until the mandrel contacts the stop sleeve, then rotate it a further 10 turns to complete the swaging operation.

(viii) Loosen the mandrel and remove the swaging tools from the pipe.

(ix) Visually inspect the fitting for damage and check the marking on the pipe to ensure that the fitting is correctly positioned. Measure the internal diameter of the swaged portion of the pipe to ensure that it is within the tolerance specified in the relevant manual.

AL/3-15

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AIRCRAFT

SYSTEMS AND EQUIPMENT

TANKS

1 INTRODUCTION This Leaflet gives guidance on the construction, installation, and maintenance of the various types of tanks used in aircraft systems. This Leaflet should be read in conjunction with the relevant Maintenance Manual and approved Maintenance Schedule for the aircraft concerned.

1.1 The Civil Aviation Authority's requirements applicable to tanks are prescribed in British Civil Airworthiness Requirements; the requirements for fuel tanks are in **Section D**, Chapter **D5-2, Section** G, Chapter **G5-2**, and **Section K**, Chapter **K5-2**, respectively, and those for oil tanks, are in **Section D**, Chapter **D5-3, Section G**, Chapter **G5-3**, and **Section K**, Chapter **K5-3**, respectively.

1.2 The following Leaflets contain information on related subjects, and should be referred to as appropriate:—

BL/1-6	Stores and Approved Release
BL/4-1	Corrosion - Its Nature and Control
BL/4-2	Corrosion - Removal and Rectification
BL/4-3	Corrosion - Methods of Protection
BL/6-4	Oxy-acetylene Welding
BL/6-5	Arc Welding
BL/6-8	De-greasing - Trichloroethylene
BL/6-16	Resistance Welding - Seam Welding Procedure
BL/6-29	Riveting
AL/3-8	Fire - General Precautions
AL/3-17	Fuel Systems
AL/3-21	Hydraulic Systems
EEL/1-6	Bonding and Circuit Testing

NOTE: This Leaflet incorporates the relevant information previously published in Leaflet ML/3-3, Issue 2, dated 15th February, 1961.

2 GENERAL There are three types of tanks in use; rigid or shell tanks, flexible tanks, and integral tanks (tanks which are formed by sealing part of the structure). Rigid tanks are generally used for oil, de-icing fluid, hydraulic fluid, water, and, in some cases, fuel, whilst flexible and integral tanks are used almost exclusively for fuel, so as to make full use of the available space, and to save weight. The construction, installation and maintenance procedures peculiar to each type of tank, are described separately in paragraphs 3, 4 and 5, and the procedures common to all types are described in paragraphs 6 and 7.

3 RIGID TANKS Rigid tanks are normally used in engine oil systems, water systems, and the fuel systems of some light aircraft. Tanks which are contained within the airframe structure are generally manufactured from aluminium alloy, and may be either riveted or welded. Some tanks, such as coolant header tanks, may be constructed from sheet brass or similar alloy, and others, which have to withstand high temperatures or corrosive fluids, may be made from stainless steel. External fuel tanks are sometimes made from non-metallic materials such as glass fibre.

3.1 **Installation.** Rigid tanks are often mounted on suitably shaped bearers, and secured by means of padded metal straps, which are joined and tightened by turnbuckles. On some wing fuel tanks, however, the lower surface of the tank is also the wing skin, and is secured to the surrounding structure by screws. In instances where the tank skin or the tank bay closing panel provides a load-bearing surface, the wing must be suitably supported before the tank is removed, and the supports must remain in position until the tank is re-installed and secured.

3.1.1 Before a tank is installed, the tank bay should be examined for cleanliness, damage and corrosion, and to ensure that there are no projections such as bolts, screws, or fasteners, which could chafe or damage the tank when it is in position. Any rectification necessary should be carried out, and protective treatment should be applied and allowed to dry. The tank bay area should then be thoroughly cleaned, fuel pipe and vent connections should be prepared to receive the tank, and electrical power to any tank connections should be isolated. Blanks fitted to the pipes should be left in position as long as possible, in order to prevent the ingress of foreign matter and moisture.

3.1.2 The tank which is to be fitted should be inspected for damage, all traces of inhibitor should be removed from it, and any components required for the tank, such as contents transmitters and booster pumps, should be installed in accordance with the appropriate Maintenance Manual. Any filters should be inspected for cleanliness and security, and the filler cap, where fitted, should be checked for effective sealing. Vents should be checked to ensure they are properly connected and unblocked. All fittings should be locked in the appropriate manner.

3.1.3 Care is necessary when installing a tank, since there is often very little clearance between the tank and tank bay, and access holes may permit only a limited view. Careless installation could result in damage to the tank, which may lead to subsequent leakage.

3.1.4 Connections should be made without bending or stretching the pipes, and, when required by the manufacturer, installation alignment tolerances should be checked. The introduction of a low point in a feed or vent pipe run could result in the collection of water at that point, which could lead to a blockage if the water were to freeze.

3.1.5 Straps should be tightened sufficiently to prevent the tank from moving, but over-tightening must be avoided. It is important that all straps are tightened equally, to permit even distribution of strain.

3.1.6 Overboard drain and vent pipes should be checked after tank installation, to ensure they do not discharge in such a manner that combustible fluids could leak into the structure or passenger compartments, and create a fire hazard.

3.1.7 The bonding of tanks which are not connected directly to the structure is most important, and all bonding strips and cords should be securely attached. After installation of the tank, bonding should be checked as described in Leaflet **EEL/1-6**.

3.1.8 The tank should then be filled, while the contents gauge is checked, as described in Leaflet **AL/10-3**, and the tank should be inspected for leaks.

3.2 **Inspection**

3.2.1 **Installed Tanks.** All applicable panels in the aircraft skin adjacent to the tank should be removed, and the tank should be inspected for security, correct adjustment of straps and slings, contamination, corrosion, superficial damage, cleanliness, chafing, distortion, and evidence of leakage from pipe connections, drains, and the tank itself. Leakage from connections may often be corrected in situ, by draining the tank and re-making the connection, but a damaged tank must, in most cases, be removed for repair.

3.2.2 **Removed Tanks.** Tanks must be drained before being removed for inspection, and other associated tanks should be isolated by means of their supply cocks, so that only the tank being removed is drained. Vent pipes must be clear, to prevent the tank from collapsing as the fuel drains out. When necessary (see paragraph 3.1), the wing structure should be supported, access covers should be removed, pipes and vents should be disconnected and blanked, and electrical services should be isolated and disconnected. The tank should be released from its mountings, then carefully removed, and laid in a suitable cradle. The tank should then be thoroughly flushed and cleaned to remove all traces of fluid, sediment and gummy substances, and the following inspections should be carried out as appropriate:—

(a) The external surfaces of the tank should be examined for evidence of leakage and corrosion, and for any other damage which may have resulted from factors such as chafing, vibration, and incorrect adjustment of mounting straps.

(b) The condition and security of all pipe adaptors, anchor nuts, and external fittings should be checked.

(c) The internal surfaces of the tank should be examined for defects such as corrosion, contamination, and, where applicable, the looseness or flaking of the internal protective treatment. All internal fittings, such as pumps, baffles, and de-aerating devices, should be examined for security, damage and corrosion

3.3 **Repairs.** Leakage from the joint surfaces of components and access panels may usually be cured by renewing gaskets or sealant, as appropriate. When the tank itself is leaking, the method by which it should be repaired will depend on its mode of construction.

3.3.1 Tanks which are constructed by riveting are normally repaired from inside. Small tanks are sealed by 'slushing' with an approved sealant, and large tanks are usually provided with access holes of sufficient size to permit entry into the tank and to facilitate the application of sealant to particular areas. The affected areas must be thoroughly degreased, and the sealant must be mixed and applied strictly in accordance with the manufacturer's instructions.

3.3.2 Welded tanks may usually be repaired by argon arc or gas welding. All traces of combustible fluid must be removed before welding is commenced, by flowing steam or water through the tank for approximately 1 hour, then drying with warm air. During welding, the use of 'dry ice', as a depressant to combustion, is often recommended (see also paragraph 7 for additional safety precautions). After welding, all traces of flux must be removed from the tank, in accordance with the manufacturer's instructions.

3.3.3 Tanks which are constructed from glass fibre may usually be repaired by replacing the damaged material. These repairs should be carried out strictly in accordance with the manufacturer's instructions, and by persons who have received proper training.

3.3.4 Tanks should be pressure tested after repairs have been carried out (see paragraph 6), and should be re-painted as necessary.

4 FLEXIBLE TANKS Flexible tanks are manufactured from rubber or plastics sheet, which is reinforced with nylon or fabric. They are tailored to fit a particular location in the wing or fuselage, and are supported by means of buttons or cords, to ensure that they maintain their shape and enable accurate contents indications to be obtained. Filler necks, pumps, vents, feed pipes and contents units, are each connected to the tank by means of a moulding at the tank aperture; the moulding being squeezed between an internal and external fitting. A controlled compression joint is often used, to prevent damage to the moulding through overtightening of the attachment bolts.

4.1 **Installation.** Tank bays for flexible tanks are designed with smooth, flat surfaces, to provide maximum support for the tank. Any projections, such as rivet heads or skin joints, are covered with tape or rubber strip, to prevent chafing of the outer surface of the tank. Before a tank is installed, the tank bay should be inspected to ensure that the protective strips are secure, that the tank bay is free from foreign objects, rags, etc., and that there are no projections or loose swarf likely to damage the tank.

4.1.1 A flexible tank should always be inspected before installation, to ensure that no damage has been sustained during transit, or through faulty storage. If damage is found, it must be repaired in accordance with the appropriate Manual, before the tank is installed. It is important also to check any life limitations before installation.

4.1.2 The tank must, generally, be folded in the manner prescribed in the appropriate Maintenance Manual, and inserted into the tank bay through an access hole; in some cases, a manhole large enough to permit entry into the tank is provided, to facilitate both installation and internal repairs. The edges of the access hole should be padded, in order to prevent damage to the tank, and, after the tank has been inserted, it should be carefully unfolded and slid into position. The use of french chalk is often recommended to assist in moving the tank into position.

NOTE: To ensure that the tank is sufficiently flexible, some manufacturers specify a minimum temperature for installation and removal.

4.1.3 When the tank fittings have been positioned, the tank securing studs or cord should be attached, using an approved lubricant to ease installation, and the tank walls should be smoothed out to eliminate creases. Where entry into the tank is necessary, soft, rubber-soled canvas shoes must be worn, and a protective rubber mat should be laid on the floor of the tank.

4.1.4 All internal fittings should then be secured, care being taken not to overtighten the attachment bolts. All servicing equipment should be removed, and the tank should be thoroughly cleaned.

4.1.5 External fittings should then be attached, and the access hole covers and manhole cover should be replaced.

4.1.6 When installation of the tank is complete, vent and drain pipes should be checked for positioning, and a bonding test should be carried out as described for rigid tanks. The tank should then be filled while the contents gauge is checked, as described in Leaflet **AL/10-3**, and the tank should be inspected for leaks.

4.2 **Inspection.** It is generally only possible to make a superficial examination of a tank after it has been installed in an aircraft, since only small parts of the external surface will be visible. With all adjacent skin panels removed all visible parts of the tank and the tank bay should be inspected for damage and damp patches. External connections should be examined for leakage. The inside of the tank should be inspected for damage, corrosion of any metal fittings, contamination, and deterioration of the lining. This inspection should be carried out using a mirror and flame-proof lamp inserted through the filler orifice or other suitable aperture. Whenever a thorough examination is required removal of the tank is usually specified in the approved Maintenance Schedule.

4.2.1 In order to remove the tank for inspection, it should be drained, and all external pipes should be disconnected and blanked. The manholes and handholes which are attached to the aircraft structure, and any items, such as booster pumps, which may hinder withdrawal of the tank, should be removed. After checking that the tank interior is free from loose articles and debris, the tank fastenings should be released, and the tank should be folded in a prescribed manner, and carefully withdrawn through the access hole. Handling straps are sometimes provided to assist in withdrawal, but external fittings must not be used as handles. Some tanks are too inflexible to be folded, and in these cases the access is sufficiently large to permit withdrawal without folding. Any sharp edges or projections should be padded prior to withdrawal of the tank, in order to prevent damage to the exterior surface. When removed, the tank should be laid on a rubber sheet, ready for inspection.

4.2.2 Any fuel which may be on the outside of the tank should be wiped off, and the following external inspections should be carried out:—

(a) Examine the tank for cuts, punctures, chafing, lifting of seams, and security of fittings.

(b) Examine all metal fittings, for security, corrosion, and evidence of leakage.

(c) Examine the tank for stains, and check whether they are the result of fuel leakage.

NOTE: A damp patch on the tank surface may not necessarily mean that the tank itself is leaking. Fuel may have leaked from, for example, a pipe connection, and have drained into the tank bay. If the tank appears to be satisfactory after it has been removed, a check should be made for leaks elsewhere in the system.

4.2.3 All inspection covers must be removed, and the tank must be freed from fuel vapour, before an internal inspection is carried out. The safety precautions detailed in paragraph 7 must be implemented, and the following inspections should be carried out:—

(a) Examine all joints, seams, and reinforcing patches, for lifting, and for signs of bubbles resulting from lack of adhesion of the lining.

(b) Examine the lining for creases, and for deterioration resulting from exposure to air.

(c) Examine any baffles or supporting pillars which may be fitted, for security and buckling.

(d) Examine all internal fittings for security, damage, corrosion and contamination.

4.2.4 Any damage, lack of adhesion, or bubbles, which are likely to result in leakage, should be repaired, and a pressure test should be carried out before the tank is returned to service.

4.3 **Repairs.** The materials used for the repair of a particular tank, will depend on the materials used in its manufacture. Tanks may usually be identified by their overall colour, and by the markings placed on the outside by the manufacturer. These markings indicate the type of construction, thickness of materials used, and any other details relevant to the particular tank; this information is essential for the carrying out of a satisfactory repair in accordance with the Repair Manual.

4.3.1 All damage should be assessed to ensure that it is within the limits permitted for repair. If the damage is outside these limits, the tank should be returned to the manufacturer for overhaul.

4.3.2 There are two methods for repairing flexible tanks. One method involves the use of cold-curing cement and cured patches, sheet, or strips; the other involves the use of repair solution and uncured materials, which are subsequently vulcanised. The materials required, and the methods to be used for a particular repair, will be stated in the relevant Repair Manual. Atmospheric conditions are important to the satisfactory adhesion of the repair; the repair shop should be maintained at a temperature of 15°C to 27°C (60°F to 80°F), and at a humidity of approximately 50%.

4.3.3 A typical repair to a flexible tank, using cold-curing cement, may be carried out as follows.

NOTE: The types of materials to be used, the methods of mixing and applying the cement, and the drying times during repair, must be strictly in accordance with the manufacturer's instructions.

(a) Clean the tank with warm water or gasolene, as recommended by the manufacturer, and dry it thoroughly.

(b) Support the tank around the damaged area, and trim off any loose material. If the damage is in the form of a slit, a hole should be punched at each end to prevent it from elongating.

(c) Prepare patches of repair material. The interior patch should overlap the damage by 50 mm (2 in) all round, and the exterior patch should overlap the damage by 60 mm (2·5 in) all round. For some large repairs, an additional patch of reinforced material is required to cover both internal and external patches, and this additional patch should overlap the larger by 35 mm (1·5 in) all round. The edges of all patches should be skived or feathered.

(d) Roughen the under surface of the exterior patch and the exterior surface of the tank in an area slightly larger than the patch, using an abrasive wheel or fine emery cloth.

(e) Prepare the cement for use. Some cement is supplied in twin-pack form, and the entire contents of both containers must be mixed in order to provide the correct proportions. Once the cement has been mixed, its application life is limited to a few hours. The application life of single part cement is also limited, once the container is opened.

(f) Clean the roughened areas with a lint-free cloth moistened with solvent, and, when dry, apply a coat of cement to the roughened area of the tank and to the inner face of the patch. In some instances a number of coats of cement may be specified, and each coat should be allowed to dry before the next coat is applied.

(g) When the cement has become tacky, centre the patch over the damage and roll it down with a hand roller, taking care to exclude all air. If a hole has been cut in the tank skin, a sheet of cellophane may be placed inside the repair, in order to prevent the patch from sticking to the opposite side of the tank.

(h) Apply the internal patch and, where required, reinforcing patches, as described in (d), (e), (f) and (g).

(j) Paint over the patches with cement and, when this has dried, apply paint or varnish, as appropriate, to the exterior surface of the repair.

(k) The tank should be left for 24 hours before it is handled, and for 72 hours before pressure tests are carried out.

4.3.4 Minor damage affecting only the outer covering, such as chafing and blistering, should be repaired by cementing any loose material, applying a fabric patch over the area, and painting as required.

4.3.5 After repairs have been carried out, the tank should be pressure tested as described in paragraph 6.

4.3.6 When tanks which have been in use for some time are removed for inspection or repair, they tend to shrink slightly on drying out. This shrinkage could cause difficulties in re-fitting, and could cause the tank lining to be strained. Although refuelling the tank will restore it to its original size, some manufacturers treat the tank with a plasticizer during repair and overhaul. This treatment may also be applied by a person carrying out repairs, but it must be carefully controlled and applied strictly in accordance with the manufacturer's instructions. The tank must be treated with plasticizer after repairs and pressure tests have been carried out, and it must be installed and refuelled within eight hours of the treatment.

5 INTEGRAL TANKS Integral tanks are often formed by sealing the whole of the wing torque box during manufacture. Chordal diaphragms both divide the wing into a number of compartments, or tanks, and also prevent surge; external or internal pipes connect the tanks into the fuel system. A number of methods are used for sealing the structure, including the use of sealant as a faying compound between mating surfaces, and the use of a filleting compound at the edges. The interior of the tank is then further protected by tank coatings, which may be applied by slushing, brushing or spraying. Any or all of these methods may be used on a particular aircraft, and may be accompanied by special paint schemes, which are designed to minimise microbiological attack. A suitable number of large access panels, hand holes, and tank connections, are included in the structure at strategic positions; the covers are normally made fuel tight by using seals or sealant at the mating surfaces.

5.1 In some cases, corrosion inhibitor cartridges are fitted in integral tanks. Typically, these cartridges consist of strontium chromate or calcium chromate tablets contained in a linen bag. It is a requirement with such cartridges that the linen bag should be thoroughly wetted with water before installation, and after tank repair operations.

5.2 **Inspection.** At the periods specified in the approved Maintenance Schedule, the fuel tanks should be inspected for leaks, corrosion or damage to internal components, freedom of operation of non-return and anti-surge valves, and microbiological contamination. Particular attention should be paid to areas of stress concentration, and holes which have been formed in the spar webs or structure for the purpose of mounting booster pumps or other heavy components, to ensure that no cracks have developed.

5.2.1 To check for leakage, the tanks should be filled to maximum capacity, and a whitening solution (e.g. dye penetrant developer) should be applied over all joints, rivets, and bolts, which may be likely sources of leaks. After a soaking period (4 to 12 hours), the external surfaces should be inspected for drips, and for any staining of the developer. If leaks are found they should be marked with a soft crayon, and should subsequently be categorized and repaired, as necessary. The developer should be removed with a soft bristle brush, and the tank should be washed off.

5.2.2 Microbiological contamination is more easily visible when it is wet, and, when access is provided in the top skin, the tanks need only be drained sufficiently to permit removal of a suitable hand hole cover. The interior surfaces which are visible through the handhole, should be inspected, using a flame-proof torch, for signs of brown, slimy deposits. This inspection should be carried out, initially, on the tanks which have been found by experience to be the most critical (usually the inboard wing tanks), but, if contamination is found, the remaining tanks must be checked. Any contamination must be removed (see paragraph 8).

5.2.3 An examination for corrosion of internal metallic parts is best carried out when the tanks are empty, so that entry into the tanks may be effected. The safety precautions outlined in paragraph 7 must be observed, and particular care must be taken not to damage the tank sealant. In some large aircraft the tanks must be drained in a prescribed order, or the aircraft must be jacked when individual tanks are drained. The treatment of corrosion in aluminium structures, is described in Leaflet BL/4-2.

5.3 **Removal of Components.** It may be necessary to partially or fully drain a tank to remove a particular component, but some components, such as booster pumps, which require regular attention, are often enclosed within an isolation chamber to eliminate the need for draining. The isolation chamber may be provided with flap valves which, when open, provide free flow from the tank to the component. When it is necessary to remove the component, the chamber is sealed by turning an external screw, which closes the flap valves.

5.3.1 The joint faces of components are normally sealed with sealing rings or gaskets, and these should always be renewed when the components are replaced. The faces should be thoroughly cleaned with a dry, lint free cloth, before making the joint.

5.3.2 Where jointing compound or sealant is specified at joint faces, it should be applied sparingly, and should not be allowed to contact the sealing ring or bolt threads. If too much sealant is applied, it could form droplets at edges, and these may later become detached and cause malfunction of fuel system components.

5.3.3 Attachment bolts should be tightened progressively, and evenly, to the torque specified by the manufacturer.

5.4 **Repairs to Sealant.** Whenever a leak is found in a tank, either during a routine leak test (paragraph 5.2) or during normal service, it must be categorised, and, if necessary, repaired in accordance with the instructions detailed in the relevant Maintenance Manual. In some cases, special repair methods are necessary, because of the method of construction, but, generally, the procedures outlined in this paragraph will apply.

5.4.1 **Categorisation of Leaks.** A leak may be broadly classified as a stain, seep, or run. In general, a stain, where leakage merely results in the staining of a small area of skin, does not require repairing, but the area should be inspected regularly to check whether the rate of leakage has increased. A seep, which may be regarded as a leak which results in the spreading of the stained area, but does not produce drips of fuel, must be repaired at the next major inspection, or when the tank is opened up for any other reason; it should also be inspected frequently to check whether the leakage rate has increased. A run, in which fuel is dripping from the tank, must be repaired immediately, or, as a temporary measure, action should be taken to reduce the leakage rate to that of a stain or seep.

5.4.2 **Temporary Repairs.** Temporary repairs are usually permitted to enable an aircraft to be flown to a maintenance base, where permanent repairs may be carried out. A temporary repair usually consists of plugging the leak at the exterior skin joint, rivet or seam, then covering the plug with sealant and a fabric patch. Only those materials recommended by the manufacturer should be used.

5.4.3 **Location of Leak Source.** The position of an external leak may not correspond to the point at which the tank sealant has failed, and investigation may be necessary to trace the leak source. The position of the external leak should be marked with soft crayon, the tank should be defuelled by stages, and the fuel level at which leakage ceases should be noted. Any seams between this fuel level and a position on the inner tank wall corresponding to the position of the external leak should be carefully examined for signs of cracking or poor adhesion of the sealant. If no evidence of a faulty seal can be found, the tank should be completely drained; the suspect area on the inside of the tank should be degreased with a suitable solvent, and a non-corrosive soap solution should be applied. A jet of dry air at a pressure of approximately 35 kN/m^2 (5 lbf/in^2) should then be applied to the position of the external leak, and the interior surface should be examined for the appearance of bubbles. The position of the leak source should be marked with a soft crayon, and all traces of soap solution should be washed off, using a water-dampened, lint-free cloth; the affected area should then be de-greased and dried.

NOTE: The use of air pressures in excess of the maximum permitted by the manufacturer could damage serviceable sealant and must be avoided.

5.4.4 **Permanent Repairs.** The adhesion of sealant to the inner surface of a tank depends on the cleanliness of the surface, and on the proper mixing and application of the sealant. Sealants are, generally, supplied in 'twin-pack' form, the quantities of sealant and accelerator being correct when the entire contents of each container are mixed. Once mixed, the compound must be used within a prescribed time, and must be 'tack-free' before a second coat is applied, and completely cured before the tank is refuelled. Application times, tack-free times, and curing times, vary between different products, and the recommendations of the particular manufacturer must be observed. In addition, sealants are normally subject to a shelf-life, and packages which have been in stock longer than this, must be discarded. Procedures for the repair of leaks in integral tanks may vary, but the following paragraphs describe a typical repair. Any variation from this method will be detailed in the relevant Maintenance Manual.

(a) The tank should be completely drained and ventilated, and the area to be repaired should be cleaned with solvent and thoroughly dried. The safety precautions detailed in paragraph 7 must be observed.

(b) The faulty fillet of sealant should be removed, and the fillet should be cut back to a position where adhesion is satisfactory. The edges of the fillet should be chamfered, and the exposed sealant and skin should be cleaned and dried.

NOTE: The tools used for cutting and removing sealant should be made from a material which will not damage the tank structural surfaces.

(c) In cases where leakage has occurred round rivets or bolts, these should be removed, and replacement items should be wet-assembled, using the specified sealing compound. It is usually recommended that the holes are drilled out, and oversize items fitted.

(d) Filleting sealant should be applied with a gun, and the fillet should be smoothed with a fairing tool. Care must be taken to prevent the inclusion of bubbles, and surplus sealant should be removed while it is still wet.

(e) When the filleting sealant has become tack-free, the primary sealant should be brushed on to the new section of fillet, and over any exposed rivet or bolt heads. A number of coats should be used to build up sealant to the original contour.

(f) Where applicable, two coats of top coat lacquer should be applied over the new sealant so as to overlap the original lacquer.

(g) Splashes of sealant or lacquer should be wiped off, and all debris should be removed.

(h) When the sealant has cured, the tank access covers should be replaced, the tank should be refuelled, and a check should be made for leakage as described in paragraph 5.2.1.

6 PRESSURE TESTS After repairs have been carried out on rigid and flexible tanks, a pressure test is usually specified to ensure that the leaks have been cured. Pressure testing of integral tanks is not normally required, but flow tests may be specified (Leaflet AL/3-17).

6.1 In order to apply pressure to a tank, leakproof blanks must be fitted to all apertures, and one blank must include a fitting suitable for the attachment of a dry air supply. A pressure gauge (normally a water manometer) should be fitted in the pressure line.

6.2 Rigid tanks may be pressure tested by filling with a few gallons of kerosene, and applying a mixture of whiting and methylated spirit to all seams, joints and other possible sources of leaks. When the mixture has dried, an air pressure of approximately 10 kN/m^2 (1·5 lbf/in^2) is applied to the inside of the tank, which is then rotated to distribute kerosene over the whole surface. Leaks will be indicated by staining of the whiting. After the test, the whiting should be washed off, the kerosene should be drained, and the tank, if not required for kerosene, should be flushed with the appropriate system fluid. As an alternative, the test described in paragraph 6.3.2, using dry air pressure and soap solution, may be used.

6.3 Flexible tanks may be pressure-tested in a number of ways; by the free test method, by the use of pressure rigs, or by a chemical method.

6.3.1 The free test method is similar to the test used for rigid tanks. The tank is filled with a few gallons of kerosene, and an air pressure of not more than 2 kN/m^2 (0·25 lbf/in^2) is applied in order to shape out the tank. The tank is then rotated in order to distribute the kerosene, and any leaks will be indicated by the presence of kerosene on the exterior surfaces.

6.3.2 The pressure rig method is carried out with the tank contained within a frame, which is designed to support the tank. The frame consists of a welded steel structure inlaid with a wide mesh screen, which permits inspection of all seams and fittings; each frame is designed for use with a particular tank. The tank is carefully located in the frame, and an air pressure of approximately 7 kN/m^2 (1 lbf/in^2) is applied to the tank. A soap solution is brushed over the tank skin, and if a leak is present, it will be indicated by the appearance of bubbles. After the test, the soap solution should be washed off, the tank should be drained, and, where necessary, the tank should be flushed with system fluid.

6.3.3 In the chemical method, a rag soaked in ammonia is inserted into the tank, which is then sealed and inflated to a pressure of 4 kN/m^2 (0·5 lbf/in^2). A large cloth is then soaked in an indicator solution containing 2·25 litres (0·5 gal) of water, 2·25 litres (0·5 gal) of ethyl alcohol and 40g of phenolphthalein crystals, wrung out, and spread over an area of the tank to be checked. Leaks will be indicated by the appearance of red spots on the cloth, and should be marked on the tank with a silver coloured pencil. The cloth should again be soaked in the indicator solution, and wrung out before checking a different area on the tank.

