Part 9 Electrical Equipment

Leaflet 9-1 Bonding and Circuit Testing

1 Introduction

1.1 The purpose of this Leaflet is to provide guidance and advice on the inspection and testing of bonding and electrical circuits after installation and at the periods specified in the Approved Maintenance Schedule for the aircraft concerned.

1.2 The subject headings are as follows:

1.3 CAAIP Leaflet 9–3 Gives guidance on Cables – Installation and Maintenance

2 General

2.1 As each test normally requires specified equipment, care should be taken that it is correctly used (e.g. good electrical contact should always be made). The methods of testing and inspection will vary with different types of aircraft and the equipment fitted, therefore, reference must be made to the appropriate Maintenance Manuals for detailed information.

2.2 To ensure the reliability of test equipment, it should be carefully serviced and certified at the periods recommended by the manufacturer. The performance of equipment should also be checked before and after use.

2.3 After completion of all tests, the installations should be inspected to ensure that all connections have been re-made and secured and that test equipment, tools, etc., have been removed. This should be carried out immediately prior to the fitting and securing of panels, covers, etc., as appropriate. As far as the installation permits, the circuits should then be proved, by making ground functioning checks of the services concerned. A dated record of all relevant figures obtained during the checks should be retained. Any disconnections or disturbance of circuits associated with flying or engine controls, will require duplicate inspection and functioning tests.

3 Bonding

3.1 Bonding is the electrical interconnection of metallic aircraft parts (normally at earth potential) for the safe distribution of electrical charges and currents.

3.2 **Function of Bonding**

Bonding provides a means of protection against charges as a result of the build-up of precipitation, static and electrostatic induction as a result of lightning strikes so that the safety of the aircraft or its occupants is not endangered. The means provided are such as to

a) minimise damage to the aircraft structure or components,

b) prevent the passage of such electrical currents as would cause dangerous malfunctioning of the aircraft or its equipment and

c) prevent the occurrence of high potential differences within the aircraft. Bonding also reduces the possibility of electric shock from the electrical supply system, reduces interference with the functioning of essential services (e.g. radio communications and navigational aids) and provides a low resistance electrical return path for electric current in earth-return systems.

3.3 **Primary and Secondary Conductors**

3.3.1 Primary conductors are those required to carry lightning strikes, whilst secondary conductors are provided for other forms of bonding. The current British Civil Airworthiness Requirements (BCAR) for bonding paths are as follows:

a) BCAR Section D D4–6 and Section K K4–6;

i) The cross-sectional area of Primary Conductors made from copper shall be not less than 0·0045 sq in, i.e. 0·25 in by 26 swg, except that, where a single conductor is likely to carry the whole discharge from an isolated section, the cross-sectional area shall be not less than 0·009 sq in, i.e. 0·5 in by 26 swg. Aluminium Primary Conductors shall have a cross-sectional area giving an equivalent surge carrying capacity.

ii) The cross-sectional area of secondary conductors made from copper must not be less than 0·001 sq in which corresponds to 44 strands of 39 swg for braided conductors. Where a single wire is used its size must be not less than 18 swg.

b) BCAR 23 ACB 23.867 and JAR–25 ACJ 25X899 (4.2);

i) Where additional conductors are required to provide or supplement the inherent primary bonding paths provided by the structure or equipment, then the cross-sectional area of such primary conductors made from copper should not be less than 3 mm^2 except that, where a single conductor is likely to carry the whole discharge from an isolated section, the cross-sectional area would be not less than 6 mm^2. Aluminium primary conductors should have a cross-sectional area giving an equivalent surge carrying capacity.

ii) Where additional conductors are required to provide or supplement the inherent secondary bonding paths provided by the structure or equipment, the cross-sectional area of such secondary conductors made from copper should be not less than 1 mm^2. Where a single wire is used its size should be not less than 1·2 mm dia.

3.4 **Bonding of Aircraft of Metallic and Non-Metallic Manufacture**

3.4.1 The skin of an all-metal aircraft is considered adequate to ensure protection against lightning discharge provided that the method of manufacture is such that it produces satisfactory electrical contact at the joints.

NOTE: An electrical contact with a resistance less than 0·05 ohm is considered satisfactory.

3.4.2 With regard to aircraft of non-metallic or composite manufacture, a cage, consisting of metallic conductors having a surge carrying capacity at least equal to that required for primary conductors and to which metal parts are bonded, forms part of the configuration of the structure and must conform to the requirements of BCAR.

3.4.3 The earth system, which in the case of aircraft of metallic manufacture is normally the aircraft structure and for aircraft of non-metallic manufacture is the complete bonding system, must be automatically connected to the ground on landing. This is normally achieved through the nose or tail wheel tyre, which is impregnated with an electrically conducting compound, to provide a low resistance path.

NOTE: On some aircraft, a static discharge wick or similar device trailed from a landing gear assembly is used to provide ground contact on landing.

3.4.4 The reduction or removal of electrostatic charges which build up on such surfaces as glass fibre reinforced plastic, can be achieved by the application of a paint, e.g. PR 934, which produces a conductive surface.

3.5 **Bonding Connections**

3.5.1 When a bonding connection is to be made or renewed, it is essential that the conductor has the specified current-carrying capacity, since the bond may have been designed to carry relatively high electrical loads, e.g. under circuit fault conditions.

3.5.2 The manufacturers of solid bonding strip and braided bonding cord usually quote the cross-sectional area on the relevant data sheet. However, in the case of renewal or repair, if the original conductor cannot be matched exactly, a replacement manufactured of the same type of material, but of greater cross-sectional area, should be selected.

3.5.3 Braided copper or aluminium cords fitted at each end with connecting tags or lugs (usually referred to as 'bonding jumpers'), should be used for bonding connections between moving parts or parts subjected to vibration and these are suitable both as primary and secondary conductors.

3.5.4 The tags or lugs on bonding jumpers are generally fitted by the 'crimping method', see Leaflet 9–3 and only the correct form of crimp and crimping tools should be used for the particular connection. During assembly of the connections to aluminium cords, anti-oxidant (crimping) compound consisting of 50% by weight of zinc oxide in white petroleum jelly and complying with DTD 5503, should be applied to the connections.

3.5.5 Where applicable, the soldering of tags or lugs fitted to braided copper cord should be carried out using a resin flux. Special care is necessary because overheating and cooling of conductors will cause brittleness, whilst a loss of flexibility up to 25.4 mm (1 inch) from the lug may occur as a result of the capillary action of the molten solder.

NOTE: Primary flexible conductors are often made of 600 strands of copper wire, 0·0048 inch in diameter and formed in a flat braid approximately 0·625 inch wide.

3.5.6 All bonding connections should be properly locked to prevent intermittent contact which may be caused by vibration.

NOTE: Intermittent contact is worse than no contact at all.

3.5.7 Bonding connections should not interfere mechanically or electrically with any associated or adjacent equipment and bonding jumpers should not be excessively tight or slack.

3.5.8 The run of all primary conductors should be as straight as possible; sharp bends must be avoided.

3.5.9 The number and location of bonding connections to the various components is important and this should be checked and verified by reference to the relevant drawing, e.g. where an engine is not in direct electrical contact with its mounting it should be bonded with at least two primary conductors, one on each side of the engine.

3.5.10 In most instances the following joints are considered self-bonding, provided that all insulating materials (e.g. anodic finish, paint, storage compounds, etc.), are removed from the contact faces before assembly, but if any doubt exists regarding the correctness of the bonds, a bonding test should be carried out:

a) Metal-to-metal joints held together by threaded devices, riveted joints, structural wires under appreciable tension and bolted or clamped fittings.

b) Most cowling fasteners, locking and latching mechanisms.

c) Metal-to-metal hinges for doors and panels and metal-to-metal bearings (including ball bearings).

i) In the case of bearings for control surface hinges it should be ascertained which bearings are classified as self bonding, e.g. metal-to-metal, nylon with conducting grease.

ii) Where applicable, bonding jumpers for control surfaces should be as flexible and as short as possible, of as low impedance as is practicable and should not be tinned. The possibility of a jumper jamming the controls must be avoided.

3.6 **Flexible Bonding Connections**

3.6.1 Flexible hose connections used for joining rigid pipes should be bonded by fitting clips around the pipes approximately 13 mm (½ inch) away from the hose and bridging with a corrugated bonding strip or jumper; the practice of tucking the ends of bonding strips between the hose and the pipe is not recommended. To obtain good electrical contact the area under each clip should be cleaned and, after the clip has been fitted, protection should be restored.

3.6.2 Not only must the flexible hose connection be bridged, but each pipe run should be bonded to earth at each end, particularly within a radius of 2.42 metres (8 feet) of any unscreened radio equipment or aerial lead, where earthing bonds should not be more than 1·5 metres (5 feet apart), or less distance apart, if called for by the manufacturer.

3.6.3 If bridging strips or bonding cords are fractured a new conductor should be fitted. The soldering of broken ends is prohibited.

3.6.4 High-pressure flexible pipe assemblies are usually self-bonding, but a bonding test should be made between the assembly end-couplings to prove the integrity of the bonding.

NOTE: The provisions of paragraph (3.6.2) above also apply to any long electrically-conducting parts (including metallic conduits and metal braiding) which are not insulated from earth.

3.6.5 Where any bonding or earth connection is made to the structure or equipment, the specified standard of protection against corrosion should be provided.

3.6.6 After a non-conducting protective coating has been removed from the connecting area, the preferred sealing and anti-oxidant treatment as specified on the relevant drawing and specification should be carried out.

NOTE: Non-conducting protective treatments include all generally used priming and finishing paints, varnishes and temporary protectives, chromic, anodic and phosphate coatings. Metallic coatings, such as cadmium and tin, are satisfactory conductors and should not be removed. If a polysulphide compound is used for sealing the earth or bonding point, it must be ensured that the anti-oxidant to be subsequently applied will not have a detrimental effect on the sealing; e.g. DTD 5503 should not be used.

3.6.7 When the connection has been made any excess compound should be wiped off, using a rag damped in methyl ethyl ketone (MEK) and the connection and adjacent area re-protected by the specified method, this depending on the materials concerned and the position of the connection.

3.6.8 When a 'corrosion washer' forms part of the connecting assembly, it should be correctly fitted and be of the correct material for the type of connection concerned.

NOTE: A corrosion washer is plated, or manufactured of a material having a potential such that when placed between materials of widely differing potentials it reduces the risk of corrosion caused by electrolytic action.

3.7 **Earth Terminals**

3.7.1 When earth-return terminal assemblies are fitted or replaced, the correct method of fitting to the structure, the corrosion protection required and the exact location on the structure should be carefully checked. The procedure for fitting and the number of terminations to be attached will vary with the design of the terminal assembly and the type of structure, therefore reference should be made to the relevant drawings and instructions to ensure both electrical and structural integrity.

3.7.2 All earth terminal assemblies should be checked for resistance between the lug attachment point(s) and the surrounding structure and this must not exceed the figure specified for the aircraft concerned (e.g. 0·025 ohm). When earth terminal assemblies are also used to carry electrical supplies, a millivolt drop test, as outlined in paragraph 4.3 must be carried out.

3.7.3 If the resistance in either case is unsatisfactory, the terminal assembly should be removed, the contacting faces cleaned with a fine abrasive (e.g. aluminium wool) and reassembled using, where applicable, new corrosion washers. The connecting area should be sealed and treated with anti- oxidant compound as specified in the relevant drawing and specification.

NOTE: Leads connected to earth terminal assemblies should be of insulated cable with terminal tags fitted by the crimping method. It is important that the cable is of the specified gauge for the service concerned and is kept as short as possible.

3.8 **Resistance Values**

The CAA’s Requirements with regard to the maximum resistance values for the various conditions of bonding are summarised in Table 1.

Table 1

Bonding Classification	Test Condition	Maximum Resistance
Primary	Between extremities of the fixed portions of aircraft of non-metallic or composite manufacture.	Estimated and declared by manufacturer.
	Between extremities of the fixed portions of metallic aircraft.	0·05 ohm
	Between bonded components and portions of main earth system to which they are connected.	
Secondary	Between metallic parts normally in contact with flammable fluids and main earth system, and also between the parts themselves.	1 ohm (See Note 1)
	Between all isolated conducting parts which may be subject to appreciable electrostatic charging and the main earth system. (See Note 2.) area whichever is the less	0·5 megohm or 100 000 ohms per sq ft of surface area whichever is the less.
	Between equipment supplied from an unearthed system, of any voltage, and the main earth system.	1 ohm (See Note 1)
	Between equipment containing circuits carrying 50 volts (rms or dc) or more, and the main earth system.	

NOTES: 1) The value of 1 ohm is chosen to allow for the inclusion of the resistance of any cable that may be employed for this bonding case, but no one contact resistance should exceed 0·05 ohm.

2) The parts concerned are those situated inside and outside an aircraft and having an area greater than 3 sq in and a linear dimension greater than 3 inch.

3.9 Bonding Carrying the Main Electrical Supply

3.9.1 The cross-sectional area of the main earth system, or any connection to it, must be such that without overheating or causing excessive voltage drop, it will carry any electrical currents which may pass through it normally or under fault conditions.

3.9.2 If, under fault conditions, it should form part of a short-circuit, not provided against by a protective device, it should be capable of carrying the full short-circuit current which can pass, without risk of fire or damage to the bonding system.

NOTE: For example, paragraph 3.9.2 may apply to bonding which under fault conditions becomes part of a starter or other heavy current circuit. Particular attention should be given to non-metallic aircraft fitted with a double-pole wiring system to which single-pole equipment has subsequently been added.

3.10 Bond Testing

3.10.1 Special test equipment, comprising a meter and two cables each of specific length, is required for checking the resistance of bonding. A meter widely used, consists of an ohmmeter operating on the current ratio principle and a single 1·2 volt nickel-alkaline cell housed in a wooden carrying case. The associated cables are 60 feet and 6 feet in length and are fitted with a single-spike probe and a double-spike probe respectively. Plug and socket connectors provide for quick-action connection of the cables to the instrument.

3.10.2 Prior to carrying out a bonding test, a check should be made on the state of the nickel-alkaline cell of the tester by observing;

a) that a full-scale deflection of the meter is obtained when the two spikes of the 6-foot cable probe are shorted by a suitable conductor; and

b) that the meter reads zero when the two spikes of the 6-foot probe are shorted by the single spike of the 60-foot probe.

3.10.3 The 60-foot lead of the test equipment should be connected to the main earth (also known as the bond datum point) at the terminal points which are usually shown diagrammatically in the relevant Aircraft Maintenance Manual. Since the length of a standard bonding tester lead is 60 feet, the measurement between the extremities of the larger types of aircraft may have to be done by selecting one or more main earth points successively, in which event the resistance value between the main earth points chosen should be checked before proceeding to check the remote point.

NOTE: When connecting the 60-foot lead to an earthing point, any protective treatment (e.g. strippable lacquer) should be removed at the point of contact.

3.10.4 The 6-foot test lead should be used to check the resistance between selected points; these are usually specified in the bonding test schedule or the Maintenance Manual for the aircraft concerned. When the two spikes of the test lead probe are brought into contact with the aircraft part, the test- meter will indicate, in ohms, the resistance of the bond.

3.10.5 As an alternative to the above, the four terminal method of resistance measurement may be adopted with the appropriate miliohmmeter (see Figure 1). With this type of instrument, a test current (approximately 2 amps) is supplied by the internal batteries and passed through the resistance via cables C1 and C2. The voltage drop across the resistance is measured (P1 and P2) and compared with the current flowing. The resultant value is then displayed (normally digitally) on the meter. The test leads may be in the form of duplex spikes (see Figure 2) or when used in association with crocodile type test leads, single spikes. In order to check that the instrument is functioning correctly, the two hand spikes should be placed on a low resistance conductor with the potential spikes (P1 and P2) closely together (see Figure 3). The result of this test should be a zero reading on the meter.

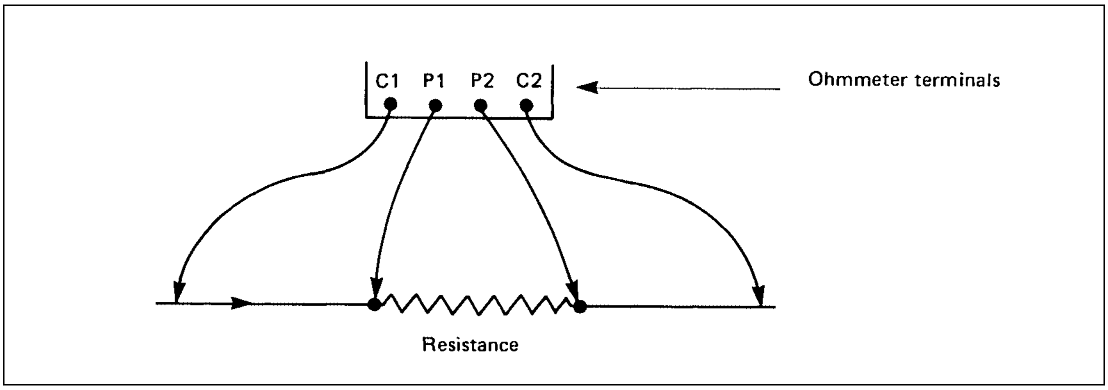

Figure 1 Four Terminal Resistance Measurement

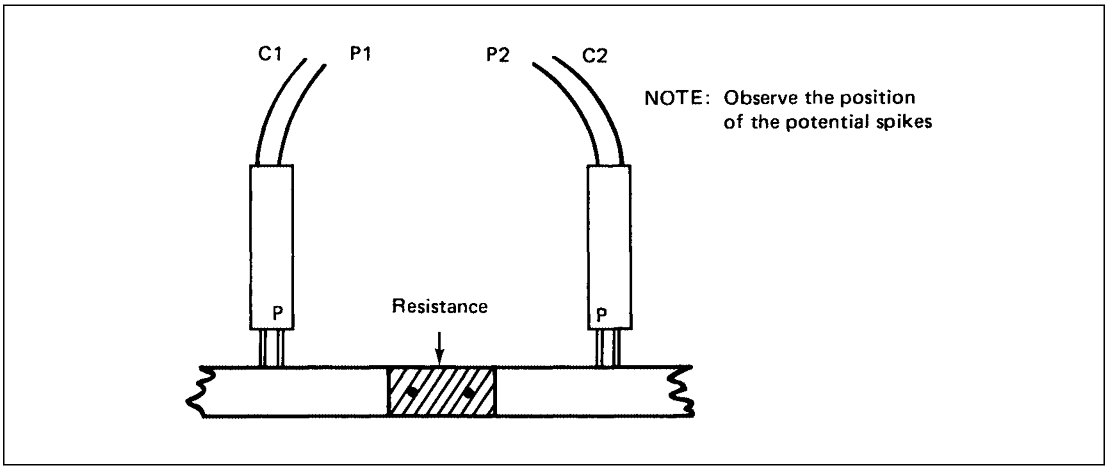

Figure 2 Duplex Hand Spikes

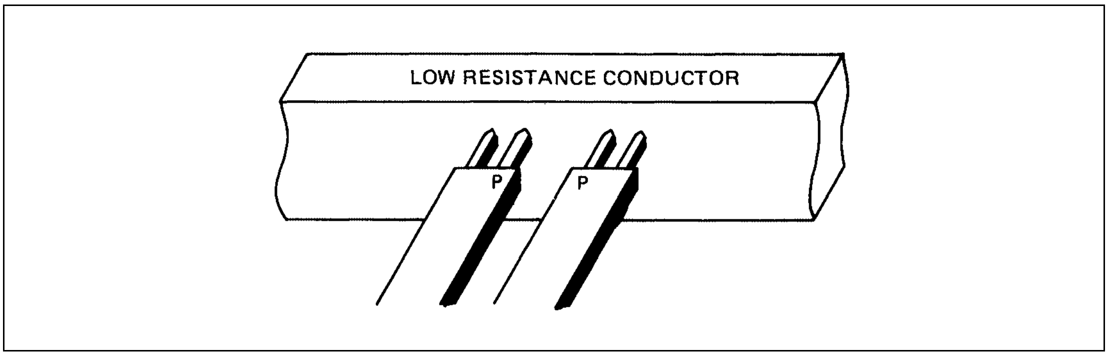

Figure 3 Test Position of Hand Spikes

3.10.6 To ensure good electrical contact at the probe spikes, it may be necessary to penetrate or remove a small area of a non-conducting protective coating. Therefore, after test, any damage to the protective coating must be restored.

3.10.7 If the resistance at a bond connection is excessive, rectification action will depend on the type of connection. The following action should be taken for the more common types of connections:

a) In the case of bonding jumpers, the connecting tag or lugs should be removed and the contacting faces thoroughly cleaned, using a slight abrasive if necessary. The bare metal thus exposed should be only just large enough to accept the palm of the tag or lug. The connecting area should be sealed and treated with anti-oxidant as specified in the relevant drawing and specification.