NOTE: Rubber gloves should be worn by all personnel involved in the handling of chemicals in this process.

7 SAFETY PRECAUTIONS Whenever it is necessary to enter a tank, in order to make an inspection, or to carry out repairs, certain precautions must be taken because of the flammability and toxicity of fuel and oil vapours. Defuelling and ventilating operations must be carried out in an open area, and no flame or spark producing equipment may be operated in the vicinity of such operations, or when fuel tank covers are open. Adequate and properly manned fire-fighting equipment must be provided, and suitable placards should be prominently displayed. The aircraft, and any ground equipment used, should be electrically earthed to a satisfactory earthing point.

7.1 After a tank has been defuelled and drained, it must be ventilated, by removing all access covers and circulating dry, filtered air, through the tank, until all fumes have been removed. The period of ventilation will vary according to ambient conditions, but must be continued until the tank walls are completely dry. Interconnecting feed and vent pipes must be blanked or isolated, in order to prevent any liquid or vapour in adjacent tanks, from contaminating the purged tank.

NOTE: Some manufacturers recommend the use of a combustible gas indicator to ensure that the tank is safe to enter, and where this is the case the readings which indicate an acceptable level of safety will be specified in the relevant Maintenance Manual. It should be noted, however, that these instruments may not be satisfactory with all types of fuels, and the manufacturer's recommendations, regarding their use, should be followed.

7.1.1 Battery cables should be removed and stowed, to prevent inadvertent sparking of electrical tank units.

7.1.2 Only spark-proof tools and explosion-proof torches may be taken into the tank, and only air-operated vacuum cleaners may be used for removing debris.

7.1.3 All tools required for a particular operation, should be cleaned and placed in a shallow open-topped box, so as to limit the movement of personnel through the access hole, and to minimize the possibility of the tank becoming contaminated with dirt and grit. A check list should be kept of all tools and equipment taken into the tank, and items should be checked off this list as they are removed, before the final inspection of the interior and the replacement of the tank covers.

7.1.4 The edges of holes through which entry is to be made, and the edges of passageways in internal formers, must be protected from damage, and protective mats must be placed on the bottom of the tank.

7.2 Personnel working in a tank must wear an air-fed respirator, and a supply of fresh air should be circulated through the tank. Protective clothing should be worn, and this should include canvas shoes, clean cotton overalls (which should be free from exposed metal buttons, buckles or fasteners), and clean cotton head covering. Goggles and rubber gloves should also be worn when solvents and sealants are to be handled.

7.2.1 Particular care must be taken when working inside water/methanol tanks, since methanol may be absorbed through the skin. For such work the protective clothing should cover the whole body.

7.2.2 A lifeline should be attached to a person who is working inside a tank, and a second person should be stationed outside the tank, to maintain contact with, and to be responsible for, the safety of the first person. Where there is an alternative access hole this should be opened, in case the person inside the tank should require assistance.

8 MICROBIOLOGICAL CONTAMINATION Microbiological contamination of fuel can cause inaccurate fuel contents indications, blockage of filters, and corrosion of aluminium alloy fuel tanks. This type of contamination does not normally occur in aviation gasoline, but is common in kerosene-type fuels. The contamination is usually in the form of a fungus (Cladosporium resinae), the spores of which are present in most kerosene-type fuels and are too small to be completely filtered out. In order to grow, these spores require a temperature of 25°C to 35°C (77°F to 95°F) and the presence of free water in the fuel. Temperatures favouring the growth of spores are quite often obtained in aircraft standing in strong sunlight or in heated hangars, and the water may result from condensation and precipitation, and may also be introduced during refuelling. Fungal growth commences at the boundary of a water droplet, and may eventually fill the water droplet, and release further spores into the fuel. Any imperfections or weak points in the tank coating will be

penetrated by the fungus, and corrosion pitting or intergranular corrosion over a larger area may result. Fungal attack can also be a contributory cause of stress corrosion cracking. Careful monitoring of bulk fuel storage facilities, and regular inspections of the aircraft tanks, are necessary to guard against the effects of microbiological contamination.

8.1 Modern integral fuel tanks are designed to provide fuel flow across the bottom of the tank, and to minimize the risk of water collecting in stagnant areas. However, even with the best possible drainage, when water droplets have wetted a surface, they will often remain attached to it, and be held by surface tension. Upward facing surfaces are most likely to be affected, and the worst contamination is usually found at the lower inboard end of each tank, and below natural drip points, such as bolts and stringer runouts in the tank roof.

8.2 **Prevention.** The use of a fungicidal additive to the fuel is often recommended by aircraft manufacturers, particularly when the aircraft is operating in areas where fungus has been encountered, or where temperatures favouring its growth are likely to be experienced. There are two main types of additives, which may be used to sterilize the fuel tanks on a continuous or non-continuous basis.

8.2.1 **Ethylene Glycol Monomethyl Ether (EGME).** EGME is widely used as an anti-icing additive, and is also a biocide. It must be thoroughly mixed with the fuel before being introduced into the aircraft tanks; for this special injection equipment is normally necessary. EGME may be used as a biocide in a concentration of 0·15% by volume, and ideally, should be used on a continuous basis. EGME is not frequently used in civil aircraft, because of the difficulties in mixing, and the fact that it cannot be air freighted in large quantities.

8.2.2 **Biobor.** Biobor may be used as a biocide, on a continuous basis at a maximum concentration of 135 parts per million (ppm), or on a non-continuous basis (e.g. once every two months) at a maximum concentration of 270 ppm. Biobor mixes easily with fuel, and may be pre-mixed in storage, mixed in the refuelling vehicle, or poured directly into the aircraft tanks. For non-continuous use, sufficient treated fuel should be introduced into each tank to cover likely areas of contamination (approximately ⅛ of tank capacity), and should be left as long as possible (ideally 3 or 4 days) to achieve maximum effect. It is important that this fuel is diluted before being burned in the engines, and the manufacturer's instructions regarding the running of engines on fuel treated with Biobor should be carefully followed. It is usually recommended that the fuel filters are checked at frequent intervals after biocidal treatment, to prevent contamination from microbiological debris.

8.3 Fungal growth is more easily discernible in a tank which contains fuel, and will generally appear as patches of a brown slimy deposit on upward-facing surfaces. Corrosion resulting from fungal attack, although not often visible, may appear as white spots through the fungus. Fungus may be difficult to see on a background of sealant, but will be easily visible on light-coloured coatings; it will usually be concentrated at the lowest point in a tank.

8.3.1 The inspection should be made through a suitable access hole, using a flame-proof torch. If the fuel vapour concentration is high, an air-fed respirator should be worn.

8.4 **Fungus Removal.** If any fungus is found in a tank its position should be noted, and it should be removed as soon as possible. The decontamination process may vary between different aircraft manufacturers, but will normally follow the procedures outlined in (a) to (e).

(a) Drain out and isolate all fuel, and ventilate the tank to permit entry. Some manufacturers may recommend the removal of booster pumps, contents units and other equipment, to avoid damage, to allow better access, and to facilitate inspection.

(b) Wash the tank with detergent and water, using a bristle brush to aid the removal of fungus.

(c) Thoroughly rinse the tank with clean water to remove the detergent, using a hose fitted with a spray nozzle.

(d) Apply a biocidal rinse to the tank to kill any remaining spores. This rinse is usually either 5% chromic acid or 50% methanol in water, and is left in the tank for a short period.

(e) Thoroughly flush out the tank with clean water to remove the rinse, mop up any pools, and dry it with warm air.

NOTE: Protective clothing and goggles must be worn by personnel mixing or applying the biocidal rinse (see also paragraph 7). A spray should not be used to apply the solution, since splashes may be harmful to unprotected personnel.

8.5 **Corrosion Removal.** After the fungus has been removed, the tanks should be carefully inspected for corrosion and damaged sealant, particularly in those areas where fungus was found. It will usually be necessary to remove sealant and protective coatings from these areas in order to investigate the extent of the corrosion. All visible corrosion should be removed by mechanical methods (Leaflet **BL/4-2**), leaving a smooth, shallow depression, and the affected area should be inspected for cracks, using a penetrant dye process. If the reduction in skin thickness resulting from corrosion removal is within the limits laid down by the manufacturer, the protective coating should be re-applied, and any areas from which sealant was removed should be re-treated (see paragraph 5.4.4). Frequent checks should subsequently be carried out, to ensure that all corrosion has been eliminated. If the reduction in skin thickness is outside the acceptable limits, an approved repair scheme must be carried out.

8.5.1 After repairs have been carried out, all debris should be removed with a vacuum cleaner, and the tank should be thoroughly cleaned before the pumps, any other components which have been removed, and the tank access panels are replaced. Filters should be checked for debris after initial engine runs, and at frequent intervals thereafter.

9 STORAGE Rigid and flexible tanks should be retained in their original packing until they are required for use, and they should be re-packed in a similar manner after removal from the aircraft for transportation or storage.

9.1 **Rigid Tanks.** Rigid tanks are normally inhibited prior to storage; all openings are sealed, and the external surface is sprayed with a strippable lacquer. The tanks are then secured to a suitably shaped, padded cradle, and installed in a crate to prevent physical damage. During storage, these tanks should be inspected occasionally for signs of corrosion on the external surface.

9.2 **Flexible Tanks.** Flexible tanks made from rubber should normally be stored in a cool, dry place, at a temperature of not more than 15°C. Different temperatures may be recommended by the manufacturers for tanks made from plastics materials.

9.2.1 A fully flexible tank should be carefully folded, with identification marks on the outside, and corrugated cardboard should be placed between the folds to prevent chafing. The tank should then be sealed inside a strong polythene bag, and placed in a cardboard carton or crate of suitable size.

9.2.2 A flexible tank containing rigid formers or fragile contents units may be transported or held in short-term storage in an air-inflated condition. Air inflation is not suitable for long-term storage however, and attachment loops are usually fitted to the tank, adjacent to internal fittings, so that the tank can be securely located in a crate, in its normal shape.

9.2.3 Tanks which have a heavy protective coating are essentially self-supporting, and, for storage purposes, generally only require to have their openings sealed and to be contained within a carton or crate.

9.2.4 Rubber tanks should be checked to confirm any shelf life storage limitations.

9.3 **Integral Tanks.** Normal storage requirements do not generally apply to these tanks, but if an aircraft is out of service for a long period, a small quantity of fuel (usually 10% of tank volume) should be retained in the tanks, so as to prevent drying out and deterioration of the sealant. This fuel should be treated with biocide to discourage fungal contamination.

AL/3-17

Issue 1.

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AIRCRAFT

SYSTEMS AND EQUIPMENT

FUEL SYSTEMS

1 INTRODUCTION This Leaflet gives general guidance on the operation, installation and maintenance of fuel systems in aircraft. Since there are considerable differences between the fuel systems fitted to different types of aircraft, this Leaflet should be read in conjunction with the Maintenance Manual and Maintenance Schedule for the aircraft concerned.

NOTE: This Leaflet contains the relevant information previously published in Leaflet **PPL/2-1**, Issue 3, dated 15th December 1965.

1.1 The following Leaflets contain information on related subjects, and should be referred to as appropriate:—

AL/3-13 Flexible Pipes

AL/3-14 Installation of Rigid Pipes in Aircraft

AL/3-15 Tanks

AL/10-3 Engine Instruments

EEL/1-6 Bonding and Circuit Testing

2 FUELS There are two main types of fuel used in aircraft, aviation gasolene, which is used in piston engines, and aviation kerosene, which is used in turbo-jet and turbo-propeller engines. It is most important that the correct type and grade of fuel, as indicated in the appropriate Maintenance Manual, should be used.

2.1 **Gasolene.** Aviation gasolene (AVGAS) is the lighter of the two fuels, having a relative density of approximately 0·72. The only grade of AVGAS generally available is grade 100L, which has an octane rating of 100 and a low lead content. Where different grades of fuel were previously specified for use in a particular engine, the use of AVGAS 100L may necessitate additional checks and maintenance to be carried out. Automobile fuel must not be used instead of non-leaded aviation fuel (Airworthiness Notice No. 70 refers).

2.1.1 Gasolene has powerful solvent properties, and it is essential that it does not come into contact with certain components such as transparent panels and tyres. Personal contact may also result in skin infections, and it should be noted that some of the additives used in gasolene are poisonous.

2.2 **Kerosene.** The fuel generally used in civil turbo-jet and turbo-propeller engines is known as AVTUR (Specification D Eng. RD 2494). It has a relative density of approximately 0·8, a high flash point, and does not give off easily-ignitable vapours at normal ground temperatures. In many instances the use of AVTAG (Specification D Eng. RD 2486) is permitted in civil aircraft, but this fuel is lighter, and has a lower flash point; the 'wide-cut' formula for this fuel includes gasolene, and it should, consequently, be treated as highly flammable.

2.3 **Fuel Quality Control.** The quality of the fuel delivered to an aircraft must be carefully controlled. Engines will operate satisfactorily when a small amount of water and dirt are present in the fuel, but the quantities must be strictly limited.

2.3.1 Bulk storage tanks should frequently be checked for contamination. Fuel is usually drawn from these tanks through a floating suction, which ensures that the contents of the lower part of the tank, where contaminants may have collected, are not drawn off.

2.3.2 After a refuelling vehicle has been filled from a storage tank, it should be left to stand for at least ten minutes, then approximately one gallon of fuel should be drawn from the sump in order to check its quality. If sediment is found, further samples should be taken, until the result is satisfactory. Suspended water in kerosene will give the fuel a cloudy appearance, and free water may often be readily visible, but in any case, a chemical water detection method should be used. If water is found, the vehicle should be driven a short distance, left to stand for a further period, and another sample taken. This process may be repeated until a clean sample is obtained. During normal use, fuel samples should be taken daily. The refueller delivery line should contain a 5 micron filter, and all equipment should be kept scrupulously clean. Nozzle caps should be removed immediately prior to refuelling, and replaced immediately after refuelling.

2.3.3 Hydrant installations are often used for direct refuelling of aircraft, and the associated tanks are generally fitted with a floating suction and a water separator. Samples should be taken from the storage tank sumps, pipelines and dispenser unit daily, and should be checked for water, sediment, and other contamination.

2.3.4 If signs of microbiological contamination are found in a sample, the storage tank should be checked for contamination. Contaminated tanks must be cleaned before being used to refuel aircraft. Leaflet **AL/3-15** describes the causes of microbiological contamination, its effect on aircraft fuel tanks, and the precautions which can be taken.

3 GENERAL A simple fuel system may consist of a gravity feed tank, a filter, a shut-off valve, and suitable rigid and flexible pipes between these components and the engine. The tank would be vented to atmosphere, and a means of indicating the fuel quantity, would be provided. This type of system is adequate for a single piston-engined, high wing aeroplane, and is often used. However, larger, multi-engined aircraft, particularly those fitted with turbo-propeller or turbo-jet engines, require a more sophisticated system, with facilities to enable transfer of fuel, electronic control of refuelling and defuelling, and controls and indicators for many functions not necessary in a simple system.

4 FUEL SYSTEMS FOR SMALL AIRCRAFT Figure 1 illustrates a simple fuel system such as may be used on a modern light aircraft. A rigid aluminium alloy tank, or a flexible tank, is housed in each wing, and feeds fuel to a selector valve, the control for which is located in the cabin. From this point fuel is fed through a filter and booster pump to the engine carburettor.

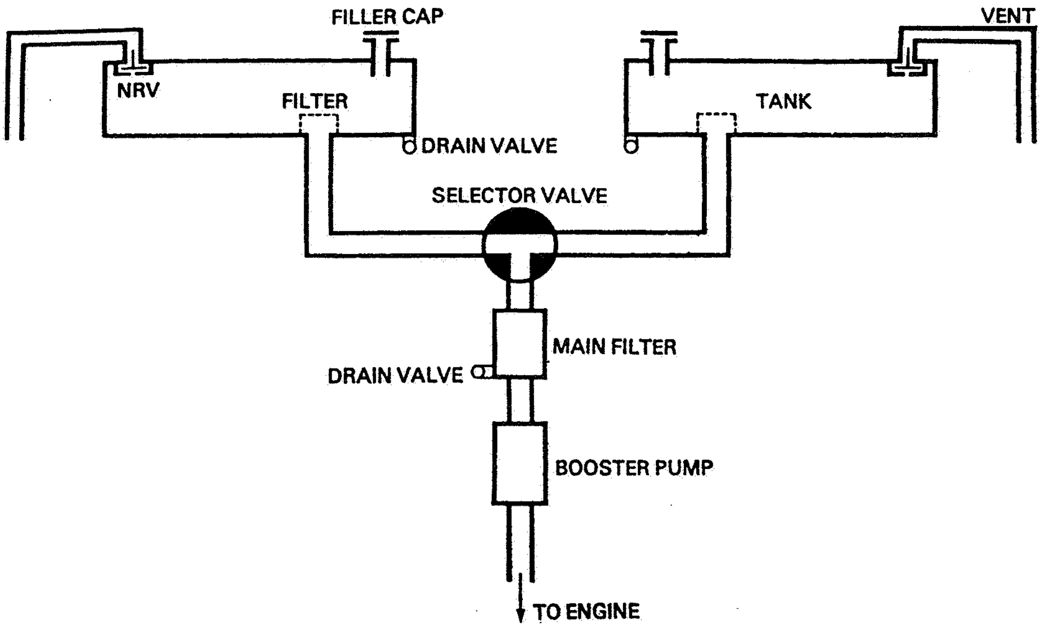

Figure 1 SIMPLE FUEL SYSTEM

4.1 Each fuel tank is fitted with a vent pipe, which has its open end outside the wing structure, in order to ensure that atmospheric pressure is maintained in the tank. A non-return valve (NRV) in the tank prevents fuel from syphoning through the vent pipe, and a bleed hole in the NRV prevents the build-up of pressure as a result of fuel expansion, when the NRV is closed. Coarse mesh filters are generally fitted at the filler openings, and at the outlet pipes, in order to prevent large objects from passing into the system. A drain valve, fitted to the lowest point in each tank, is used to drain off fuel and any water which may have collected through condensation, or have been introduced during refuelling. The fuel tanks of light aircraft should be filled as soon as possible after a flight, to minimize condensation; a small quantity of liquid should be drained off through the tank and main filter drain valves before flight, in order to remove any water which may have accumulated. Tanks are fitted with a contents gauge, which may be a float operated mechanical unit, a float operated electrical unit, or an electrical capacitance type unit (see Leaflet **AL/10-3**).

4.2 The selector valve enables the engine to be fed from individual tanks, or both tanks together, and an OFF position is also usually provided to enable the supply to be turned off. This latter position is particularly important with those high wing aeroplanes which have engines fitted with float chamber carburettors, since a small leak past the float valve could result in complete loss of fuel when the aircraft is parked; it is also essential to be able to turn off the fuel supply in the event of an engine fire. Selector valves are usually rotary valves, and the operating lever may be mounted directly on the valve, or located remote from the valve and connected to it by mechanical linkage. In either case it is important that the operating lever is accurately aligned with the valve, and represents the true position of the valve at all selected positions; a detent at each position assists proper selection.

4.2.1 In some systems an additional valve may be fitted in the fuel feed line, to isolate the tanks for maintenance purposes. This valve will usually be wire locked to the ON position for normal operations.

4.3 The main fuel filter is usually fitted to the lowest point in the system, so that water and sediment, being heavier than fuel, will collect at this point. The filter is designed to remove both water and dirt from the fuel by trapping them in the sediment bowl. The sediment bowl is attached to the body of the filter by a quick-release fitting, thus assisting easy removal for cleaning and examination of the filter element.

4.4 The booster pump is electrically operated, by direct current, and is fitted to ensure a positive fuel supply to the engine for starting, take-off, climb, high altitude, flight through turbulence, and landing, and to safeguard the engine in the event of engine-driven pump failure. Pumps are usually of the centrifugal type, and are sometimes fitted with two speed controls, the higher speed being used for emergency operation. Pumps are often mounted in the bottom of the fuel tanks, but in some cases are located in the fuel lines as illustrated in Figure 1.

4.4.1 Seals are fitted between the pump and its motor to prevent fuel and vapour from leaking into the motor. However, any slight leakage which does occur is drained overboard, and some motors are vented by passing air through the casing.

4.4.2 Different types of pumps are used in some instances, but the inherent advantages of centrifugal pumps, are that they separate fuel and vapour, thus providing a vapour-free fuel supply, and they do not require pressure relief or by-pass valves.

4.5 Pipelines aft of the firewall in light aircraft fuel systems are generally made from aluminium alloy, and are joined by standard aircraft couplings; because of the modest fuel requirements of small piston engines, the pipelines are seldom larger than 25 mm (1 in) diameter. Fuel pipelines in British aircraft (except those inside the tanks) are labelled, for recognition purposes, in accordance with British Standard M23. The marking consists of an adhesive label wrapped around the pipe at intervals, with the word FUEL in black, on a red background, and a symbol in the form of a black four-pointed star on a white background. In addition, the word FLAM (flammable) and the purpose of the pipe (e.g. VENT) may be added.

4.6 Fuel tanks are marked, adjacent to the filling point, with the type of fuel required and the usable tank capacity. The filling points of other systems are also marked, in order to prevent a system from being filled with the incorrect fluid.

5 FUEL SYSTEMS FOR MULTI-ENGINED AIRCRAFT A fuel system for a typical multi-engined aircraft is illustrated in Figure 2. The basic requirements for the system are the same as those described in paragraph 4, but the multiplicity of engines necessitates additional tanks, piping, valves and pumps. In addition, different venting and refuelling systems are necessary, and additional functions such as fuel jettisoning, fuel heating, cross-feeding, and instrumentation have to be provided for.

5.1 **Fuel Feed.** In modern turbine-powered aircraft, the fuel is usually contained in a number of integral tanks (Leaflet **AL/3-15**), in the wings and centre section, and, occasionally, in the fin. Individual engines are usually fed from an associated tank, or group of tanks, but cross-feed and inter-engine valves may be provided to enable the engines to be fed from any desired group of tanks, and also to permit fuel transfer between tanks. Fuel supplies for auxiliary power-units and combustion heaters, where fitted, are normally taken direct from a suitable tank or from a feed line.

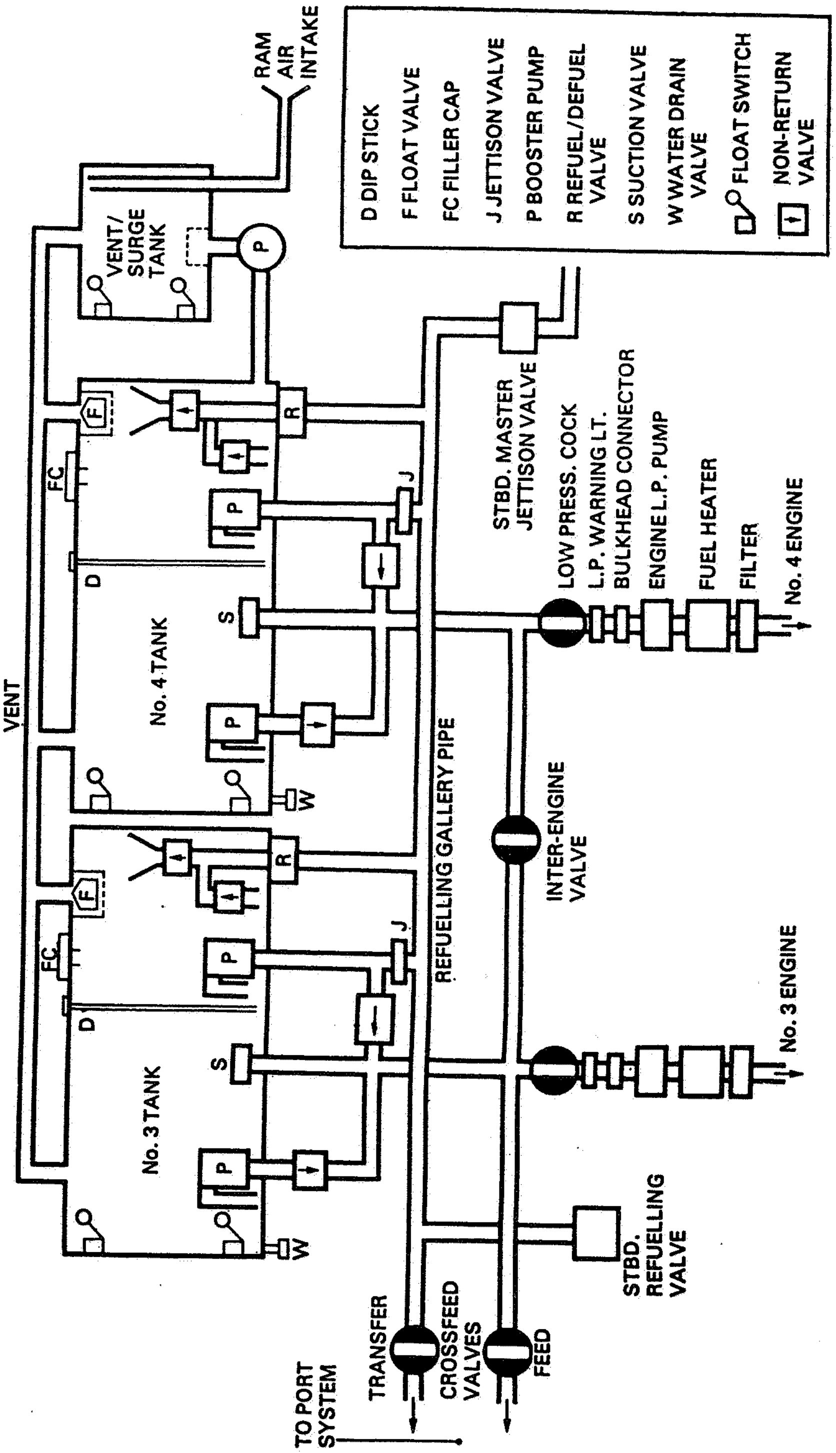

Figure 2 FUEL SYSTEM FOR MULTI-ENGINED AIRCRAFT

5.1.1 **Pumps.** In the fuel system illustrated in Figure 2, two booster pumps are fitted in each tank. These pumps are designed for continuous operation, and either pump can supply the needs of any one engine. In the event of failure of both pumps in a tank, fuel is drawn from that tank by the associated engine-driven, low-pressure pump, via the suction valve, but in some cases this may be inadequate to provide full engine power at high altitude, and operating limitations may be imposed. The booster pumps are electrically operated, but, unlike the pumps fitted to light aircraft, may be operated by alternating current. They vary considerably in design, but are usually powered by induction motors, and may include a two stage impeller. In some instances the motor is of the flooded type, in which the motor runs submerged in fuel, thus obviating the need for seals. Overheat protectors are usually fitted, which cut off power to the motor when the pump temperature rises above a pre-determined value. Pumps are often fitted in isolation chambers within the fuel tank, which enables them to be removed and re-fitted without draining the tank.

5.1.2 **Valves.** Low-pressure valves, cross feed valves and inter-engine valves, are usually ball-type, full-flow valves, and may be either mechanically or electrically operated. A typical valve is illustrated in Figure 3; in this type a form of pressure relief is provided, to bleed off excess pressure which may occur, through variations of temperature downstream of the valve, when the valve is closed. This is a two position valve only, and either internal or external mechanical stops are provided, to limit movement to 90°; a visual indication of valve position is also provided. When the valve is electrically operated, a reversible electric motor, equipped with an electro-magnetic brake, is mounted on the valve casing, and drives the valve through a gear train. Limit switches cut off power to the motor at the fully-open and fully-closed positions, and the brake operates automatically as the motor is de-energised; the brake is magnetically released when a reverse selection is made. The limit switches may also be used to operate position indication lights or magnetic indicators in the crew compartment.

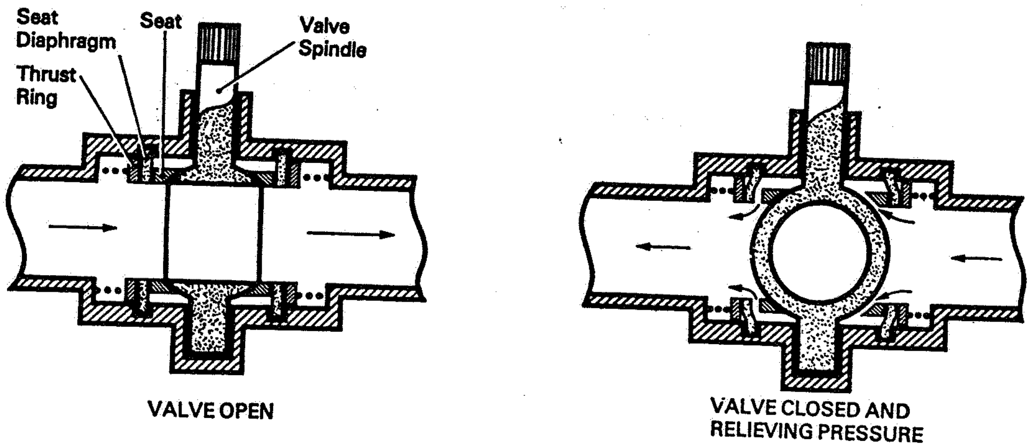

Figure 3 BALL-TYPE VALVE

5.1.3 Suction valves are fitted to enable fuel to be drawn from the tanks by the engine-driven pumps; they are closed when booster pumps are operating normally. A suction valve is illustrated in Figure 4; it is a simple flap type valve, which closes when a pressure exists in the pipeline, and opens when suction is applied to the pipeline.

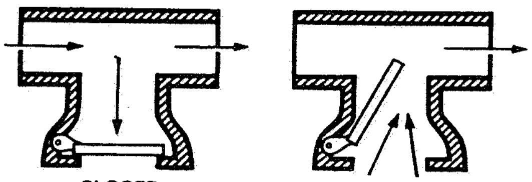

Figure 4 SUCTION VALVE

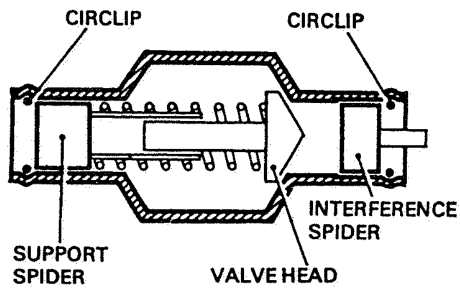

Figure 5 NON-RETURN VALVE

5.1.4 Non-return valves may be fitted in several places in the fuel system, to provide flow in one direction only. A typical non-return valve is illustrated in Figure 5. The casing is marked with an arrow to show the direction of flow, and, in the valve illustrated, an interference spider is fitted to the inlet side, in order to prevent the valve from being fitted the wrong way round.

5.2 **Venting.** The tank venting system provides positive venting of the tanks during flight. A ram air intake maintains a slight positive pressure in the vent system, thus decreasing fuel vaporization, and preventing negative pressures in the tanks through changes in aircraft attitude and fuel usage. In some aircraft, the vent system also prevents the building up of dangerous pressures in the tanks during refuelling, should the automatic cut-off fail, by dumping excess fuel. Generally, there are two vent pipes in each tank, the inboard vent is open-ended, but the outboard vent is fitted with a float valve, the purpose of which is to minimize fuel transfer both between tanks and into the vent/surge tank during changes of aircraft attitude. Fuel which is spilled into the venting system, collects in the vent/surge tank. On some aircraft the vent/surge tank drains under gravity into the main tanks, but on other aircraft an automatic pumping system is used. The pumping system may operate on a continuous basis, using 'jet' pumps, or on an intermittent basis using float switches and a separate electrically-operated pump. In a jet pump, output from a normal booster pump passes through a jet nozzle, which is contained within a concentric pipe leading from the vent/surge tank. The flow of fuel through the jet nozzle automatically draws fuel from the vent/surge tank. With an intermittent system, a high-level float switch switches the transfer pump on, thus transferring fuel from the vent/surge tank to a main tank, and a low-level float switches the transfer pump off. A time-delay may be incorporated in the pump circuit, to prevent intermittent operation as a result of fuel surge.

5.2.1 Vent valves are generally either a caged cylindrical float which itself acts as a valve to close the vent, or a simple lever-type flap valve; typical examples are shown in Figure 6.

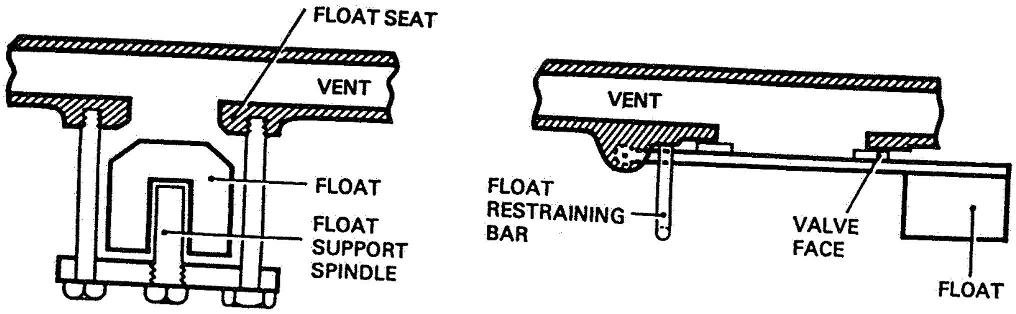

Figure 6 VENT VALVES

5.2.2 Float-operated switches are often of a magnetic type, similar to the one shown in Figure 7, and are designed to isolate the electrical mechanism from the fuel tank, for safety reasons. Upward movement of the float brings the armature closer to the magnet, and, at a pre-determined fuel level, it has sufficient influence to attract the magnet, which results in operation of the micro-switch. As the fuel level and the float fall, the attraction of the armature is eventually overcome by the combined forces of the counterweight and the micro-switch spring, and the counterweight falls, changing the micro-switch circuit.

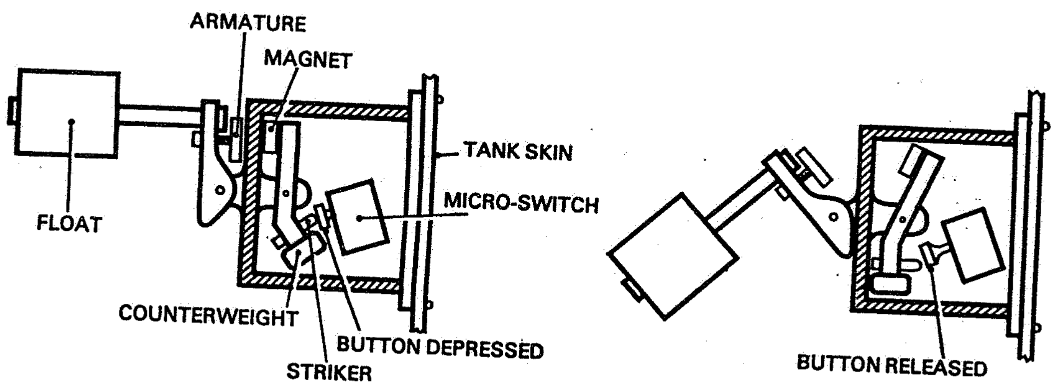

Figure 7 FLOAT SWITCH

5.3 Compartments in which rigid or flexible tanks are contained, and bays or conduits through which fuel system pipes pass, are usually ventilated and drained to prevent the build-up of vapour pressure, and to release condensation or fuel which may have leaked into them. These regions are invariably sealed to prevent vapour leakage into crew and passenger compartments, and pressure tests are normally required at specified intervals, and after repairs have been carried out or components have been replaced.

5.4 **Refuelling/Defuelling.** Light aircraft fuel tanks are usually filled through over-wing filler caps, and drained by means of suitable cocks or plugs in the tanks or pipelines. These features are often retained on large transport aircraft for emergency refuelling and for draining individual tanks, but as these methods are very slow, refuelling and defuelling are normally carried out through pressure refuelling connections situated in the lower wing or fuselage surfaces. Using a tanker or hydrant, and delivery pressures of up to 350 kN/m^2 (50 lbf/in^2), refuelling rates of up to 1,000 gal/min (4500 litres/min) may be achieved; defuelling is carried out using the same system, but suction is then applied to the pressure connections. The system includes the pressure connections, individual refuel/defuel valves for each tank, a load control panel, and suitable pipelines and tank valves as illustrated in Figure 2. In systems fitted with electrically-operated refuel/defuel valves, the refuel/defuel valves are opened by selector switches on the load control panel, but may be closed by these switches, by the float switches in the tanks when the tanks are full, or by electronic controls on the load control panel when complete refuelling is not required. In systems fitted with mechanically-operated refuel/defuel valves, the valves are opened manually, and closed either manually, or by means of pressure operated valves in the tanks. The refuelling discharge pipes in the tanks are usually fitted with a diffuser, the purpose of which is both to prevent any erosion of, or damage to, the sealant, which may result from a high pressure jet, and also to prevent static discharge within the tank.

NOTE: Refuelling points should be marked with the type of fuel to be used, and overwing filling points should also be marked with the capacity of each tank. Similarly, refuelling/defuelling containers and storage vehicles should be identified as to the type of fuel they contain.

5.4.1 A typical load control panel, suitable for the system illustrated in Figure 2, is shown in Figure 8; it is in the form of a 'mimic' diagram of the relevant parts of the fuel system, and includes a master switch, automatic/manual selector switch, switches for each refuel/defuel valve, a function (refuel/defuel) switch, contents indicators for each tank, and magnetic indicators to show the position of each refuel/defuel valve.

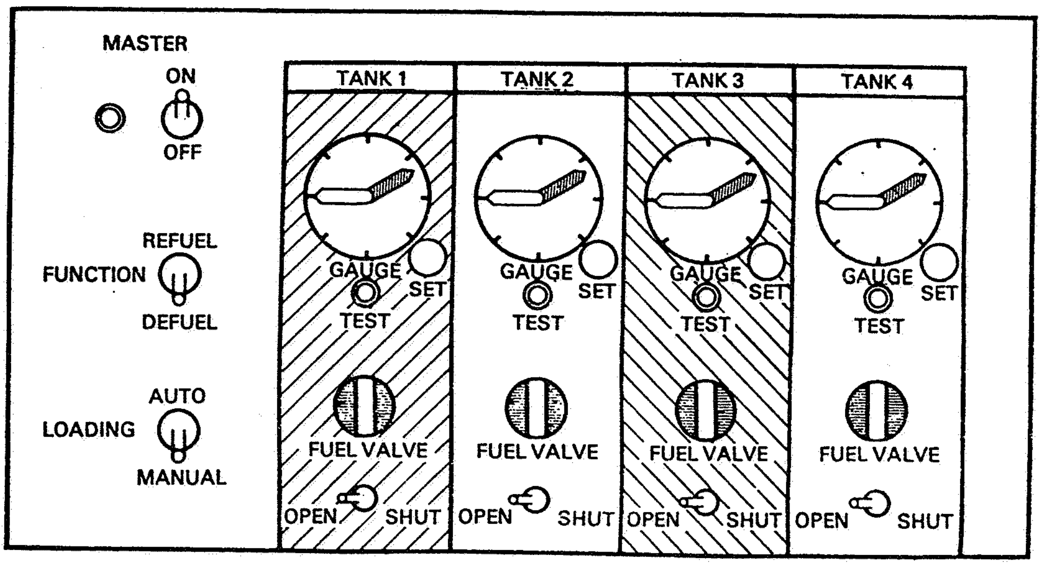

Figure 8 LOAD CONTROL PANEL

5.4.2 A typical refuel/defuel valve is illustrated in Figure 9; it is actuated by either of two solenoids, one for refuelling and one for defuelling. When the refuel solenoid is energised, the associated plunger opens the passage from the inner cylinder to the exhaust port, and fuel pressure at the refuelling inlet opens the valve. When this solenoid is de-energised, the passage is closed, and pressure builds up on the inner face of the piston; the area of the piston is greater than that of the valve, so the valve closes. When the defuel solenoid is energised the inner cylinder is open, via the by-pass duct, to the refuelling inlet side of the valve, and suction applied to this side of the valve will create a pressure differential across the piston, moving the piston inwards and opening the valve. When the defuel solenoid is de-energised, the by-pass is closed, and fuel enters the inner cylinder by leakage past the piston; pressure builds up on the inner face of the piston and this pressure, assisted by the spring, closes the valve. Any pressure which builds up in the refuelling inlet line when the valve is closed, is relieved via the non-return valve and spring-loaded refuel solenoid plunger, to the tank.

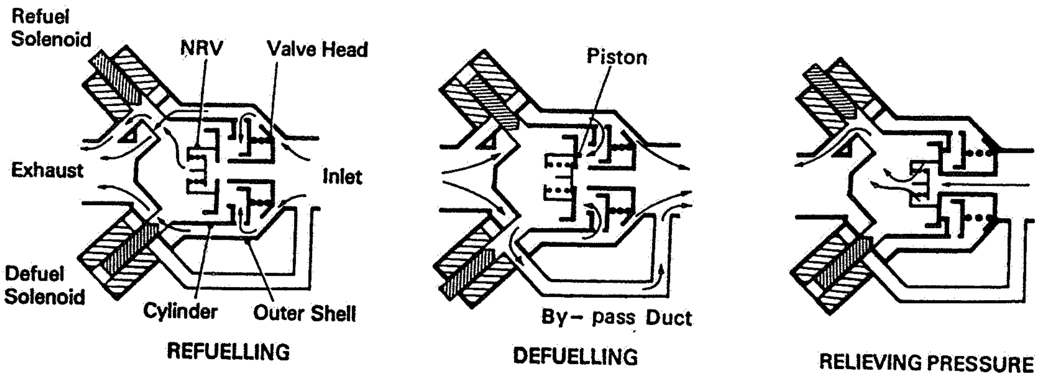

Figure 9 REFUEL/DEFUEL VALVE

5.4.3 The fuel contents gauges on the load control panel are dual pointer instruments. One pointer indicates actual tank contents, and the other pointer is used for pre-selecting the required quantity, whether refuelling or defuelling (automatic load control system). The pre-selector mechanism includes two micro-switches, one connected to the refuel solenoid of the refuel/defuel valve and the other connected to the defuel solenoid of the refuel/defuel valve. Pre-selection of a quantity greater than the actual tank contents will operate the micro-switch controlling the refuel solenoid, and pre-selection of a quantity smaller than the actual tank contents will operate the micro-switch controlling the defuel solenoid. When the pre-selected fuel quantity is obtained, the appropriate micro-switch circuit is broken and the refuel/defuel valve closes.

5.4.4 When refuelling using the automatic load control system, the master switch is selected 'on', the function switch to 'refuel', and the loading switch to 'auto'. The contents indicator pre-selector pointers are set to the amount of fuel required in each tank, and the refuel/defuel valve selector switches moved to 'open'. The circuits to the refuel/defuel valves are now complete, and the valves open as pressure is applied. When the quantity of fuel pre-selected for a particular tank has been uplifted, the pointers on that indicator coincide, the appropriate micro-switch circuit is broken, and the associated refuel/defuel valve closes.

5.4.5 Manual refuelling is carried out by selecting 'on', 'refuel', and 'manual' on the appropriate switches, and filling the tanks individually by use of the refuel/defuel valve selector switches; the appropriate selector switch should be tripped as each tank contents indicator pointer reaches the fuel quantity required.

5.4.6 Defuelling is carried out in a manner similar to that described in paragraphs 5.4.4 and 5.4.5 for refuelling, except that the function switch is selected to 'defuel'. The system functions in the same way as for refuelling, the refuel/defuel valves being tripped either by the indicator micro-switch, or by the selector switches, when the excess fuel has been off-loaded.

5.5 **Fuel Jettisoning.** Many transport aircraft are equipped with a means of jettisoning excess fuel in an emergency. Fuel is pumped or drained from each tank through a stand pipe, which ensures that a pre-determined quantity of fuel remains. One type of system makes use of the refuelling gallery pipe, which is extended outboard to a position near each wing tip, and terminates in a large diameter open-ended pipe at each trailing edge. One of the booster pumps in each tank, which may be run at a higher speed for the jettisoning operation, is used to off-load the fuel, and the fuel feed to the engines is protected by non-return valves. Individual jettison valves are located at selected tank outlets, and a master jettison valve is located adjacent to each discharge nozzle; this type of system is illustrated in Figure 2. In another type of system, fuel is jettisoned through a pipe in each wing, the pipe being lowered into the airstream by an electrically-operated actuator. A short manifold is fitted between the main tanks in each wing, and a jettison valve controls flow from each tank into the manifold; auxiliary tanks are fed into the main tanks by the normal transfer valves, the transfer pumps being inter-connected with the circuits operating the jettison valves. When the jettison pipe is in the retracted position it forms a seal at the manifold, and acts as a master jettison valve; the circuits to the jettison valves are not armed until this pipe is locked in the extended position. Both types of systems are controlled from a special panel at the crew station, which contains switches for the pumps and valves, and warning lamps or magnetic indicators to show the positions of the valves and the jettison pipes.

5.6 **Controls and Indicators.** All controls and indicators for the main fuel system, are grouped together on a fuel control panel in the crew compartment. To simplify control and management of the system, the various components are arranged in the form of a mimic diagram as in Figure 10 which shows a fuel control panel suitable for use with the system illustrated in Figure 2. The operation, installation and maintenance of the instruments shown in Figure 10 are described in Leaflet **AL/10-3**, and reference should also be made to the appropriate Maintenance Manual for details of the particular installation. In addition to the fuel quantity gauges fitted to the fuel control panel and load control panel, most large aircraft are also provided with a means of physically checking the quantity of fuel in each tank, during maintenance. For the methods described below, the aircraft must be levelled both laterally and longitudinally to obtain accurate readings.

5.6.1 A 'dip stick' is a rod with a screwed fitting at the top, which screws into a mating fitting in the top skin of the tank. It protrudes into the tank and is calibrated to indicate the contents of the tank between certain limits. When unscrewed, the fuel level is indicated by the limit of fuel-wetting on the rod.

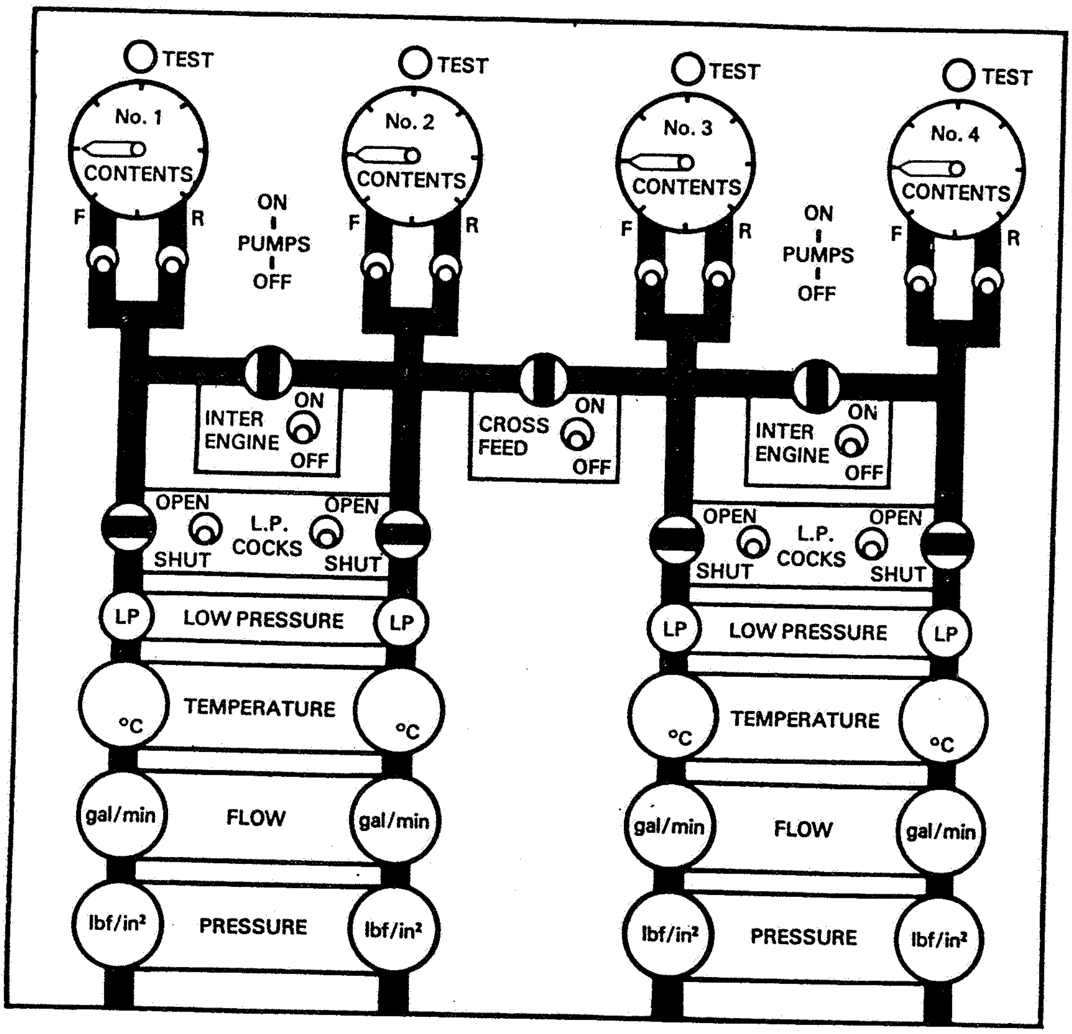

Figure 10 FUEL CONTROL PANEL

5.6.2 A 'drip stick' consists of a short outer tube, which is attached to an adaptor in the lower wing skin and protrudes upwards into the tank, and a long inner tube (calibrated in gallons or inches), which slides in the outer tube, and is secured to the adaptor by a bayonet fitting. The gap between the tubes is sealed against fuel leakage. To check fuel contents, the inner tube is unlocked and slowly withdrawn downwards; when the top of this tube falls below the fuel level, fuel will flow through it, and drain out of a hole in its base. The length of tube protruding from the adaptor, will indicate the tank contents. The volume of fuel, in gallons, may be obtained from tables provided in the aircraft Maintenance Manual.

5.6.3 A 'magnetic level indicator' is similar to a drip stick, but the top of the outer tube is sealed. A magnet mounted on a float which surrounds the outer tube rises and falls with the fuel level. A magnet is also mounted inside the top of the inner tube, and when this tube is unlocked, it may be carefully withdrawn downwards until the magnetic fields coincide. At this point the inner tube will be magnetically supported, and the contents will be indicated in the same way as with a drip stick.

5.7 **Fuel Heating.** Water may enter the fuel system during refuelling, or as a result of condensation in the tanks, and, when the fuel temperature falls below 0°C, the suspended water droplets may freeze. These frozen droplets collect at the low pressure filters, and may restrict or block fuel flow to the engines. To prevent this, a filter by-pass and blockage indicator may be fitted, or a de-icing additive such as methyl alcohol may be used in the fuel. However, in most large aircraft provision is made for heating the fuel before it enters the filters.

5.7.1 Fuel heaters are usually heat-exchangers, and may utilize engine oil, or air tapped from the engine compressors, as the heating medium. On some aircraft the engine oil coolers, which are in continuous use, are oil/fuel heat exchangers, and serve the additional purpose of heating the fuel. A heat exchanger operated by hot compressor air may be used in addition to the oil cooler, or may be used by itself for the purpose of heating the fuel. Oil/fuel heat exchangers are automatic in operation, oil flow being thermostatically controlled, but air/fuel heat exchangers may be either manually or automatically controlled.

5.7.2 A manually controlled fuel heating system usually consists of a pressure differential switch on the fuel filter, which operates a warning lamp in the crew compartment, and an electrically-operated valve on the heat exchanger, which is controlled by a switch adjacent to the warning lamp; a second warning lamp may also be included, to signify that the heating valve is open. When fuel flow through the filter becomes restricted by ice, the differential pressure across the filter increases, until it is sufficient to operate the icing warning lamp. The heat-exchanger valve should then be opened to admit hot compressor air to the heat-exchanger and to warm the fuel. Fuel temperature on the outlet side of the filter is indicated by an instrument on the fuel control panel. With this type of system, the period and frequency of operation of the heat exchanger may be limited.

5.7.3 An automatically controlled fuel heating system consists of a thermostatically controlled air inlet valve on the heat exchanger, which progressively opens and closes to maintain fuel outlet temperature within pre-set limits above 0°C. Actual fuel temperature is indicated on an instrument on the fuel control panel, but no action is required by the crew.

5.8 **Pipelines and Couplings.** Pipelines in aircraft fuel systems are not subjected to high pressures, and rigid pipes are generally manufactured from aluminium alloy tubing, although fire resistant and fireproof materials, such as stainless steel or titanium, must be used forward of the engine bulkhead and in other specified areas. Pipe ends are flared or beaded to accept the specified type of coupling. Some vent and jettison pipes are built into the structure, and in certain cases are of square section for ease of manufacture. Standard AGS or AS pipe couplings (Leaflet **BL/6-15**) are available in sizes up to 2½ in. diameter, and these are often used in aircraft fuel systems; however, where flexibility is required in joints, because of flight loads and temperature variations, specially designed couplings may be employed. A number of non-standard couplings are described and illustrated in the following pages.

5.8.1 **Flexible Couplings.** Two types of flexible coupling are illustrated in Figure 11. Sketch (A) shows a coupling which has provision for a certain amount of misalignment, as well as both angular and axial movement of the pipes. The pipe ends are beaded, and the surfaces within the joint are smooth and polished, so that the seals may slide freely over the pipes. A split retainer encloses the beads. When the coupling nut is tightened on the body, the O-rings are squeezed between the gland washers and the split retainer, and expand to form a seal between the body and the pipes. Sketch (B) shows a coupling which is less flexible, but which has provision for a limited amount of misalignment and movement. When the inner and outer sleeves are screwed together pressure is applied to the split collars, and the rubber seal is squeezed out to form a seal between the inner sleeve and the pipe beads.

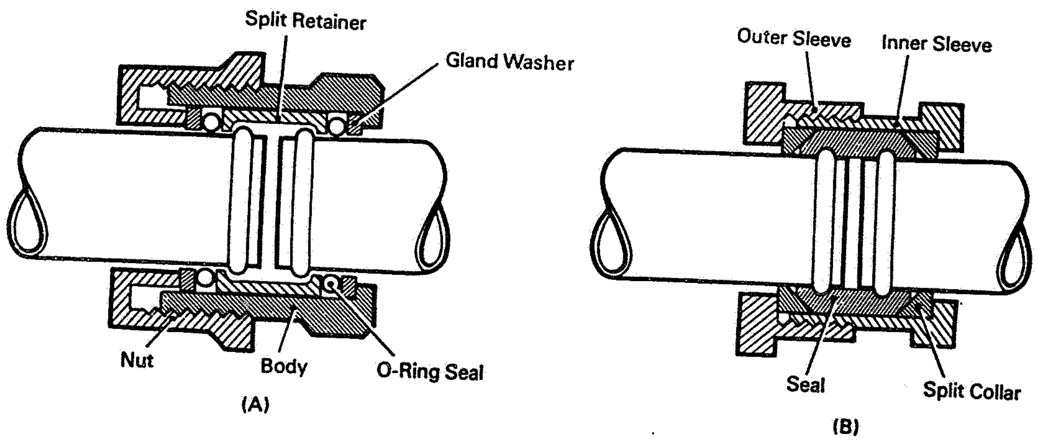

Figure 11 FLEXIBLE COUPLINGS

5.8.2 **Vee-clamp Couplings.** Figure 12 illustrates a typical Vee-clamp coupling. With this coupling a special fitting is welded to each pipe end, and the two fittings are held together by a pair of vee-section, semi-circular clamps. The seal is formed by an O-ring, which is located in a groove in one fitting, and is pressed against the face of the other fitting when the clamps are tightened. In some instances, fail-safe links are fitted to the clamps.

5.8.3 **Sliding Couplings.** Where only air or vapour passes through a pipe, a sliding coupling (Figure 13) may be used. As with vee-clamps, a special fitting is welded to each pipe end. An O-ring forms the seal, and the coupling is assembled by sliding the inner sleeve into the outer sleeve, so that the O-ring is located centrally.