NOTE: Where an abrasive has been used it is important to ensure that all traces of it are removed.

b) Where equipment is bonded through a holding bolt, the bolt should be removed and the area under the bolt-head, or nut, thoroughly cleaned and protected as recommended in paragraph 3.10.7 a). The correct washer (both with regard to size and material) should be fitted before the bolt is replaced and tightened.

c) Where the required bond value cannot be obtained at a structural joint the advice of the manufacturer should be sought.

NOTE: Corrosion tends to form at a bonding or earth connection and is often the cause of excessive resistance.

3.10.8 The resistance between the main earth system and a metal plate on which the earthing device (e.g. tyre) is resting should be measured and should not exceed 10 megohms when measured with a 250-volt or 500-volt resistance tester, as specified in the test schedule.

NOTE: After carrying out tests, all areas where the protective coating has been removed should be re-protected using the appropriate scheme.

3.11 Bonding Tester Servicing

3.11.1 A tester requires little in the way of servicing, apart from periodic attention to the alkaline cell, which should be removed at prescribed intervals for routine servicing. When replacing the cell, it is most important that the polarity of connection is correct. The ohmmeter is normally sealed in its case and no attempt should be made to open it; if a fault should develop, then the complete instrument should be withdrawn from use and overhauled.

3.11.2 The leads are an integral part of the tester and being carefully matched to the meter unit must not be modified or altered in any way. All contact surfaces of plug pins and probes must be kept scrupulously clean and the points of the probe spikes should be reasonably sharp to give effective penetration of protective finishes, etc., on metal surfaces.

3.11.3 The accuracy of the tester should be checked periodically by using it to measure the resistance of standard test resistors. Normally, three such resistors are supplied for testing purposes and the readings obtained should be within 10% of the standard ohmic values.

4 Inspection and Testing of Circuits

4.1 Inspection of Wiring System

4.1.1 Before carrying out tests, or when inspection is specified in the Approved Maintenance Schedule, all aircraft circuits, together with plugs, sockets, terminal blocks and equipment terminals, should be examined, as appropriate, for signs of damage, deterioration, chafing, poor workmanship and security of attachments and connections. It is not intended, for the purpose of this examination, that electrical apparatus should be removed from its mountings or that cables should be unduly disturbed, but if modifications or repairs, for example, have been carried out in the vicinity, looms should be closely inspected for ingress of metallic swarf between cables. Whenever a structure is opened over wiring which is not normally visible through available inspection panels, circuits so exposed should be thoroughly inspected.

4.1.2 The primary purpose of the inspection is to determine the physical state of the wiring system, especially at bends, points of support, duct entries, etc., or where high temperature or contamination could cause local deterioration. Where cables are grouped together, the state of the outer cables is generally indicative of the condition of the remainder.

4.1.3 Cables completely enclosed in ducts obviously cannot be examined along their length, but should be checked for continuity and insulation, especially if oil or water ingress is suspected. Where there is evidence of damage to the ducts, the cables should be exposed to ascertain their condition.

4.1.4 Terminations must be secure and good electrical contact obtained without strain on the threads of terminal pillars or studs. Torque loadings, where appropriate, should be within the limits specified.

4.2 **Continuity Testing**

4.2.1 A concealed break in a cable core or at a connection may be found by using a continuity tester which normally consists of a low voltage battery (2.5 volts is satisfactory) and a test lamp or low reading voltmeter.

NOTE: In some testers incorporating a test lamp, semiconductors are included in the test lamp circuit and, to prevent damage, the currents should be limited to 120 milliamps.

4.2.2 Before testing, the main electrical supply should be switched off or disconnected. A check should be made that all fuses are intact and that the circuit to be tested is not disconnected at any intermediate point. All switches and circuit breakers, as appropriate, should be closed to complete the circuit.

4.2.3 When carrying out a low voltage continuity check, it is essential to work progressively through the circuit, commencing from the relevant fuse or circuit breaker and terminating at the equipment. Large circuits will probably have several parallel paths and these should be progressed systematically, breaking down as little as possible at plug and socket or terminal block connections. In testing of this nature, it is valueless to check several low resistance paths in parallel.

4.3 **Millivolt Drop Test**

Excessive resistance in high-current carrying circuits can be caused by loose terminal connections, poorly swaged lead ends, etc. Faults of this kind are indicated by low terminal voltage at the connections to the service load and by heating at a conductor joint. If such faults are suspected, a millivolt drop test as described below is recommended, but it is also acceptable to check along progressive sections of the system with an accurately calibrated voltmeter:

a) For continuously-rated circuits, the test should, whenever possible, be made with the normal operating current flowing, the power being derived from an external source. For short-rated circuits, a suitable resistance or other dummy load should be used in lieu of the normal load and the current should be scaled down to avoid overheating.

NOTE: The test voltage may be reduced for safety reasons.

b) The millivolt-meter should be connected to each side of the suspected joint and a note made of the volt drop indicated. The indicated reading should be compared with the figures quoted in the relevant publication (an approximate guide is 5 mV/ 10 amps flowing).

4.4 Insulation Resistance Testing

4.4.1 In the following paragraphs general test procedures are outlined; however, as a result of the wide variation in electrical installation and equipment which exists with different aircraft, the routing charts and Approved Test Schedule for the aircraft concerned must be consulted. All ancillary equipment should be tested separately in accordance with the appropriate manufacturers' publications.

4.4.2 After installation and where specified in the Approved Maintenance Schedule or Test Schedule, aircraft circuits should be tested by means of a 250-volt insulation tester which should have its output controlled so that the testing voltage cannot exceed 300 volts. In all systems having nominal voltages over 30 volts, cables forming circuits essential to the safety of the aircraft should be tested individually. Other circuits may be connected in groups for test. However, the numbers of circuits which may be grouped for test is governed by the test results; where the insulation resistance so measured is found to be less than the appropriate minimum value stated in paragraph 4.5.4, the number of circuits grouped together should be reduced.

4.4.3 Immediately after an insulation test, functioning checks should be made on all the services subjected to the test. If the insulation test or subsequent functioning tests should reveal a fault, the fault should be rectified and the insulation and functioning tests should be repeated in that sequence on the affected circuits.

4.4.4 Preparations Prior to Test

Before beginning an insulation test on a system, the following preparations should be made, details of which will depend on the installation concerned:

a) The aircraft battery and any external supply should be disconnected.

b) Where applicable, circuit breakers should be closed.

c) The power selector switch should be switched to the position appropriate to that required for normal in-flight operation.

d) All switches in the circuit concerned should be 'ON', dimmer-switches should be set at the minimum resistance position and micro-switches operated to the 'ON' position.

e) All items of ancillary equipment which are supplied by the system concerned should be disconnected. This includes all rotary equipment (e.g. generators, motors, actuator units, etc.), radio equipment, capacitors, semiconductors, voltage regulator coils, electrical instruments, fire extinguishers, etc.

f) In cases where the insulation resistance with the items concerned is not less than 2 megohms, the disconnection may be made by the earth lead, leaving the item connected to the circuit.

NOTE: Bonded earth connections to the airframe structure should, if possible, remain undisturbed for the purpose of these tests.

g) Components such as cut-outs and relays which are normally open should have their terminals bridged to ensure continuity of the circuit and disconnected leads from suppressors should also be bridged for similar reasons. Where a suppressor cannot be bridged and plug and socket connections are used, the capacitors should be discharged before the circuit is re-connected, otherwise arcing and burning of the pins may occur. Items in series which are disconnected should also be bridged so that part of the circuit is not omitted.

4.5 Testing the System

4.5.1 Double-pole systems on some older types of aircraft can be tested by connecting the leads of the insulation tester to each of the battery leads and measuring the resistance between them and, afterwards, checking the resistance between each battery lead and earth; fuses should be left in position for this test. On some large aircraft with double-pole systems, cables may be grouped as for single-pole systems, the earthing checks being made between bunched positive and earth and bunched negative and earth.

4.5.2 To test single-pole systems, one lead of the tester should be connected to earth and the other to the cable or bunch of cables to be tested. When cables are bunched together, it is advisable to limit the number to the smallest convenient figure. If the insulation resistance is less than the appropriate value quoted in paragraph 4.5.4, the number of circuits should be reduced. Testing should continue until, by process of elimination, any defective cables have been identified.

4.5.3 Test Results

The results of insulation tests are of little significance unless they are related to test results obtained on other occasions. The insulation resistance values are likely to vary with changes in the temperature and humidity of the local atmosphere, e.g. if the aircraft has been in damp conditions for some time before the test, low readings can be expected. Results of tests and the temperature and humidity conditions at the time of the test should be recorded, so that any pronounced drop in resistance found on subsequent tests can be checked and rectified as necessary.

4.5.4 British Civil Airworthiness Requirements do not specify minimum values of insulation resistance, but gives guidance on values that may be expected during maintenance testing. These values can be, and frequently are, exceeded considerably on new installations. The values given are as follows:

a) Wiring (including accessories for jointing and terminating):

In engine nacelles, undercarriage wheel wells and other situations exposed to weather or extremes of temperature	2 megohms
Galley and other non-essential services, lighting, signalling and indication services	5 megohms
Other services	10 megohms

NOTE: The above values relate to single circuits or small groups of circuits.

b) Wiring accessories alone (e.g. terminal blocks, connectors, plugs and sockets, etc.):

Between terminals	100 megohms
Between terminals bunched together and earth	$\frac{200}{\text{number of terminals}}$ megohms

c) Rotating machinery whichever is the greater of $\frac{\text{rated voltage}}{150}$ or 0·5 megohms

d) All other equipment (including indicating instruments) 5 megohms

4.6 Functioning Tests

4.6.1 Before conducting any tests, all precautions for aircraft and personnel safety should be taken. Whenever possible, functioning tests should be carried out using an external supply coupled to the ground supply connector. Tests must ensure proper functioning of individual and integrated sections of circuits and should be in accordance with schedules established by reference to details in the relevant Maintenance Manual, Wiring Diagram Manual or, where appropriate, instructions relating to the incorporation of a modification or any substantial rewiring.

NOTE: Where applicable, when one or more engines are running, the power supply can be obtained from the associated generators, due reference being made to the functioning of any isolating relays.

4.6.2 For certain circuits (e.g. standby lighting), functioning tests can only be carried out using the aircraft battery system, but this battery should be used as little as possible.

4.6.3 After the normal functioning test of an individual circuit has been completed and the circuit switched off, the fuse should be removed or the circuit breaker tripped and the circuit again switched on to check the isolation of the circuit concerned.

4.6.4 When the operation of a circuit (e.g. generator equaliser circuit) depends on the inherent resistance value of the circuit, the resistance should be measured with a low reading ohmmeter (such as that used in a bonding tester) to determine that the resistance is within the specified limits.

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Leaflet 9-2 Charging Rooms for Aircraft Batteries

1 Introduction

This Leaflet gives guidance on the setting-up and operation of rooms equipped for the purpose of charging aircraft batteries.

1.1 Mandatory provisions for the setting-up and operation of battery charging rooms are contained within the Factories Act.

1.2 The following Leaflet contains information associated with the subject covered by this Leaflet and reference should be made to it, as appropriate.

1–8 Storage Conditions for Aeronautical Supplies

2 Building and Equipment

2.1 General

2.1.1 In no circumstance should the same facility be used for both nickel-cadmium and lead-acid battery charging; and the ventilation arrangements shall be such that no cross contamination can occur.

2.1.2 Buildings and rooms used for the purpose of charging batteries should be well lit and cool and should have a ventilation system which is capable of exhausting all the gases and fumes which may be present during the servicing and charging operations. The floor surface should be of a material which is impervious to acid and alkali, has non-slip qualities and is quick drying and able to be washed down easily. Examples of such materials are dustless concrete, bituminous compound or tiling. Adequate and suitable drainage should be provided for washing down purposes. Because of the fire risk, it is strongly recommended that doors should be fitted so that they open outwards, thus facilitating easy evacuation from the building in the event of fire. To permit free and easy movement of batteries, steps and thresholds should, where possible, be eliminated. If, however, different levels are unavoidable they should be linked by inclines.

2.2 Water Supply

At least one tap in each room where battery charging is carried out should be connected to a mains fresh water supply. Sinks and draining boards and a hot water supply should also be provided.

2.3 Lighting

The level of lighting within the charging rooms should be sufficient to enable the level of the electrolyte in individual cells of batteries to be easily determined without additional lighting. To prevent accidental ignition of gases all electrical fittings should be of a sparkproof design.

2.4 Ventilation

Hydrogen is given off at all stages of lead-acid battery servicing; the highest concentration being at the end of the charging cycle. Hydrogen is also produced when nickel-cadmium batteries reach the fully charged state; i.e. at the 'overcharge' point and for a 24 hour period thereafter. Heavy corrosive fumes are also emitted when mixing of electrolytes takes place. Therefore, a ventilation system is required which is capable of extracting all gases and fumes, whether heavier or lighter than air.

2.5 Temperatures

2.5.1 Electrolyte Temperature

The maximum permissible electrolyte temperature during charging is normally 50°C (122°F), but some batteries of special design, however, have lower limits; for such batteries the temperature limitations will be specified in the manufacturer's publication for that battery.

2.5.2 Environmental Temperature

Environmental temperatures exceeding 27°C (81°F) for lead-acid batteries and 21°C (70°F) for nickel-cadmium batteries impose time penalties in reaching the fully charged state and may also be deleterious to the batteries. The temperature of battery charging rooms should, therefore, be maintained at a temperature consistent with specified limitations and with a free air flow around each battery or cell.

3 Charging Boards and Benches

3.1 Detailed differences exist between the various types of charging board, but in general each board consists of a pair of terminals, to which the rectified a.c. supply is connected (or in the case of a board which has a built-in rectifier unit, to which the mains supply is connected), together with a number of pairs of output terminals, to which the batteries are connected for charging.

3.2 All the output circuits are internally connected in parallel and are, therefore, independent of each other, with the level of charge being controlled separately for each output circuit. Each pair of output terminals is normally designed to have one group of batteries or cells connected in series.

NOTE: Parallel connection of batteries to one pair of output terminals is not permitted.

3.3 Charging boards should be mounted directly above the rear of the benches so that the necessity for long connecting cables is avoided.

3.4 Battery connecting cables should be well insulated and should be of a sufficient capacity to carry the charging current required. The free ends of connecting cables should be fitted with suitable connectors, which should be firmly secured to the battery and charging board before commencing charging operations. Connections to the charging boards should not be made or broken when power is switched on. On completion of the charging cycle, power should be switched off and the charging cables should be disconnected, first from the battery and then from the charging board.

3.5 Benches

3.5.1 Benches and associated equipment should be sited so that the need for personnel to lean over batteries is kept to a minimum. It is recommended that the height of battery charging benches be approximately 0·5 m (20 in) from the floor. At this height, lifting strain is minimised and a more effective visual inspection of the batteries can be made.

3.5.2 The surfaces of battery charging benches should be acid and alkali resistive and should facilitate cleaning. It is generally considered that batteries should not be allowed to stand directly on wood or concrete, but should rest on suitable grids.

4 Power Supplies

4.1 Transformer/rectifiers which normally provide rectified a.c. for charging board supplies should be sited in a fume free, dry and cool position, preferably in a separate room, located as near as possible to the charging boards. Charging boards which require 240 volts mains supply, should be supplied from a ring main system.

5 Storage

5.1 **Batteries**

In order to preserve an orderly flow of work through a battery charging room, storage facilities should be provided such that incoming unserviceable batteries may be separated from those ready for issue, preferably in clearly placarded areas. The storage facilities should be further grouped for those batteries requiring initial charge and those awaiting routine servicing. Batteries which are serviceable and awaiting issue are best stored in an area which is not subjected to excessive vibration. It is essential that whilst in store, lead-acid batteries be segregated at all times from nickel-cadmium batteries; preferably in separate store rooms. For further information on the long term storage of batteries, reference should be made to Leaflet 1–8.

5.2 **Electrolytes**

5.2.1 The handling and storage of electrolyte materials should always be in accordance with the manufacturer's instructions. It is, however, essential that when undertaking the mixing or breaking down of these chemicals, separate areas are provided. Glass, earthenware or lead-lined wood containers are suitable for the storage of lead-acid battery electrolyte (sulphuric acid), whilst plain iron, glass or earthenware containers are suitable for the storage of nickel-cadmium battery electrolyte (potassium hydroxide). Galvanised containers or containers with soldered seams must not be used. Each container should be clearly marked as to its contents and should be stored accordingly. Waste or surplus materials should be disposed of in accordance with locally approved instructions. If, however, doubt exists, all electrolytes should be neutralised prior to disposal (paragraph 5.4). All mixing vessels, mixing rods and other similar items should be clearly marked with 'acid only' or 'alkaline only' and their use should be restricted accordingly.

5.2.2 Stocks of electrolyte materials which are retained in a battery charging room should be restricted to the quantities required for immediate use. The storing of electrolytes mixed ready for use should be avoided as far as possible.

a) Sulphuric acid containers should be kept tightly sealed when not in use, to prevent contamination. Only the container which is required for immediate use should be retained in the charging room.

b) Potassium hydroxide is supplied in solid form contained in steel drums. Once a drum has been opened the contents are liable to carbon dioxide contamination. The entire contents should, therefore, always be mixed as soon as a drum has been opened. Any unused mixture should be stored in a stoppered glass container.

5.3 De-mineralised and distilled water are generally supplied in carboys and should be stored separately from the electrolytes, so as to avoid contamination. Carboys should be firmly stoppered when not in use and should be clearly marked as to the contents. Only the water container used for 'topping up' should be kept in the charging room and the stopper should be refitted immediately after use.

5.4 The neutralising agents for the two types of electrolytes are given below, together with the action that should be taken in the event of contamination and/or spillage.

5.4.1 **Sulphuric Acid**

The neutralising agents are:

a) Saturated solution of bicarbonate of soda.

b) Ammonia powder.

c) Borax powder.

The acid should be soaked up with sawdust which should then be removed and buried. The affected area should be treated with one of the above, followed by washing down with copious amounts of fresh water.

5.4.2 **Potassium Hydroxide**

The neutralising agents are:

a) Boric acid solution.

b) Boric acid crystals or powder.

The alkali should be soaked up with sawdust, which should then be removed and buried. The affected area should be treated with one of the above, followed by washing down with copious amounts of fresh water.

5.4.3 Containers of sawdust and neutralising agents should be clearly marked with their contents and use and sited in readily accessible positions.

6 Protection

6.1 To prevent the risk of burns, such personal items as rings, metal watches, watchstraps and identification bracelets should be removed, to avoid contact with connecting links and terminals. Personal protection against the harmful effects of acid and alkali contamination should be in accordance with the provisions of the Factories Act.

6.2 In general, smoking should only be permitted in rooms which do not have a direct access to battery charging rooms or chemical mixing areas. Naked lights, non-safety matches and automatic lighters should not be taken into battery charging rooms.

6.3 Fire extinguishers of the CO_2 type and buckets of sand should be placed at strategic points inside the building for use in the event of any chemical fires.

7 Documentation

7.1 Records of battery servicing should be maintained.

8 Servicing and Test Equipment

8.1 Servicing of aircraft batteries should be carried out in accordance with the instructions contained in the manufacturers' Maintenance Manual.

8.2 In addition to the general engineering hand tools which may be required for aircraft battery servicing, the following specialised items will also be required:

a) Hydrometers.

b) Thermometers.

c) Battery kits (as supplied by battery manufacturers).

d) Capacity test sets.

e) Leakage tester (lead-acid batteries).

f) Filler pumps (for transferring of liquids from one container to another).

g) Calibrated test equipment:

i) Insulation resistance tester.

ii) Universal test meter.

iii) Digital voltmeter.

8.2.1 To prevent cross-contamination between the two types of aircraft batteries, two sets of equipment should be held, each being contained in separate cupboards and clearly marked 'acid only' or 'alkaline only' as appropriate to the application. Wherever possible, tools and equipment comprising the sets should be those manufactured of an insulating material. Each item should be identified as to its application and in the case of hydrometers and thermometers, this is usually best done on the instrument case.

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Leaflet 9-3 Cables – Installation and Maintenance

1 Introduction

1.1 This Leaflet gives guidance on the installation of the various types of electrical cables used for the wiring of general services in aircraft and their attachment to various forms of terminations, but does not include information on the types of cables designed for specific functions, e.g. high voltage ignition supplies or radio-frequency services. The CAA requirements for electrical installations in aircraft are prescribed in BCAR Sections D, K, G and JAR–25, the relevant parts of which should be read in conjunction with this Leaflet.