5.8.4 Bonding of fuel system pipes is very important, since many of these are contained within the fuel tanks, and static electricity must be prevented from causing sparks in this explosive atmosphere. Bonding strips or cables are used to form a conducting path across couplings, and between pipes and adjacent structure. A typical bonding installation is included in Figure 14.

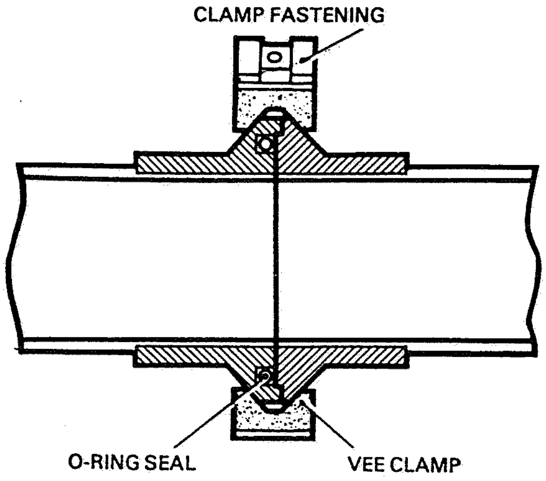

Figure 12 VEE-CLAMP COUPLING

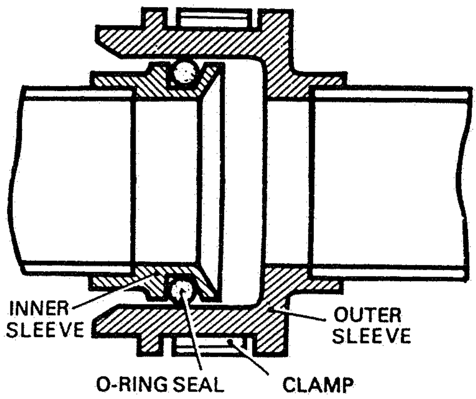

Figure 13 SLIDING COUPLING

5.8.5 In certain positions in the aircraft, couplings may be enclosed in drip shields, or heat shields, for safety reasons. Draining facilities are often provided on these shields, and a typical installation is shown in Figure 14.

5.8.6 Pipes are marked for identification purposes (see paragraph 4.5).

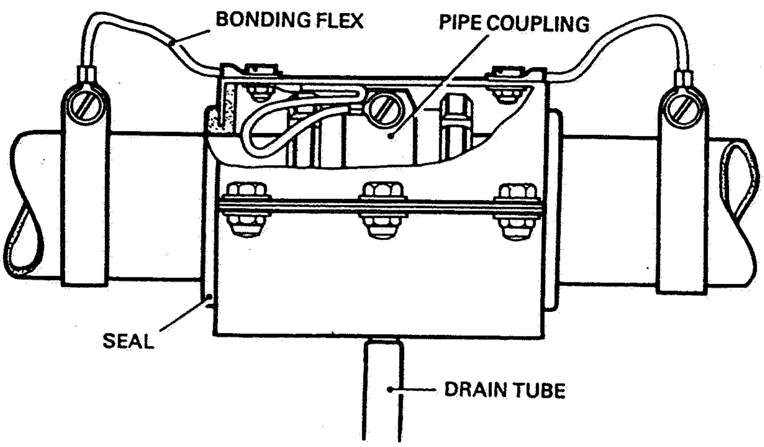

Figure 14 DRIP SHIELD, SHOWING BONDING CONNECTIONS

6 MAINTENANCE The fuel system is very important to the safe and efficient operation of an aircraft, and particular care must be taken to ensure that the instructions and precautions contained in the relevant manuals, schedules, and servicing instructions, are properly carried out.

6.1 **Safety Precautions.** The flammability of a fuel depends to a large extent on its flash point, and the different types of fuel vary considerably in this respect. Kerosene is far safer to handle than gasolene, but, regardless of the type of fuel used in a particular system, it is essential that precautions are taken to prevent the combustion of fuel vapours during servicing operations. In addition, precautions must be taken to prevent the harmful effects to health which may result from handling fuel or inhaling fuel vapour. The following general precautions should be observed whenever the fuel system is being worked on, and the relevant manuals should be consulted for any requirements which are applicable to a particular aircraft or fuel system. The special safety precautions necessary when entry into a tank is to be made, are detailed in Leaflet **AL/3-15.**

(a) The aircraft should be electrically earthed, and any ground equipment or containers should be earthed to the aircraft.

(b) Suitable and adequately manned fire-fighting equipment should be available, and suitable warning notices should be prominently displayed.

(c) Aircraft electric supplies should be switched off, and no live electrical cables should be left disconnected.

(d) Only spark-proof electrical equipment should be operated in the vicinity of the aircraft.

(e) Explosion-proof lamps and torches should be used.

(f) When draining fuel, any precautions detailed in the relevant Maintenance Manual regarding centre-of-gravity movement or maximum permitted jack loads, must be observed.

(g) To prevent undue spillage of fuel, tanks and pipes should be drained or isolated as appropriate, before breaking a connection or removing a component.

(h) Air-fed respirators should be worn in areas of high vapour concentration, e.g. near an open tank access hole.

6.1.1 **Refuelling/Defuelling.** When the aircraft is to be refuelled or defuelled, precautions must be taken to provide a path to earth for any static electricity which may be present, or which may build up as a result of the fuel flow. Refuelling and defuelling should normally be carried out in the open air, and suitable fire extinguishing equipment should be available and adequately manned. Both the aircraft and the refuelling vehicle should be earthed to a point which is known to be satisfactory, and an 'escape route' for the refuelling vehicle should be kept clear. When the aircraft is to be pressure refuelled the earthing wire on the refuelling pipe should be connected to the earth point provided on the aircraft, before connecting the refuelling pipe, and when the aircraft is to be refuelled through the over-wing filler port, the earthing wire on the refuelling pipe should be connected to the earth point provided on the aircraft before removing the filler cap and inserting the nozzle. The earthing wire should remain in position until after the refuelling pipe is disconnected, or the filler cap replaced, as appropriate. Similarly, when defuelling, the earthing wire should be connected first and disconnected last. No radio or radar equipment should be operated while refuelling or defuelling is taking place, and only those electrical circuits concerned with these operations should be switched on.

NOTE: Since pressure refuelling rates are high, the failure of an associated float switch or fuel level shut-off valve could cause a rapid build-up in pressure, and possibly serious damage to the tanks. Persons refuelling an aircraft should be prepared to shut off the supply instantly, should the automatic cut-off system fail to operate.

6.1.2 **Fuel Leakage.** When leakage or spillage of fuel has occurred, care must be taken to ensure that all traces of fuel and vapour are removed. Where lagging has become contaminated with fuel in areas adjacent to passenger cabins and crew compartments, the lagging should be removed and cleaned, and any residual fuel should be mopped up. Where fuel has leaked into a compartment which is vented and drained, the venting and drainage arrangements should be checked to ensure that they are functioning correctly, and that there is a flow of air through the compartment. It is sometimes specified that a check of the venting system of such a compartment should be carried out with the cabin pressurised. In the event of a gross leakage, consideration should be given to the effects that fuel may have on other materials and components, such as cable insulation, seals, transparencies and bearings.

6.2 **Cleanliness.** Scrupulous cleanliness is essential for correct and safe operation of an aircraft fuel system. This applies not only to the installed fuel system, but also to any ground equipment (e.g. test rigs, containers, refuelling vehicles and storage tanks) used in connection with it; a check for contamination in ground equipment should be carried out on a regular, planned basis. Foreign matter or contaminants in an aircraft fuel system can cause serious corrosion or damage to tanks and components, and may result in engine malfunction.

6.2.1 Whenever an orifice or a connection in a fuel system has unavoidably to be left open, protection against the entry of foreign matter must be provided, by the use of blanks or specially designed covers; these blanks or covers must remain in place until the orifice or connection is finally closed. The blanking of all openings in components removed from a fuel system is equally important, especially when the components are being returned for investigation; any foreign matter retained in the component may provide a clue as to the cause of the failure or malfunction.

6.2.2 In many cases, standard AGS blanks, made from rubber, plastic or metal, may be suitable for use in a fuel system, but many components have non-standard connections, and these necessitate the use of blanks which are specially designed for the purpose, and made from a material which is compatible with the fuel. No material from which particles are easily detached (e.g. cotton, paper, wood and cork) should be used for blanking purposes. Blanks must be designed so that it is impossible to re-connect the attaching component with a blank in place.

6.2.3 When jointing compound is used during installation or assembly of a component, care must be taken not to use an excessive amount, otherwise surplus compound may enter the system, and block or damage components such as valves, pumps and filters. Surplus compound should be wiped off whilst still wet.

6.2.4 The tanks, filters, and the lowest points in a number of feed and vent pipes, are fitted with drain valves, by means of which fuel samples may be taken after refuelling, and at the periods specified in the approved Maintenance Schedule. Fuel samples are normally collected in a glass jar, and should be inspected for the presence of free water, sediment and microbiological contamination. If excessive free water or sediment is found in the samples, all fuel should be drained from the system, and the tanks should be partially filled with clean fuel. This fuel should then be drained through the drain valves until samples are satisfactory. If microbiological contamination is found in the samples, the tanks should be visually inspected for fungal deposits, which, if present, must be removed (Leaflet **AL/3-15**). After removal of fungus, the fuel feed system must be flushed through to remove microbiological debris. Whenever excessive contamination of any sort has been found, the system filters should be inspected, and cleaned or replaced as necessary.

6.3 **Component Removal and Installation.** In order to remove a component (except for those in the top of a tank) it will usually first be necessary to drain some, if not all, of the fuel in a tank, or to close the low pressure, transfer, or servicing valves, so as to isolate part of the system. The normal defuelling system should be used to remove large quantities of fuel, but small quantities may be drained into suitable containers, using the water drain valves. The fire and safety precautions detailed in paragraph 6.1 should be observed when defuelling and when working on the fuel system. Actual procedures for removing or installing components should be obtained from the appropriate Maintenance Manual, but the following general points should be taken into account.

6.3.1 **Removal**

(a) Any electrical circuits which have to be disconnected, should first be isolated by removing the associated fuse, or by tripping the associated circuit breaker, as applicable.

(b) Care should be taken not to twist or strain the pipes, when removing union nuts; the use of two spanners is recommended wherever possible.

(c) In order to remove a component, it may be necessary to remove adjacent pipe clips in order that pipes may be withdrawn without damage. Care must be taken not to dent or score pipe flares or mating surfaces when removing the associated component.

(d) Provision should be made for the collection of any fuel which may drain from the pipes when they are disconnected. Any spillage should be mopped up.

(e) Any nuts and washers which are removed should be retained, but seals and gaskets should be discarded.

(f) Blanks or covers should be installed on openings and pipe ends, including those on the component which was removed.

6.3.2 **Installation**

(a) A component which is drawn from stores for installation on an aircraft, should be checked to ensure that it is the correct part, is to the required modification standard, and has the appropriate test and inspection markings; the remaining life of any seals or rubber components should also be checked. An inspection should be made for any damage or corrosion which may have occurred during storage. Any position indicators on the component should be checked for correct setting. Components such as valves, which have adjustable stops, should be checked to ensure that the stops are adjusted to the correct position of the valve.

(b) Any component which is treated with inhibiting oil, should be thoroughly flushed with system fluid, and dried with a lint-free cloth.

(c) New seals and gaskets should be fitted, blanks should be removed, and the component should be installed in position. Care should be taken not to damage associated joint faces, pipes, or threads. Mating parts should be checked for alignment and fit; they should not be forced into position.

(d) Modern aircraft fuel system components are so designed that it should be impossible to install them incorrectly. However, when fitting physically reversible units, or components with adjacent unions of similar size, care should be taken to ensure that the pipes are correctly connected.

(e) Where recommended, anti-seize compound should be applied to threads. To prevent contamination of the system, the compound should be applied sparingly, and should only be applied to the male thread on a pipe union. Seals should normally be lubricated with mineral jelly or an approved alternative; joint gaskets are normally fitted dry, but use of a sealant or jointing compound may be recommended in some instances.

(f) Nuts, bolts and pipe unions should be tightened to the recommended torque values, and the bonding wires and clips which were removed from adjacent parts should be replaced as originally installed.

(g) Any electrical connections to the component should be made before re-connecting the supply, and the unit should, where appropriate, be checked for full and free movement in the correct sense.

(h) Manual controls on valves should be checked to ensure that the valve operates in the correct sense, and reaches its stops before the associated control; the clearance between the control and its stops should be checked and adjusted to within the limits specified in the relevant manual. Controls should be locked after adjustment.

(j) The operation of limit switches on electrically-operated mechanisms, should be checked against the position of the component, and should be adjusted as necessary.

(k) Any indicators in the crew compartment, such as magnetic indicators and warning lamps, which are associated with the component being installed, should be checked for correct operation.

(l) Bonding should be tested as described in Leaflet **EEL/1-6.**

(m) When installation is complete a flow test and/or pressure test should be carried out.

6.4 **Refuelling.** Although there may be occasions when weight and centre-of-gravity considerations will limit the fuel load, light aircraft fuel tanks are normally completely filled before flight. With transport aircraft, however, the carriage of fuel not actually required for a particular journey would mean limiting the payload; only the quantity of fuel actually required (plus safety reserves) is therefore carried, and the tanks are seldom completely filled. Fuel gauges are normally compensated for changes in fuel density (Leaflet **AL/10-3**), and therefore indicate fuel weight, but it is general practice to check the tank contents by means of the dip sticks (paragraph 5.6), and since these indicate fuel level only, corrections must be made for the actual Specific Density of the fuel and the aircraft attitude. Some aircraft are fitted with an aircraft attitude indicator, and charts and tables are provided in the aircraft Maintenance Manual, by means of which correction factors may be applied to the dip stick readings obtained, when checking the fuel load.

6.5 **Filters**

6.5.1 A light aircraft fuel filter normally consists of a housing, a filter element, a sediment bowl, and a drain valve. Water and sediment may be drained from the bowl prior to flight, and the bowl should be removed periodically for cleaning and inspection of the filter element. These filters are often placed in the suction line to the pump and, when replacing the bowl, care should be taken to ensure that it forms a good seal with the housing; a leak could result in inadequate fuel supply to the engine.

6.5.2 The main filters fitted to turbine engined aircraft are usually fitted to the engine, and consist of a housing, a felt or paper filter element, a filter case, and a drain valve; in some aircraft the housing incorporates a differential pressure switch, which operates an icing warning lamp in the flight compartment. The drain valve may be used to take fuel samples (paragraph 6.2.4), but precautions may need to be taken to avoid the need to bleed the engine fuel system; these precautions normally include closing the high pressure fuel cock, opening the low pressure fuel cock, and using the tank booster pump to discharge the fuel sample. New filter elements should be fitted at the periods specified in the approved Maintenance Schedule, and whenever breakdown, repairs, or contamination of the system have taken place. To remove a filter element, the high and low pressure fuel cocks should be closed, the associated electrical services should be isolated, and the element and case should be removed; any debris should be examined, and the source located. Before fitting a new filter element, the case should be washed out with kerosene or trichloroethylene, and old seals or gaskets should be replaced; it is usually recommended that seals are lubricated with kerosene or petrolatum prior to installation. After fitting a filter element, it is usually necessary to run the associated engine, and to check the system for satisfactory operation and freedom from leaks.

7 PRESSURE TESTS Pressure tests are normally required at regular intervals, after repairs, modifications, and replacement of components, and whenever leakage is suspected. In those vent systems which utilise part of the wing structure (e.g. top hat sections) to form the vent duct, vent pressure tests may also be required after structural repairs. The tests required will be specified in the relevant Maintenance Manual, and should be carefully carried out. Test rigs, capable of supplying fuel or air under pressure, are required, and should include an accurate pressure gauge, a relief valve, and, in the case of a fuel pumping rig, a flowmeter. All test rigs should be clearly identified with the certification (or re-certification) date. In addition, special blanks, plugs, cover plates, and dummy components may be required. The vent, feed, and transfer systems are usually tested separately since different test pressures are generally prescribed.

7.1 **Vent System Pressure Test.** For this test, the vent system on each side of the aircraft should normally be tested separately. All vent openings should be blanked, and it will often be necessary to gag float-operated valves, or to replace them with dummy components. Alternative means of venting the tanks during the tests should be provided. Air pressure should be applied to the system either through a water drain valve, or through an adaptor fitted to one of the blanks, and the pressure should be slowly raised to the test pressure quoted in the relevant Maintenance Manual. When the air pressure supply cock is turned off, any decrease in pressure will indicate leakage, and the drop in pressure over a prescribed time should be noted. The source of any leakage in excess of that permitted should be traced and rectification action should be taken.

7.2 **Feed System Pressure Test.** The feed system from a tank to its associated engine should be tested individually. Cross-feed and inter-engine valves should be closed, and the low-pressure cock should be opened. On some aircraft the feed systems are pressurized by switching on both pumps in the tank concerned, whilst on others the booster pumps are replaced by dummy components, and fuel pressure is applied by means of an external test rig. In some systems (see Figure 2) there will be flow through the bleed hole in the suction valve, and this must be within prescribed limits. Rates of flow indicated on the test rig flowmeter, which are in excess of these limits, will be indicative of either an internal or external fuel leak. All pipes, connections, and valves should be checked visually for signs of leakage under pressure; no leakage is normally permitted.

NOTE: In systems in which drip shields or heat shields are fitted to some couplings, the test pressure must be applied for a sufficient length of time to enable any leakage to collect and flow through the drain. Alternatively, a separate pressure test of the drip shield may be specified, or the shield may be required to be removed for the test.

7.3 **Transfer System Pressure Test.** The pipes and couplings in the fuel transfer system may be pressure tested in a similar manner to the feed system. Pipes should be disconnected and blanked at the positions specified in the relevant Maintenance Manual, and fuel pressure should be applied by means of the transfer pump, or by use of an external test rig, supplying fuel through a dummy pump. No leaks should be evident, and no fuel flow should be recorded on the test rig flowmeter.

7.4 **Additional Pressure Tests.** A number of other pressure tests may be specified, in order to ensure that there is no leakage which could prove hazardous, or prevent proper operation of the fuel system. One example is the pressure testing of conduits which pass through the fuel tanks, and house electrical cables. These conduits are usually sealed by means of a pressure bung or pressure seal, and are tested by applying air pressure to the inside, through a drain pipe, or special adaptor. When the air supply is shut off, there should be no drop in pressure over a prescribed period of time. If leakage is evident at the pressure bung, it is usually permissible to apply sealant to seal the bung and the holes through which the cables pass.

8 FLOW TESTS Flow tests should be carried out in accordance with the relevant Maintenance Manual, as and when required by the approved Maintenance Schedule, or when necessitated by repairs, replacements or modifications. The tests are designed to ensure that the system will provide a fuel flow to each engine which is in excess of the requirements of the engine when it is operating at maximum power, and at a pressure suitable for proper operation of the carburettor or engine-driven pump, as appropriate. For all tests the aircraft should be levelled laterally and longitudinally, and the fuel tanks should contain the minimum quantity of fuel (i.e. unusable fuel plus sufficient for the test only); tank vents should be clear, and overwing filler caps should be fitted. All equipment used should be bonded and electrically earthed.

8.1 **Full Flow Test.** A full flow test is normally only required after initial installation or major breakdown of the system. Fuel flow test rigs are required for the test, and should be located adjacent to each engine, with the test rig pump at the same level as the engine-driven pump. The rig inlet hose is usually connected to a self-sealing coupling on the engine bulkhead, and the outlet directed to a suitable container. An external electrical supply should be connected to the aircraft, in order to operate the fuel system valves and to check operation of the associated warning lamps and indicators. The test includes suction feed operation (using the test rig pump), pressure feed operation (using the aircraft booster pumps), and all possible combinations of cross-feeding, to ensure that fuel flow is satisfactory under all flight conditions. The schedule of test operations, and the flow rates and pressures which should be achieved, are detailed in the relevant Maintenance Manual.

8.1.1 For the suction test, the test rig pump is used to draw fuel from the tanks. Valve selections should be made according to the test schedule, and the flow rates and pressures obtained at each stage of the test should be recorded. These results should be within the limitations prescribed for the suction test.

8.1.2 For the pressure test, the aircraft booster pumps should be used to pump fuel from the tank. The test rig pump is switched off, and its by-pass opened. Selections of pumps and valves should be made in accordance with the test schedule, and the flow rates and pressures obtained at each stage of the test should be recorded. These results should be within the limitations prescribed for the pressure test.

8.2 **Limited Flow Test.** A limited flow test is often considered as a satisfactory method of checking a fuel system after a component has been changed; only that part of the system affected by the component change needs to be tested. The fuel feed pipe is disconnected at the engine, or, in some instances, a drain pipe is connected to a special drain valve at the engine, and a suitable container is positioned to catch the drained fuel.

8.2.1 The appropriate low pressure cock should be turned on, and the flow rates should be checked with the associated pumps operating separately and together. For each part of the test, when the fuel flow is free from bubbles, it should be directed into a calibrated container, and the time taken to pump a given quantity of fuel should be recorded. These figures should be converted to flow rates, which should not be less than the minimum flow rates specified in the relevant Maintenance Manual.

8.3 **Gravity Feed Test.** To check a gravity feed system such as is fitted to some light aircraft, the feed pipe should be disconnected at the carburettor, and a suitable container should be positioned below the engine. With the fuel outlet positioned at the same height as the carburettor, and the fuel valve turned on, the fuel should be checked for freedom from bubbles and for full-bore flow, then directed into a calibrated container. The time taken to drain a given quantity of fuel should be recorded, and the equivalent flow rate should not be less than the minimum flow rate specified in the relevant Maintenance Manual.

9 STORAGE Components should be stored as detailed in Leaflet **BL/1-7.** Further particulars regarding the storage of tanks may be obtained from Leaflet **AL/3-15.**

AIRCRAFT

SYSTEMS AND EQUIPMENT

TYRES

1 INTRODUCTION This Leaflet gives general guidance on the care and maintenance of aircraft tyres. It should be read in conjunction with the manufacturer's manuals for the tyres concerned, since minor variations may occur between the various manufacturers' products. The topics discussed are as follows:—

1.1 Information on the maintenance and overhaul of wheels and brakes is given in Leaflet **AL/3-19.**

1.2 The high take-off and landing speeds of most transport aircraft have resulted in tyres being operated under increasingly severe and intensive loading conditions, therefore a high standard of maintenance and inspection is essential at all times to ensure the continued serviceability of the tyres. The CAA recommends that, in all cases where doubt exists regarding the condition of aircraft tyres, the tyres should be changed and the tyre manufacturer's representative should be consulted.

2 GENERAL

2.1 **Tubed Tyres.** Tubed aircraft tyres consist of two component parts, i.e. inner tubes and outer tyres. The general construction of a typical tyre is shown in Figure 1, but the detailed construction varies considerably according to the manufacturer and the duties for which the tyre is intended.

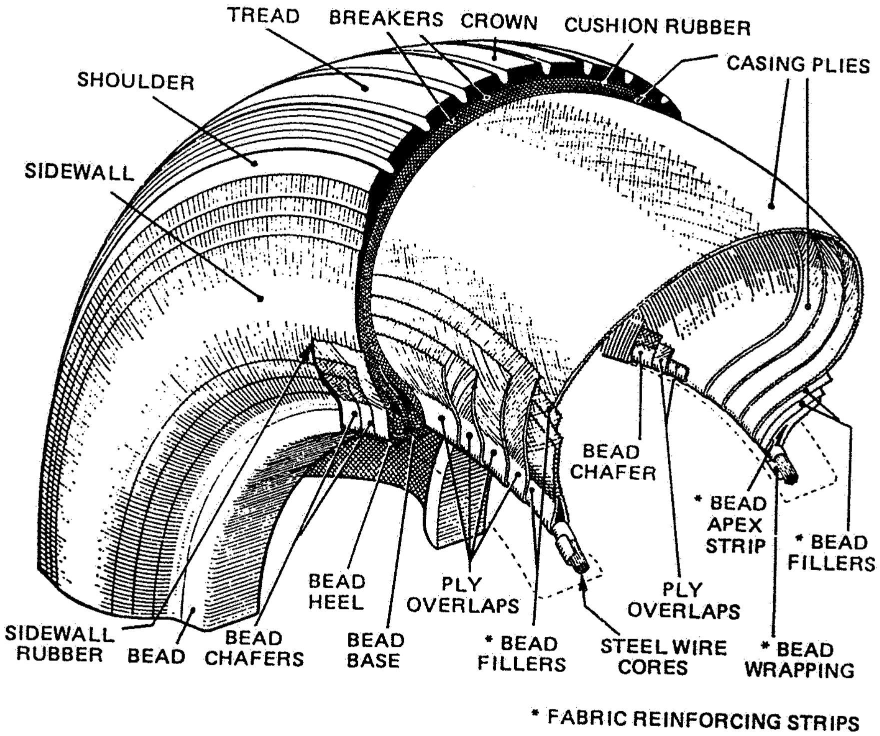

Figure 1 CONSTRUCTION OF TYPICAL TUBED TYRE

2.2 **Tubeless Tyres.** Basically a tubeless tyre is identical to a tubed tyre except that the tube is replaced by an air-retaining inner lining and the beads are designed to prevent air leakage at the rim of the wheel. Some of the advantages derived from the use of tubeless tyres include about 7½% saving in weight compared with using a tyre and tube, a reduction in permeability losses, cooler running by about 10°C, less danger of deflation due to puncture, and the elimination of tube troubles. Because it is necessary to keep the bead areas in good condition, tubeless tyres are not fitted to well-base wheels.

2.3 **High Pressure Tyres.** Some aircraft tyres are inflated to pressures of 1400 kN/m² (200 lbf/in²) or more. Because of their strength and rigidity, such tyres, whether tubed or tubeless, are normally fitted only to divided or detachable-flange wheels. Special precautions are necessary to protect personnel from injury during initial inflation (paragraph 7.1).

2.4 **Tyre Venting.** During manufacture all tubeless tyres are provided with vents by partially piercing the rubber covering with an awl (of approximately 1·5 mm (0·0625 in) diameter) at several places, usually around the tyre immediately outside the area of the wheel flanges, but, in some instances, also on the crown and shoulder areas. These vents are provided as a means of releasing air under pressure from the tyre casing, and are marked with a green or grey spot. Such air may be residual air in the casing cords after manufacture, which is compressed to a high pressure on inflation of the tyre, or air which accumulates in the casing by normal permeation through the inner lining. If a free passage of air were not provided, the residual or permeating air could cause looseness or lifting of rubber on the tread or sidewalls of the tyre. Aircraft tyres to which tubes are fitted, are vented through the complete casing at the bead position in order to allow air trapped between the tube and tyre to escape.

2.5 **Tread Patterns.** The tread pattern on a tyre is usually designed to suit specific operating conditions, aircraft weights, and aircraft take-off and landing speeds.

2.5.1 Ribbed (i.e. circumferentially grooved) tread tyres are probably used more than any other types, and there are a number of variations on the basic pattern such as the number of ribs and the width of grooves. A ribbed tread provides a good combination of long tread wear, good traction, and directional stability, particularly on hard surfaced runways.

2.5.2 Diamond pattern (or 'all-weather') tyres are also widely used and give good performance on all types of surfaces. They are particularly suitable for unpaved (e.g. turf or packed earth) airfields.

2.5.3 Plain tread was at one time very common, particularly on British aircraft, but has gradually been replaced by ribbed and diamond pattern treads. It is, however, still used on some light aircraft and helicopter tyres.

2.5.4 Some nosewheels are fitted with tyres having twin-contact tread, i.e. a tread consisting of a large circumferential rib at each side of the crown, which is designed to assist in preventing shimmy.

2.5.5 Some nosewheel tyres are also fitted with a water deflector (or 'chine') on the upper sidewall, to deflect water away from rear-mounted engines. This deflector may be on one side for twin-wheel installations or on both sides for single-wheel installations.

2.5.6 Water dispersing treads, which have many small holes incorporated in the crown and shoulder rubber, are also fairly common as a means of helping to prevent aquaplaning.

3 TYRE MARKINGS Tyres have certain markings imprinted on their sidewalls for identification purposes. These markings vary according to the manufacturer but usually include size, part number, serial number, date of manufacture, tubed/tubeless, speed rating, ply rating, and the type and number of retreads carried out. These markings are explained in paragraphs 3.1 to 3.7.

3.1 **Size.** Tyres are identified for size in the following way:—
Example: 26 × 10·00-18.
The first number (26) indicates the outside diameter (A in Figure 2) in inches.
The second number (10·00) indicates the width (C in Figure 2) in inches.
The third number (18) indicates the bead diameter (B in Figure 2) in inches.
It will be found that some tyres do not specify all three dimensions. Some tyres of American manufacture may quote only the outside diameter (e.g. 26) but otherwise the tyre width will always be stated, either preceded by the outside diameter (e.g. 26 × 10·00) or followed by the bead diameter (e.g. 10·00-18).

NOTE: Dimensions (A) and (C) may, alternatively, be quoted in millimetres.

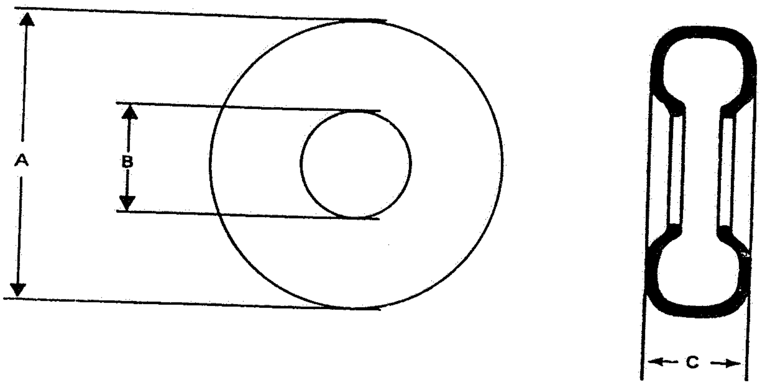

Figure 2 TYRE DIMENSIONS

3.2 **Part Number.** The part number usually includes the manufacturer's identification, the drawing to which the tyre is manufactured, and letters to indicate the tread type, and whether it is tubed or tubeless. The part number is the only positive means of identifying a tyre, and size markings alone should not be used for this purpose. Example: DR 7153 T.

3.3 **Serial Number.** The serial number is usually marked in conjunction with the date of manufacture, which may be in the form of a code indicating the day, week, or month, and the year.
Example: 2283 Nov 72 or 23202283.

3.4 **Ply Rating.** The term 'ply rating' is used to identify a tyre with its maximum recommended load and pressure. It is the index of the tyre strength and does not necessarily represent the number of cord plies used in its construction. The marking may be imprinted in full, e.g. 10 PLY RATING, or abbreviated, e.g. 10PR.

3.5 **Speed Rating.** Most high speed tyres (i.e. those which may be used at speeds over 160 mile/h) have the speed rating imprinted on the tyre to indicate the maximum speed for which they are designed, e.g. 200 mile/h.

3.6 **Other Markings.** Other markings which may be found on new tyres include the following:—

(a) Military Stores Reference Number.

(b) Green or grey spots indicating the positions of the awl vents.

(c) A red spot or triangle indicating the light part of the tyre.

3.7 **Retreads.** Retreaded tyres are usually marked in accordance with a system peculiar to each manufacturer. The markings usually include the tyre part number, the name of the retreader, the number and date of the last retread, and in the case of retreads in which the sidewalls are covered with new rubber, the tyre serial number, manufacturer, speed, size and ply rating.

4 FITTING TUBED TYRES The successful fitting of tyres is not difficult provided that a suitable procedure is employed and the correct type of tool is used for each operation. However, careful attention to detail is essential throughout the process, since visual inspection after the tyre is fitted is obviously limited.

4.1 When a new tyre is required on those aircraft fitted with tubed tyres, it is advisable to fit a new tube since any stretching or local thinning present in the original tube may result in the formation of wrinkles during refitting, leading to early failure of the tube. If it is decided to refit the original tube it should be carefully examined for signs of damage or defects before refitting.

4.2 Care should be taken to ensure that the tyre and tube are of the correct size, and of types authorised for use on the particular wheels of the particular aircraft. It is also important to ensure that the correct type of valve cap is fitted, since an incorrect type of cap may foul the airframe structure when the landing gear is retracted.

4.3 **Tyre Balance.** The balance of tyres and tubes is checked and brought within specified limits by the tyre manufacturer (often by the addition of a balancing patch). Where balance is not perfect the lighter side of the tyre is marked with one or two circular or triangular spots above the bead heel and the heavier side of the tube is marked with a red or yellow band approximately 10 mm (0·375 in) wide; fitting the tyre and tube with these markings together will achieve the best state of balance.

4.4 **General Fitting Precautions.** When fitting tyres and tubes to any type of wheel, the following general precautions should be observed:—

(a) Care must be taken to ensure that nothing is left inside the tyre, e.g. labels, paper or tools, and that the rim of the wheel is clean, free from oil and grease and from damage which, apart from other considerations, might be harmful to the tyre or affect its form.

(b) Wheels should be rested on rubber or felt mats to prevent damage during assembly.

(c) The outer surface of the tube and the inner surface of the tyre should be dusted with French chalk, any excess being shaken off.

(d) Tyre and tube balance marks (paragraph 4.3) should be aligned during assembly.

(e) After fitting a tube into a tyre, the tube should be smoothed out with the hand to remove any creases; this will help to prevent the trapping of air inside the tyre during inflation.

(f) Care should be taken to ensure that valves of the correct part number are fitted. The inflation valves for all high pressure tyres should have hexagonal valve caps and should be fitted with cores having stainless steel springs.

4.5 **Well-base Wheels**

4.5.1 **Preparation for Fitting.** When fitting a tyre to this type of wheel, all air should be expelled from the tube before it is fitted into the tyre. This should be done by removing the core from the valve and rolling the tube tightly until it is completely deflated; the core should then be refitted.

4.5.2 **Fitting the Lower Bead.** The tyre should be inclined to the wheel and the lower bead pushed on by hand to just over half-way, ensuring that the bead enters the well. The fitting of the bead should be completed in a series of small 'bites' with the appropriate lever, using water or an approved bead lubricant to facilitate fitting.

4.5.3 The tube should be placed on top of the tyre so that the position of the valve stem corresponds to the valve hole in the wheel. The valve-bearing portion of the tube should then be pushed into the tyre, the valve inserted into the valve hole and loosely secured with the valve cap or extension piece. Finally, the remainder of the tube should be pushed into the tyre and, after ensuring it is clear of the bead seat, inflated gently until it adopts its correct contour, so that it can be checked for freedom from twisting or creasing. While it is inflated, the position of the valve should be checked to ensure that it is concentric with the hole.

4.5.4 **Fitting the Top Bead.** The top bead should be fitted with the appropriate lever, ensuring that the bead section adjacent to the valve is the last to be fitted and using a lubricant as before. Care must be taken to ensure that the bead enters the well without nipping the tube.

4.5.5 After the tyre has been fitted it should be inflated to a pressure sufficient to position the beads on the bead seats. The tube should then be slowly deflated, care being taken not to disturb the bead positions, and slowly re-inflated and tested as outlined in paragraphs 7 and 8 respectively. The purpose of deflation is to ensure that the tube adopts a position free from creases, and that the minimum amount of air is trapped between the tyre and tube.

4.6 **Divided Wheels**

4.6.1 **Preparation for Fitting.** The wheel should be dismantled by removing the nuts, collars, locking plates and bolts, and then the upper half of the wheel should be lifted off.

4.6.2 **Fitting the Tyre.** The tube should be placed in the tyre and then inflated until it just adopts its correct contour. Great care is necessary when fitting tyres to this type of wheel, since if the tube is not sufficiently inflated it may become trapped between the two halves of the wheel; conversely, if the tube is over-inflated, the halves of the wheel will not meet. The tyre, with the tube inflated as described above, should be placed on the lower half of the wheel, with the valve in alignment with the valve hole.

4.6.3 The upper half of the wheel should then be fitted, two opposite bolts being inserted to guide it into position; care should be taken to ensure the valve is centrally positioned in its hole. On pressing the two halves of the wheel together, a metallic noise should be heard when they meet; this is a good indication of whether or not the tube has been nipped. When it is ensured that the tube is not trapped, the remaining bolts should be inserted and the nuts fitted, but not tightened at this stage since tightening may cause the wheel to turn in the tyre and so damage the valve stem.

4.6.4 The tyre should now be inflated to a pressure sufficient to position the beads on the bead seats, and as soon as one bead grips the wheel, the bolts should be progressively tightened, taking opposite bolts in a sequence similar to that shown in Figure 3. The final tightening should be in the order and to the torque values recommended by the manufacturer.

NOTE: If the tyre has fitting lines on its walls just above the wheel rim, these should be used as a guide to the correct fitting of the tyre.

4.6.5 The nuts should then be locked, as appropriate, and the tyre inflated and tested as outlined in paragraphs 7 and 8 respectively.

4.7 **Detachable Flange Wheels**

4.7.1 **Preparation for Fitting.** The lock-ring and loose flange should be removed from the wheel, the method of removing the lock-ring depending on the type fitted.

(a) To remove the split type lock-ring, a screwdriver should be inserted in the slot and, after the flange has been pushed inward and clear of the lock-ring, the lock-ring should be gently prised from the groove. Lock-rings of the coil type can be removed with the fingers.

(b) When the flange has been removed, the wheel should be laid flat on a block to allow the tyre to drop to the full depth of the wheel.

4.7.2 **Fitting the Tyre.** The tube should be placed inside the tyre and inflated to shape, after which the tyre should be positioned on the wheel, care being taken to ensure that the valve is correctly positioned in relation to the valve slot.

4.7.3 The loose flange should be placed in position and pushed down clear of the lock-ring groove in the wheel; the lock-ring should then be fitted. If the lock-ring is of the split type, care must be taken to ensure that the collar, if fitted, is correctly positioned in the notches in the wheel and the flange. Coil type lock-rings must be fitted by hand. Finally, the tyre should be inflated and tested as outlined in paragraphs 7 and 8 respectively.

5 FITTING TUBELESS TYRES Prior to fitting the tyre, the wheel should be examined for scratches and other damage in the flange, bead seat and rim areas. Any damage should be blended out within the limits permitted by the relevant Maintenance or Overhaul Manual. The beads and inner liner of the tyre should be checked for damage, and the wheel sealing ring should be checked for defects such as deformation, permanent set and ageing. The precautions outlined in paragraph 4.4 should be observed, as applicable.

5.1 **Fitting the Tyre**

5.1.1 The seal spigot joint faces of divided wheels and seal register area, should be cleaned and lightly lubricated with a preparation recommended by the manufacturer. The seal should then be stretched evenly onto the wheel, ensuring that it is seating correctly in its location groove.

5.1.2 The tyre bead and wheel bead seat areas should normally be kept dry, but some manufacturers permit or recommend the use of a bead lubricant to facilitate mounting. The tyre should be positioned on the wheel with the balance mark on the tyre in alignment with the balance marks (if any) on the wheel. When the wheel has no balance marks, the tyre balance mark should be aligned with the valve location.

NOTE: It is important that the tyre beads should not become contaminated with wheel grease.

5.1.3 With divided wheels, the bolt threads should be lightly lubricated with a grease recommended by the manufacturer and the bolts progressively tightened, in a sequence similar to that shown in Figure 3, to the recommended torque value. Wet assembly of the bolts may be specified by the manufacturer.

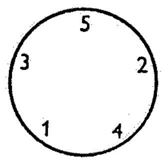

Figure 3 TIGHTENING SEQUENCE

5.1.4 With the valve core removed to permit the maximum flow of air, the tyre should be inflated as rapidly as possible to spread the tyre walls until the beads seat on the rim. Once this condition has been achieved, inflation should be discontinued immediately. If inflation cannot be effected, as a result of, for instance, tyre distortion caused by storage or transit, the assembly should be stood vertically and a load applied to the crown.

5.1.5 When the beads are correctly seated, the valve core should be refitted, and the tyre should be inflated and pressure tested as outlined in paragraphs 7 and 8 respectively.

5.2 **Sidewall Valves.** Some tubeless tyres are fitted with a sidewall valve (Figure 4) which is in the form of a rubber self-sealing insert in the tyre wall. A central aperture in this insert permits the insertion of a servicing needle for inflation and deflation purposes. Before inflating a tyre of this type, the servicing needle must be inspected for cleanliness and lubricated with the felt pad contained in its sheath.

NOTE: Servicing needles should be inserted and removed using a twisting motion.

6 WHEELS SUITABLE FOR TUBED OR TUBELESS TYRES Detachable flange wheels are available to which either tubeless tyres or tubed tyres can be fitted. This is effected by means of special adaptors which permit an inflation valve assembly to be used for both purposes. For tubeless tyres the special adaptor is secured by a nut and washer, and is made leakproof by a rubber 'O' ring clamped between the washer and the outer chamfered seating of the adaptor housing, as illustrated in Figure 5(A). For tubed tyres the adaptor is integral with the inner tube and is similarly secured by a nut and washer, but in this instance an additional rubber 'O' ring is fitted between the head of the adaptor and the inner chamfered seating of the adaptor housing, as shown in Figure 5(B).

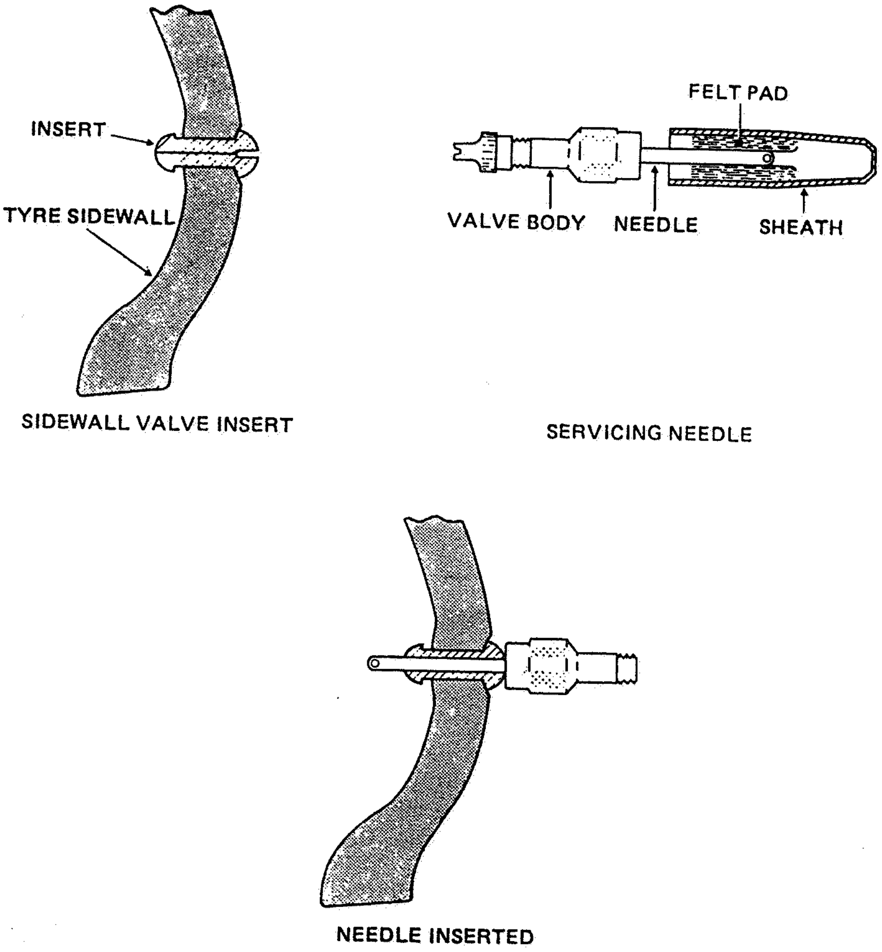

Figure 4 SIDEWALL VALVE

6.1 **Fitting Tubeless Tyres.** If the adaptor has been removed, ensure that its sealing face and also the sealing face of the wheel are not damaged or corroded. The adaptor should be placed in position, and the outer 'O' ring should be lightly lubricated with an approved grease and carefully passed over the adaptor threads. The assembly should be secured to the wheel with the washer and nut, and the adaptor should be wirelocked to its retaining nut. The tyre should be fitted as recommended in paragraph 5.1, and should be pressure tested as indicated in paragraph 8. If the duration pressure test (paragraph 8.2) is employed, the efficiency of the outer 'O' ring and the inflation valve seal should be checked by the local application of an acid-free soapy water solution (prepared with non-corrosive soap). After this test the solution must be washed off with clean water and the part thoroughly dried.

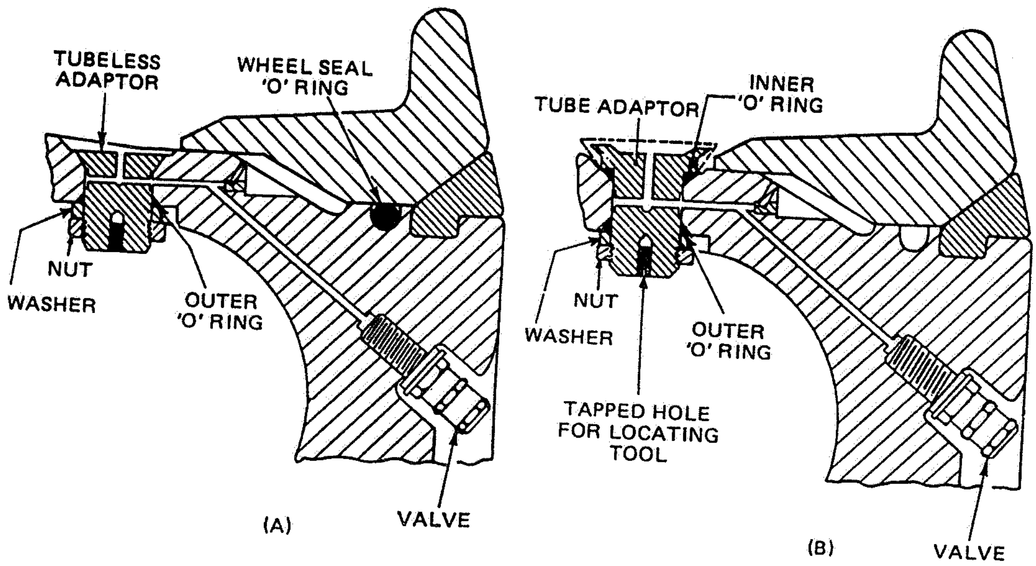

Figure 5 ADAPTORS FOR COMBINATION SCHEME

6.2 **Fitting Tubed Tyres.** The tube must be fully deflated (paragraph 4.5.1) before it is fitted into the tyre. The inner 'O' ring should be lightly lubricated with an approved grease and carefully passed over the adaptor threads until it seats around the shoulder adjacent to the tube.

6.2.1 The end of a special adaptor locating tool should be screwed into the end of the adaptor, and the tyre should be placed on the wheel, aligning the adaptor with its housing.

6.2.2 The locating tool should be passed through the adaptor housing in the wheel and, after re-checking the alignment, the tyre should be fitted, ensuring that the adaptor remains located in its housing. Finally, the wheel should be assembled, but in this instance the 'O' ring between the loose flange and the wheel (Figure 5(B)) should not be fitted.

6.2.3 **Assembling the Wheel.** The wheel should be placed with the fixed flange uppermost, and the adaptor should be pulled carefully into position. The outer 'O' ring should be greased and threaded over the locating tool, followed by the washer and nut, after which it should be passed carefully over the adaptor threads. The adaptor should be secured by finger-tightening the nut, and the locating tool should be removed. The special retaining tool should be used to compress the inner 'O' ring, after which the adaptor nut should be fully tightened. The loose flange should then be fitted (paragraph 4.7.3).

6.2.4 **Inflation and Testing.** The tyre should be inflated (paragraph 7) and pressure tested (paragraph 8), and on completion of the test, the tightness of the adaptor nut should be rechecked, after which it should be wirelocked. The sealing efficiency of the outer 'O' ring should be checked by applying an acid-free soapy water solution over the crevices between the wheel, lock-ring and flange. The gap between the ends of the lock-ring should be blocked with rags or paper to prevent the solution draining into the wheel.

NOTE: This test on the inner 'O' ring should not be carried out until at least one hour after inflation in order to allow air trapped between the tyre and tube to escape first.

7 INFLATION AFTER FITTING After fitting, both tubed and tubeless tyres should be inflated to the test pressure specified in the relevant manual.

7.1 A suitable supply of dry air or nitrogen should be connected to the valve; nitrogen is preferred, but air may be used provided that the moisture content, measured in the expanded condition, is less than 0·02 g/m^3. A screw-on type of connector should be used on tyres which are to be inflated to a pressure in excess of 700 kN/m^2 (100 lbf/in^2), and the tyre and wheel assembly should be contained within a safety cage to prevent injury to the operator.

7.2 All tyres should be inflated slowly, and this is particularly important with tubed tyres. With tubed tyres, inflation to 140 kN/m^2 (20 lbf/in^2) should take at least two minutes, and further inflation to full test pressure should take at least another four minutes. This procedure will reduce the possibility of trapping air between the tyre and tube.

8 TESTING The testing of either tubed or tubeless tyres should normally be by means of a duration pressure test, but an immersion test may sometimes be permitted on tubeless tyres when insufficient time is available. Pressure loss will occur on most tyres during a test, because of tyre stretch, and will be most apparent during the first 12 hours; the figures quoted for the duration pressure test take account of this loss.

8.1 **Venting.** With a tubeless tyre, venting from the awl vents (paragraph 2.4) occurs in three stages. The first stage of venting results from residual air in the casing and may be fairly rapid, but virtually ceases after 20 minutes. The second stage is a slow seepage of residual air from the casing and may last for several hours. The third stage is a continuing process and results from normal permeation through the inner lining. Tubeless tyres should, therefore, be tested after the first stage of venting has ceased, or misleading results could be obtained.

8.2 **Duration Pressure Test.** This test should normally be carried out as follows:—

(a) The valve cap should be removed and the valve checked for leakage.

(b) The actual tyre pressure should be checked and recorded.

(c) The assembly should be left for 12 hours, and the pressure should again be checked and recorded.

(d) If the loss in pressure from that originally recorded exceeds 10% the assembly should be rejected. If the loss in pressure is less than 10% the tyre should be re-inflated to the original pressure.

(e) The assembly should be left for a further 12 hours, and the pressure again checked and recorded.

(f) If the pressure loss is more than 2½% the assembly should be rejected, but if less than 2½% the assembly may be considered serviceable and returned to service.

NOTE: When recording tyre pressures allowance should be made for changes in ambient temperature. A temperature change of 3°C will result in approximately a 1% change in pressure. Application of the tyre pressure gauge will also result in a slight loss of pressure.

8.3 **Immersion Test.** After the first stage of venting, i.e. 20 minutes after inflation, the wheel and tyre should be mounted on a suitable bar and suspended in a tank of water so that the water covers the lower cross-section of the tyre and valve, but does not reach the wheel bearings. The wheel should then be slowly rotated and checked for leakage from the beads seats, seal area, valve, fusible plugs (see Leaflet **AL/3-19**) and wheel hub. A continuous stream of bubbles from any of these areas is cause for rejection. After testing, the wheel and tyre assembly should be thoroughly dried, using a jet of compressed air.

8.4 After tests have been satisfactorily carried out, the pressure should be reduced to 20% of unloaded inflation pressure for storage and transit, and the valve cap should be refitted and tightened to the specified torque value.

9 TYRE CREEP When wheels are first fitted to an aircraft, the tyres tend to move slightly as they settle down on the rims, the initial movement varying according to load, pressure, braking, shimmy and outside diameter of the tyre in relation to rim diameter. After the settling down period, circumferential movement may continue gradually and, if this extends beyond a certain limit, the valve may be torn from the tube.

9.1 In order that creep may be detected, marks are moulded into the lower wall of most tyres. The marks usually consist of two arrows, spaced 25 mm (1 in) apart on tyres up to 600 mm (24 in) nominal outside diameter and 38 mm (1·5 in) apart for all larger tyres. The marks usually commence at the wheel rim and extend outward, the surface between being knurled.

9.2 The knurled surface should be painted white, the paint mark being carried down on to the rim. The width of this mark represents the maximum circumferential movement permitted with tubed tyres, and if the tyre creep mark becomes out of alignment with the mark on the wheel by more than the width of the mark the wheel should be removed and the tyre and tube taken off and reassembled; before reassembly, the valve should be checked to ensure that it is undamaged. In the case of tubeless tyres, creep is not considered to be detrimental provided that bead condition is satisfactory and any pressure loss is within limits.

9.3 When tyre replacements are made, the old marking on the wheel should be removed with a suitable solvent and a new creep mark applied.

10 MAINTENANCE OF TYRES Unsatisfactory tyre maintenance can significantly affect tyre performance and reliability, and jeopardise aircraft safety. Serious accidents and incidents have occurred when engine, airframe and aircraft systems have suffered damage as a result of neglected or incorrect tyre maintenance. Various studies indicate that a significant number of tyre failures and premature removals could have been prevented by careful attention to recommended tyre maintenance procedures and practices.

NOTE: Where removal of a tyre is recommended in this paragraph, it should be understood that this implies removal of the tyre and wheel assembly from the aircraft.

10.1 **Tyre Pressures.** The importance of keeping tyres inflated to the correct pressure cannot be overstated. Under-inflated tyres may creep to such an extent that the valve could be torn out, causing the tyre to deflate rapidly, whilst over-inflation can cause excessive vibration when taxying, uneven tyre wear and high pressure bursts. In addition, where two wheels and tyres are mounted on the same axle, unequal tyre pressures will result in one tyre carrying a greater share of the load than the other, with possible operation above its rated capacity; the undercarriage may also be subject to additional stress.

10.1.1 Tyre manufacturers specify a rated inflation pressure for each tyre, which applies to a cold tyre not carrying any load. The pressure to which a tyre should be inflated when it is subject to aircraft weight, is determined by adding a pressure allowance (normally 4%) to the rated inflation pressure. A tolerance of 5% to 10% above the loaded inflation pressure is generally specified, and tyre pressures up to this maximum are permitted and may benefit tyre reliability. The loaded inflation pressures for the tyres on a particular aircraft may be specified in the relevant Maintenance Manual as the maximum and minimum pressures permitted, or in the form of a graph with pressure being a function of aircraft weight.

10.1.2 After an aircraft has landed, or has been subject to prolonged taxying, individual tyre pressures may vary because of the absorption of energy by the tyre and heat transfer from the brake units, and a pressure rise of up to 10% can be expected. This pressure should not be reduced to normal working pressure as this could result in under-inflation at normal temperatures.

10.2 **Inflation Procedures.** Dry air or nitrogen should be used for inflating all tyres, and the applicable precautions outlined in paragraph 7 should be observed. The particular gas specified by the aircraft manufacturer should always be used, and should not be mixed with the alternative unless specifically authorised. If a dial-type gauge is used, the required inflation pressure should register in the centre of the dial; all gauges should be checked for accuracy at frequent intervals. When using a high pressure storage bottle, a pressure reducing valve must be incorporated in the delivery line.

10.2.1 The normal procedure for inflating a tyre is as follows:—

(a) Check the pressure required by reference to the aircraft Maintenance Manual.

(b) Remove the valve cap and connect the supply to the valve (ensuring that a screw-on connector is used for pressures above 700 kN/m^2 (100 lbf/in^2)).

(c) Adjust the regulator on the inflation trolley to the required pressure.

(d) Slowly inflate the tyre to the required pressure.

(e) Disconnect the supply, check the valve for leakage, then refit the valve cap.

10.2.2 **Cold Tyres.** When checking the pressure of tyres which are at ambient temperature, any tyre which is more than 10% below loaded inflation pressure should be rejected, together with the companion tyre on the same axle. Any tyre which is between 5% and 10% below loaded inflation pressure should be re-inflated to the correct pressure and checked at the next daily check; if the pressure is again more than 5% low the tyre should be rejected.