NOTE: New text covering electrical systems has been included in BCAR Sections D, G and K. Section J will now remain unamended at Issue 3 and should not be used for new certifications.

1.2 To maintain general environmental suitability, only the types of cables specified by the aircraft or equipment manufacturer, or approved equivalents, should be used. This will ensure that the cables will be suitable for the voltages which will be applied to them under the conditions of operation and test, and that the current ratings will be such that when the cables are installed and carrying the most onerous loads in the most adverse ambient temperatures probable, the temperatures attained by the conductor will not cause damage to the cables.

NOTE: British Standard G212 gives general requirements for aircraft electrical cables.

1.3 The following Leaflets contain information associated with the subject covered by this Leaflet, and reference should be made to them as appropriate:

9–1 Bonding and Circuit Testing

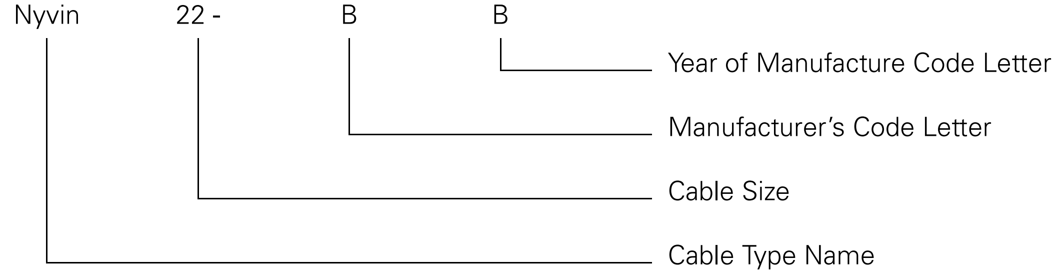
11–5 Aircraft Electrical Cables

1.4 To obviate the need for the revision of this Leaflet when new issues of the specifications referred to are published, the prefix or suffix indicating the issue number of the specification has been omitted.

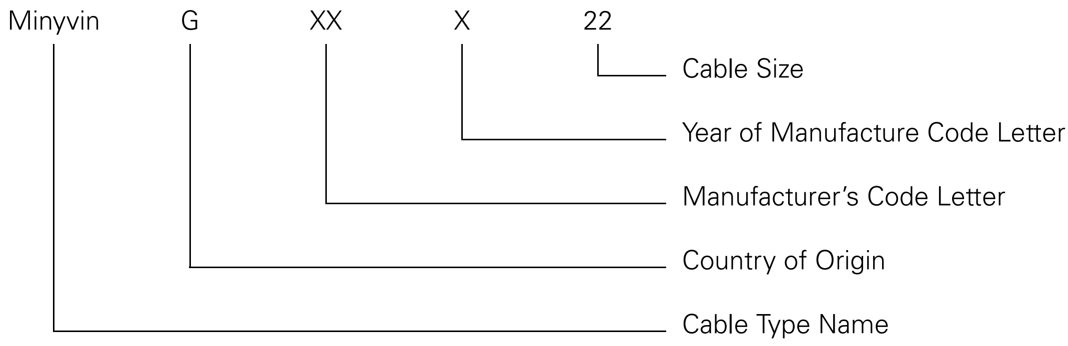
2 Cable Identification

Aircraft electrical cables are normally marked with an identification code as shown in the following examples:

a) **Period 1963 to Mid 1970s:**



b) **Period Mid 1970s to 31st December 1978:**



c) With effect from 1st January 1979 the country of origin code for Great Britain was changed from G to GBx, although the rest of the code remained unchanged.

2.1 There is a further requirement that an adequate means of identification be provided for cables, connectors, terminals, plugs and sockets, etc., when installed in the aircraft, methods of so doing for cables are described in paragraph 9.

3 Deterioration

Aircraft cables are designed to provide the best possible combination of resistance to deterioration caused by extremes of temperature, mechanical damage and contamination by fluids and, in general, are suitable for installation without additional mechanical protection. Working conditions and environment, however, may necessitate the provision of extra protection in those places where the cables are exposed to the possibilities of local damage or conditions which could cause deterioration, such protection is described in paragraph 7.3.

4 Receipt and Storage of Cables

Prior to delivery, cable ends are sealed, so far as is practicable, to prevent ingress of moisture, and the cables are generally supplied on drums suitably labelled and protected to prevent damage during transit or storage. Smaller sizes of cable may sometimes be supplied in wrapped coils. Visual examination of cables on receipt, by nature of the packing, is often restricted to the outer turns. Such an examination is of little value in checking for faults in the cable, therefore, if the condition of the packing, as received, gives rise to doubt regarding the soundness of the cable, it should be returned to the manufacturer.

4.1 Cables should be stored in a clean, well-ventilated store. They should not be stored near chemicals, solvents or oils and, if necessary, protection should be provided against accidental damage. Loose coils, whether wrapped or not, must not be stored so that a heavy weight is imposed on them, since this may cause unacceptable distortion of the insulation or damage to the protective coverings. The ends of cables in store should be sealed against the ingress of moisture by the use of waterproof tape or a suitable sealing compound.

5 Handling of Cables

It is important that cables should be handled carefully at all stages of storage and installation.

5.1 When taking long lengths of cable from a drum or reel, the cable should not be allowed to come in contact with rough or dirty surfaces. Preferably the drum or reel should be mounted so that it can rotate freely, but heavy drums may need some means of control over rotation.

5.2 Care should be taken to remove the twist out of each turn of cables drawn from loose coils, otherwise severe kinking, with consequent damage to the cable, may occur.

6 Made-up Cabling

Cable looms and cable runs made-up on the bench should be inspected before installation in the aircraft to check the following:

a) That all cables, fittings, etc., are of the correct type, have been obtained from an approved source, have been satisfactorily tested before making up and have not deteriorated in storage or been damaged in handling.

b) That all connectors and cable looms conform to the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing in respect of terminations, length, angle of outlets and orientation of contact assemblies, identification and protection of connections.

c) That all crimped joints (see paragraph 7.5.7) and soldered joints (see paragraph 7.5.8) have been made in accordance with the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing, are clean and sound and that insulating materials have not been damaged in any way.

d) That cable loom binding and strapping is secure.

e) When required by the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing; continuity, resistance and insulation tests should be carried out in accordance with those instructions. For further details and guidance see Leaflet 9–1.

7 Installation of Cabling in Aircraft

In addition to the checks outlined in paragraph 6, the cabling should be installed in accordance with the requirements of the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing. Guidance on the factors requiring special attention during the installation is given in the following paragraphs.

7.1 Contamination

To prevent moisture from running along the cables and seeping into the associated equipment, the cables should be so routed as to run downwards away from the equipment. Where this is not possible, the cable should incorporate a descending loop immediately before the connection to the equipment. Where conduits, tubes or ducts are used, they should be installed in such a way that any moisture accumulating in them will be able to drain safely away. Cables which are routed through such fittings should be capable of withstanding any such moisture as may be encountered.

7.2 Interference

Interfering magnetic fields may be set up by electrical equipment, electrical currents in the cabling, or the aircraft structure and also by magnetic materials. Cables are required, therefore, to be installed so as to reduce electrical interference to a minimum and to avoid interaction between the different electrical services.

7.3 **Protection of Cabling**

The cables are required to be protected from abrasion, mechanical strain and excessive heat and against the deleterious effects of fuel, oil and other aircraft fluids, water in either liquid or vapour form and the weather. Cables should be spaced from the skin of the aircraft so as to reduce the effect of the high skin temperatures likely to be reached in the tropics. The cables should not be run near the hot parts of an engine or other hot components unless a cooled-air space or heat barrier is interposed.

7.3.1 Cables must not be supported or allowed to bear on sharp edges such as screw heads or ends, or on the edges of panels, metal fittings, bulkheads or lightening holes.

7.3.2 Where cables are routed through metal fittings or bulkheads, etc., the edges of the holes through which they pass must be radiused and smoothed and fitted with an insulated bush or sleeve. Cables which are drawn through holes or tubes must be an easy fit requiring only a moderate, steady pull, care being taken to keep the cables parallel to one another and to avoid the formation of kinks (which may cause fracture of the conductor).

7.3.3 Conduits, ducts and trunking used for carrying cables should have smooth internal surfaces. Rigid ducts and conduits should be adequately flared at the outlet or bushed with insulating material.

7.3.4 Cables being fitted through pressure bungs should be fitted into the correct size holes for the size of cable, to ensure efficient sealing. Only the recommended cable threading tool should be used for this purpose to avoid damaging the bung membrane. Bungs without membranes should have filler plugs fitted in unwired holes.

7.4 **Support of Cabling**

The cabling must be adequately supported throughout its length and a sufficient number of cable clamps must be provided for each run of cable to ensure that the unsupported lengths will not vibrate unduly, leading to fracture of the conductors or failure of the insulation or covering. Bends in cable groups or bundles should not be less than eight times the outside diameter of the cable group or bundle. However, at terminal blocks, where the cable is suitably supported at each end of the bend, a minimum radius of three times the outside diameter of the cable, or cable bundle, is normally acceptable.

7.4.1 Cables must be so fitted and clamped that no tension will be applied in any circumstances of flight, adjustment or maintenance and so that loops or slackness will not occur in any position where the cables might be caught and strained by normal movement of persons or controls in the aircraft, or during normal flying, maintenance or adjustment.

7.4.2 Where it is necessary for cables to flex in normal use, e.g. connections to retractable landing gear, the amount and disposition of slack must be strictly controlled so that the cable is not stressed in the extended position and that the slack will not be fouled, chafed, kinked or caught on any projection during movement in either direction.

7.4.3 Cables should normally be supported independently of, and with maximum practicable separation from, all fluid and gas carrying pipelines. To prevent contamination or saturation of the cables in the event of leakage, cables should be routed above rather than below liquid carrying pipelines. Cables should not be attached to, or allowed to rub against, pipelines containing flammable fluids or gases.

7.5 **Cable Terminations**

There are several methods by which cables are terminated, but the one most commonly used is the solderless or crimped termination. The soldered method is also used, but is generally confined to the joining of internal circuit connections of consumer equipment and in some cases, to the connection of single core cables and plug and socket contacts. The means of terminating cables and effecting junctions between cables and equipment must be in accordance with the requirements of the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing. Therefore, the information given in the following paragraphs is of a general nature and is intended only as a guide.

7.5.1 **General Requirements**

The conductors should be firmly secured to the connections on the equipment, using the appropriate method for the particular installation. The surfaces of electrical contacts should be clean and the mating parts should be in contact over the full area. The protective sleeves fitted over connections should be undamaged and positioned correctly. Holding screws and nuts should be properly locked where provision is made for this to be done; particular care should be taken where varnish is the locking medium as it must not be allowed to spread onto, or over, the electrical contact surfaces. Torque loading of holding screws or nuts should be to the recommended values and should be marked in accordance with the maintenance instructions. The connections should not place either the cable or the equipment in a state of tension. Twisting and kinking in the vicinity of the connection should be avoided, as this may lead to a fracture if the cable is subjected to vibration.

7.5.2 To facilitate installation, maintenance and repair, cable runs and looms are broken down at specified locations by junctions, such as connectors or terminal blocks. Before assembly to these junctions, cables should be cut to the required length, with the cut being clean and square and the wire conductor not deformed. If necessary the conductors of large diameter cables should be re- shaped after cutting. Good cuts can only be made if the blades of cutting tools are sharp and free from nicks. A dull cutting edge will deform and extrude the conductor strands.

7.5.3 Before cables can be assembled to connectors, terminals, crimps, etc., the insulation must be cut back and stripped from the connecting ends to expose the wire conductors. Care should be taken when stripping cable that the conductor strands are not cut or nicked. If the lay of the wire conductor strands is disturbed, it should be re-imposed by a light twisting action. Excessive twisting should be avoided as this will increase the diameter of the cable and may result in a defective joint.

7.5.4 On small diameter cables, only the recommended stripping tools should be used for removing the insulation. On no account should a knife or side cutting pliers be used because of the high risk of damage to the conductor strands. For size 8 or larger diameter cables a knife may be used to make lengthwise cuts partially through the outer covering and insulation; these should then be bent back and cut off with side cutters or scissors. The stripped cable should be examined for signs of damage, severed strands and cleanliness, before it is connected up.

7.5.5 The following general precautions are recommended when stripping any type of cable:

a) When using any type of cable stripper, hold the stripper so that the cutting blade is square to the cable.

b) Follow the manufacturer's instructions when adjusting automatic stripping tools, to avoid damaging the conductor strands by cutting or nicking; this is especially important for aluminium cables and the smaller sizes of copper cables. Cut-off and re-strip (if length is sufficient), or reject and renew any cable which has been so damaged.

c) Ensure that the outer covering and the insulation are clean cut, with no frayed or ragged edges.

d) When using hand operated strippers to remove lengths of insulation longer than 19 mm (0·75 in), the stripping should be accomplished in two or more operations.

e) Re-twist conductor strands by hand, or with pliers, if necessary, to restore the natural lay and tightness of the conductor strands.

7.5.6 **Aluminium Cables**

The use of aluminium cables in aircraft has been brought about chiefly by the weight advantage of this metal over copper. However, in order to obtain satisfactory electrical connections, certain special installation techniques are necessary.

a) Aluminium cables should be stripped very carefully, since individual conductor strands will break very easily after being nicked.

b) Bending of aluminium cables will cause 'work hardening' of the conductor strands, resulting in failure or breakage of strands much sooner than in cables with copper conductors.

c) Aluminium, when exposed to the atmosphere, forms an oxide film which acts as an insulator. This film can, if left untreated, cause corrosion at connecting joints and as it also increases in thickness as heat is generated by current flow, it will further increase the electrical resistance of that joint (see paragraph 7.5.7 d)).

7.5.7 **Crimped Connections**

A crimped connection is one in which a cable conductor is secured by compression to a termination so that the metals of both are held together in close contact. A typical crimp termination has two principal sections, crimping barrel and tongue (see Figure 1), together with, in some types, a pre-insulated copper sleeve which mates with the crimping barrel at one end and is formed, during the crimping process, so as to grip the cable insulation at the other in order to give a measure of support. The barrel is designed to fit closely around the cable conductor so that after pressure has been applied a large number of points of contact are made. The pressure is applied with a hand or hydraulically operated tool fitted with a die or dies, shaped to give a particular cross-sectional form to the completed joint.

a) The precise form of the crimp is determined by such factors as the size and manufacture of the conductor, the materials and the dimensions of the termination. It is, therefore, most important that only the correct type of die and crimping tool should be used and that the necessary calibration checks have been made to the tool.

NOTES: 1) British Standard G178 gives information regarding the production and testing of crimped joints for general purpose electrical cables. Reference should also be made to the appropriate manufacturer’s technical literature on this subject.

2) British Standard G180 gives information on the permanent splicing of aircraft electrical cables.

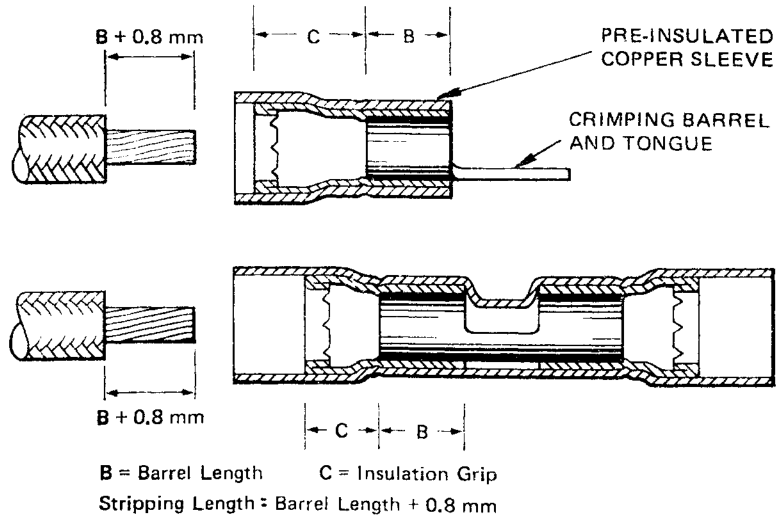


Figure 1 Typical Crimp Terminations

b) Hand crimping tools (see Figure 2) normally have a self-locking ratchet which prevents opening of the tool until the crimping action is complete. Some tools are equipped with a nest of various size dies to allow for a range of different sizes and types of terminations, while others are suitable for one size and type only. In addition, many of the tools and/or dies are colour coded to correspond with the colour marking used on some terminations. It is essential that the recommendations and instructions of the relevant aircraft or equipment manufacturer should be strictly complied with when undertaking work of this nature.

c) There is a vast range of terminations available, many of which are colour coded, suitable for use only with specific types of aircraft cable. It is, therefore, vital that the appropriate manufacturer's instructions regarding the use of cables and terminations are followed.

d) Only aluminium or bimetal (AlCu) terminations should be used to terminate aluminium cables and the cable should be stripped immediately prior to making the joint. The barrel of some aluminium terminations may contain a quantity of inhibiting compound, others not so filled require that inhibiting compound be applied before crimping takes place. Some specifications also require additional sealing after crimping. The compound will also minimise later oxidation of the completed connection by excluding moisture and air.

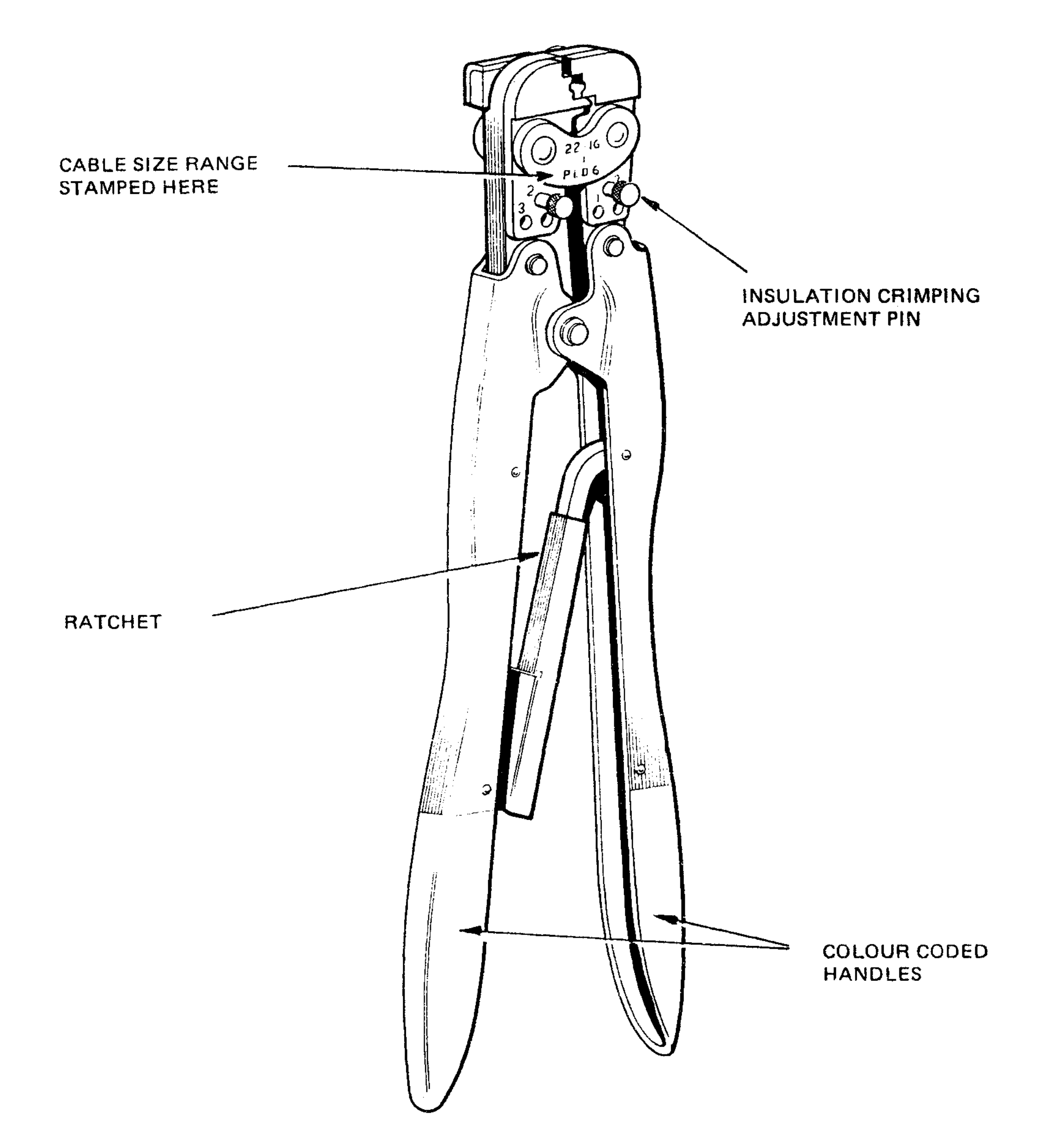


Figure 2 Example of a Hand Operated Crimp Tool

e) The following general precautions are recommended when making crimped cable joints:

i) When initially inserting the appropriate termination tongue-first into the barrel crimping jaws of the crimping tool, ensure that the termination barrel butts flush against the tool stop (see Figure 3).

ii) When positioning the prepared cable end into the terminal barrel of an uninsulated termination, ensure that the cable dielectric butts flush against the end of the barrel, or for a pre-insulated termination to the top of the insulation support.

iii) Ensure that the tool handles of a hand operated tool are squeezed fully together, or in the case of power operated tools, the pressure relief valve has operated, to ensure that the crimp has been completed and allow release of the jaws.

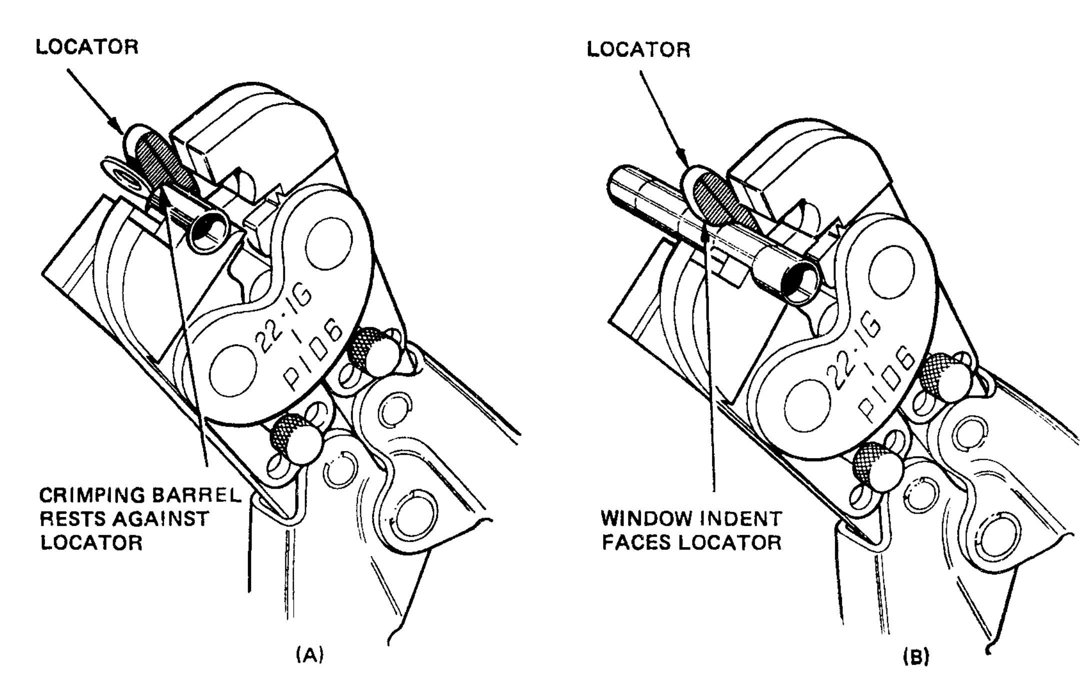


Figure 3 Correct Location

7.5.8 **Soldered Connections**

In general, aircraft installations are such that it should not be necessary to make soldered joints within the aircraft. If, however, soldering is required, it should be carried out strictly in accordance with the procedures in the relevant aircraft Maintenance Manual or Wiring Diagram Manual. Soft soldering and silver soldering are the two methods used for aircraft electrical cabling systems.

a) **Soft Soldering.** Where electrical connections are made by the soft soldering method special care is necessary because overheating and slow cooling of conductors or terminal fittings will cause brittleness. The connections to socket inserts, plug pins, etc., should be free from excess solder which may cause short-circuits, impair the operation of spring contacts, or obstruct the mating of plugs and sockets.

b) **Silver Soldering.** Low temperature brazing, also known as silver soldering, is a brazing process which uses filler alloys based mainly on silver and copper, with a melting range of 505°C to 850°C. Silver soldering is typically employed on certain EGT/JPT/TGT compensating lead terminations.

7.5.9 **Looped Connections**

In the case of some small instruments on older types of aircraft, the wire conductors may be looped around the terminal screw, but it should be ensured that the wire conductors are securely held between a plain washer and the metal base or insert. To reduce the likelihood of breakage under vibration, such connections should not normally be soldered, unless a double-back loop is formed and reinforcement is provided at the end of the soldered portion and care is taken to ensure that wicking does not occur.

7.5.10 **Screened Cables**

a) There are several methods of connecting the metal braided screens of cables, each depending on the circuit application and type of cable being used. Therefore, for precise details, reference to the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing should be made. In general, however, the connections will normally be made utilising either soldered sleeves or crimping and in one of the following forms:

i) 'High'– fitted with no ground wire.

ii) At the end with a ground wire.

iii) At the end with link wires to other screens and ground wire.

iv) Mid-span with a ground wire.

v) Mid-span with link wires to other screens and ground wire.

b) When preparing screened cables for the required screen termination, care should be taken to ensure that removal of any outer protective covering does not cause damage, in the form of cuts and nicks, to the metal braiding. If the connection is such that the metal braiding has to be cut off it should be done squarely and cleanly, ensuring that the braiding is not frayed at the cut edge. Where the braiding is to form the tail of the connection, it should be picked out of its mesh and the individual wires should be carefully twisted together. When cutting and preparing the metal braiding, care should also be taken to avoid damaging the insulation of the conductor.

8 Plug and Socket Connectors

To prevent damage and the entry of dirt, the protective caps which are provided with connectors should be fitted at all times other than when the connectors are being worked on. During work, protection may then be in the form of a linen or plastic bag, totally enclosing the connector and secured to the cables. This temporary protection should only be removed just prior to connection being made in the aircraft. When a connector is disconnected, and it is intended that it be left open for a period of time, then both plug and socket should be protected to prevent damage and the entry of dirt.

8.1 Miniature Connectors

Extreme care should be taken when handling and connecting miniature and sub-miniature connectors. Both plugs and sockets should be checked for any signs of dirt, bent pins or physical damage to the shells before attempting to connect. If connectors will not mate, check for the reason and rectify or renew as necessary. On no account should force be used to effect mating.

8.2 Lubrication

Some ranges of plugs and sockets require the engaging threads to be lubricated with a suitable lubricant to ensure that they can readily be disconnected. Lubrication should be carried out in accordance with the recommendations in the relevant aircraft Maintenance Manual, Wiring Diagram Manual or Modification Drawing.

8.3 Assembly and Maintenance of Electrical Plugs and Sockets

There are many different types of plug and socket connectors, each having its own maintenance requirements, therefore, reference should always be made to the relevant manufacturer's Maintenance Instructions and aircraft Maintenance Manual or Wiring Diagram Manual for precise details of cable preparation, special tool requirements (including insertion and extraction tools) and crimping information. The following paragraphs are, therefore, only intended as a guide on general maintenance practices and the safety precautions which should be observed.

8.3.1 **General Maintenance and Repair**

a) The appropriate contacts and inserts for all the contact holes should be selected.

b) All unused holes in the cable sealing grommet should be fitted with an approved filler plug.

c) For connectors with cable clamps which are not provided with resilient bushings, it may be necessary to increase the diameter of the cables to enable a firm clamp to be obtained without distorting the cables. This may be achieved by one or more of the following methods, but whichever method is used, care should be taken to ensure that cables are not forced against any metal parts of the clamp; that the clamp is not over-tightened so as to crush or deform the cables; or that any cables connected to an outer ring of contacts are not forced to the clamp centre causing the holes in any sealing grommet to become deformed and consequently straining the contact joints.

i) A plain insulation sleeve may be fitted over the cable bundle.

ii) A plain insulation sleeve may be fitted over each individual cable.

iii) The cable bundle may be wrapped around with a number of turns of a suitable tape.

iv) A small roll of a suitable tape may be placed in the centre of the cable bundle.

d) Where cable clamps are fitted with resilient bushings, care should be taken to ensure that the bushings used are of such size that the cables are firmly held in place but do not crush or deform the cable insulation when the clamp is tightened. To provide the proper fit for bushings, the following procedure should be applied. The smallest size or sizes of bushings to be omitted or the next smallest size or sizes shall be added, whichever is required.

e) Some connectors have a 'ground' connection point, provided with a 'grounding' screw and washer, which should always be removed if a ground wire is not being connected.

f) When connectors are installed as a provision for the installation of equipment at a later date, they should be protected by dust caps. Unused connectors supported only by the cables should be protected with an insulating sleeve pulled over the connector and cables so that it extends sufficiently to enable the end to be folded back and secured. This should then be clamped to the aircraft structure.

8.3.2 **General Maintenance and Repair Procedures**

The following procedures should be followed for the maintenance and repair of aircraft electrical plugs and sockets:

NOTE: No attempt should be made to straighten bent contacts since the resulting work-hardening may result in failure of the contacts.

a) **Preparation**

i) The cable clamp securing screws should be loosened and any packing should be discarded.

ii) The threaded backshell should be unscrewed and eased back over the cables.

b) **Removal of Wired Contacts.** There are two basic types of contact retention used in plug and socket connectors in aircraft, one with the contacts being released for removal from the rear of the contact insert and the other from the front. Each system requires the use of different types of insertion/extraction tools, therefore, it is essential that the correct procedures and tools are used for a particular type of plug or socket.

i) **Rear Release.** The appropriate extraction tool should be positioned over the cable connected to the contact to be removed. To ensure that the contact retention system has been released (see Figure 4(A)), the extraction tool should be slid slowly into the contact insert hole in the plug or socket until a positive resistance to further movement is felt. With the cable held against the extraction tool, the contact should be removed by pulling the cable and tool from the plug or socket insert.

ii) **Front Release.** The appropriate extraction tool should be positioned over the contact to be removed and, with the central plunger of the tool held back, pushed into the plug or socket to release the contact retention system (see Figure 4(B)). Depressing the central plunger of the extraction tool will eject the contact rearwards, out of the plug or socket. Extreme care should be taken when using this type of tool as their tips are easily damaged, which unless identified and replaced with a serviceable one, can cause damage to inserts and contacts.

NOTE: In repair operations only one contact at a time should be removed and repaired, so as to avoid the possibility of misconnection.

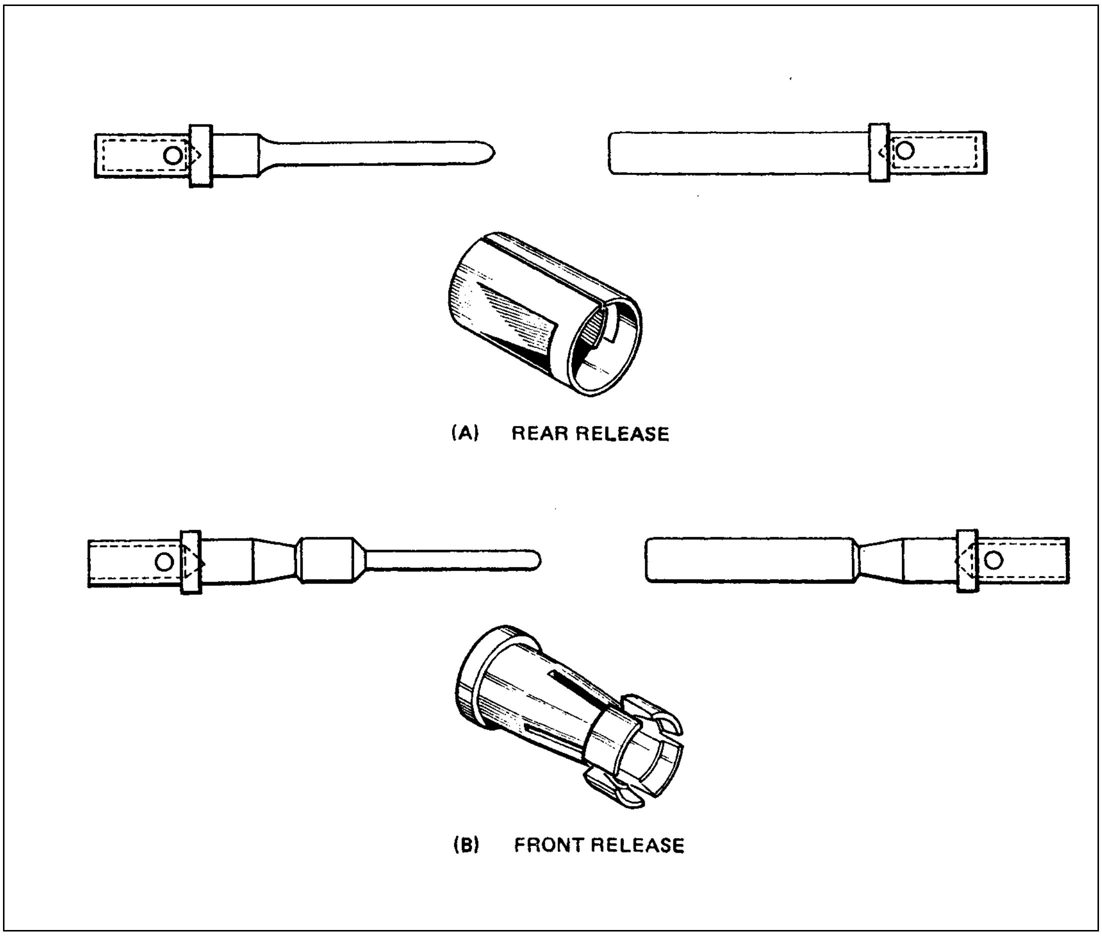


Figure 4 Comparison of Release Systems

c) **Removal of Unwired Contacts.** The sealing plug should be removed and the appropriate unwired contact extractor should be slid slowly and straight, into the contact insert hole. Stopping of the extractor will indicate that it has bottomed on the contact shoulder. The contact should then be removed by slowly pulling the extractor and contact from the plug or socket.

d) **Preparation of Cable and Crimping the Joint.** Stripping of coverings and insulation of cables should be done as recommended in paragraph 7. It should be noted, however, that if wire strands are damaged during this operation, the cable end should be cut off and the stripping procedure repeated.

   i) The appropriate contact for the plug or socket should be selected and the prepared cable should be inserted into the contact barrel ensuring that the wire conductors are visible through the inspection hole positioned at the base of the crimp barrel of the contact.

   ii) Where more than the required length of wire is exposed between the insulation and the contact, the wire end should be trimmed by cutting off the surplus without deforming the wire end. If the wire becomes deformed, the complete end must be cut off and the preparation should be repeated.

   iii) The contact should be inserted into the appropriate crimping tool and the prepared cable should be positioned and then the handles of the recommended calibrated crimping tool should be closed in a continuous movement. Most hand operated tools are provided with a ratchet assembly which will not release the jaws until a full stroke has been completed.

   iv) A check of the contact for any distortion because of a faulty tool or die should be made. If distortion has occurred the tool should be replaced with a serviceable one, the bent contact cut off and a new joint made.

e) Inspection for a correctly formed crimp joint should be carried out in the following manner:

   i) It should be ensured that the conductor is visible through the inspection hole of the crimp connection barrel.

   ii) The crimp pattern should be clean, with the crimp indentations evenly spaced.

   iii) The crimp identification pattern must not break over the cable entry end of the connection barrel or the shoulder of the contact.

   iv) There must not be any cracks visible at the edge of the inspection hole or at the cable entry end of the connection barrel.

f) Insertion of wired contacts into the plug or socket should be carried out in the following manner:

   i) The connected cable should be placed into the recommended insertion tool with the tool tip butting against the contact shoulder. The contact should be pushed slowly and straight into the rear of the contact insert. Firm stoppage of the contact indicates that it has seated in the insert. The cable should then be released from the tool and the tool removed by pulling it backwards.

   ii) If contacts are to be inserted into holes near the edge of the insert, the open side of the tool should always face the edge of the insert; this avoids excessive strain on the insert.

   iii) The proper size contacts and sealing plugs should be fitted into any vacant contact insert holes and the plug or socket should be reassembled by screwing on the backshell. Re-fitting of the cable clamp assembly is described in paragraph 8.3.1 c) and d).

8.3.3 Inspection and Testing

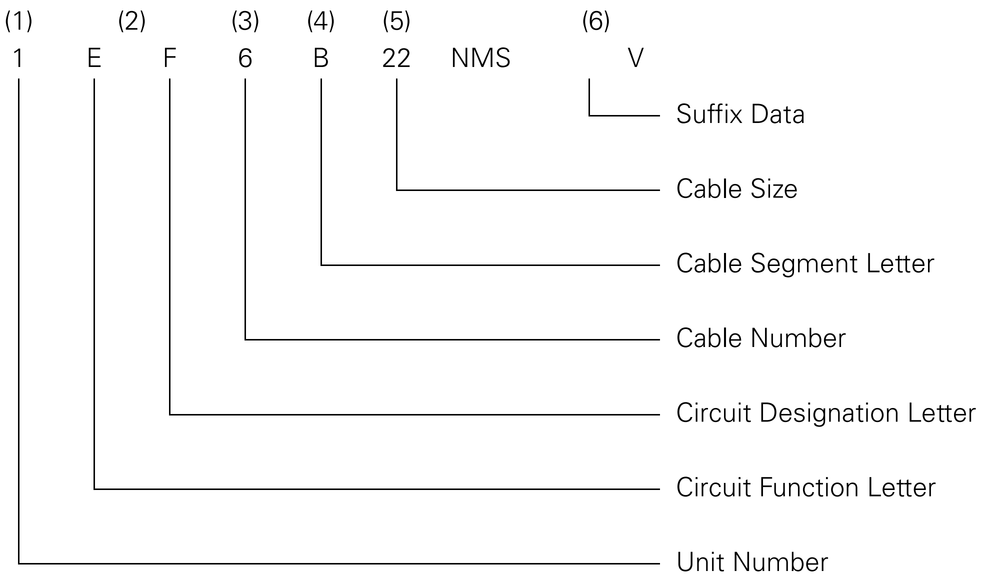
The test probes used for inspection and testing should be of such size that the contacts are not damaged or spread. On socket contacts the test probes should be of the same size or less than the mating plug contact. This is most important as the use of oversize test probes can result in open circuits and intermittent connections when the plug and socket are mated.

9 Identification of Installed Cables

Aircraft cables are normally marked with a combination of letters and numbers to provide the necessary information to identify the cable, the circuit to which it belongs, the cable size and any additional information necessary to relate it to a circuit diagram or routeing chart. Such a code is usually either of the aircraft manufacturer's own specification or one devised by the Air Transport Association of America under Specification 100 (ATA 100) which has been accepted as a standard.

9.1 The ATA 100 Specification basic coding consists of a six position combination of letters and numbers, which are printed on the outer covering of the cable. The identification code is normally printed at specified intervals along the length of the cable. Where printing is not practical the code is printed on non-metallic sleeves and positioned along the cable length.

9.1.1 Basic Cable Coding System



Position 1	Unit number, used where components have identical circuits.
Position 2	Circuit function letter and circuit designation letter which indicate circuit function and the associated system.

Position 3 Cable number, allocated to differentiate between cables which do not have a common terminal in the same circuit. Generally, contacts of switches, relays, etc., are not classified as common terminals. Beginning with the number one, a different number is given to each cable.

Position 4 Cable segment letter, which identifies the segment of cable between two terminals or connections, and differentiates between segments of the circuit when the same cable number is used throughout. Segments are lettered in alphabetical sequence, excluding the letter I and O. A different letter is used for each of the cable segments having a common terminal or connection.

Position 5 Cable size.

Position 6 Suffix data, used to indicate the type of cable and to identify its connection function. For example, in the example code NMS V indicates nyvin-metsheath ungrounded cable in a single-phase system.

NOTE: Full details of the cable coding system will be found in the Maintenance Manual or Wiring Diagram Manual for the relevant aircraft.

9.1.2 To assist the fitting and positioning of insulating or indentification sleeves to cables, full use of the recommended lubricants should be made. To prevent over extension of small diameter sleeves, it is recommended that thimble jigs or needle tools are used. Three-prong fitting pliers can damage overlays on sleeves and should only be used on the larger diameter sizes and then only extended to approximately 300% of the sleeve internal diameter. When positioning sleeves on cables, care should be taken to ensure they slide and not roll.

10 Inspection and Testing of Circuits

10.1 Before carrying out tests, or when inspection is specified in the approved Maintenance Schedule, all aircraft circuits, together with plugs, sockets, terminal blocks and equipment terminals, should be examined, as appropriate, for signs of damage, deterioration, chafing, poor workmanship and security of attachments and connections. Information and guidance on the inspection and testing of electrical circuits are given in Leaflet 9–1.