10.2.3 **Hot Tyres.** It may often be necessary to check the pressures of tyres which are still hot following a landing. The pressure of each tyre should be checked and noted, and compared with the pressures of the other tyres on the same undercarriage leg. Any tyre with a pressure of 10% or more below the maximum recorded on the same leg should be re-inflated to that maximum pressure but should be rejected if a similar loss is apparent at the next check.

10.3 **Examination of Fitted Tyres.** A careful visual examination of tyres should be carried out prior to each flight, rotating the wheels wherever possible to ensure that the whole surface of the tyre is checked. Manufacturers prescribe limits of damage within which a tyre may be kept in service; tyres damaged in excess of these limits should be removed from the aircraft and repaired or scrapped as appropriate. The following paragraphs summarise the actions which should be carried out.

10.3.1 **Embedded Stones, Flints and Glass.** The outer surface of the tyre should be examined for embedded objects and any found should be carefully removed.

10.3.2 **Cuts and Scores.** All cuts should be probed with a suitable blunt tool in order to assess the depth and extent of any damage to the casing. Minor damage may be defined as that which does not affect the casing cord: cuts in both the tread and side rubber, providing they do not expose the casing cord, do not appreciably weaken the tyre. Such defects should be filled with a tyre dough compound, since continued exposure permits the entry of water and grit, which tends to cause chafing and rotting. Tyres damaged beyond the limits described above should be rejected.

10.3.3 **Bulges.** The presence of bulges may indicate a partial failure of the casing, and the tyre should be removed for further examination. If it is obvious that the casing has failed, i.e. if the fabric is fractured, the tyre should be rejected, but if not it should be returned to the manufacturer for possible repair.

10.3.4 **Wear.** The extent to which tread has been removed from a tyre is not always easy to assess and may be either general or local; methods of indicating wear are shown in Figure 6. Local wear may be in the form of a 'flat spot' caused by severe abrasion or skid burns and these may occur as a result of excessive braking, hard touch-downs or aquaplaning. The probability of aquaplaning increases as the depth of tread is reduced. It is recommended that tyres be removed when wear has reached the limits defined below:—

(a) Patterned tread tyres may be used until the tread is worn to the depth of the pattern.

(b) Ribbed tyres with marker tie bars may be used until worn to the top of the tie bars.

(c) Ribbed tyres without marker tie bars may be used until worn to within 2 mm (0·080 in) of the bottom of the wear indicator grooves.

(d) Twin contact tyres may be used until the centre of the crown shows sign of having been in contact with the ground.

(e) Plain tread tyres may be used until either the grey cushion rubber is exposed (on early tyres only), or when the shape of the casing cords can be seen through the cushion rubber.

NOTE: On tyres with reinforced tread, several layers of fabric are moulded into the tread rubber and will become visible during normal use; the threads so exposed should not be confused with the casing cords. These tyres are provided with marker tie bars which should be used to assess the wear as in (b).

10.3.5 **Creep.** Tyre creep should be dealt with as indicated in paragraph 9.

10.3.6 **Sponginess.** Tyres which are only slightly affected by fuel, oil or glycol and which, after being wiped and allowed to dry, show no appreciable signs of swelling or softening, may be considered serviceable; tyres affected beyond this stage should be rejected.

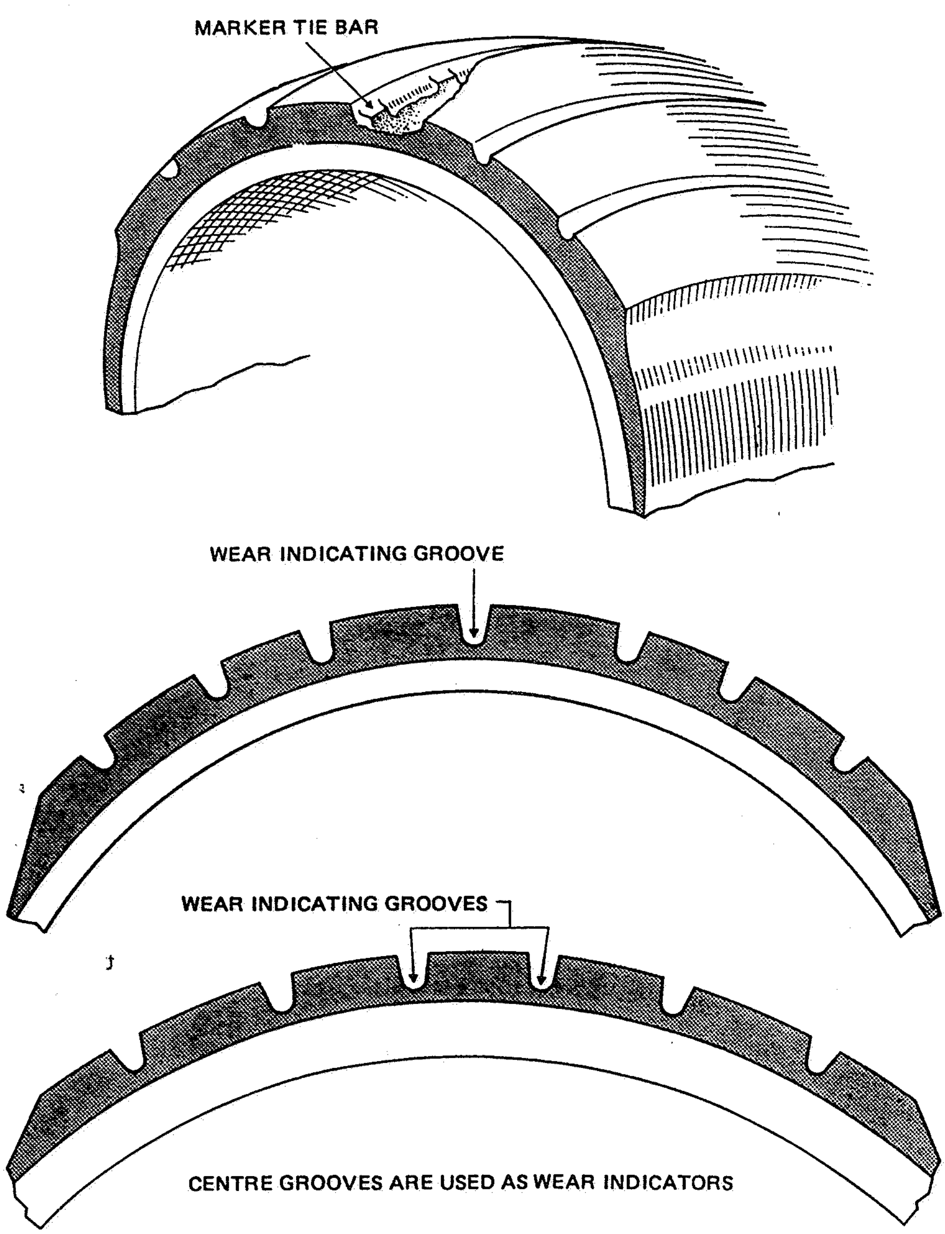

Figure 6 INDICATION OF TYRE WEAR

10.3.7 **Flat Spots on Nylon Tyres.** Tyres having nylon casings may, due to their lack of elasticity, develop a temporary 'flat spot'. This should not be confused with the flat worn on the tread as described in paragraph 10.3.4, but is caused by the local relief of tension in the cords at that section of the tyre and is usually the result of the tyre being subjected to static load for a lengthy period.

(a) Stretch of the nylon cords is considerable and progressive, and when the load is removed the cords do not immediately resume a tension equal to that of the cords in the rest of the casing.

(b) Normally the flat spot works itself out during the period of taxying before take-off, but should this not be the case, the tyre will be out of balance and set up vibration in the aircraft during take-off.

(c) Precautions against the occurrence of flat spots can, however, be taken; these include occasionally moving aircraft which are to be stationary for lengthy periods in order to transfer the load to different sections of the tyres.

(d) If a flat spot has developed, it can normally be remedied by rolling or taxying the aircraft for a short distance.

10.3.8 **Heat Transmission.** On aircraft main wheels, excessive braking may result in the transmission of heat to the beads of the tyres. If this is evident from indications of excessive heat on the wheels (such as discolouration, paint flaking or melting of fusible plugs) the tyres should be carefully examined. The results of overheating are indicated by 'tackiness' of the tyre bead and, in severe cases, a deposit from the tyre will adhere to the wheel flanges and bead seats. Tyres affected in this manner should be rejected.

10.3.9 **Deflated Tyres.** Tyres which have been under load while in a deflated condition should be removed from the aircraft. If the aircraft has taxied with a tyre in this condition, the deflated tyre and its axle companion should be scrapped, but if a single tyre deflates while static (except when deflated for servicing purposes) it should be removed and inspected in accordance with the relevant Maintenance Manual. If more than one of the tyres on a multi-wheel undercarriage are found to have been run in a deflated condition, all the tyres on that undercarriage should be scrapped.

10.3.10 **Rejected Take-offs.** A rejected take-off at high energy levels may have resulted in the overstressing or overheating of all the main wheel tyres, although no evidence of damage may be visible. Reference should be made to the relevant Maintenance Manual for guidance on the action to be taken.

10.3.11 **Replacement Tyres.** New and retreaded tyres have slight differences in external diameters, and replacement tyre and wheel assemblies for twin or multi-wheel undercarriages should be selectively fitted to ensure that both or all tyres take an equal share of the load.

10.4 **Protection.** Tyres must be protected from excessive heat, dampness and bright light, and from fluids such as oil, fuel, glycol and hydraulic fluid, since all of these have a harmful effect on the rubber. If the aircraft is to be parked for any length of time, or if any of the above-mentioned systems are to be drained, an oilskin cover should be placed over the tyre. Any fluid inadvertently spilt or allowed to drip on to the tyre should be wiped off immediately.

11 REMOVING TYRES Defects in tyres, particularly those which would be difficult to find once the air pressure is released, should be marked with wax crayon before the tyre is removed. It is recommended that the tyre pressure should always be reduced before removing a wheel from an aircraft and that a screw-on type deflator is used to deflate a tyre or tube.

11.1 **Tubed Tyres**

11.1.1 **Well-base Wheels**

(a) The tube should be deflated and the valve core removed; the bead should then be unseated by levering it away from the rim of the wheel on the valve side.

(b) The valve should be pushed in and tucked away under the tyre, the bead being levered off by commencing at approximately 60° from the valve and working away from it, using levers lubricated with acid-free soapy water.

(c) The wheel should be turned over and the other bead unseated as in (a). Some difficulty may be experienced in levering the bead from the rim on this side of the wheel, owing to the heat generated by the brakes. In this instance also, the levers should be lubricated with acid-free soapy water.

(d) The tube should be removed by grasping it diametrically opposite the valve and pulling it out of the tyre, the valve being the last part of the tube to emerge.

(e) The bead should be pressed into the well of the wheel and a lever placed between the bead and the wheel flange with its tip positioned at the valve hole. When pressure is applied to the lever, the tyre should come off quite easily.

11.1.2 **Divided Wheels.** Great care must be taken to ensure that the tyre is completely deflated before any attempt is made to remove the loose members. (See also paragraph 11.3.)

(a) The tube should be deflated and the valve core removed; the bead opposite to the valve should be unseated by levering it away from the wheel rim, using acid-free soapy water as a lubricant.

(b) The second bead should be unseated in a manner similar to that used for the first bead and the bolts should be removed from the wheel.

(c) An aligning mark, to assist reassembly, should be placed on both halves of the wheel below the valve, after which the upper half of the wheel should be lifted off and the tyre removed.

(d) If a tyre is not to be fitted to the wheel immediately, the wheel should be re-assembled.

11.1.3 **Detachable Flange Wheels.** Great care must be taken to ensure that the tyres are completely deflated before any attempt is made to remove the loose members. (See also paragraph 11.3.)

(a) The tube should be deflated and the valve core and flange locking device removed; the detachable flange may then be levered away from the tyre bead. The wheel should be turned over and the second bead loosened, after which the tyre and tube should be removed from the hub, care being taken to ensure the tube valve is not damaged in the process.

(b) If a tyre is not to be fitted to the wheel immediately, the wheel should be re-assembled.

11.1.4 **Wheels Embodying Combination Adaptor Scheme.** Deflate the tyre by removing the valve cap and core, but before attempting to remove the flange and locking device, remove the adaptor nut, washer and outer 'O' ring. The adaptor should be pushed well into the tyre with a blunt wooden probe to avoid the possibility of damage to the adaptor during dismantling. The wheel and tyre assembly may then be dismantled as outlined in paragraph 11.1.3.

11.2 **Tubeless Tyres.** The tyre should be deflated and the valve core removed, or, where a sidewall valve is used, deflated by removing the core from the servicing needle and inserting the needle in the valve insert. The valve core and cap should be refitted or the servicing needle removed as appropriate. The beads should be unseated from the taper bead seat by means of a special tyre removal machine which exerts an even pressure circumferentially round the wheel on both sides of the tyre. Sharp tools or tyre levers must not be used to unseat the beads as this may impair the sealing properties of the tyre and wheel. Finally, the wheel assembly should be dismantled according to its type and the rubber sealing rings removed.

11.3 **High Pressure Tyres.** During deflation of these tyres the valve stem may become blocked with pieces of ice. The use of probing devices to remove the ice is unnecessary, since the ice formation will break down under normal ambient temperatures, permitting the further passage of air. However, it must be noted that blockage of the valve by ice may take place several times during deflation, and it is essential to allow sufficient time to elapse between the removal of the valve core and the commencement of dismantling to ensure that the air has been completely exhausted.

12 INSPECTION OF TYRES AND TUBES REMOVED FROM AIRCRAFT Paragraph 10 details the checks to be made on tyres during running maintenance; at the periods specified in the Maintenance Schedule, the tyres should be removed from the aircraft and examined as described in the manufacturer's Service Manual. Guidance on inspections and typical defects is given in this paragraph.

12.1 **Tyres**

12.1.1 **Fractures.** The inside of the tyre should be examined for fractures caused by fatigue or concussion. The latter defect may be caused by heavy impact on a protrusion, e.g. striking a stone during touch-down. External detection of the fracture may be difficult, but a dark stain on the tyre, or a very slight smooth bulge, may be visible where the rubber is bruised.

(a) If a fracture has occurred, internal inspection will reveal a diagonal line or a 'star', dark in colour, at the point where the impact occurred.

(b) The interior examination of a large tyre may be facilitated by rolling it along the floor and observing closely the area which is flattened by contact with the ground, since this tends to open the fracture.

(c) Tyres so damaged should be scrapped and labelled accordingly.

12.1.2 **Bead Failure.** Tyres showing any signs of bead chafing or break-up of the bead should be returned to the manufacturer for assessment of possible repair.

12.2 **Tubes.** The base of the tube, i.e. that part of the tube which has been in contact with the tyre, on the brake side, should be examined for evidence of thinning of the rubber caused by heat generated during normal braking operations.

12.2.1 Tubes which have thinned at the base, are perished or cracked, have 'grown' or stretched unduly, or show bad creases, must be discarded.

12.2.2 Valve stems should be examined for bending, cracks or damaged threads, and, if damaged beyond local repair, the tube should be rejected. Valve cores with bent pins or damaged threads, or showing signs of corrosion, should be renewed.

12.2.3 Cuts in tubes may be repaired by a vulcanising process, except where they occur in the region of the valve. Vulcanising is a specialised process and should only be done by trained personnel using suitable equipment.

12.3 **Tubeless Tyres.** The tyre should be thoroughly cleaned with clean water, and inspected for damage, paying particular attention to the inner lining and the entire bead area. It is essential that the beads should be clean and free from grease.

13 REPAIR OF TYRES AND TUBES Tyres and tubes which have been removed from aircraft because of damage which is considered to be in excess of the limits defined in paragraph 10, may still be repairable locally provided the necessary tools and vulcanising equipment are available. These repairs must not exceed the limits laid down in the manufacturers' Repair Manual and must be carried out by personnel having the specialised knowledge and experience necessary and using only those materials specified by the manufacturer. The method of repair is to remove the damaged rubber and replace it with unvulcanised sheet rubber repair compound which is then vulcanised to the existing rubber by heat and pressure. During the vulcanising process the repair compound is converted into a material with properties almost identical to the surrounding rubber. A typical procedure for carrying out a repair is summarised in the following paragraphs.

13.1 **Classification of Damage.** The tyre or tube should be carefully inspected and all damage marked. A probe should be used to ascertain the depth and extent of cuts.

13.1.1 Minor damage to tyres is damage to tread or sidewall rubber not affecting the casing cords, up to a maximum of 38 mm (1·5 in) diameter. Numerous repairs of minor damage may be carried out.

13.1.2 Damage involving cut cords may be repaired in the tread area only, provided that not more than 20% of the cord layers or a total of four are damaged.

13.1.3 Small holes in tubes may be plugged with compound and larger damaged areas may be repaired up to an area of 50 mm × 50 mm (2 in × 2 in). Both types of repair must be vulcanised.

13.1.4 Tyres or tubes which are damaged beyond these limits should be returned to the manufacturer for possible repair.

13.2 **Repairs to Tyres.** For all types of repair, the tyre should be mounted on a wheel and inflated to a pressure of 140 to 210 kN/m² (20 to 30 lbf/in²) for crown and shoulder repairs, 70 to 140 kN/m² (10 to 20 lbf/in²) for sidewall repairs. A chalk line should be drawn round the damaged area to indicate the extent to which the rubber is to be removed.

13.2.1 The rubber is removed within the chalk circle by using a hollow drill, rotary rasp or knife as appropriate to the area affected, bevelling the edges at 45° and taking care not to damage the cords.

13.2.2 Where cords are damaged, the gap between the cord ends should be treated with tyre repair solution and filled with a suitable piece of tyre repair compound well rolled down.

13.2.3 The walls of the cavity and surrounding rubber should now be roughened with a rotary wire brush, and the rubber remaining on the cord surface removed to expose the cords. The roughened rubber surface and exposed cords should now be given two coats of the tyre repair solution, the first coat being brushed well in and allowed to become tacky before lightly applying the second coat.

13.2.4 The repair area should now be built up with successive layers of tyre repair compound, each layer being well rolled down to exclude any air bubbles. When the level of the repair is slightly higher than the surrounding rubber, the surplus compound should be removed with a sharp knife (lubricated with water as necessary), leaving a slightly raised crown in the centre. The surface should then be cleaned, dried and dusted lightly with French chalk.

13.2.5 The pre-heated vulcanising unit, fitted with a suitably-shaped base plate, should now be clamped centrally over the repair and left in position for a period of time appropriate to the thickness of the repair as specified by the manufacturer. The temperature is controlled automatically at approximately 150°C (300°F).

13.2.6 After removal of the vulcanising unit, the repair should be tested by probing with a blunt pencil point; if the pencil springs back the repair is correctly vulcanised, but if an indentation is left in the rubber the vulcanising unit should be replaced for a further 15 minutes.

13.2.7 The final stage of repair is the replacement of the tread pattern, which should be re-cut using either a hollow drill or knife.

13.3 **Repairs to Tubes**

13.3.1 **Solution.** The solution used for repairing tubes is prepared by cutting thin strips of tube repair compound, covering them with the solvent specified by the manufacturer and leaving them for 24 hours in a sealed container. The liquid thus obtained is then stirred and thinned down with solvent to the consistency of thin paint. Only small quantities of solution should be prepared as it is highly volatile and deteriorates quickly.

13.3.2 **Small Holes.** The hole should be roughened right through and the adjacent area cleaned with solvent and treated with solution. The plug should be made from a strip of tube repair compound, fed through the hole and trimmed off slightly proud of the surrounding material. The repair is completed by rolling down the plug and vulcanising for a period of time specified by the manufacturer.

13.3.3 **Large Holes.** A circular hole should be cut round the damaged area using a pair of curved scissors. Holding the scissors flat against the tube and working in a clockwise direction will ensure that the edge of the hole is correctly bevelled. The edges of the hole and surrounding area should now be roughened with a wire brush and cleaned with a muslin cloth dipped in solvent.

13.3.4 To prevent the repair from sticking to the opposite wall of the tube, a thin piece of paper, slightly larger than the hole, should be inserted through the hole and located centrally. The solution should then be applied on top of the paper and the roughened tube area, and rubbed well in. When the solution has reached a dry, tacky, state the repair should be built up and vulcanised in the same manner as described for tyres in paragraphs 13.2.4 and 13.2.5, but using a flat base plate on the vulcanising unit and working on a suitable flat bench.

14 REMOULDING TYRES Most aircraft tyres, when worn beyond safe, usable limits, may have their useful life extended by replacement of the tread rubber; this operation may, however, only be carried out by the original manufacturer or by an approved specialist organisation. The term 'retread' is normally used where the crown and shoulder rubber is replaced and cured in a specially designed mould. The term 'remould' is normally used where the tyre is similarly processed, but is cured in a mould similar to that in which the tyre was originally made; the new tread is therefore cured, and the sidewall rubber re-cured without being renewed. Tests have shown that the strength of a tyre casing does not deteriorate appreciably throughout its life; up to 10 remoulds have been carried out on specific tyres with only a 1% decrease in strength. The casing life for almost all aircraft tyres is therefore determined by initial tyre quality and the exercise of proper maintenance practices while the tyre is in service. One exception to the general rule is the case of the high performance aircraft where skin friction temperatures in continuous high-speed flight could result in prolonged high wheel-bay temperatures and consequently a diminished tyre life.

14.1 On new aircraft types the first few tyres are returned after service for a thorough examination by the manufacturer. If this examination is satisfactory the next few tyres are used to develop a remoulding technique and to evaluate the tyre's structural life. On successful completion of these tests the tyre is approved for one remould life. From this stage the process is repeated until a particular type of tyre can be released for its optimum number of remoulds.

14.2 **Initial Inspection.** The initial inspection of a tyre received by a manufacturer for repair or remould is carried out by personnel with a wide experience in the manufacture and servicing of tyres. The degree of damage which can be allowed depends on the use for which the tyre was designed and the aircraft type to which it is to be fitted. The inspector must take account of every type of deterioration to which the tyre has been subjected throughout its service life. Even though individual damage may be repairable, the general condition of a tyre often results in its rejection. The various types of damage which can occur are cracking, skin burns, oil contamination, excessive wear, tread separation, cuts, ply separation and damaged cords, The most highly stressed portion of the tyre is the bead area where only very minor damage is permitted.

14.3 **Buffing.** Depending on the extent of remoulding approved for a particular tyre the required amount of rubber is removed on a buffing machine. This operation also provides the opportunity for a further inspection of the tyre, as many defects such as cuts and broken cords, can only be seen when the tread is removed.

14.4 **Remoulding Process.** After the original rubber is removed, the casing is treated with a layer of cement and the complete new tread carefully rolled on under pressure. The whole assembly is then mounted in the appropriate mould, where heat and pressure are applied until vulcanising is complete. The vulcanising time and temperature are pre-determined by the manufacturer for the type, size and ply rating of the tyre.

14.5 When the remoulding process has been completed the tyre is balanced and re-inspected before being finally released for further service.

15 STORAGE Excessive light and heat will cause cracking and general deterioration of rubber, therefore tyres and tubes should be stored in a darkened room having a dry temperature of from 10 to 27°C (50 to 80°F). and should be kept away from radiators, steam pipes, electric motors or other sources of heat. It should be ascertained that the possibility of contamination from oil or grease does not exist, since this would also cause rapid deterioration of the rubber.

15.1 **Tyres.** Preferably, tyres should be stored vertically in special racks embodying support tubes, so that each tyre is supported at two points. Two-thirds of the tyre should be above the support tubes and one-third below. By this method, the weight of the tyre is taken by the tread, and distortion is reduced to a minimum. The tyres should be turned to a new position every two or three months.

15.1.1 Where space does not permit the use of the above method, tubed tyres may be stored horizontally in stacks on a level floor. The height of stacks should be limited to four tyres so that the weight does not cause distortion of sidewalls and tread on the lower tyres which could lead to failure in service. Staggering the tyres in piles tends to distort the bead wires and casing. If possible a stack of tyres should be graded so that the largest tyre is at the bottom and the smallest at the top. This method of storing should not be used for tubeless tyres, as the beads could be pressed close together and make mounting and inflation more difficult.

15.1.2 Where tyres are delivered in bituminised hessian wrappers, the wrappers should be left on during storage.

15.2 **Tubes.** Tubes should preferably be stored in their original wrapping; if they cannot be stored in this manner they should be slightly inflated and stored inside tyres of appropriate size.

15.3 **Assembled Wheels.** The tyres on assembled wheels not required for immediate use should be inflated to a pressure of 140 to 210 kN/m^2 (20 to 30 lbf/in^2) for storage and shipment.

15.4 **Shelf Life.** Provided that the ideal storage conditions are maintained, tyres and tubes may be kept in storage for up to seven years from the date of manufacture, without deterioration. It is recommended, however, that stocks be limited to a quantity which will ensure that a storage life of four years is not exceeded. This will ensure that the most advantage is taken of improvements in design and manufacturing techniques. After seven years in storage, tyres should be returned to the manufacturer for assessment.

16 RECORDS When required by the Maintenance Schedule, a record should be kept of the number of landings for each tyre on the aircraft.

AL/3-19

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AIRCRAFT

SYSTEMS AND EQUIPMENT

WHEELS AND BRAKES

1 INTRODUCTION This Leaflet gives guidance on the installation and maintenance of aircraft wheels and brakes. It should be read in conjunction with the relevant approved Maintenance and Overhaul Manuals and Maintenance Schedule, from which details of the construction and maintenance requirements of the particular components may be obtained.

1.1 Information on hydraulic systems is contained in Leaflet **AL/4—1,** on pneumatic systems in Leaflet **AL/5—1,** on flexible pipes in Leaflet **AL/3—13,** on rigid pipes in Leaflet **AL/3—14** and on tyres in Leaflet **AL/3—18.**

NOTE: This Leaflet incorporates the relevant information previously published in Leaflets **AL/8—2,** Issue 2, and **AL/8—3,** Issue 2, published 16th October, 1961.

2 GENERAL Aircraft wheels and wheel brakes are often subjected to severe conditions of operation, including shock loading and exposure to high temperatures, and the utmost care is necessary during installation and maintenance to ensure that their condition remains satisfactory during service. Owing to the risk of explosion caused by heat generated by friction in the brakes during landing and taxying, special safety precautions may be necessary when handling or servicing brake, wheel, and tyre assemblies, particularly in an extreme situation such as immediately after an abandoned take-off, when the components may be overheated.

2.1 On light aircraft, where aircraft weight and landing speed are low, single wheels are fitted at all landing gear positions. Wheel brakes on older types of aircraft are often of the expanding shoe type, similar to conventional automobile practice, and may be operated by cables or by a simple independent hydraulic system. In these systems a single hand brake lever may be used to apply both brakes together, or each brake may be operated individually from a pedal attached to the rudder bar. Modern high performance light aircraft are more usually fitted with hydraulically operated disc brakes.

2.2 With larger and modern types of aircraft, where aircraft weight and landing speed are high and aerodynamic drag is low, multiple wheels are generally used at all undercarriage positions, to spread the aircraft weight over a greater area and facilitate stowage in the airframe structure. Some older types of medium sized aircraft are fitted with large single wheels and pneumatically actuated drum brakes, but most modern transport aircraft are fitted with twin nose wheels and twin wheels or a four-wheel bogie arrangement at each main undercarriage position. Brakes are of the multiple disc type and are operated from the normal aircraft hydraulic system.

3 WHEELS

3.1 **Construction.** Wheels are usually made from aluminium or magnesium alloy forgings or castings and are of three main types (Figure 1), known as well-base, detachable flange and split hub. Well-base wheels are only fitted on light aircraft and are normally used in conjunction with tubed tyres. Nose wheels which do not house brake units, are usually of simpler construction than main wheels, but in some instances all wheels on an aircraft are interchangeable for ease of provisioning.