10.1.1 The methods of testing and inspection will vary with different types of aircraft and the equipment fitted, therefore, reference must be made to the relevant Maintenance Manuals for detailed information.

10.2 **Test Equipment**

Each test requires specified equipment and care should be taken that it is correctly used. To ensure the reliability of test equipment, it should be carefully serviced and certified at the periods recommended by the manufacturer. The performance of equipment should also be checked before and after use.

10.2.1 After completion of all tests, the installation should be inspected to ensure that all connections have been re-made and secured, and that test equipment, tools, etc., have been removed. This should be carried out immediately prior to the fitting and securing of panels, etc. The circuits should then be proved, as far as the installation permits, by making ground functioning checks of the services concerned.

10.3 Any disconnection or disturbance of circuits associated with flying or engine controls will require duplicate inspection and functioning test.

Leaflet 9-4 Antistatic Protection

1 Introduction

1.1 Certain semi-conductor devices are susceptible to damage from electrostatic charges and are at risk in any environment where they may come into contact with such charges. The prime risk during maintenance activities is the static charge held on personnel and tools, whilst in storage the risk is from the charge held on personnel and non-conductive packaging materials.

1.2 The metal oxide semi-conductor (MOS) and complementary MOS (CMOS) family of devices is most prone to damage from static electricity. Bi-polar devices which are also susceptible to this type of damage include, but are not limited to, Operational Amplifiers, Emitter-coupled Logic (ECL) devices and Transistor-transistor Logic (TTL) devices. In addition, there is evidence to show that thick and thin film resistors, multi-metal-layer hybrid substrates, discrete transistors and diodes, Field Effect Transistors (FET) and Schottky TTL devices also suffer damage from electrostatic discharges.

1.3 The information given in this Leaflet, although based on practices which, when carried out by properly trained personnel, are proving to be effective, is intended to serve only as a general guide to the establishment of certain minimum standards of conduct during handling, packaging, storing and testing of these devices.

2 MOS Device Manufacture

2.1 In an electronic circuit, a MOS device functions as a voltage-controlled resistor in which the MOS equivalent resistance between the drain and source is varied by a voltage applied to the gate electrode (see Figure 1). Physically, the gate electrode is a thin layer of metal deposited on a very thin layer of silicon dioxide (SiO_2 (glass)), typically 1000 to 1400 Angstroms thick. This layer of glass effectively insulates the gate electrode from the substrate, in essence, forming a capacitor, the plates of which are the gate electrode and substrate with the dielectric being the layer of glass between the gate electrode and substrate.

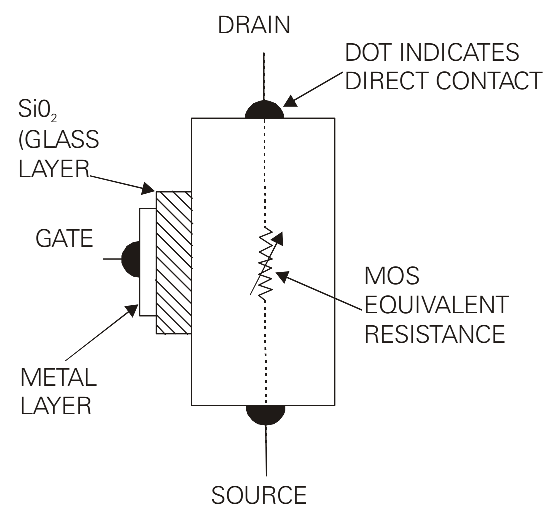


Figure 1 Typical MOS Device Showing the Insulated Gate

2.2 The dielectric strength of glass is approximately 101 V/cm, which means that a voltage in the range of 100 to 140V can cause a rupturing of the glass, which would result in catastrophic damage to the device, usually as the result of a short circuit of the gate (electrode) to the source, drain or substrate. To avoid damage from overvoltage, manufacturers of MOS/CMOS devices usually incorporate protective circuitry on the gate electrode input pins (usually some type of resistor-diode network) so designed as to provide an alternative path for transient voltage such as electrostatic discharges. It is not the voltage discharge to ground but the potential difference between the pins on the device which causes the damage. With the elimination of such potential difference the damaging effects of an electrostatic discharge can be prevented.

2.2.1 For an unprotected MOS device the resistance at the input pins is approximately 10^{14} ohms. Using this figure it can be calculated that a current of approximately 10^{-12} ampere (10 pA) can generate a 100 V potential which can rupture the layer of glass and destroy the device. Since all protective devices require the addition of some P-region the resistance can normally be reduced to approximately 10^{10} ohms. Although the effectiveness of the protective circuitry varies, most provide protection from human body electrostatic discharges only up to several hundred volts. Thus, such circuits can provide only limited protection against electrostatic discharges, which, in uncontrolled areas, can be measured in thousands of volts.

2.2.2 Figure 2 gives a schematic representation of a typical protected MOS device, as indicated by the presence of a built-in zener diode. The source, gate and drain electrodes are the equivalent of the emitter, base and collector electrodes of the typical bi-polar transistor (the substrate lead of the device is normally connected to the source lead). In most cases, the zener diode which protects the MOS device conducts at approximately 50 V. However, selection of a value for the substrate resistance can present a problem to the manufacturer as this resistance value must be great enough to limit current flow to prevent destruction of the zener diode, but must not be so high that the sum of the voltage drop across the zener-resistance combination exceeds the breakthrough voltage of the glass layer.

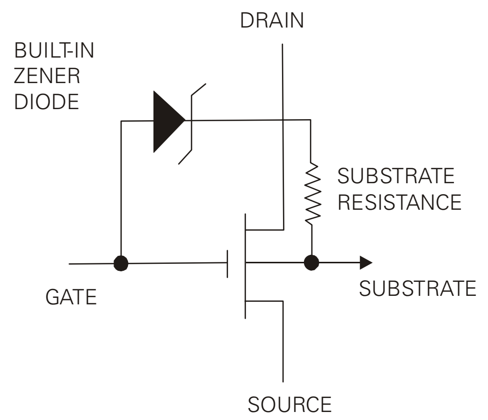


Figure 2 A Typical Protected MOS Device

3 Cause of Static Electricity

3.1 **Positive and Negative Charges.** Whether or not an item becomes subject to 'positive' or 'negative' electrostatic charges stems from the atomic or molecular structure of the materials involved in its manufacture. Materials which will readily give up electrons become charged positively, whereas others which have an affinity for electrons become charged negatively. Whenever two items are brought into contact and then separated, there is likely to be electron transfer and thus electrostatic charging, which can result both from rubbing or non-frictional contact/separation. The net charges on the two materials will be equal but the conductivity (or resistivity) of the materials will greatly affect the potential electrostatic charges involved.

3.1.1 The charges tend to dissipate quickly over the entire surface of conductive materials, which not only lowers the electrostatic potential but increases the possibility of further dissipation to other materials which are in contact directly or via an air space.

3.1.2 On non-conductive materials the electrostatic charge can remain in localised areas at high potentials, creating electrical fields between themselves and other materials at different potentials and ground. Materials entering these fields can be charged by induction, which takes place when electrons of the material entering the field are attracted to those areas closest to any one of positive potential, leaving behind positive charged areas and creating negative charged areas. This transfer of electrons and consequent electrostatic charging by contact/separation is known as the 'triboelectric' effect.

3.2 **Prime Electrostatic Generators**

Materials common to electronic maintenance, repair and testing, which can be factors in the generation of electrostatic charges, include the human body, all work surfaces, floors (especially if waxed), furniture, personal clothing (including clean room garments), tools and all non-conductive packaging materials. Some type of motion is required for the generation of electrostatic charges and some non-conductive materials are extremely good generators of such charges. Nylon shirts or smocks, for example, can easily become charged to 20 000 V or higher. However, the human body is, in all likelihood, the most frequent source of damage to sensitive electronic components as a result of electrostatic discharge.

3.2.1 The electrostatic potential of the human body is a function of many variables, such as body capacitance, clothing material and style, body activity, relative humidity of the air, footwear, etc. A widely accepted electrical model for the human body is a capacitor (C_{HB}) and a series resistor (R_{HB}). There must, obviously, be a wide range of published values for both parameters, as many variables can affect them, e.g. body size, muscle tone, skin ruptures (spots, cuts, etc.), skin moistness, contact area, footwear, position in relation to the work piece, etc. However, the consensus of opinion would appear to support 200 pF as a reasonable approximation for C_{HB} and 1000 ohms for R_{HB} (including contact resistance). Table 1 gives representative data under typical industrial conditions.

Table 1 Typical Measured Static Charges for the Human Body

Situation	Relative Humidity of Air	
	Low 10-20%	High 65-90%
	Volts	Volts
Walking across a carpet	35 000	1 500
Walking over vinyl floor covering	12 000	250
Worker at bench	6 000	100
Vinyl envelopes containing work instructions	7 000	600
Polythene bag picked up from bench	20 000	1 200
Work chair padded with urethane foam	18 000	1 500

3.2.2 Clothing, floor coverings and furniture are not the only generators of static electricity. So, too, are many of the usual materials which are, unfortunately, still used for the packaging and transportation of electrostatic-sensitive semi-conductors and, in many instances, complete printed circuit board assemblies. Tools which have normally been used in electronic engineering and which have been thought to be safe, are often not. One particularly dangerous tool to use on an electrostatic-sensitive device is the plastics de-soldering tool; the sudden rapid movement of the plastics piston in the piston sleeve of the tool can generate a very high electrostatic potential. Another potentially dangerous tool is the electrical soldering iron which, unless it is 'grounded' at the tip, can also be a dangerous electrostatic carrier.

4 General Handling Procedures for All Semi-conductors

4.1 It is not possible to lay down a degree of electrostatic protection which would cover all types of semi-conductor. However, there is a strong consensus of opinion that a significant reduction of dangers related to electrostatic charges can be achieved by making personnel aware of possible electrostatic generators and improved general handling techniques, such as:

a) Not removing or replacing line replaceable units with electrical power applied.

b) Not unnecessarily touching the connectors, leads or edge connectors, etc., of printed circuit boards containing such devices.

c) By using conductive packaging, shorting plugs, bands or wire when provided or prescribed in the relevant aircraft or equipment Maintenance Manual.

d) By paying particular attention to stores procedures to ensure that protective packaging is not removed during any goods-inwards inspection.

5 Electrostatic-free Work Station

5.1 General

If, by the nature and volume of work, it is considered necessary to set up an electrostatic-free work station, guidance may be obtained from the following paragraphs which set out the various options which are open.

5.2 Humidity

A factor which needs to be considered when working with electrostatic-sensitive devices is the humidity of the working environment. The air in a very low-humidity environment is dry and has a very high resistance, such air will not discharge the static electricity as quickly as a moist air. Therefore, the working environment for an electrostatic-free work station should ideally, have a relative humidity of between 30 and 50%.

5.3 Working Environment

There are two basic methods of achieving a safe working environment in which to handle electrostatic-sensitive devices. One is dependent upon the provision of a conductive work surface, which, together with the operator and tools in use, is bonded electrically to a common ground. The other makes use of the conductive properties of an ionised atmosphere to dissipate static electrical charges.

5.3.1 **Conductive Work Surface Technique**

a) The work surface of a bench is covered with a sheet of conductive material, e.g. plastics, or mat which is secured to the bench to prevent it from moving. The floor area in front of the bench is also covered with conductive material and electrically bonded to the work surface by means of a bonding strap. To be effective the bonding strap should have a resistance of approximately 2000 to 4000 ohms per linear foot and should be as short as possible. A further bonding strap is used to link a wrist strap, worn by the operator, to the work surface and this should have a resistance of 200k ohms to 1M ohms. To complete the system the work surface is connected to a suitable ground point. In addition the work seat may be covered with a conductive seat cover.

NOTE: Under no circumstances should the work surface of a static-free work station be connected to the electrical power supply ground circuit of the building.

b) The main disadvantage of the conductive work surface is its conductivity. As each element of the system is bonded to a common ground to which the operator is connected via a wrist strap, immediately the operator is in direct contact with the work surface, which normally has a surface resistivity of approximately 3000 ohms, the wrist strap resistance is rendered ineffective.

5.3.2 **Conductive Atmosphere Technique**

a) Electrical Ionisation

i) An ozone laden atmosphere can be produced by several electrical methods. The safest and most acceptable method relies upon a capacitive connection between its ozone emitting needles and the conductor. The system for producing ozone consists of a rod made up of three separate elements. The outer element is a tube, made of an insulating material, which has stainless steel needles embedded at right angles at intervals along its length; the blunt ends of these needles protrude through to the second element, which is another tube of the same material coated with rings of a silver compound which are in contact with the needles. The third element which forms the centre of the rod is standard HT conductor cable (motor car ignition type) which is connected to an 8000V secondary winding of a mains operated transformer. The complete rod is housed in a metal shroud which both protects and supports it. The effective range of this type of electrostatic eliminator is normally 13 cm (5 in) but can be increased to 61 cm (24 in) by providing an air boost, at a pressure of 14 kN/m^2 (2 lbf/in^2).

ii) The conductive atmosphere technique depends upon ozone which in concentrations exceeding 1·0 parts per million (ppm) causes discomfort. It has been demonstrated that the ozone concentration 50 mm (2 in) from the nozzle of the eliminator is less than the 0·05 ppm which the Institute of Aviation Medicine states is a maximum for long term exposure. Electrically, the eliminator is completely safe despite the high voltage involved and the emitter rod can be freely handled during operation.

NOTE: Extended periods of working in such an atmosphere may, nevertheless, cause extreme drowsiness.

b) In special circumstances when the setting up of an electrostatic-free work station is impractical, an air ioniser could be used. A blower projects a stream of air containing both positive and negative ions onto the work surface and onto the operator’s hands temporarily neutralising the static charges in the region. These blowers may also be used in conjunction with a conductive work surface when high levels of electrostatic charging are being experienced.

5.4 **General Operating Procedures**

5.4.1 **Conductive-Surface Work Station**

a) Following the initial setting up the station should be checked for an effective ground and periodically monitored thereafter. In order to establish that wrist straps have not developed any faults, periodic checks should be made on their resistive value.

b) Under no circumstances should the operator, or anybody else, touch electrostatic-sensitive devices, or assemblies containing such devices, without first having placed a wrist strap indirect contact with their wrist.

c) When a conductive surface station is equipped with an air-ioniser blower, the normal operating procedure is to allow the blower to operate for approximately two to three minutes before performing any work. The operator should also move their hands into the ionised airstream for a few seconds, to allow for charge dissipation, before handling electrostatic-sensitive devices.

5.4.2 **Conductive Atmosphere Work Station**

Before commencing work it should be ensured that the ionising bars are working properly. This can be done by checking for the smell of ozone, thus establishing the presence of a cloud of ionised air. Satisfactory operation of the eliminator should also be determined by the vibration felt when it is held loosely in the hand, while the flow of boost air can be felt by passing a hand close to the emitter nozzle.

5.4.3 The effectiveness of an electrostatic-free work station can be further checked by the use of an electrostatic-detecting meter. Such meters are normally capable of detecting the presence, indicating the polarity and level of static electricity and can be read on various scales, ranging from 30 to 50 000 V at distances of 6.5 to 30 cm (2.5 to 12 in).

6 Ground Connections

6.1 For grounding purposes a copper mat or plate should be sunk into the earth to a depth which will ensure that it will be constantly damp. A typical grounding arrangement is shown in Figure 3. Ideally, electrostatic-free work stations should be connected to the grounding mat with a connecting strip of the shortest possible length, so reducing the possibility of radio frequency pick-up.

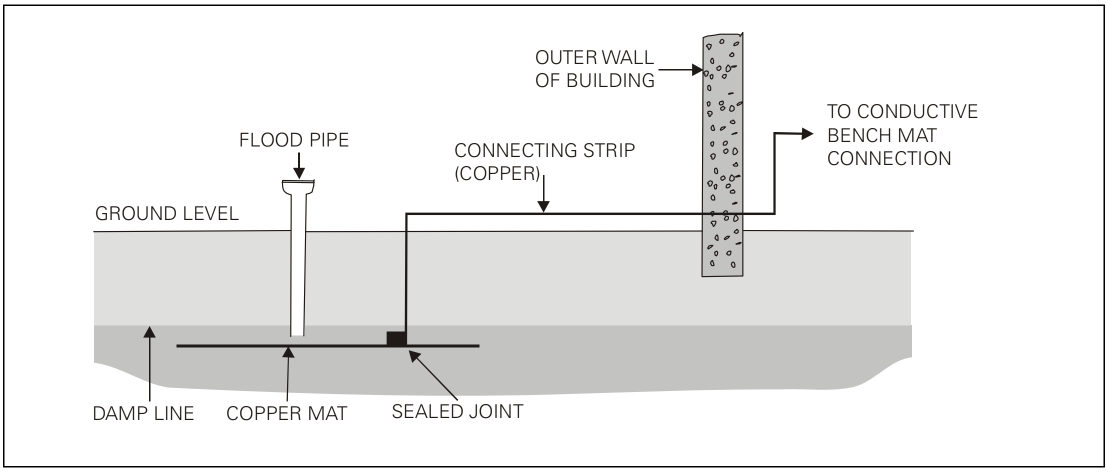


Figure 3 Typical Grounding Arrangement

6.1.1 Care should be taken to use a material for the connecting strip which will not create a potential of more than 0·25 V with the material to which it is joined. If the connections are made by welding or soldering, they should be thoroughly cleaned to remove all traces of flux residue and should then be completely covered with a sealing compound or other insulating covering.

6.1.2 In well drained locations, it is recommended that a pipe should be sunk over the ground mat to permit occasional flooding of the mat.

6.1.3 Where an outside wall position is not possible, a ground mat should be sited under the floor of the building or, alternatively, the work stations may be connected to grounding spikes.

7 Additional Precautions

7.1 General

Providing an electrostatic-free work station will not, on its own, ensure that no electrostatic-sensitive devices will be damaged or destroyed. Complete protection may only be achieved when certain standard operating and handling procedures are also adhered to. Only then will the complete effectiveness of the work station be realised.

7.1.1 Persons engaged in maintenance or repair work should be electrostatic conscious and should consider the avoidance of damage by electrostatic charges as a normal responsibility. They should also be aware of the necessity for the elimination of electrostatic generation such as plastics envelopes, non-conductive tapes and other commonly used items made from plastics, nylon and rubber.

7.1.2 The effectiveness of an electrostatic-free work station should be regularly checked with a static-detecting meter (see paragraph 5.4.3).

7.1.3 Work which involves the handling of exposed electrostatic-sensitive devices should not normally be undertaken outside the confines of an electrostatic-free work station. Such devices and any modules containing them should always be handled by their cases and the unnecessary touching of connecting leads, pins or edge connectors, even if grounded, should be avoided. Modules, printed circuit boards or components should never be removed or replaced with electrical power supplies switched on. Devices which are supplied with pin shorting links or wires should only have such links or wires removed after the devices have been fitted into the circuit.

7.1.4 Soldering irons should always be used with a grounded bit, except for those which are normally used in conjunction with an isolation transformer, as grounding of this type of soldering iron may be hazardous to personnel. Any accumulated electrostatic charge on other hand tools should be discharged prior to the tool being used. No attempt should be made to test electrostatic-sensitive devices with a multimeter.

7.1.5 For both serviceable and unserviceable electrostatic-sensitive devices, modules and printed circuit boards the same precautions should be observed. It is, therefore, advisable to retain any conductive or anti-electrostatic packaging material removed from serviceable equipment for re-packaging of the unserviceable items, ensuring that the package is suitably labelled to show that the contents are unserviceable but contain electrostatic-sensitive devices.

8 Testing

8.1 General

All testing of equipment containing electrostatic-sensitive devices should be strictly in accordance with the relevant manufacturer's instructions. The following paragraphs only draw attention to the more general precautions which should be observed during testing of electrostatic-sensitive devices and/or printed circuit boards or modules.

a) In general, such items should not be inserted or removed from their installed positions unless all electrical power is switched off, as transient voltages may cause permanent damage.

b) When bench testing, input test signals should not normally be injected into such items without electrical power being applied. All unused input connections should also, normally, be connected to a power source or to ground.

c) Much of the test equipment used for the testing of such items will also contain electrostatic- sensitive devices. While calibration of this type of test equipment will not normally require the operator to wear a wrist strap, if a repair or replacement has to be made involving an exposed device or module, then a wrist strap should be worn and the electrostatic damage-prevention measures of this Leaflet should be implemented.

9 Storage

9.1 General

The creation of a safe storage environment does not depend on the provision of the same kind of facilities which have been outlined. The packaging of equipment precludes the use of a conductive atmosphere technique; therefore, adequate protection is dependent upon the provisioning of a conductive surface. Whilst it is advisable to store electrostatic-sensitive equipment in grounded metal racks and cupboards this alone will not necessarily completely protect such equipment.

9.1.1 It is known that plastics and polymer based packaging materials will retain static charges which produce voltage gradients across the surfaces; accordingly, electrostatic-sensitive equipment must never be stored alongside non-electrostatic-sensitive equipment.

9.1.2 Electrostatic-sensitive equipment should be packed in a conductive material, such as will ensure that the whole of the package is maintained at the same potential and should then be stored in grounded metal racks or cupboards.

9.2 **General Precautions**

9.2.1 All packages containing goods inward should be checked for the presence of electrostatic-sensitive devices by reference to external markings and reference numbers. Any package not so marked should, if it contains electrostatic-sensitive devices, be labelled accordingly and should be handled and stored in accordance with the recommendations of this Leaflet.

9.2.2 The conductive packaging of such equipment should never be removed outside the confines of an electrostatic-free work station.

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Leaflet 9-5 ATC Transponders And Traffic Alert and Collision Avoidance Systems (TCAS) Ground Testing

(was previously AN No. 68 Issue 1, 9 November 1992)

1 Introduction

This Notice is to provide general guidance material to aircraft maintenance organisations and maintenance personnel relating to ATC Transponder and Traffic Alert and Collision Avoidance Systems (TCAS). It includes information on the TCAS system together with precautions to be considered when ground testing ATC Transponders in order to minimise the possibility of causing nuisance advisory warnings on TCAS equipped aircraft.

2 General

A number of aircraft operating within airspace regulated by the United Kingdom are now equipped with TCAS. This equipment provides flight deck crew with an independent back-up to visual search and the ATC system by alerting them to potential collision hazards. In the case of the more sophisticated systems which predominate in number, the equipment provides advice to the flight deck crew on how best to manoeuvre so that adequate separation may be maintained or achieved between potentially conflicting aircraft.

3 System Description and Operation – TCAS II

3.1 TCAS comprises a dedicated computer unit with associated aerials. Visual and voice advisories are provided for the flight deck crew.

3.2 The TCAS computer requires the presence of a mode S transponder which provides a data link between TCAS equipped aircraft. Sensor inputs to TCAS include radio height and pressure altitude.

3.3 TCAS can provide two distinct forms of advisory information to the flight deck crew, Traffic Advisory (TA), and Resolution Advisory (RA).

a) Traffic Advisory (TA), is aural and visual information provided in the cockpit to advise the flight deck crew as to the position of a potential threat aircraft.

b) Resolution Advisory (RA), is aural and visual information provided in the cockpit to advise the flight deck crew that a particular manoeuvre should, or should not, be performed to maintain safe separation from a threat aircraft.

NOTE: Resolution Advisories can not be produced if a potential threat aircraft does not provide altitude information.

3.4 TCAS equipped aircraft operate by interrogating the mode S or mode A/C transponders in proximate aircraft. The replies from mode S and mode C transponders are tracked in range, bearing and altitude. This data is passed on to the system logic for TA and RA processing and display.

3.5 Mode A/C transponders which are not equipped with an altitude encoder or when the altitude reporting is switched off, reply with no data in the altitude field, therefore, the TCAS will track in range and bearing only. This information is passed to the collision avoidance logic for TA detection and display.

4 Testing Considerations

4.1 Recognising that airborne TCAS aircraft operate by interrogating operational transponders, it is apparent that they will elicit replies from transponder equipped aircraft on the ground if they are in range and the equipment switched on.

4.2 This, therefore, presents the possibility that a ground operated transponder may trigger a nuisance advisory on a TCAS equipped aircraft operating in the close vicinity. If the ground target is providing altitude data the TCAS logic should declare the aircraft to be on the ground and ought not to generate an advisory.

If no altitude data is provided the TCAS will generate a TA if the threat criteria are met. If the ground is providing altitude data other than surface altitude, as may happen with a defective altitude encoder, or if a test pressure is being applied to the altitude encoder, the TCAS may generate both a TA and a RA if the threat criteria are met.

4.3 Maintenance organisations and personnel who are involved in the ground testing of transponders and TCAS equipment are requested to establish procedures and take precautions to ensure that the risks of causing nuisance advisories are recognised and kept to a minimum.

4.4 It is considered that nuisance advisories may be caused to any TCAS equipped aircraft flying in the vicinity of transponders which are being tested, this may also include aircraft passing overhead at medium altitudes. The problem may be more noticeable where ground testing of transponders takes place at airfields located beneath Terminal Control Areas or in the vicinity of Control Areas and Zones where air traffic movements are likely to be numerous.

4.5 The following advice is provided to minimise the possibility of causing nuisance advisories to TCAS equipped aircraft when ground testing transponders and/or TCAS:

a) When not required ensure that transponders are selected to ‘OFF’ or ‘Standby’.

b) For transponders under test, when equipped for altitude reporting, set the control unit to ‘Mode A/C’ and select Altitude Reporting ‘ON’.

c) Where possible, carry out testing inside a hangar to take advantage of any shielding properties it may provide.

d) Always use the antenna transmission absorption covers when these are provided with the test set.

e) When testing mode C operation which require the altitude to be increased, radiate directly into the ramp test set via the prescribed attenuator.

f) In between test parameters, select the transponder to the standby mode.

g) The simulation of TCAS operation by the radiation from an antenna located on, or remotely based from a workshop, is not permitted.

NOTES: 1 The FAA have advised their staff of operational problems resulting in nuisance advisories caused by ground based transponders installed on hangars for the purpose of testing TCAS installations. Maintenance organisations are reminded that all UK aeronautical radio stations are required to be licensed by the Department of Trade and Industry and the CAA.

2 Air Traffic Control Units may be advised when testing is to be carried out if it is considered that there is a possibility of nuisance advisories being caused by the activity due to its proximity to operational runways.

Leaflet 9-6 Electrical Generation Systems – Multi-engined Aircraft not Exceeding 5700 kg Maximum Authorised Weight

(Previously issued as AIL/0031)

1 Document Scope

This CAA Leaflet was originally written to give guidance for compliance with CAA Airworthiness Notice (AN) No. 82. This AN has been notified to the European Aviation Safety Agency (EASA) under Article 10.1 of Regulation (EC) 1592/2002, and therefore the content is still appropriate. AN No. 82 has been transferred to CAP 747, Mandatory Requirements for Airworthiness, Appendix 1, as Generic Requirement (GR) No. 4. These GRs are pending EASA review and concurrence. The resulting EASA Policy will supersede the validity of this Leaflet.

NOTE: CAA ANs that are notified to EASA have been transferred to CAP 747, Mandatory Requirements for Airworthiness, Appendix 1 as Generic Requirements. CAP 747 provides a single point of reference for all mandatory information for continuing airworthiness, including Airworthiness Directives, as applicable to civil aircraft registered in the UK.

The technical content and the paragraph numbering of GR No. 4 is identical to that of AN No. 82, issue 2, dated 29 October 2001. Therefore, the guidance given in this Leaflet is also valid for GR No. 4. This Leaflet has been updated to reflect the changes in requirement references.

2 Purpose

The purpose of this Leaflet is to provide guidance information for achieving compliance with CAP 747 GR No. 4, which requires that all multi-engine aircraft not exceeding 5700 kg maximum authorised weight are provided with:

a) clear visual warning of failures of the electrical generating system,

b) at least 30 minutes duration on the battery, for the provision of power to certain equipments under such failures, and

c) precise crew drills to cover these conditions.

For precise details and the applicability of the requirements reference should be made to CAP 747 GR No. 4.

NOTE: Although the GR does not apply to single engined aircraft the CAA encourages owners and operators of such aircraft to fit generator/alternator failure or low bus voltage warning lights under minor modification procedure.

3 References

CAP 747 Mandatory Requirements for Airworthiness, Generic Requirements (GRs) No. 4, Issue 2 dated 31 January 2005.

4 Introduction

This Leaflet gives general guidance on:

a) The introduction of the failure indication. Reference GR No. 4 paragraph 2.2.

b) The preparation of evidence in support of the required battery endurance, Reference GR No. 4 paragraph 2.3, including a number of assumptions or approximations which are intended to help readers to determine numerical answers and reach conclusions with an acceptable degree of accuracy.

c) The preparation of crew drills. Reference GR No. 4 paragraph 2.5.

NOTE: Aircraft that are not fitted with vacuum instrument supplies and have only electrically powered attitude reference instruments (i.e. Bank and Pitch and Turn and Slip Indicators) must be the subject of a detailed design investigation to establish compliance with GR No. 4 paragraphs 2.4 and 2.4.1. Such aircraft are in a minority and outside the terms of this Leaflet.

5 Generator Failure Detection

Basically there are three acceptable methods of detecting generation system failures, the objective of each being to alert the pilot to an abnormal state by the operation of warning lights. They are as follows:

a) **Generator Output Detection**

The most positive method is to detect the output from each generator/alternator as close to the bus bar system as possible, because this ensures not only that the generator/alternator is supplying an output but that there is no break in the cabling or associated control equipment between it and the bus. However a reverse current blocking system is required such as a diode or reverse current relay, in order to isolate the generators from the battery, and this may not be provided on the aircraft as basic equipment.

b) **Alternator Auxiliary Output**

Certain alternators have an auxiliary output terminal which when connected to a suitable voltage detector or relay can be made to operate a failure warning light. This system has the advantage of separate warning lights for each alternator although it cannot detect failures of cable connections or equipment between the alternator and bus bar.

c) **Low Bus Voltage Detection**

This comprises a voltage level detector connected to the main distribution bus which illuminates a warning light should the battery commence to supply the bus system. Several detector systems are available as compact items which include voltage detector and warning light in a single unit and usually only operate when both generators/alternators have failed.

Other methods of generator/alternator failure are feasible but not covered within the context of this Leaflet.

6 Location of Warning Lights

The warning lights should be located as close to the pilot's normal scan of vision as possible in any reasonable position on the left or centre instrument panels where they will not be obscured. They must be coloured red and undimmable. Exceptions to these rules may be made in certain circumstances by agreement with the CAA Certification and Approvals Department. Should any operator wish to fit a flashing red light, in accordance with paragraph 2.3 of the GR then the flashing characteristic must be cancellable after the pilot has taken action in order to eliminate annoyance especially during night flying.

7 Battery Load Analysis

In order to prove compliance with GR No. 4 paragraph 2.3 which requires a battery duration of not less than thirty minutes should the generation system fail, it is necessary either to carry out a practical test or to calculate the battery endurance when supplying certain specified systems or equipments.

7.1 **By Practical Test.** This could be carried out on the ground or in the air by simulating the failure and subsequent drills in accordance with an agreed schedule, which must be based on the battery voltage not falling below that stipulated in GR No. 4 paragraph 3.1.1. The actual state of charge and capacity of the battery must also be known before commencing the tests. The main problem with a ground test is that 'dummy' electrical loads will be necessary to simulate such apparatus as pitot heads that cannot be operated continuously on the ground. An air test could lead to a dangerous situation if the battery became flattened below the voltage stipulated in GR No. 4 paragraph 3.1 and the generation system could not be restored. If an operator wishes to carry out either of these tests reference should be made to the CAA Certification and Approvals Department to ensure that the proposed procedures are acceptable unless they have been agreed previously for a similar aircraft.

7.2 **By Calculation.** An accurate theoretical assessment of the battery performance requires a load analysis to be compiled and the discharge figures checked against the battery manufacturers discharge curves and data sheets.

Because the full battery data may not be available, a simplified load analysis format together with guidance on the necessary calculations is shown on Appendix 1 of this Leaflet.

The battery being a source of stored electrical power will during its life gradually lose its ability to retain this energy, and for this reason a stipulation is made that only 75% of the name plate rating may be considered as available. This figure is an approximation on the basis that when in service batteries are typically only 90% charged and may be retained on the aircraft down to 80% of the name plate capacity.

The capacity of a battery is:

Rate of Discharge (amps) x Time to Discharge

normally expressed in ampere hours but for load analysis calculations it is almost invariably expressed in amp-mins for convenience (i.e. amp-hours x 60). However this is not a linear function for with heavier discharge currents the discharge time decreases more rapidly so that the power available is less (i.e. reduced efficiency).

For Example – When discharging a 25 ampere hour battery down to 21.6 volts it may give:

150 amps for 5 mins	=	750 amp-mins
45 amps for 20 mins	=	900 amp-mins
18 amps for 1 hour	=	1080 amp-mins

10 amps for 2 hours	=	1200 amp-mins
5 amps for 5 hours	=	1500 amp-mins

Therefore in order to make an accurate assessment of battery duration, reference should be made to the manufacturers discharge curves. However it is recognized that these may not be available and certain assumptions and approximations are given in the following text to overcome this difficulty.

Because of this problem of definition of capacity it is first necessary to ensure that all calculations are based on the 1 hour rate. Some manufacturers however do not give this on the name plate and quote a 5 hour rate. For these calculations as a 'rule of thumb' it may be assumed that the 1 hour rate is 85% of the quoted 5 hour rate.

Following the generator system failure and before the pilot has completed the load shedding drills the battery may be subjected to high discharge currents with a resultant loss of efficiency and capacity on the principle explained in the previous paragraph. To make allowance for such losses the calculated power consumed during the pre-load shed period should be factored by an additional 20% if the average discharge current in amps is numerically more than twice the 1 hour rating of the battery.

When compiling this load analysis all electrical services operating during a normal night cruise pre-load shed period should be listed. De-icing loads, for example, need not be included.

The minimum equipments to be retained after load sheet are given in paragraph 3.1 of GR No. 4. However it may not be possible to switch off all of the unwanted services due to duplication of services on circuit breakers, lack of switches or inaccessibility of fuses, and in such cases these loads must also be listed in the electrical load analysis.

It is the operator's choice whether to have the minimum services operating for a period longer than the thirty minute minimum or to have the maximum services available to meet the required duration.

Should the determined battery duration be less than the required thirty minutes it is recommended that the operator should seek advice from the CAA Certification and Approvals Department before considering the fitment of larger batteries in the aircraft in order to verify the load shedding procedures being proposed. Further, as the calculations are known to be based on conservative approximations CAA may accept up to 3 minutes short on the calculated battery endurance.

Although some aircraft are equipped with generator/alternator failure lights in accordance with paragraph 2.2 of the GR, it is still necessary to ensure that the Flight Manual or Pilots Notes include the necessary drills and battery duration times as required by paragraphs 2.3 and 2.4. Where the requirements are not met it is the responsibility of the owners or operators to prepare and submit the necessary documentation.

7.3 **Crew Drill.** An example of the wording for the crew drill is shown on Appendix 2 attached. This format is recommended in order to help reduce the workload on all concerned in the preparation of the appropriate manuals.

APPENDIX 1 Sheet 1

Battery Capacity Analysis Modification No BH001

Sheet 1 of 1

Aircraft type A.R.BEE Registration G-CAA

Battery type AIRDIV AD 1 Capacity 20 AH (1 hour rate) 24 volts

(Lead acid/~~Ni-Cadmium~~)

1	2	3	4	5	6	7	8
Equipment	**No. Fitted**	**Load per Unit (amps)**	**Time on (mins)**	**Pre-Load Shed Power Consumed ~~5~~/10 min Period. (amp-mins)**	**Remaining Cruise Load After Load Shed (amps)**	**Landing Power Consumed 5 mins Period. (amp-mins)**	**Notes**
Internal Lights	2	.5	Int	5.0	.5	2.5	
Instrument Lights	1 set	2.0	Cont	20.0	2.0	10.0	
Nav. Lights	1 set	4.0	Cont	40.0	-	-	
Anti-Collision Beacons	2	2.0	Cont	40.0	-	-	
Pitot Heater	1	3.0	Cont	30.0	-	-	
Fuel Pumps	2	2.0	Int	-	-	20.0	
Engine Instruments	1 set	3.0	Cont	30.0	3.0	15.0	
Warn Lights	1 set	1.0	Int	10.0	1.0	5.0	
Inverter	1	6.0	Cont	60.0	-	-	
De Mist Fan	1	2.0	Int	-	-	-	
VHF Comm 1	1	REC 4.0 TX	Cont	10.0	1.0	5.0	
VHF Comm 2	1	1.0 REC 4.0 TX	Cont	10.0	-	-	
ADF	2	1.0	Cont	20.0	-	-	
VHF NAV	1	1.0	Cont	10.0	1.0	5.0	
Audio	1	1.0	Cont	10.0	-	-	
Radar	1	10.0	Cont	100.0	-	-	
Turn & Slip	2	.5	Cont	5.0	.5	2.5	
Land. Light	2	10.0	Int	-	-	20.0	
U/C Operation	1	6.0	Int	-	-	3.0	
U/C Warning	1	.5	Int	-	-	2.5	
	TOTALS			400	9.0	90.5	

Duration of Flight on Battery = 52 Minutes

For calculations see sheet 2

APPENDIX 1 Sheet 2

DATA

a) Battery rated capacity (1 hour rate) ....**20**......... amp-hours

b) Battery capacity available (a x 75%) ....**15**......... amp-hours

.........**900**......... amp-mins

c) Pre-load shed power consumed ....**400**......... amp-mins

d) Pre-load shed power consumed correct for battery efficiency (c x 1.20)

.........**480**......... amp-mins (See note (v))

e) Cruise load night ....**9.0**......... amps

f) Landing power consumed ....**90.5**......... amp-mins

CALCULATION

Cruise duration = $\frac{\text{b-(d+f) amp min}}{\text{e amp}}$ = $\frac{\mathbf{900 - (480 + 90.5)}}{\mathbf{9}}$

= ....**37**......... mins

Duration of battery

= pre-load shed time + cruise duration + landing time

= ....**52**......... mins

APPENDIX 1 Sheet 3

NOTES:

1 Battery capacity shall be such that in the event of a complete loss of generated electrical power, adequate power will be available for a period of not less than 30 minutes following the failure and be capable of supporting those services essential to the continued safe flight and landing of the aircraft. This includes the pre-load shed period of 10 minutes (or 5 minutes) from operation of a failure warning for completion of the appropriate crew drills (see CAA CAP 747 GR No. 4 paragraph 2.3).

2 For the purpose of calculating the battery endurance:

i) Only normal night cruise loads need be considered (e.g. it can be assumed that de-icing loads are not applied at the time of failure).

ii) Landing period is assumed to be 5 minutes.

iii) Cruise duration =

$$\frac{\underset{b)}{\text{Battery capacity}} - (\underset{d)}{\text{Pre-load shed}} \text{ and } \underset{f)}{\text{landing loads}})}{\underset{e)}{\text{Cruise load}}}$$

iv) Battery capacity available = 75% of rated capacity (amp-hours at 1 hour rate). Capacity at 1 hour rate = 85% of 5 hour rate.

v) Pre-load shed power consumed – if this figure is more than twice the battery rating in amps (1 hour rate) a factor of 20% must be added to the power consumed to compensate for loss of battery efficiency under these heavy discharge loads.

vi) Consideration must be given to any loads that cannot be switched off.

3 If compliance with the 30 minute operational period depends on certain equipment being switched off, the nominated minimum required equipment must be detailed in the aircraft Flight Manual or equivalent document.

Where duration permits only limited use or 'one-shot' operation of equipment (e.g. flaps, landing gear) such restrictions and suitable operating instructions must be shown in the aircraft Flight Manual or equivalent document.

APPENDIX 2 Sheet 1

(Example Only)

FLIGHT MANUAL SUPPLEMENT DATA

CAA CAP 747 GR No. 4

Aircraft type	A R BEE
Aircraft Registration	G-CAA
Aircraft Serial No.	001
Supplement to Flight Manual	FM2/74

This supplement is required in accordance with the requirements of CAA CAP 747 GR No. 4 paragraphs 2.3, 2.4, and 2.5.

Paragraph 2.3

Duration of batteries following total generation system failure.

Night - 52 mins

Paragraph 2.4

The attitude indicator installed in the left-hand instrument panel is vacuum operated In the event of total generation system failure reference can be made to this instrument.

Example only – when low bus volts warning is fitted.

Paragraph 2.5

Crew Drills

Pre Flight Check

Before engine start

Gen/Alt 1 and 2	- Off
Battery	- On
Low volts warn light	- On

After engine start

Gen/Alt 1 or 2	- On
Battery	- On
Low volts warn light	- Out

APPENDIX 2 Sheet 2

Emergency Procedure

Low volts warn light - On

Check Gen/Alt 1 and 2 ammeters - Zero

If both read zero –

Switch off all electrical service except the following:

Internal Lights

Instrument Lights

Engine Instruments

Warning Lights

VHF COMM No. 1

VHF NAV

Turn and Slip Indicator (Pilot)

Landing Light

Undercarriage Operation

Undercarriage Warning

NOTE:

a) A landing should be made as soon as possible but under the generation failure conditions the battery endurance should be 52 mins.

b) VHF communication transmission should be restricted to maximum of 3 minutes during total flight.

c) Other electrical services may be used at the pilots discretion but the battery endurance will be reduced pro rata.