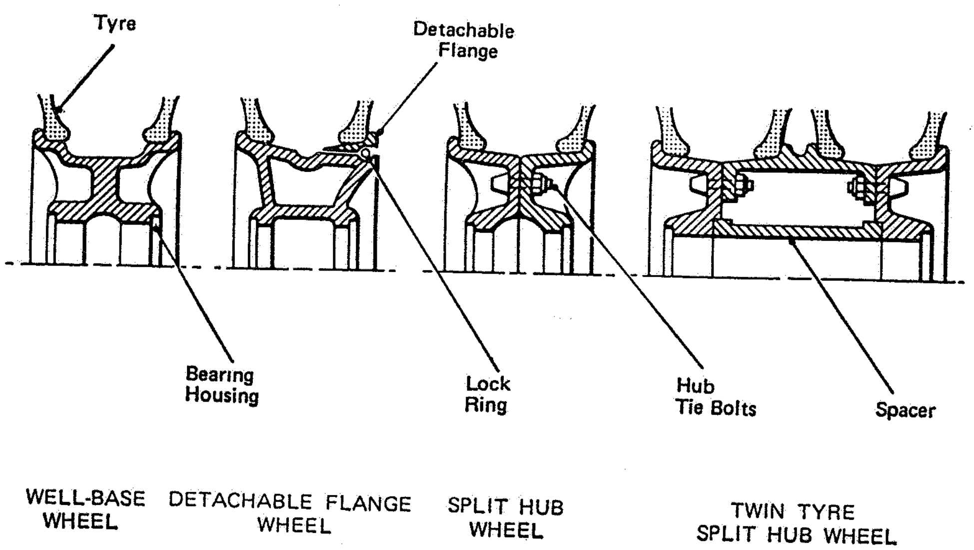

Figure 1 WHEEL TYPES

3.1.1 Heat generated by braking action is dissipated by radiation and conduction through the wheel and tyre, and every effort is made to keep heat transference to a minimum. Wheels are designed to permit optimum ventilation, and cylindrical stainless steel heat shields may be installed around the brake unit. On some aircraft, an electric motor mounted within the axle, or a series of motors installed in the brake housing, drive fans which provide a forced draught through the wheel and relieve the build-up of heat.

3.1.2 To prevent the danger of tyre explosion, the main wheels of many modern aircraft are fitted with fusible plugs which melt at a predetermined temperature (approximately 150°C), allowing a piston to be blown out of the plug bore and thus deflating the tyre.

3.1.3 Some aircraft wheels are also fitted with a pressure relief valve, the purpose of which is to prevent over-inflation of the tyre.

3.1.4 In general wheels are mounted on ball or roller bearings which fit directly on to the axle, or on to a bearing sleeve which is keyed to the axle. In some cases, nose wheels are mounted rigidly on to a "live" axle, which itself rotates within bearings in the nose wheel leg.

3.2 **Removal.** Before removing a wheel, the aircraft must be prepared and jacked up in accordance with the approved Maintenance Manual. These preparations may be very simple, such as chocking the opposite wheels and lifting the wheel which is to be removed by means of a bottle jack, but on large transport aircraft additional procedures, such as fitting ground locks to the landing gear, landing gear doors and steering mechanism, may be necessary. In some cases one wheel of a twin wheel arrangement may be lifted clear of the ground by running the other wheel up an inclined block. On aircraft with multi-disc brakes it is usual to set the brakes on before removing the wheel in order to keep the rotating discs in alignment with the driving keys in the wheel hub; on aircraft with drum brakes, however, application of the brakes would prevent removal of the wheel and they should be released.

3.2.1 A typical removal procedure is described below:—

(i) Prepare aircraft for jacking in accordance with the appropriate aircraft Maintenance Manual.

(ii) Raise axle or bogie, as appropriate, until the tyre is clear of the ground.

(iii) Deflate tyre or reduce pressure to a low value.

NOTE: During release of tyre pressure, icing of the valve may occur and give a false indication of complete deflation. Sufficient time must elapse after the air flow has ceased to ensure that any ice has melted and that the tyre is sufficiently deflated.

(iv) Where applicable, remove cooling fan or hubcap assembly.

(v) Remove axle nut locking device.

(vi) Remove axle nut and install thread protector.

(vii) Position wheel trolley and remove wheel carefully so as not to damage the axle.

NOTE: On some aircraft it is recommended that an approved extractor is used when removing the wheel.

(viii) Remove grease seals and bearings.

(ix) Install axle protector.

(x) Fit protective cover over the brake assembly if the wheel is not to be re-fitted immediately.

3.3 **Installation.** Before installing a wheel and tyre, the general condition of the wheel, tyre and bearings should be checked (paragraph 3.4 and Leaflet **AL/3—18**). The axle should also be checked for corrosion, scores and other damage, particularly in the bearing support area and, if an axle sleeve is fitted, this should be checked for allowable wear at the bearing area and correct fit on the axle. Bearings on new or replacement wheels may be packed with storage grease, and this should be cleaned out and replaced by grease specified for service use.

3.3.1 A typical installation procedure is described below:—

(i) Grease inner bearing and seal with the specified grease, and install on axle.

(ii) Slide wheel into position on axle, using the appropriate aligning fixture as necessary to line up the brake disc driving keys in the wheel hub with the slots in the rotating discs.

(iii) Grease and install the outer bearing and seal.

(iv) Remove thread protector and lubricate axle threads.

(v) Install axle nut and tighten to the recommended initial torque, rotating the wheel as the nut is tightened.

(vi) Slacken axle nut then, again rotating the wheel, tighten to the specified final torque and fit the locking device.

(vii) Replace cooling fan or hub cap assembly.

(viii) Check tyre pressure and tyre growth clearance, retracting landing gear where necessary to facilitate this check, then lower the aircraft and remove the ground locks installed to prevent operation of the steering mechanism or landing gear doors.

3.4 **Maintenance.** A superficial inspection and minor repairs may be carried out with the wheel installed on the aircraft. A more detailed inspection is made when the wheel is removed for tyre replacement following operation with a deflated tyre (or with the companion tyre deflated on a twin wheel arrangement), and at the intervals specified in the approved Maintenance Schedule. Some wheels may require overhaul after a specified number of landings.

3.4.1 **Installed Wheels**

(i) The wheel should be examined for cracks, corrosion, distortion, dents and scores, particular attention being given to the wheel flanges. Small dents on the outside of the flanges may usually be blended within specified limits, but in general no damage is permissible where the flange is in contact with the tyre. When a dent or abrasion is blended out, the exposed metal should be closely inspected for cracks and the protective treatment renewed. It is particularly important to give prompt attention to protective treatments following repairs to magnesium alloy wheels.

(ii) Wheel hub tie bolts and nuts, inflation valves, balance weights and, where visible, the axle nut locking device, should be inspected for security and damage. If any tie bolt is found defective, the wheel should be removed and the complete set renewed.

(iii) The wheel, brake and tyre should be examined for signs of overheating, such as blistered or discoloured paint, distortion, and leakage of grease from the wheel bearings.

NOTE: If a fusible plug is found to be blown out, the tyre should be scrapped and all fusible plug seals renewed, but the wheel may be satisfactory subject to certain checks (paragraph 3.4.2).

(iv) Periodically the wheels should be raised clear of the ground in order to check for free rotation and end float in the bearings.

3.4.2 **Wheels Removed from Aircraft**

(i) The tyre must be completely deflated before any attempt is made to dismantle a wheel or remove a tyre.

(ii) Dismantled wheels should be thoroughly cleaned in a suitable cleaning fluid and then examined for cracks, corrosion, distortion or other damage.

(iii) Some manufacturers require that paint should be completely removed from wheels before checking for cracks. Where chemical paint strippers are used it is essential that the chemical is removed by thorough washing.

(iv) A careful examination should be made for cracks around bolt holes, in the radius at the base of the wheel flange (tyre bead seat) and at other highly stressed points or changes of section. These examinations are normally made using ultrasonic or eddy current methods.

(v) Light surface corrosion can be cleaned off, and damage blended out within specified limits, but deep corrosion, scores, dents or cracks beyond these limits will render the wheel unserviceable.

(vi) Brake drums should be examined for signs of distortion, wear, scores and cracking and there should be no evidence of drum movement relative to the wheel. With disc type brakes the drive blocks in which the discs are tenoned should be checked for security, damage, wear and hammering.

NOTE: The braking surface of bi-metal brake drums is subject to crazing; this condition is acceptable until it advances beyond the limits specified in the relevant manual.

(vii) Wheels should also be inspected for distortion and concentricity, by mounting the wheel on a mandrel in vee-blocks and checking at the flange with a dial test indicator. Distortion may also be checked using large calipers. After this check the wheel should be statically balanced.

(viii) Wheels which may have been damaged by overheating but which are not found to be distorted and are otherwise serviceable, may be required to be given a check for material hardness. When this check is specified, the method and the acceptable range of hardness numbers will be found in the approved Maintenance Manual.

(ix) Bearings may sometimes be inspected in position, but they must often be removed (using an extractor where necessary) in order that they may be thoroughly cleaned and inspected. They should be cleaned in a solvent such as white spirit and examined for corrosion, brinelling of the races, chipped balls or rollers, retaining cage condition, roughness and discolouration. If serviceable, bearings should be packed with approved grease immediately after inspection, and protected from dust and dirt.

(x) Tie bolts, i.e. those used for clamping the two halves of a split hub, should be checked for corrosion, distortion, cracks and condition of threads. Any damage found on these bolts will necessitate their replacement. In some instances, self-locking nuts which are found to have a satisfactory locking torque may be re-used, but the manufacturer may require all stiffnuts to be discarded after disassembly.

(xi) Wheels should be painted and reassembled in accordance with the manufacturer's recommendations, and particular care should be paid to the sequence of assembly and torque tightening of the tie bolts. It is usually recommended that new seals should be fitted during re-assembly.

(xii) When a tyre is assembled on a wheel, the complete unit should be statically balanced.

4 DRUM BRAKES Although used extensively on earlier aircraft, drum brakes have largely been superseded by hydraulically operated disc brakes, on most modern high performance aircraft. Pneumatically operated drum brakes may still be found in service, however, and the construction, operation and maintenance of a typical brake unit of this type is described in the following paragraphs.

4.1 **Construction.** The main components of the brake unit are the back plate, brake drum, expander tube (pressure bag) and brake linings (Figure 2).

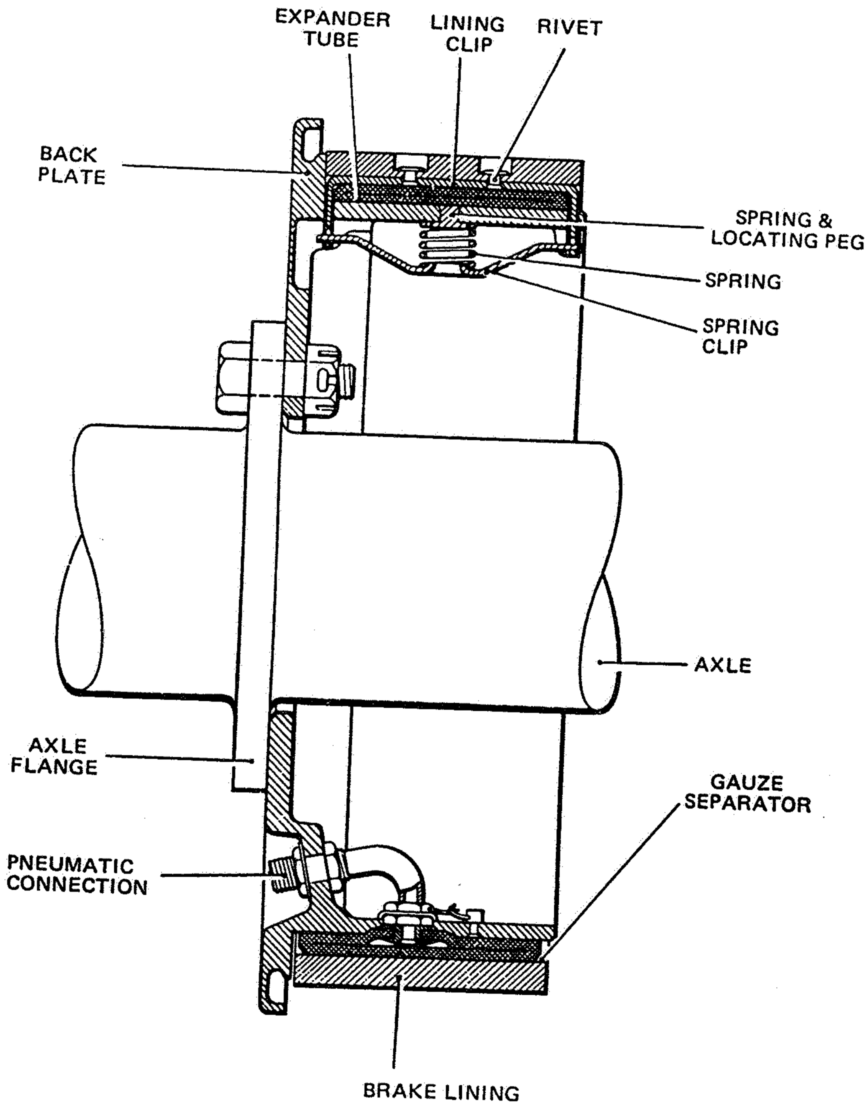

Figure 2 DRUM BRAKE

4.1.1 **Back Plate.** This unit is cylindrical in shape and is attached to a flange on the axle. It houses the expander tube, brake linings and pneumatic connections.

4.1.2 **Expander Tube.** This is a circular, reinforced rubber tube of flat cross-section, and is fitted around the back plate. It has a pneumatic connection leading through the back plate to the aircraft pneumatic system.

4.1.3 **Brake Linings.** The complete brake lining assembly is made up of a number of segments of heat-resisting friction material which form a ring around the expander tube and are shaped to conform to the inside radius of the brake drum. Each segment is bonded or riveted to a metal fitting, which protrudes through the back plate and is secured by a spring clip.

4.1.4 **Separators.** Phosphor-bronze gauze separators are fitted between the ends of the brake lining segments to reduce heat penetration to the expander tube and to exclude carbon particles.

4.1.5 **Brake Drum.** The brake drum is a heavy steel cylinder, attached to and rotating with the wheel, and against which the brake lining segments expand to produce the braking action.

4.2 **Operation.** When the pilot's control is operated, air pressure is applied to the inside of the expander tube, which expands and forces the brake linings against the brake drum. When air pressure is released the expander tube collapses and the brake linings are withdrawn from the brake drum by the action of the return springs.

4.3 **Removal/Installation.** Before attempting to work on the brake system or to remove a wheel, it is important to ensure that all air pressure is exhausted from the system. Disconnecting a pipe joint containing air pressure is a dangerous practice, and, if a wheel is removed with the brake system connected and pressurised, inadvertent operation of the brake could cause the expander tube to burst and possibly damage other parts of the system. In many pneumatic systems a pressure maintaining valve is used to safeguard the brake pressure in case of a leak elsewhere or failure of the compressor, so that lack of pressure in the brake system must be confirmed from the brake system pressure gauge and not by reference to the general system pressure.

4.3.1 When the wheel has been removed, the brake unit can be removed by disconnecting and blanking the air pressure connection and removing the bolts attaching the back plate to the axle flange.

4.3.2 When installing a new brake drum, the protective treatment applied for storage purposes should first be removed with a suitable solvent such as methylated spirits; petrol or paraffin should not be used.

4.3.3 When installing the brake unit, care must be taken to ensure that oil or grease do not come into contact with the linings; operators should also avoid handling the linings as the natural oils from the skin may have an adverse effect. If brake linings do become contaminated they must be considered unserviceable; no attempt should be made to clean the surface with solvents.

4.4 **Inspection**

4.4.1 Drum brakes are not normally accessible for visual inspection when installed on the aircraft. During a pre-flight inspection the back plate and wheel should be examined for signs of overheating, and the flexible pneumatic hose between the brake units and the landing gear leg should be checked for damage, security or leaks. Operation of the brakes may be checked by means of the brake pressure gauge and also by checking that air is discharged from the brake relay valve (Leaflet **AL/5—1**) when the brakes are released.

4.4.2 At the times specified in the approved Maintenance Schedule, and whenever unsatisfactory operation is suspected, the brake unit should be removed for inspection and overhaul. Disassembly, which should be carried out on a rubber or felt covered bench, is normally straightforward, but reference should be made to the approved Maintenance Manual for details of any special procedures or tests required. It may be found that the expander tube is stuck to the back plate and extreme care is necessary to prevent damaging the tube; the careful use of smooth, broad tyre levers is sometimes recommended. The assembly position of each brake segment should be marked so that, in the event of their being suitable for further service, they can be returned to their original positions.

(i) Brake segments should be examined for wear by measuring the thickness of the remaining material, the minimum thickness permitted for replacing the linings being stipulated in the approved Maintenance Manual. Any carbon deposits which may have been formed should be removed with a stiff bristle brush.

(ii) The back plate should be examined for distortion, damage or corrosion, and elongation or cracking at bolt holes and lining clip slots. Protective treatment should be renewed as necessary.

(iii) The expander tube should be examined for signs of overheating, which is usually indicated by hardening or flaking of the rubber. The connection threads and nuts should also be in good condition.

(iv) The brake lining rivets should be examined for security, and the lining clips for cracks or damage, particularly at the corner radii.

(v) The brake drum should be checked for cracks, corrosion and distortion. The friction surface should be free from deep scoring which is likely to cause excessive lining wear, and any trace of grease or dirt should be removed with a suitable solvent. If any grease or oil is found on the drum, the cause should be investigated to prevent a recurrence.

(vi) New separators should be fitted when the brake is reassembled.

4.4.3 **Test After Reassembly.** Following reassembly the complete brake unit should be installed in an appropriate sized test brake drum, and submitted to pressure tests as prescribed by the manufacturer. No leakage should occur, and the linings should return to the "off" position as soon as air pressure is released. The most suitable means of detecting a leak in the expander tube connection is by applying a solution of non-corrosive soapy water which, subsequently, must be washed off. Bubbles will indicate the position of a leak.

5 DISC BRAKES Most modern aircraft are fitted with hydraulically-operated disc brakes (also known as plate brakes). Light aircraft generally have a single-disc type and larger aircraft a multi-disc type.

5.1 **Single-disc Brake Units.** A simple single-disc brake unit is shown in Figure 3 and is of a type found on many light aircraft. A single operating cylinder is shown but two or three are often used for increased braking performance, and larger aircraft may have brakes using five or six cylinders. The brake unit consists basically of a light alloy torque plate shaped for attachment to the landing gear leg or axle flange, housing a caliper-type hydraulic jack unit and a pair of friction pads. A steel disc is slotted into the wheel and rotates between the friction pads. When the brakes are operated, fluid pressure is applied to the cylinder and forces the operating piston towards the disc, thus squeezing the disc between the operating and fixed friction pads and thus resisting wheel rotation. When the brakes are released the disc is free to rotate between the friction pads.

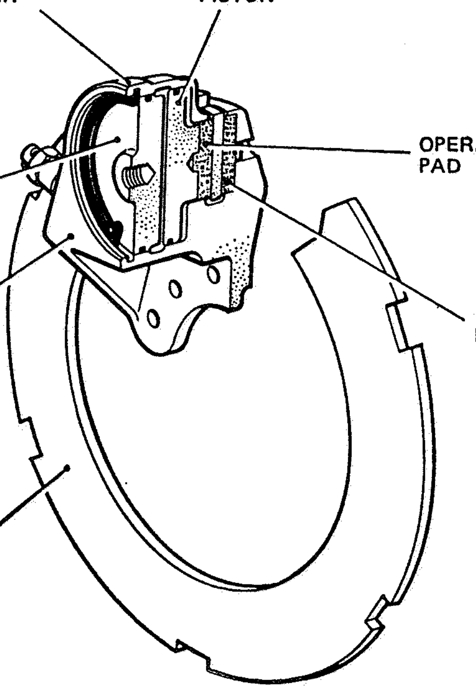

Figure 3 SINGLE DISC BRAKE

5.1.1 The brake unit should be examined periodically for fluid leaks, damage or corrosion, the friction pads for wear and the disc for scoring or pick-up of surface plating. The single discs used on light aircraft brakes are prone to corrosion and pitting during periods of idleness, and this may lead to rapid wear of the friction pads. Discs in poor condition should be replaced or machined to give a clean surface as appropriate. Replacement of worn pads is normally a very simple procedure once the wheel has been removed, and often does not necessitate breaking down the hydraulic system. The servicing and repair procedures discussed in paragraph 5.2 are also applicable to single disc brakes but reference should be made to the approved Maintenance Manual for details of any particular limitations, procedures, tests or special tools recommended by the manufacturer.

5.2 **Multi-disc Brake Unit.** Multi-disc brakes are designed to provide increased friction surfaces for braking purposes. The general arrangement is basically similar to the single-disc brake, but the single disc is replaced by a stack of alternate stationary and rotating discs, and a number of operating cylinders are equally spaced around the torque plate. The friction elements are normally in the form of pads attached to either side of the stationary discs, but on some types the rotating discs have sintered surfaces or pads. This type of brake is operated from the aircraft's main hydraulic system, through valves connected to the pilot's rudder pedals.

5.2.1 **Construction.** A typical multi-disc brake unit is shown in Figure 4. In this unit a torque plate and torque tube assembly fits over the axle and is bolted to a flange on the axle; alternative designs are often similarly mounted but prevented from rotating by means of a torque arm attached to a suitable fixture on the landing gear leg or bogie. A number of cylinders are spaced around the torque plate, connected to the hydraulic brake system and house pistons which apply load to the pressure plate. The disc pack (also known as the heat pack) contains alternate stationary and rotating discs, the stationary discs being keyed to the torque tube and the rotating discs being keyed to drive blocks in the wheel hub. In this unit the stationary discs house the brake pads and the rotating discs are segmented to prevent heat distortion and brake drag. Correct working clearance in the disc pack is maintained by means of adjuster assemblies (paragraph 5.3). Pins attached to the pressure plate and protruding through the torque plate on this brake unit, indicate the amount of wear which has taken place in the disc pack.

5.2.2 A further type of multi-disc brake is known as a trimetallic brake. Construction is similar to the brake described in paragraph 5.2.1, except that the rotating discs have a metallic compound sintered to their faces, and steel segments, known as wear pads, are riveted to the faces of the stationary discs. Alternatively, the faces of both sets of discs may be sintered, or the stationary discs may be plain.

5.2.3 **Operation.** When the brakes are selected "on", hydraulic pressure is admitted to the cylinders and moves the operating pistons against the pressure plate. The disc pack is clamped between the pressure plate and thrust plate, and the friction loads generated between the stationary and rotating members provide the required braking action. When the brakes are released, springs in the adjuster assemblies move the pressure plate back to maintain a working clearance in the disc pack and permit free rotation of the wheel.

5.2.4 **Maintenance.** Contamination of the friction surfaces of a brake unit by fluids used in aircraft servicing operations is highly detrimental to brake operation. It is essential, therefore, to protect brakes from contamination by fuel, oil, grease, paint remover, de-icing fluid, etc., when operations involving their use are undertaken, and the condition of the brake units should subsequently be confirmed by inspection.

5.2.5 Installed disc brakes may be inspected for signs of fluid leakage, external damage, corrosion, disc pack wear and overheating, and the associated hydraulic pipes for security, distortion, chafing or leaks. Brake disc pack wear can be checked by measuring wear pin protrusion, the limits being specified in the approved Maintenance Manual.

5.2.6 In some installations a worn disc pack may be exchanged after removing the wheel and thrust or back plate, and without disconnecting the hydraulic system, but in order to carry out a detailed inspection the brake unit must be removed from the axle.

5.2.7 At the periods specified in the approved Maintenance Schedule the brake unit should be removed for inspection and overhaul. The wheel should first be removed (paragraph 3.2) and the hydraulic pipe couplings should be disconnected at the brake and fitted with suitable blanks. In some cases fluid will drain from these pipes and bleeding will be necessary (paragraph 5.4) after re-connection, but in other cases connection is by self-sealing couplings which isolate the hydraulic system from the brake unit. The brake unit attachment bolts (and, where fitted, the torque link) should then be removed and the unit carefully withdrawn.

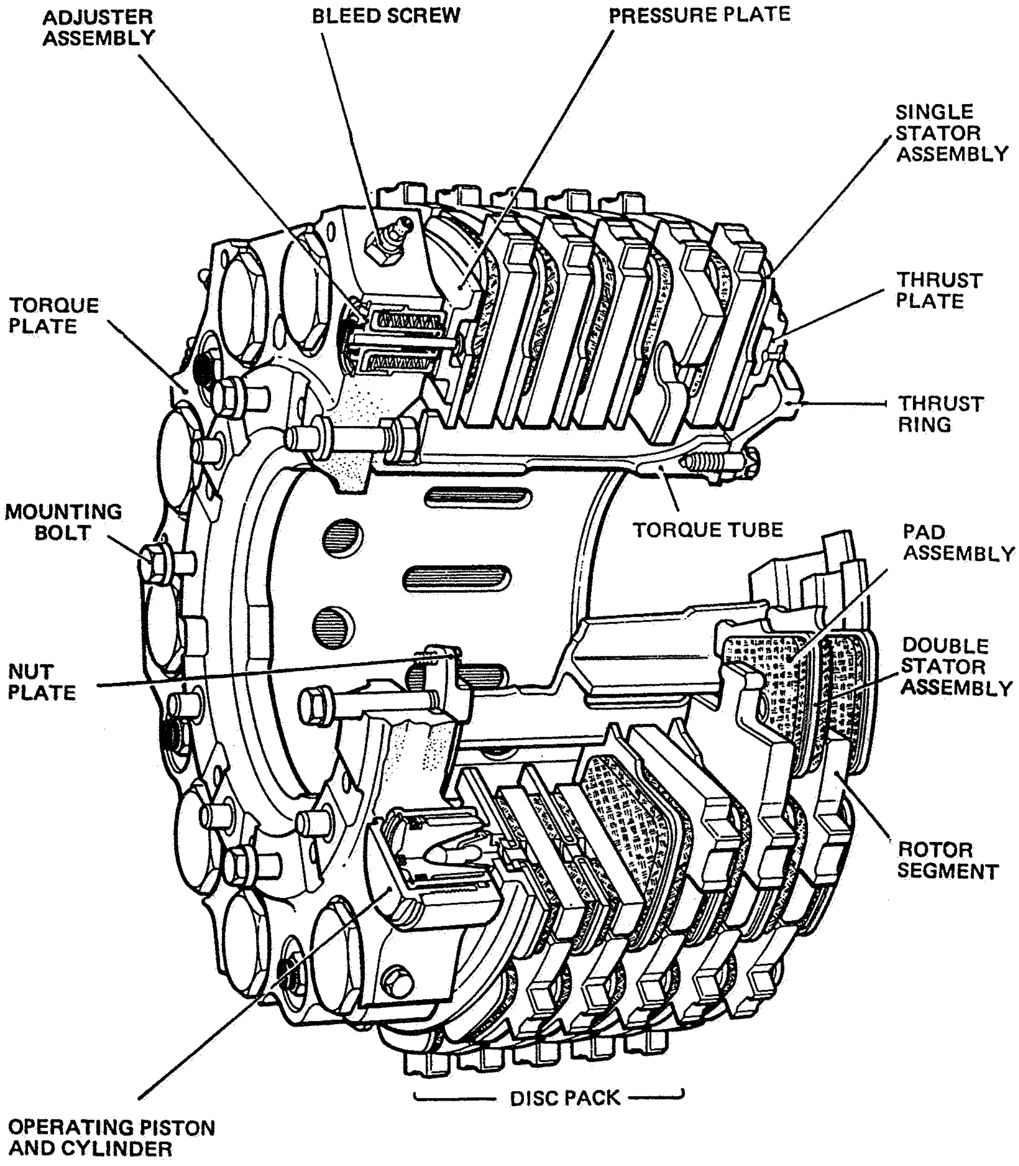

Figure 4 MULTI-DISC BRAKE

5.2.8 Following its removal, the brake unit should be dismantled, cleaned and inspected. All metallic components should be thoroughly cleaned and dried; if chemical solvents are used they must not be allowed to come into contact with the elastomeric seals. Inspection of components should be related to any limitations or repair schemes specified by the manufacturer and will normally include the following:—

(i) Rotating discs should be checked for excessive scoring, corrosion, distortion and wear on the friction surfaces and driving slots. Light surface damage which would not cause excessive wear of the friction pads may be acceptable, but deep scores or corrosion should be ground out within prescribed limits. Heat damage may cause surface cracking and, if present, must be within limits specified by the manufacturer for the disc to be re-used.

(ii) Brake friction pads should be inspected for excessive wear (normally checked by measuring individual pad thickness and weighing the complete pack), burning, flaking, cracking, security of attachment to the stationary disc and contamination by oil or grease. It is normally specified that, if any pad is damaged or worn beyond limits, or contaminated with oil or grease, the complete set should be changed. In some instances it is also specified that the rotating discs should be changed. If part-worn pads are to be re-used they must be reassembled in their original location.

(iii) The torque plate, torque tube and thrust plate should be examined for cracks, corrosion, distortion and damage, particular attention being paid to bolt holes and other highly stressed areas. Cylinders and pistons should be inspected for scores or other damage, and springs inspected for corrosion and given a load/compression test as specified by the manufacturer.

(iv) Operation of the self-adjusting mechanism should also be checked, and the friction force applied to the retraction pin measured (Figure 5).

5.2.9 Protective treatment should be applied as necessary to the metal components, and the brake unit reassembled and tested for leaks and correct operation. It is normally specified that new seals, gaskets and self-locking nuts should be used for reassembly, and all fasteners torque loaded in accordance with the manufacturer's recommendations. The unit should be primed with hydraulic fluid, and blanks fitted to all connections.

5.2.10 When re-installing the brake unit on the axle, care must be taken not to spill fluid on the disc pack. Jointing, sealing or anti-seize compounds should be used where specified, and all fasteners and pipe connections should be torque loaded and locked to the manufacturer's requirements.

5.3 **Adjuster Assemblies.** The diagrammatic arrangement of a typical adjuster assembly is shown in Figure 5. At least two adjuster assemblies are fitted to the majority of disc brakes, their purpose being to maintain a suitable running clearance in the brake pack. In a single-disc brake the retraction pins are often attached directly to the operating pistons but on multi-disc brakes they are usually attached to the pressure plate. In operation, movement of the piston or pressure plate is transmitted via the retraction pin and friction bush to compress the adjuster spring and move the guide until it abuts the torque plate. When the brakes are released the adjuster spring pulls the guide back until it contacts the spring housing, the clearance between the guide and torque plate being the designed running clearance. As wear takes place in the discs the pressure plate has to move further forward, thus pulling the retraction pin through the friction bush by an amount equal to disc wear, but maintaining the design clearance when brakes are released. On some brake units wear may be assessed by measuring the protrusion of the retraction pin.

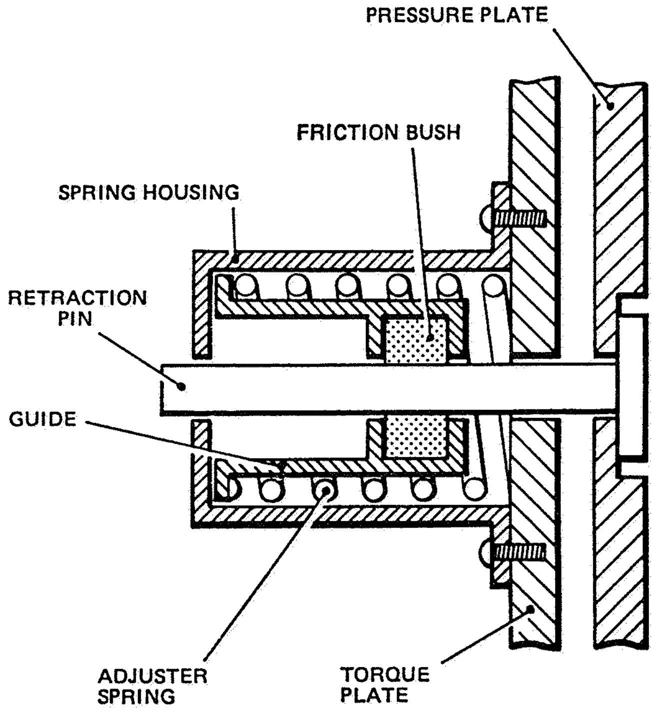

Figure 5 ADJUSTER ASSEMBLY

5.3.1 On initial assembly of the adjuster a special tool is used to position the retraction pin at the position of maximum protrusion through the friction bush. The pin takes up its initial operating position when the brakes are first pressurised.

5.3.2 On some types of disc brakes a conical friction bush is used, and friction is adjusted by torque loading the retaining nut to a specified value, whilst on others, provision is made for manual adjustment of the working clearance.

5.3.3 Correct operation of the adjuster assemblies must be checked whenever the brakes are tested, and should result in free rotation of the wheel when brakes are released.

5.4 **Bleeding the Brakes.** The presence of air in the hydraulic brake system will degrade the performance of the brakes, and must be removed after initial installation and whenever brake response becomes sluggish.

5.4.1 The exact method of bleeding the brakes will depend to a large extent on the particular aircraft system, and reference should be made to the approved Maintenance Manual for the aircraft concerned. However, the normal method of bleeding is to pressurise the brake system and open the bleed screws fitted to the brake units, allowing hydraulic fluid to flow through the system until bubble-free fluid is discharged; the bleed screws are then closed and brake operation tested. Bleed fluid should be piped to a suitable container, and must not be allowed to come into contact with the disc pack.

5.4.2 On low pressure systems fluid is forced through the brake unit by slowly pumping the appropriate brake pedal. Care must be taken to ensure that the reservoir is kept topped up during this operation, since further air might be introduced if the fluid level is allowed to fall too low.

5.4.3 On high pressure systems the associated hydraulic accumulator is pressurised, and as the brake pedal is depressed, fluid is forced out of the bleed screws under pressure. In this type of system it is sometimes recommended that only a specified quantity of fluid is discharged, and it may be necessary to bleed other parts of the system such as, where fitted, the servo system from the brake pedals to the control valves, or the normal and emergency accumulators, before bleeding the brakes. After bleeding, the appropriate reservoir should be topped up as necessary.

5.5 **Testing the Brakes.** Brakes are normally tested after overhaul, and after installation on an aircraft, while the aircraft is still jacked up. The brakes should be applied several times then released; there should be no leakage and the brakes should restrain wheel movement when pressurised and permit wheel rotation when released (free rotation is important, because binding brakes can cause overheating and increase take-off ground-run distance). Operation of the emergency and parking brake controls should be checked and, on completion, a full brake sense check should be carried out in a manner which will ensure correct brake operation for any brake application. Special care should be taken to ensure that the hydraulic systems are correctly connected and in particular that the main system, and not the emergency system, is connected through the anti-skid device.

6 BRAKE TEMPERATURE MONITORING SYSTEM On some aircraft, in order to inform the pilot of excessive build-up of heat in the wheel brakes, a brake temperature monitoring system is fitted. A typical system includes a temperature sensor at each wheel, which supplies information to a central monitor and warning unit on the flight deck. The monitor contains a temperature gauge and a selection button for each wheel. The gauge normally records the temperature at the hottest brake, and a button illuminates when the associated brake temperature exceeds a predetermined amount. When any button is pressed, the gauge records the temperature at the associated brake.

6.1 For testing purposes, operation of a test switch on the control unit will cause all buttons to illuminate and the gauge to read within a test signal range when all circuits are serviceable.

6.2 Installations vary considerably between aircraft, and trouble-shooting charts are normally included in the appropriate Maintenance Manual to enable faults to be traced. Routine maintenance should include inspection of the sensors and associated wiring for security and damage, and functional tests of the system using the appropriate test switches.

7 SKID CONTROL The braking systems of most modern aircraft are provided with a means of preventing the wheels from skidding on wet or icy surfaces and of ensuring that optimum braking effect can be obtained under all conditions, by modulating the hydraulic pressure to the brakes. Anti-skid units sense the rate of change of wheel deceleration, decreasing the hydraulic pressure applied to the brakes when a high rate of increase in deceleration (i.e. consistent with an impending skid) occurs, and restoring it as the wheel accelerates again. A modulator is often fitted in conjunction with the anti-skid unit, to restrict the flow of fluid to the brakes after initial brake application and to conserve main system pressure. There are basically two types of anti-skid systems in use, the mechanically controlled and the electronically controlled.

7.1 **Mechanical System.** The anti-skid unit is mounted either on the brake unit torque plate or within the axle bore, and is connected into the brake hydraulic circuit at the brake unit. The anti-skid unit consists of a valve assembly connected to a flywheel, which is driven by the associated wheel.

7.1.1 **Operation.** During normal braking action (i.e. when no skid is present) the flywheel rotates at the same speed as the drive and the valve is closed, allowing maximum hydraulic pressure to be applied to the brake operating pistons. When the rotational speed of the wheel decreases rapidly, as when a skid begins to develop, the inertia of the flywheel alters its angular relationship with the drive shaft and, through the action of a cam and push rod arrangement, the valve opens to relieve the pressure applied to the brake, thus reducing braking action and allowing the wheel to increase its rotational speed. As the wheel accelerates, the angular relationship between flywheel and drive returns to normal, and the valve closes, increasing pressure to the brake. If the wheel bounces clear of the ground after brakes are applied, the adjustment of the anti-skid unit allows the brake to be completely released for a sufficient period of time to ensure that the brake is off when the wheel contacts the ground again.

7.1.2 **Installation.** The mounting details of the various types of mechanical units vary considerably, and reference should be made to the appropriate Maintenance Manual for details of any particular installation. An external unit is driven by means of a rubber tyre surrounding its flywheel housing and engaging in a track on the landing gear wheel. The whole unit is spring-loaded, or the mountings shimmed, to maintain satisfactory driving contact with the track. The tyre loading is normally checked after installation by measuring the flat produced on the rubber tyre at its point of contact with the track. An axle mounted unit is driven by means of a shaft, which is splined into the anti-skid unit at one end and into a drive housing bolted to the wheel hub, at the other. All types of units are marked with the correct direction of rotation, and this must be checked before installation.

(i) Bleeding of the anti-skid unit is normally achieved when bleeding the main brake system but independent bleeding may be necessary after installing a unit. This is accomplished by fitting a drain pipe at the exhaust connection, rotating the drive smartly in the direction of rotation, then bringing it to rest. Each time rotation is stopped fluid will be discharged from the exhaust port, and bleeding should be continued until the discharged fluid is free from air, then the pipe connections remade.

7.1.3 **Inspection.** At the periods specified in the approved Maintenance Schedule the anti-skid unit should be inspected as follows:—

(i) The unit should be cleaned and inspected for security, signs of corrosion, external damage, and cracks.

(ii) With brakes applied, the unit should be checked for signs of external leakage of hydraulic fluid.

(iii) The pipelines should be checked for damage or distortion and the connections for security of attachment.

(iv) The driving tyre and wheel track should be inspected for correct loading and alignment, and the tyre for excessive wear.

NOTE: It is possible to lock the spring-loaded type units out of contact with the wheel track by inserting a pin in the mounting stud. This is normally done to facilitate wheel removal, but it is recommended that a red streamer should be attached to the pin as a visual reminder that the anti-skid unit is out of operation.

7.1.4 At the end of its overhaul life an anti-skid unit should be returned to the manufacturer or an approved firm for overhaul. Testing after overhaul requires the use of specialised equipment which is not normally held by operators. After removal, all fluid connections and orifices should be properly blanked, the fluid being retained as a guide to the internal condition of the unit. Packing should be suitable for the method of transit and the destination.

7.2 **Electronic System.** The system comprises a wheel speed transducer, a control unit and an anti-skid valve in the brake pressure line, together with associated switches, and check-out and warning lamps. The wheel speed unit may supply either d.c. or a.c. depending on the type of system used. Operation is basically similar to the mechanical system but the use of sophisticated logic circuits in the later types of electronic control units enables much finer control to be exercised. Further refinements such as strut oscillation damping circuits, touch-down protection and locked wheel protection, may also be incorporated, and some systems automatically de-activate at low speed to prevent interference with normal taxying manoeuvres.

7.2.1 The method by which the wheel speed signal is processed in the control unit varies from type to type, but all operate on the basis that if any brake produces more torque than can be supported by the friction between the tyre and ground for the existing wheel load, the resulting impending skid will produce a smaller rotational velocity signal from the affected wheel. This reduced signal is detected by the anti-skid control circuits, which send a signal to the anti-skid control valve, causing brake pressure to be reduced sufficiently to correct the skid condition. Brake pressure will be re-applied to a level just below that which caused the skid, and will then increase at a controlled rate.

7.2.2 Control units normally contain circuits which provide warning of failure in the system, and a self-test facility which enables the serviceability of the various components to be checked. Controls for the operation and testing of the anti-skid system are contained in the control unit and in the flight compartment.

7.2.3 Some systems operate by providing a continuous bleed from the brake pressure line, and in these cases the parking brake operates a cut-off valve in the brake return line.

7.2.4 **Maintenance.** The inspection, testing and maintenance of any particular anti-skid system will vary considerably between different installations, and details should be obtained from the approved Maintenance Manual. However, the self-test facility normally enables complete testing of the system to be carried out and the test circuit is designed to facilitate location of faulty components. A visual inspection of the system should include the following:—

(i) The various components should be examined for damage, security, and, where appropriate, fluid leaks.

(ii) Pipelines should be examined for security, chafing and fluid leaks, particularly at connections.

(iii) Electrical cables should be examined for security, chafing and damage by fluids or heat.

7.2.5 The removal and installation of components in the anti-skid system often requires the observance of certain safety precautions. These precautions are detailed in the approved Maintenance Manual and normally include the fitting of landing gear ground locks and door locks, and depressurising the appropriate hydraulic system.

8 LOW PRESSURE BRAKE SYSTEMS Most light aircraft are fitted with an independent hydraulic system for each brake, similar to that shown in Figure 6. On some aircraft a handbrake system is connected to each brake through a shuttle valve, while on others a parking brake control applies a mechanical lock to the footbrake linkage when brakes are applied. The main components in each system are a fluid reservoir and master cylinder, connected mechanically to the brake pedals and hydraulically to the brake operating cylinder.

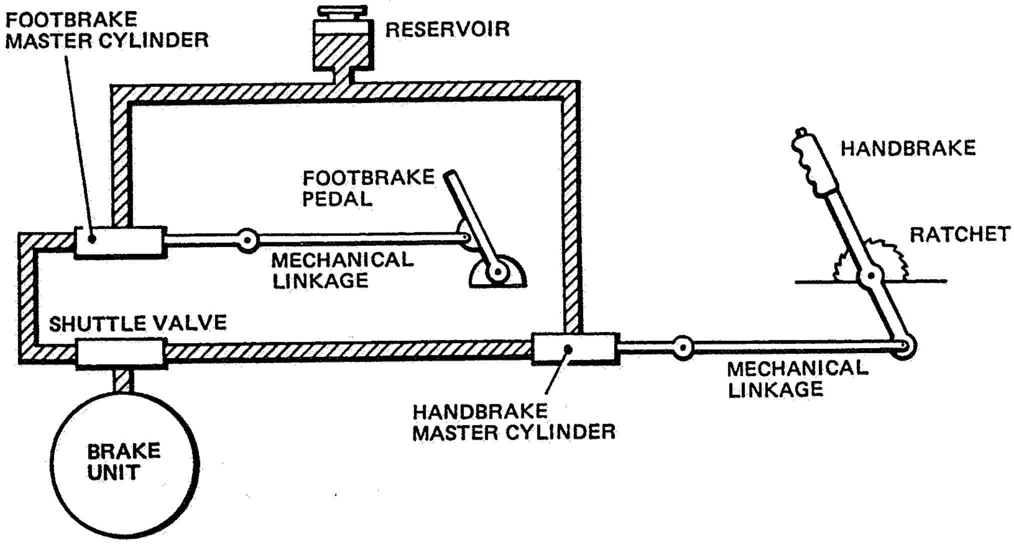

Figure 6 SIMPLE LOW-PRESSURE BRAKE SYSTEM

8.1 **Operation.** As the brake pedal is pressed, a piston in the master cylinder forces fluid through the pipelines to the brake operating cylinder, the braking force depending on the force exerted on the brake pedal. When the pedal is released, a return spring in the master cylinder returns the piston to its original position, and pressure is relieved. Handbrake operation is similar except that the shuttle valve moves to allow pressure to the brake unit and close off the port from the footbrake master cylinder; brakes are held on by a ratchet device in the handbrake mounting. With the alternative parking brake system, the brake should be set by applying pressure with the footbrake, then the parking brake operated to lock the footbrake linkage; subsequent footbrake application will release the locking catch.

8.2 **Bleeding and Testing.** After installing the braking system and whenever faulty system operation is suspected, the aircraft should be jacked up and the following procedure carried out, subject to specific instructions contained in the approved Maintenance Manual.

(i) Ensure that the brake fluid reservoir is topped up.

(ii) Undo the bleed screw in the brake unit and position a container to catch draining fluid. It is usually advisable to fit a tube between the bleed screw and container, to avoid contaminating the brake pads.

(iii) Pump the brake pedal slowly until bubble-free fluid issues from the bleed screw, topping up the reservoir as necessary, then tighten the bleed screw.

(iv) Apply the footbrake and ensure that the brake is operating, then release the brake and ensure that the wheel rotates freely.

(v) Hold the footbrake fully on for 30 seconds and check for hydraulic leaks. The brake should still be applied, with no apparent pedal movement, at the end of this time.

(vi) Repeat (v) using the handbrake or parking brake as appropriate.

8.3 **Maintenance.** Little maintenance is required with this type of brake system except for ensuring that the reservoir is kept topped up to the required level with the specified fluid. Use of the correct fluid is most important, since the piston and shuttle valve seals are often manufactured from a material which is compatible with a limited range of fluids and might deteriorate rapidly if a different fluid were introduced. Cleanliness is also an important aspect and every care should be taken to prevent the introduction of dust and dirt into the system when topping up the reservoir.

8.3.1 The components and pipelines should be inspected periodically for security, fluid leakage and correct operation. Flexible pipes are often fitted between the brake unit and landing gear leg, and it should be confirmed that the pipes are secure and have freedom of movement throughout the range of movements of the landing gear.

8.3.2 Spongy operation of the brakes may be caused by air in the system, which should be bled as described in paragraph 8.2. Fluid bled from the brakes should not be replaced in the system.

8.3.3 Loss of brake pressure, or inability to hold the brakes on, may be due to faulty or worn seals in the master cylinder or shuttle valve. Extreme care is necessary when replacing these seals, as they usually have to be expanded over the valve or piston. The use of an assembly tool is often recommended and the seals should be lubricated with system fluid before fitting. Cleanliness is of the utmost importance since dirt and grit could prevent proper sealing and possibly score the piston or cylinder surfaces.

9 HIGH PRESSURE BRAKE SYSTEMS High pressure braking systems use the normal aircraft hydraulic system to provide fluid, under pressure, to the brake units. A brake system accumulator stores energy in the brake system for use in the event of normal system pressure not being available, and an emergency pneumatic system is frequently included to safeguard brake operation in the event of complete hydraulic failure. A simplified system is shown in Figure 7.

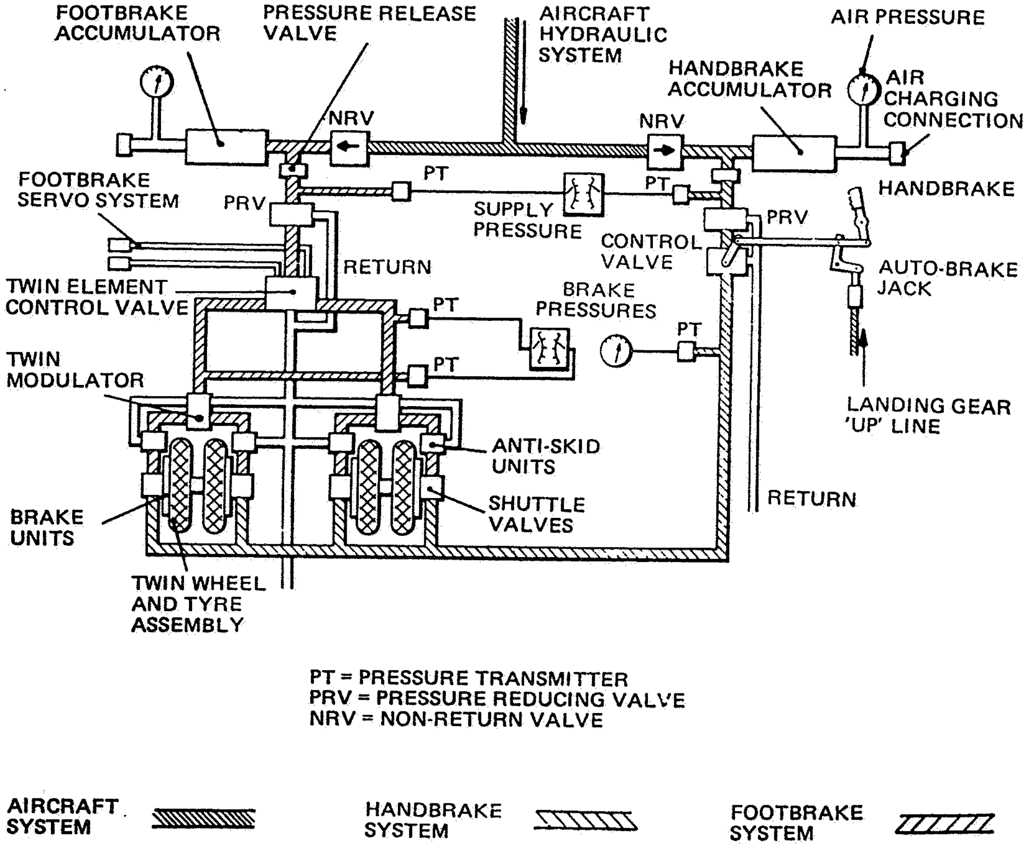

Figure 7 SIMPLE HIGH-PRESSURE BRAKE SYSTEM

9.1 Operation of the brakes can be controlled from either pilot's position, by brake pedals attached to the rudder bar. Application of left or right pedals at either pilot's station causes operation of the associated left or right brakes.

9.2 The brake pedals are linked through a system of levers and cables, or a hydraulic servo system, to a control valve (normally located adjacent to the main wheel bays to minimise the length of pipe run) which controls hydraulic pressure according to the position of the brake pedals. This pressure is often reduced through a pressure reducing valve, and modulated by an anti-skid valve, before being applied to the brake cylinders.

9.3 **Adjustment.** The accurate setting-up of the mechanical linkage between the rudder pedals and control valve is very important since it controls the brake pressure in relation to pedal movement and must be identical in both left and right braking systems. Details of the setting-up procedure for a particular aircraft system will be found in the approved Maintenance Manual, but in a normal system, levers and bellcranks are locked in position by the insertion of rigging pins and the connecting rods and cables adjusted to fit these fixed locations. Alternatively, graduated quadrants may be fitted to show the angular positions of particular levers so that the connecting components may be correctly adjusted. Cables should be tightened to the tension quoted in the Maintenance Manual.

9.4 **Bleeding.** Bleeding of the hydraulic braking system is normally carried out using an approved hydraulic servicing rig connected into the aircraft system at selected quick-release couplings. It is normal practice to bleed the main hydraulic system first to ensure the fluid passing to the brakes is free from air. A typical procedure would be as follows:—

(i) Install landing gear ground locks and door locks, and chock wheels.

(ii) Release parking brake.

(iii) Connect hydraulic servicing rig to aircraft system and adjust to normal operating pressure.

NOTE: Cleanliness of the rig connections and fluid are most important and every precaution must be taken to prevent the ingress of foreign matter into the aircraft system.

(iv) Apply and release brakes several times.

(v) Set hydraulic pressure to a low value (as specified in the Maintenance Manual) and slowly pump the brake pedals to discharge the brake accumulator, then set the parking brake.

(vi) Release brake unit bleed screws and bleed until bubble-free fluid is discharged, then close bleed screws.

(vii) Reset hydraulic pressure to normal system pressure and release parking brake.

(viii) Operate foot brakes several times and check operation and release of brakes by observing movement of the disc return springs.

(ix) Remove servicing rig, check level of fluid in hydraulic reservoir and restore aircraft to normal.

9.5 **Testing.** Operation of the wheel brakes may be checked by operating the brakes normally and visually observing the action of the disc return springs, and their efficiency may be assessed during taxying. When a full functional check is required however, such as after initial installation or following major component change, a more detailed procedure must be followed. This will normally entail the installation of landing gear ground locks and door locks, or jacking the aircraft, and carrying out the following operations:—

(i) Install a suitable pressure gauge at each brake unit bleed fitting.

(ii) Provide hydraulic power (by connection of a hydraulic test rig or by running an aircraft hydraulic pump).

(iii) Check operation of brake system warning lights and gauges by reference to the relevant Maintenance Manual.

(iv) Fully depress each brake pedal in turn, note the pressure recorded at each pressure gauge and check brake operation.

(v) Release brake pedals, visually or physically check that the brakes are off and check that the readings on the pressure gauges are zero or less than a specified maximum pressure.

(vi) Repeat checks with parking brake and, where fitted, the alternative hydraulic system.

NOTE: On some aircraft which are fitted with an automatic brake system to stop the wheels during landing gear retraction, the test may also include selecting the landing gear up and carrying out a function check.

9.6 **Maintenance.** The main items of maintenance common to all modern aircraft with high pressure braking systems are the checking of fluid levels and accumulator gas pressures, followed by replenishment as necessary. When recharging the gas in accumulators the system hydraulic pressure should be fully released, and when topping up a hydraulic reservoir it must be ensured that all the hydraulic rams are in their appropriate positions. The various components and pipelines should also be inspected at frequent intervals for chafing, security, satisfactory bonding and freedom from leaks.

NOTE: High pressure air or nitrogen charging cylinders should be fitted with relief valves, and extreme care taken to ensure that specified accumulator gas pressures are not exceeded.

9.6.1 The procedure necessary for the replacement of components in a braking system will be found in the approved Maintenance Manual, and particular attention should be given to the prescribed safety precautions. In particular, since a high pressure braking system contains a pressurised accumulator, the system will always be under pressure whether the normal aircraft hydraulic system is operating or not, and this pressure must be released before a disconnection is made. The normal method is to slowly pump the brake pedals until the accumulator is discharged, and this also provides a means of checking internal leakage in the system by observing the number of full brake applications available.

10 OVERHEATED BRAKES The action of braking converts kinetic energy into heat and the temperature of brake units will, therefore, rise during use. There is a limit to the amount of heat which can be absorbed and dissipated by a brake and wheel unit, and excessive use of the brakes, such as during a rejected take-off or prolonged periods of taxying, can lead to overheating and combustion and, in extreme cases, result in rupture of a wheel assembly.

10.1 One of the main problems associated with overheated brakes or brake fires, is how to cool the wheel without inducing uneven contraction of the metal. This could cause fracture of the wheel and explosive release of the air in the tyre. Serious, and sometimes fatal, accidents have been known to occur as the result of the application of an incorrect extinguishant to a brake fire.

10.2 A small fire, due perhaps to combustion of grease on the wheel, would probably cause less damage in burning itself out than might be caused by attempting to extinguish it. A short period should be allowed, therefore, to check the progress of the fire before attempting to put it out. In some cases however, such as when the fire is fed by leaking hydraulic fluid, immediate action will be necessary; some aircraft wheels are made from magnesium alloys which, once ignited, burn fiercely and are difficult to extinguish.

10.3 Tests have shown that the safest extinguishant to use is a dry chemical agent, and this must be used whenever possible. It should be applied by an operator standing in line with the tyre's rolling path and at a safe distance; an overheated wheel should never be approached in line with the axle.

10.4 If a wheel fire has to be extinguished and no dry chemical is available, CO_2 or foam may be used but extreme caution is necessary. The extinguishant should be applied as lightly as possible from a distance of at least 20 feet to reduce the likelihood of uneven cooling, and the area should be kept clear after the fire has gone out, until such time as the wheel and brake are completely cooled.