Prepared by ....

CAA Surveyor ....

Date ....

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Leaflet 9-7 Nickel Cadmium Batteries

(Previously issued as AIL/0056)

1 Purpose

This Leaflet is intended to provide guidance material on methods of assessing standards of battery maintenance. This Leaflet replaces that issued on 9 January 2002 under the same subject title. This document recognises actions taken by manufacturers and users since that time and is intended to provide further revised guidance material on methods of assessing standards of battery maintenance. This document also attempts to recognise the improvements made to affected battery types since the original publication on this topic in February 1974.

In addition, Appendix 1 of this Leaflet gives general guidance on the maintenance and installation of nickel-cadmium batteries (in particular of the semi-open type), which provide a standby source of DC power in aircraft. It should be read in conjunction with the Maintenance Manuals and Overhaul Manuals issued by the battery manufacturers, relevant aircraft Maintenance Manuals and approved Maintenance Schedules. It should be noted that Appendix 1 of this Leaflet was previously published as CAIP EEL/1-3 Issue 1 (Dated 14 November 1975).

2 Background

In general, industry has been aware of the dangers of poor nickel cadmium battery maintenance. Whilst the actual number of battery ‘runaway’ and severe overheating failures have been seen to decrease over the years, it is considered prudent to continue to be vigilant and as such this Leaflet highlights continuing good maintenance practices.

3 Battery Failure Modes

The prime method of assessing any battery is essentially the measurement of discharge capacity and this is sufficiently well appreciated as to require no further comment here. However, for Nickel Cadmium cells of the non sealed type, which are the subject of this document, it is essential that the plate separator is in good condition. Unfortunately, the detection of failure requires close monitoring of cell voltage and it is quite possible for a battery containing cells with failed separators to give acceptable capacity.

The separator in a Nickel Cadmium cell has the obvious task of providing a physical isolation between the plates and less obviously, a significant function in terms of the electrochemistry of the cell. It is composed of a build up of woven nylon or similar material and a non-porous membrane of cellophane. The cellophane acts both as a physical screen against metallic particle penetration and as a gas barrier to prevent oxygen generated by the positive plates during charge from reaching the negative plates. Unfortunately, these separator materials are the first to be damaged as battery temperature is increased and we no longer have the obvious warning signs of distorted cell boxes to show that overheating has occurred as was the position with earlier cells.

Should a damaged separator remain in service, local overheating will occur because of catalytic action at the negative plates and this in turn will cause poor charge acceptance. This generally results in a loss of balance with the other cells, poor capacity, or more seriously an active failure in terms of cell burning. The majority of such burns are relatively minor and can only be seen when a cell is removed from the battery but it is this same mechanism which can develop to give cell to cell, or cell to case, shorts which may then create significant hazards.

The causes of separator failure can be placed into two broad categories, namely:

a) adverse aircraft operating conditions – including system management problems, or

b) poor maintenance – either in terms of battery workshop practice or length of time between servicing.

Clearly, these sub-divisions represent an over simplification but it is convenient to proceed in this document under these headings and to discuss these factors in relation to battery failure in general and cell separator failure in particular.

4 Aircraft Operating Conditions

Basically, there are two groups of aircraft batteries in terms of size and duty, namely high discharge rate units for use with main power systems and small 'dedicated power supply' batteries, of which the Inertial Navigation System unit is typical. This second group is clearly less prone to operational failure because the environment is under closer control and the battery is accommodated within a system design. It follows that the prime concern is to see that batteries remain in a good state of charge and do not become 'sleepy' and this will be considered as a maintenance function (see Paragraph 5).

The main power system batteries can be sub-divided into those which are connected directly to the bus and therefore receive a 'constant potential charge' and those which are connected via a special charging unit which usually provides a combination of limited constant potential charging and constant current charging.

Batteries which 'float' on a main DC bus operate in a very narrow band of acceptable conditions of voltage and temperature and for this reason the larger aircraft do not now use this system. A twenty cell battery which is subject to regular discharge loads is unlikely to regain adequate charge unless it receives 28.5 volts at its terminals but should its temperature be raised by say, engine starting, it is possible that 'thermal runaway' could be initiated at 29.0 volts. These are approximate figures but they do serve to show the importance of ensuring that the voltage of each cell is adequate because the loss of perhaps 0.1 volt from the 'top of charge potential' of each of several cells, can lead to charge instability of the battery. Such voltage reductions will be evident if separators have been damaged and we do have a classic 'cause and effect' problem to consider when such batteries are returned as unserviceable. Because of the disruptive nature of some of the extreme failures experienced in recent years, it is now generally required that batteries operating on a constant potential bus-bar should be monitored for high temperature levels. Typically, there may be an indication available to flight crew that a battery has reached 50°C and a further warning should a battery reach 70°C, at which point electrical disconnection is required.

Batteries which are charged from their own special system are not generally monitored by temperature in the flight deck but the battery may be temperature sensed as part of the method of charge control. The charging current is usually displayed to flight crew and this enables the charging mode to be observed so that disconnection may be made if abnormal operation occurs. Whilst the dramatic 'thermal runaway' is far less likely to occur on such systems, nevertheless, cell burning can and does occur. Examples are known of maintenance staff 'topping up' batteries on an aircraft, in itself an undesirable practice, only to realise that a failure existed because water issued from ruptured cell boxes.

To summarise, the main causes of cell failure, acting singly or in combination to create a battery failure, are:

a) excessive discharge duty;

b) high operating temperature which may be caused either by high discharge current or by ambient conditions;

c) high DC voltage; or

d) inadequate maintenance, which will now be considered.

4.1 Battery Capacity Levels

In some instances, it may be necessary to establish the battery duration (e.g. for the purpose of producing an Electrical Load Analysis for an aircraft).

The capacity of a battery is defined by the following:

Rate of Charge (Amps) x time to discharge

Normally expressed in ampere, but typically expressed in amp-mins (i.e. amp-hours x 60). However, this is not a linear function and with heavier discharge currents the discharge time decreases more rapidly so that the power available is less (i.e. reduced efficiency).

Therefore, in order to make an accurate assessment of battery duration, reference should be made to the manufacturer's discharge curves. However, it is recognized that these may not be available and certain assumptions and approximations are provided in the following paragraphs to allow for this case.

Because of the problem of definition of capacity, it is first usual to ensure that all calculations are based on the one-hour rate. Some manufactures however do not give this on the nameplate and quote the five-hour rate (i.e. 5C). For these calculations, as a general rule, it may be assumed that the one-hour rate is 85% of the quoted five hour rate.

For the purpose of calculation, a battery capacity at normal ambient conditions of 80% of the nameplate rated capacity, at the one-hour rate, and a 90% state of charge, may be assumed (i.e. 72% of the nominal demonstrated rated one hour capacity at $+20^{o}C$). The allowance for battery endurance presumes that adequate requirements for periodic battery maintenance have been established.

In some cases, a higher capacity can be recognized (i.e. minimum of 80% of the nominal demonstrated rated capacity at $+20^{o}C$ in lieu of 72%) provided it can be shown that the component maintenance manual (CMM) has a manufacturer's limitation on the state of charge following a battery shop maintenance cycle (e.g. minimum state of charge of 110% following battery shop maintenance cycle). This would then allow a higher duration of the battery to be established.

5 Maintenance

Probably the most contentious aspect of battery maintenance is that of frequency of removal from aircraft for workshop servicing. The major battery manufacturers usually indicate periods which can be as low as 50 hours and seldom exceed 500 flying hours or 3 months installed life for batteries connected to a constant potential system. If the quantity of 'consumable electrolyte water' is known, then by monitoring each cell for consumption it may be seen if this amount is being exceeded. Ideally, the measured water addition to each cell should not exceed this volume (25 cm^3 is a typical value) when the battery is returned from service. If a charge controller is fitted to the aircraft and this limits the overcharge current accurately for a given battery, then these maintenance periods may extend, in a typical case, to 1,000 flying hours.

A major factor in determining the frequency of battery maintenance may be the need to 'balance' cells. If it is remembered that a battery is an assembly of 20 or more cells in series and that the capacity of these may range by 30%, it will be apparent that the lowest capacity units may become excessively discharged or even 'reverse' charged. All manufacturers now recommend that, on a regular basis, cells are fully discharged and then individually shorted out. Frequent APU or engine starting is the major cause of unbalance, whilst inactive batteries such as those fitted within an INS will show apparent loss of capacity ('sleepiness') which can only be restored by workshop cycling. Thus installed life has to be determined for each type of operation as well as for each type of cell and due regard should be taken of the rate of consumption of 'electrolyte water'.

Battery manufacturers have now produced maintenance instructions which are of an acceptable standard and it is not proposed to repeat such data here. Additionally, Appendix 1 of this Leaflet gives supporting information but it is appropriate to emphasise the following points:

a) Record cards showing a history for each battery and including details of the history of each cell are essential.

b) Cell replacement by units of identical type obtained from the battery manufacturers is permitted. However, the addition of more than 5 cells in a 20 cell battery contributes to unbalance and it is strongly recommended that users assemble new cells into battery sets and use older surviving cells from rejected batteries to make up complete batteries of older cells. In this way it becomes possible to retire an old battery when cell failures accelerate and not thereby scrap some reasonably new cells.

   It is recognized that some USA battery manufactures market rebuilt cells, which are appropriately identified. Because these originate from the original manufacturer, with all that this implies for assurance of performance, they may be considered as 'new' cells. Cells rebuilt by other agencies must not be used as spare units (see Rebuilt Batteries below).

c) No battery should ever be allowed to rotate through a battery shop without having the 'top of charge' voltage measured for each cell and the manufacturers' pass criteria applied.

d) Battery room staff should have a method for reporting serious defects so that air safety procedures can be considered. (Significant failures would include burnt cell boxes or signs of arcing at interconnecting links.)

e) The recording of water addition to batteries should be encouraged and it should be appreciated that a cell with a poor separator tends to use less water than one with a good separator.

f) Facilities and procedures should exist for regular calibration of temperature sensing devices and wiring should be checked thoroughly as this is particularly vulnerable within batteries.

6 Battery Shops

There has been an upsurge in the range of equipment for charging and testing batteries and some of the equipment does not permit a conventional constant current charging schedule to be applied. For example, one type of equipment now widely used has a charging regime which includes rapid discharge pulses and it is therefore essential that battery workshops' staff have full instructions on the application of such equipment for all the battery types being serviced. These instructions should be officially authorized by a competent engineer and battery history cards should cross reference to the instructions used. Any procedure which does not involve the voltage measurement of every cell is not acceptable. Because of the length of time required to service nickel cadmium batteries, the quantity of work in progress usually demands a considerable working area. This area must be clean and well ventilated and free from an accumulation of scrap batteries.

In no circumstances should the same facilities be used for both nickel-cadmium and lead acid batteries and the ventilation shall be such that no cross contamination can occur.

APPENDIX 1

1 Introduction

1.1 The information provided by this Appendix is set out as follows:

2 General Description

Nickel-cadmium batteries may be divided into three ranges of basic design, as described below.

2.1 **Sealed Batteries**. This range of batteries consists of those having the cells completely sealed. In general the batteries are of small capacity, and may be used for emergency lighting purposes.

2.2 **Semi-Sealed Batteries**. The cells in this range of batteries are usually mounted in steel containers and are fitted with safety valves. The batteries may be charged fairly rapidly but are very sensitive to overcharge, thus, for aircraft usage, they are usually fitted with a thermal protective device. Under normal conditions the battery requires practically no maintenance beyond periodic cleaning and capacity checks.

2.3 **Semi-Open Batteries**. These batteries are generally used as the main aircraft batteries. The cells are similar in appearance to those of the semi-sealed type, but are deliberately allowed to 'gas' to avoid excessive heating should the battery be on over-charge. The cell cases are usually manufactured from nylon. Because of gassing, the electrolyte has to be 'topped-up' at periods which vary according to the duty cycle of the battery and the conditions under which it is operated. 'Topping-up' periods are specified in the approved Maintenance Schedule for the aircraft concerned (see also Paragraph 4.3).

3 Construction

The plates comprise a sintered base on a nickel-plated steel support. The active materials are nickel hydroxide on the positive plates, and cadmium hydroxide on the negative plates, and these are impregnated into the sintered base by chemical precipitation. This type of plate construction allows the maximum amount of active material to be employed in the electrochemical action.

3.1 After impregnation with the active materials, the plates are stamped out to the requisite size. The plates are then sorted into stacks according to the type of cell into which they are to be mounted. Usually there is one additional negative plate for a given number of positive plates. The plates are then welded to connecting pieces carrying the cell terminals, after which a separator is wound between the plates and the insulation is checked under pressure. The plate group is then inserted in the container, the lid secured and pressure-tested for leaks. The separators are usually of the triple-layer type, one layer being made from cellophane film, the other two being woven nylon cloth. Cellophane is used because it has low electrical resistivity and is a good barrier material which contributes to the electrical and mechanical separation of the positive and negative plates, and keeps finely divided metal powder particles from shorting out the plates while still permitting current flow. It also acts as a gas barrier, preventing oxygen given off at the positive plate during overcharge from passing to the negative plate where it would combine with active cadmium, reduce cell voltage, and produce heat as a result of chemical reaction. The cellophane is prone to damage at high operating temperatures, and failure will result in an adverse change in the operating characteristics of a battery (see also Paragraph 4.5.8(a)).

3.2 The electrolyte is a solution of potassium hydroxide and distilled water, having a relative density of 1.24 to 1.30. It is impregnated into cells under vacuum, after which the cells are given three formation cycles, re-charged, and then allowed to stand for a minimum period of 21 days. The discharge characteristics at the end of this period enable the cells to be matched.

3.3 In a typical battery each component cell is insulated from the others by its moulded plastic case. All the cells are interconnected via links secured to the terminals of the cells, and are contained as a rigid assembly in the battery case. A vent cap assembly is provided on the top of each cell and, in general, is constructed of plastic, and is fitted with an elastomer sleeve valve. The vent cap can be removed for adjustment of the electrolyte level, and acts as a valve to release gas pressure generated during charging. Except when releasing gas, the vent automatically seals the cell to prevent electrolyte spillage and entry of foreign matter into the cell.

3.3.1 Two venting outlets, a pair of carry-strap shackles, and a two-pin plug for quick-release connection of the aircraft battery system cables, are embodied in the battery case. A removable cover completes the case, and incorporates a pair of slotted lugs which engage with attachment bolts at the battery stowage location.

3.4 **Chemical Principle**. During charging a ‘change of ions’ takes place; oxygen is removed from the negative plates and is added to the positive plates, bringing them to a higher state of oxidation. These changes continue in both sets of plates for as long as the charging current is applied or until both materials are converted; i.e. all the oxygen is driven out of the negative plates and only metallic cadmium remains, and the positive plates become nickel hydroxide.

3.4.1 The electrolyte acts only as an ionized conductor and is forced out of the plates during charging. It does not react with either set of plates in any way, and its relative density remains almost unchanged. Towards the end of the charging process and during overcharging, gassing occurs as a result of electrolysis which reduces only the water content of the electrolyte. Gassing is dependent on the temperature of the electrolyte and the charging voltage (see also Paragraph 4.5.5).

3.4.2 During discharge, the chemical action is reversed; the positive plates gradually losing oxygen while the negative plates simultaneously regain lost oxygen. The plates absorb electrolyte to such an extent that it is not visible at the top of the cells.

4 Maintenance

Nickel-cadmium batteries must be prepared for service, charged, tested and otherwise generally maintained, in a well ventilated workshop area which is entirely separate from that used for the servicing of lead-acid batteries. This also applies to servicing and test equipment, tools and protective clothing, all of which should carry some form of identification. Anything associated with lead-acid batteries (acid fumes included) that comes into contact with a nickel-cadmium battery or its electrolyte can cause severe damage to this type of battery.

4.1 **Introduction**. Precise details of inspection and maintenance procedures, and the sequence in which they should be carried out, are given in the relevant battery maintenance and overhaul manuals, and other approved supplementary servicing instructions; reference should, therefore, always be made to such documents. The information given in the following paragraphs is intended to serve as a general guide to the procedures to be carried out appropriate to battery service life and condition, and also to the precautions to be observed.

4.2 **Inspection**. The following checks are typical of those comprising a battery inspection schedule:

a) The battery should be identified to establish any known history. If the battery is a new one a servicing record card should be raised (see Paragraph 7).

b) The outside of the battery case should be examined for evidence of damage, and of locally overheated areas.

c) The battery cover should be removed and its rubber lining inspected for condition. Cover latches should operate smoothly and provide proper security of the cover. Extreme care must be exercised when working around the top of a battery with its cover removed. Tools should not be dropped onto the cell connecting links, as severe arcing will result with possible injury to personnel and damage to the battery. Such personal items as rings, metal watch straps and identification bracelets should be removed, to avoid contact with connecting links and terminals.

d) There should be no evidence of arcing having occurred between the battery and the aircraft structure. The section near the bottom of the case and the slotted lugs of the cover tie-down strap are areas which are most likely to be affected. If signs of arcing are present, the aircraft battery compartment should be inspected and the battery should be completely dismantled and overhauled.

e) The battery should be inspected for signs of electrolyte leakage and should be cleaned where necessary (see Paragraph 4.4).

f) The battery receptacle should be checked for evidence of bums, cracks and bent or pitted terminals. Defective receptacles, which can overheat, cause arcing and depress output voltage, should be replaced.

g) All cell links should be checked for security and evidence of overheating, and their terminal nuts should be tightened to the specified torque values. Any cell link showing damage to its plating should be replaced.

h) Vent caps should be checked for security and also to ensure that gas exit holes are free from dirt or potassium carbonate crystals. Clogging of vents causes excessive pressures to build up, resulting in cell rupture or distortion of parts. Cell valves, when fitted, should also be checked for security and freedom from dirt or crystal formation. Dirty vent caps or valves should be removed and cleaned (see Paragraph 4.4.3).

NOTE: Potassium carbonate is a white crystal formed by the reaction of potassium hydroxide with carbon dioxide in the air; it is non-corrosive, non-toxic and non-irritating.

i) Temperature sensing devices, when installed, should be checked for secure attachment with leads and connectors showing no signs of chafing or other damage. Electrical checks and/or calibration of these devices should be carried out at the periods specified in the approved Maintenance Schedule.

4.3 **Electrolyte Level and Adjustments**. The level of the electrolyte should, depending on manufacturer's recommendations, only be adjusted when a battery is at the end of charge, while still charging, or after a specified standing time. If electrolyte level adjustments were to be made in the discharged or partially discharged condition, then during a charge electrolyte would be expelled from the cells, resulting in corrosive effects on cell links, current leakage paths between cells and battery case, and a reduction of electrolyte density. The manufacturer's instructions regarding checks on electrolyte level and adjustments should be carefully followed and the maintenance kit equipment designed for a particular type of battery should be used.

NOTE: Adjustments should not be made when batteries are installed in aircraft.

4.3.1 Only the purest water available, preferably pure de-mineralised or distilled water, should be used for adjusting electrolyte levels, and a record of quantity added to all cells should be maintained, because it is largely on this evidence that periods between servicing are determined (see also Paragraph 7). The 'consumable' volume of electrolyte is normally specified in manufacturer's manuals, but in the absence of such information, a useful guideline is that batteries should not be left for periods which would require the addition of water to any cell by an amount in excess of 1 cc per ampere-hour capacity.

4.3.2 In the event that the electrolyte becomes contaminated, particularly with oil, foaming of the electrolyte will occur. In such cases, a neutralizing fluid, which is available from the relevant battery manufacturer, should be added to the electrolyte, strictly in accordance with the manufacturer’s instructions.

4.3.3 Additional potassium hydroxide should not normally be required, but if electrolyte in solution is necessary for topping-up it must be ensured that it is in the proportions specified in the relevant manual.

NOTE: Contamination of the electrolyte with tap water, acids, or other non-compatible substances, will result in poor performance or complete failure of a battery.

4.3.4 Potassium hydroxide should be kept in special containers, and because of its caustic nature, should be handled with extreme care to avoid contamination of the person or clothing. Rubber gloves, a rubber apron and protective goggles should always be worn. If contamination does occur, the affected parts should be immediately rinsed with running water. If available, vinegar, lemon juice or a mild boric acid solution may also be used for treatment of the skin. Immediate medical attention is required if the eyes have been contaminated. As a first-aid precaution, they should be bathed with water or a weak boric acid solution, applied with an eye bath.

4.4 **Battery Cleaning**. Dirt, potassium carbonate crystals, or other contaminating products, can all contribute towards electrical leakage paths (see also Paragraph 4.6) and be a prime cause of unbalanced cells. Cleanliness of batteries is therefore essential.

4.4.1 Deposits should be removed from the tops of cells by using a cloth soaked in de-mineralised or distilled water and a stiff fibre bristle brush. Wire brushes or solvents should not be used. If any contaminating product is caked under and around cell connecting links, the links should be removed, if necessary, to facilitate cleaning. Care should always be taken to ensure that debris is not forced down between cells, and in some cases it may be better to scrape deposits loose and then blow them with low-pressure compressed air. The air itself should be clean and dry, and goggles should be worn to protect the eyes.

4.4.2 Some manufacturers specify periodic flushing of cell tops and battery case with de-mineralised or distilled water while brushing away deposits. This method is not recommended, and batteries in a dirty condition, or showing low resistance, should be dismantled and completely serviced.

4.4.3 When it is necessary to clean vent caps and valves, they should be removed from the cells, using the correct extractor tool, and should be washed in warm water to dissolve any potassium carbonate crystals which may have accumulated within the outlet orifices. They should then be rinsed in de-mineralised or distilled water, dried and re-fitted. Valves should also be tested for correct functioning in accordance with manufacturer's instructions before re-fitting.

NOTE: Cells should not remain open for longer than is necessary.

4.5 **Charging of Batteries**. New nickel-cadmium batteries are normally delivered complete with the correct amount of electrolyte, and in the fully discharged condition. Following a visual check for condition, they must, therefore, be charged in accordance with the manufacturer's instructions before being put into service. Once in service, batteries must then be charged at the periods stated in the approved aircraft

Maintenance Schedule. The following information on charging methods and associated aspects is of a general nature only. Precise details are given in relevant manufacturer's manuals and reference must, therefore, always be made to such documents.

4.5.1 **Constant-Current Charging**. This method is the one which should normally be adopted for the workshop charging of batteries, the charging equipment being adjusted and monitored throughout the charging period to supply current at either a single rate, or at several different rates in a stepped sequence. Although more time-consuming than the constant potential method which is often adopted in aircraft battery systems, constant current charging is more effective in maintaining cell balance and capacity. The hour rate of charge current required must be in accordance with that specified by the relevant battery manufacturer.

NOTE: The hour rate of a battery refers to the rate of charge and discharge expressed in multiples of "C" amperes, where "C" is the 1-hour rate. For example, if a battery has a capacity of 23 ampere-hours, then "C" would be 23 amperes and for a 10-hour rate the charge or discharge current rate would be C/10 amperes, i.e. 2.3 amperes.

4.5.2 **Vent Caps**. Before charging, the battery cover should be removed, and with the aid of the special wrench provided in the battery maintenance kit, the vent cap of each cell should also be removed.

4.5.3 **Connection to Charging Equipment**. Charging equipment should not be switched on until after a battery has been connected and the charging circuit has been checked for correct polarity connections.

4.5.4 **Electrolyte Level**. The electrolyte level should be checked and adjusted, as necessary, in accordance with the manufacturer's recommendations (see also Paragraph 4.3).

4.5.5 **Gassing**. Gassing of cells occurs within the region of final charge, as a result of the electrolysis of water into hydrogen and oxygen gases. When gases escape from a cell, the quantity of fluid electrolyte is reduced; vigorous prolonged gassing should therefore be avoided. A 'dry' cell is more likely to suffer separator damage, and any cell running hotter than its neighbours should be investigated.

The gassing/temperature phenomena provide a useful indication of impending failure of cells; e.g. a cell that gasses sooner and more actively than its neighbours is going to lose more electrolyte, and as a result will run hotter and tend to dry out. Minor differences in gassing are hard to detect, but large differences should be noted and investigated.

4.5.6 **State of Charge**. The state of charge cannot be determined by measurement of the electrolyte relative density or battery voltage. Unlike the lead-acid battery, the relative density of the nickel-cadmium battery electrolyte does not change. Except for 'dead' batteries, voltage measurements at either open circuit or on-load conditions do not vary appreciably with state of charge. The only way to determine the state of charge is to carry out a measured discharge test (see Paragraph 4.7).

4.5.7 **Charging of Individual Cells**. Individual cells must be in an upright position and adequately supported at the sides parallel to the plates during charging. A special frame may be built to fit a cell, or boards or plates may be placed on each side and held together with a clamp. After charging and removal from its support, the sides of a cell should be inspected to ensure there are no bumps or bulges which would indicate an internal failure.

NOTE: Cells should always be fully discharged before removal from a battery and before re-assembly.

4.5.8 **Thermal Runaway**. In some small aircraft the battery may be charged by constant potential supplied directly from the DC bus-bar. Under correct conditions of temperature and voltage, the internal voltage of the cells rises gradually as the electro-chemical action takes place, and it opposes the charging voltage until this is decreased to a trickle sufficient to balance continuous losses from the cells. The energy supplied to a fully charged battery results in water loss by electrolysis and in heat generation. For a battery in good condition, a point of stability will be reached where heat as a result of trickle current will just balance radiated and conducted heat losses. At low temperatures, a battery will appear to have a limited capacity, and will require more voltage to accept a given amount of charge. As the battery becomes warm, however, its responses return to normal. Operation at high temperatures also limits the capacity, but in such conditions, a battery is subjected to the danger of a 'thermal runaway' condition.

a) At higher than normal temperatures, the heat loss of the battery through radiation and conduction is lower than the heat generating rate and this results in a higher battery temperature. This, in turn, reduces the internal resistance of the battery, so that higher than normal charge current is admitted resulting in an increase in chemical activity, additional heat and a further increase in charging current. This recurring cycle of temperature rise, resistance and voltage drop, and charge current rise, progressively increases the charging rate until sufficient heat is generated to completely destroy a battery.

b) Other factors which can cause overheating of a battery are as follows:

i) Voltage regulator of aircraft generating system incorrectly adjusted.

ii) Frequent or lengthy engine starts at very high discharge rates.

iii) Loose link connections between cells.

iv) Leakage currents between a cell and battery container and the airframe structure. Periodic measurement of leakage current and removal of any electrolyte that may have accumulated around and between cells should be carried out to prevent high leakage and short circuits from developing (see also Paragraph 4.6).

v) Use of unregulated, or poorly regulated, ground support equipment to charge a battery, particularly a battery which has become hot as a result of excessive engine cranking or an aborted engine start.

vi) High initial charging currents imposed on a hot battery.

vii) Unbalanced cells. Cell unbalance (see Paragraph 4.9) refers to an apparent loss of capacity and to variations in cell voltage at the end of charging cycles. These variations can develop over a period of time, particularly when subjected to operating conditions like those occurring in aircraft utilising charging circuits of the constant potential type. Other factors which may also contribute to cell unbalance are cell position in the battery, e.g. centre cells run warmer than outer cells, and the self-discharge of individual cells.

c) In some types of aircraft, the batteries specified for use incorporate a thermostat type detector which illuminates a warning light at a pre-set temperature condition. In addition, a thermistor type sensing network may also be incorporated. The network operates in conjunction with a special solid-state, pulse-charging unit, and its function is to monitor the charging current and to de-energize the charging circuit when the battery temperature exceeds a safe operating limit. Detection devices should be checked at the periods stated in the approved aircraft

Maintenance Schedule and in accordance with the relevant manufacturer's instructions.

4.6 **Electrical Leakage Check**. Electrical leakage refers to current flowing in a path other than that desired, and in connection with batteries, this means current between the terminals or connectors of cells and any exposed metal on the battery case. The only pertinent measure of leakage of importance to a cell is the rate of discharge caused by the leakage, and this is only significant when its value approaches that specified for the particular type of battery. In one type for example, a leakage of up to 0.020 amps is quoted as the permissible value. Typical methods of determining electrical leakage are described below.

4.6.1 The positive lead from the terminal of a multi-range testmeter should be connected to the positive terminal of the battery and, after selecting the appropriate scale range (usually the one amp. range) the negative terminal lead from the testmeter should be touched on any exposed metal of the battery case. If a pointer deflection is obtained it will denote a leakage and the testmeter scale setting should be adjusted, if necessary, to obtain an accurate reading which should be within the limits specified.

The foregoing check should be repeated between the battery negative terminal and battery case, when again any readings obtained should be within limits. If either of the readings obtained exceed the specified limits the battery should be thoroughly cleaned (see Paragraph 4.4) and the checks again repeated.

4.6.2 If, after thorough cleaning, the leakage current is in excess of the limits it is probable that one of the cells is leaking electrolyte and is therefore defective. This cell may be found by measuring the voltage between each cell connecting link and the battery case. The lowest voltage will be indicated at the connecting links on each side of the defective cell which should be replaced (see also Paragraph 4.12).

4.7 **Capacity Test**. The capacity or state-of-charge of a fully-charged battery is checked by discharging it at a specified rate (preferably automatically controlled) after it has been standing for a certain time period, and noting the time taken for it to reach a specified on-load voltage. For example, a 23 ampere-hour battery is left to stand for 15 to 24 hours and is then discharged at 23 amperes, i.e. the 1-hour rate, to 20 volts. A battery should give at least 80% of the capacity specified on its nameplate, or the minimum authorised design capacity, whichever is the greater.

NOTE: Some batteries of U.S. origin have initial capacity ratings which are significantly higher than those specified on their nameplates. When the nameplate ratings are no longer obtainable such batteries are rejected.

4.7.1 True capacity must always be recorded, meaning that a full discharge is required, and not one which is terminated when the minimum acceptable level has been reached. Because it is essential to monitor a number of cell voltages very closely, the service of two persons is desirable towards the end of discharge for measurement and recording. At this stage, voltages fall very quickly, and it is highly desirable that measurements be made with a digital voltmeter.

NOTE: No cell should be allowed to go into reverse polarity before the measured discharge is complete, and the terminal voltage should not go below 1 volt per cell, since excessive gassing may result.

4.8 **Capacity Recycling Procedures**. The purpose of recycling is to restore a battery to its full capability and to prevent premature damage and failure. The discharge rates and voltage values appropriate to the recycling procedures vary between types of battery, and reference should always be made to the relevant manual. The figures quoted below are typical, and serve only as a guide to the limits normally specified.

4.8.1 The battery should be discharged at a current equal to or less than the one-hour rate, and as each cell drops below 0.5 volts (measured by a digital voltmeter) it should be shorted out by means of a shorting strip. The cells should remain in this condition for a minimum period of 16 hours, preferably 24 hours.

NOTE: A battery should not be discharged at an excessively high rate and cells then short-circuited since this produces severe arcing and excessive heat generation.

4.8.2 The shorting strips should then be removed, and the battery charged for 24 hours at the specified recycling charging rate. After approximately five minutes of charge, individual cell voltages should be measured and if any cell voltage is greater than 1.50 volts, distilled water should be added. The amount of water required depends on the rated ampere-hour capacity; a typical maximum value is approximately 1 cc per rated ampere-hour.

4.8.3 After approximately 10 minutes of charge, individual cell voltages should again be measured. Any cell measuring below 1.20 volts or above 1.55 volts should be rejected and replaced.

4.8.4 After 20 hours of charging, individual cell voltages should be measured and recorded, and, if necessary, distilled water should be added to the normal level appropriate to the type of battery.

4.8.5 At the end of the 24 hours charge period, cell voltages should again be measured and compared with those obtained after 20 hours. If the 24 hour voltage reading is below the 20 hour reading by more than 0.04 volts, the cell concerned should be rejected and replaced.

4.9 **Cell Balancing**. If a battery fails to give 80% capacity on test, and if premature ageing of some cells is suspected, a cell balancing test should be carried out. The procedure for carrying out the test appropriate to a particular type of battery is prescribed in the relevant manual, and reference should always be made to such document. The following details, based on the test specified for a typical 23 ampere-hour battery, are given only as a general guide.

4.9.1 Note the time, and discharge the battery at 23 amperes until the terminal on-load voltage falls to 20 volts, then stop the discharge. During the discharge, the voltage of each cell should be frequently checked with a digital voltmeter. A zero reading early in the discharge indicates a short circuit cell; a reverse reading indicates a weak cell. In either case the discharge should be stopped, even if the overall battery voltage has not yet fallen to 20 volts. The weak or faulty cell should be shorted out, preferably through a 1 ohm resistor.

4.9.2 Note the time and recommence the discharge at the lower rate of 2.3 amperes. Frequently check the voltage of the cells and short out each cell (with individual shorting strips) as it falls below 1 volt. Record the lapsed time of discharge for the cell to fall below 1 volt, thereby obtaining an indication of the relative efficiency of the cells.

Some manufacturers specify 0.5 volts as the point at which shorting of the cells should be carried out. This is satisfactory providing that sufficient time is available to permit shorting of all cells before any are subjected to reverse voltage resulting from the charging effect of stronger cells.

4.9.3 The discharge should be stopped when all the cells are shorted out. The battery should be left in this condition, and also with the main terminals shorted together, for as long as possible, but never less than 16 hours.

4.9.4 The battery should then be charged and the cell-balancing procedure repeated. The discharge times recorded for each cell to fall below 1 volt should show an improvement over those previously recorded.

4.9.5 Weak and internally short-circuited cells should be replaced in accordance with the instructions detailed in the relevant battery Maintenance Manual (see also Paragraph 4.12).

4.10 **Voltage Recovery Check**. This check, which should be made at a given time after shorting strips have been removed from the cells or main battery terminals, provides a ready means of detecting high resistance short-circuits and damaged connections within a battery. A typical procedure for this check is given below.

1 Shorting strips of one ohm resistance should be connected between cells, and the battery should be allowed to stand for 16 to 17 hours. At the end of this period, the voltage of individual cells should be measured to ensure that they do not exceed the minimum value specified for the battery (a typical minimum value is 0.20 volts).

2 The shorting strips should then be removed, and after a further standing period of 24 hours, individual cell voltages should again be measured to check their recovery to within normal operating values. A typical minimum value specified as a basis for rejection of a cell is 1.08 volts.

4.11 **Insulation Resistance Test**. A test for insulation resistance may be specified by some manufacturers as the means of checking for electrical leakage. Reference should, therefore, be made to the appropriate maintenance manual for the procedure to be adopted, for permissible values, and for any remedial action to be taken.

4.12 **Cell Removal and Replacement**. Cells should be removed from a battery whenever they are suspected of leakage of electrolyte, internal short-circuits, when they fail to balance (see also Paragraph 4.9) or if the insulation resistance is found to be below the value specified for the particular battery. The method of removing and replacing cells may vary between types of battery, and the instructions issued by the relevant manufacturers must, therefore, always be carefully followed. The information given below, although based on a specific type of battery, is intended to serve only as a guide to the practical aspects generally involved.

4.12.1 The battery should be discharged and the cell links disconnected and removed both from the faulty cell and from the adjoining cells. The cell position should be noted for subsequent entry in the battery record card.

4.12.2 The vent cap should be loosened using the special key provided with the battery maintenance kit.

4.12.3 A cell extractor tool should then be fitted to the cell on the terminals normally used for connecting the cell links. The battery is then held firmly and the cell withdrawn vertically upwards without using undue force. When one cell is removed and all other cell links are disconnected, it is relatively simple to withdraw the remaining cells without the aid of the extractor.

NOTE: After removing a cell, its vent cap should be retightened.

4.12.4 Cells and the inside of the battery case should be thoroughly cleaned and dried (see Paragraph 4.4).

4.12.5 After carrying out all necessary checks, serviceable cells should be replaced in the battery case in their correct positions, and a cell-to-cell voltage check should be carried out to ensure that polarities are not reversed. It must be ensured that any new cells are of the same manufacture, part number, and are of matched capacity rating.

NOTE: A steady force should be used on terminals to press cells into place. Tight cells should not be hammered into place. For easiest assembly, the cell at the middle of a row should be inserted last.

4.12.6 The surfaces of cell terminals and connecting links should be clean, and, after ensuring the correct positioning of links, terminal nuts should be tightened to the specified torque value, and in a sequence commencing from the battery positive terminal. Care should always be taken to ensure that nuts actually tighten the connector assemblies, and are not binding as a result of thread damage or bottoming.

NOTE: Once a tightening sequence has been started it should be completed, thereby ensuring that a nut has not been overlooked. One loose connection can permanently damage a battery and may cause an explosion.

4.12.7 On completion of cell replacement procedures, the battery should be re-charged, tested for insulation resistance, and, if any new cells have been fitted, a capacity test should also be carried out.

4.13 **Rejected Batteries or Cells**. Any batteries or cells which are rejected should be conspicuously and permanently marked on their cases to indicate that they are to be used only for general ground use.

5 Installation

It should be ensured that the battery is of the correct ampere-hour rating, fully charged, and that the electrolyte is at the correct level. Depending on the service history of the battery, appropriate tests, e.g. capacity test, capacity recycling and cell balancing, must also have been carried out in the manner prescribed for the particular battery. Reference should be made to the relevant aircraft Maintenance Manual for details of the battery system and associated installation instructions. Before coupling the system connecting plug, a check should be made to ensure that the battery system switch is OFF, and that all electrical services are isolated.

NOTE: Batteries are heavy units, and they require the use of approved handling methods to prevent possible injury to personnel and damage to the cases or components adjacent to the battery location. Vent pipes should not be used for lifting purposes.

5.1 The battery compartment should be thoroughly clean and dry, and the battery should be securely attached in its mounting. Clamp nuts should not be over-tightened since distortion of the battery cover may result, which could affect the venting arrangements.

NOTE: If a battery compartment has been previously used for lead-acid batteries, it should be washed out with an acid neutralising agent, dried thoroughly, and painted with an alkaline-resistant paint.

5.2 The supply cables from the battery, and, where appropriate, thermostat and battery charging system cables, should be checked for signs of chafing or other damage. Cable connecting plugs should be securely made, without any strain on the plugs or cables.

5.3 Battery installations are normally designed so that in flight, sufficient air is passed through the compartment to dilute the hydrogen gas given off by a battery, to a safe level. Ventilation systems should therefore be checked to ensure there is no obstruction or, if integral venting is used, the connections should be checked for security and leaks.

NOTE: In some ventilation systems, non-return valves are incorporated in the battery compartment vent lines. These valves should also be checked for security and correct location.

5.4 After installation, a check should be made that the electrical connections of the battery supply cables have been correctly secured by switching on some electrical services for a specific time period and noting that readings of the aircraft voltmeter remain steady. A typical load and time is 30 amperes for 30 seconds. For battery systems having a separate 'in situ' charging unit, the unit should be switched on and its electrical settings checked to ensure proper charging of the battery.

6 Maintenance of Installed Batteries

Batteries should be inspected at the periods specified in the approved aircraft Maintenance Schedule. The details given below serve as a general guide to the checks normally required.

6.1 The battery mounting should be checked for security, and the outside of the battery case should be examined for signs of damage and for evidence of locally overheated areas. The latches of the cover should operate smoothly and should firmly secure the cover in position.

Connecting plugs of the battery receptacle, thermostat and battery charger units, where fitted, should be checked for signs of contamination, burns, cracks, and bent or pitted terminal fittings.

6.2 The tops of all cells and vent caps should be inspected for signs of electrolyte leakages and should be cleaned where necessary.

6.3 The electrolyte level should be checked, and if any adjustments are necessary, these should be made after removing the battery from the aircraft and checking that it is in the fully charged condition. The amount of water added to the cells should be noted on the battery record card. A cell requiring more than the specified amount should be regarded as suspect, and the battery should be replaced by a serviceable unit. In aircraft having an independent charging unit, the unit should be switched on and the battery charged in accordance with the procedure specified in the relevant aircraft Maintenance Manual.

NOTE: When removed, the battery cover and cell vent caps should not be placed on any part of the aircraft structure or equipment.

6.4 The battery ventilation system should be checked to ensure security of connection, and freedom from obstruction.

7 Battery Records

A technical or service record should be maintained on each battery in service. Discretion may be exercised as to the layout of such a record and the extent of the details it should contain. It should, however, provide a fairly comprehensive history of the specific battery, so that in the event of a malfunction it will assist in establishing the fault. The example shown in Figure 1 is intended only as a guide.

8 Storage and Transportation

Nickel-cadmium batteries should be stored in a clean, dry, well-ventilated area and should be completely segregated from lead-acid batteries. The area should also be free from corrosive liquids or gases. It is recommended that they should be stored in the condition in which they are normally received from the manufacturer, i.e. filled with electrolyte, discharged and with shorting strips fitted across receptacle pins. Cell connecting strips and terminals should be given a coating of acid-free petroleum jelly (e.g. white vaseline).

8.1 The temperatures at which batteries may be stored are quoted in the relevant manuals, and reference should therefore be made to these. In general, a temperature of 20ºC is recommended for long-term storage.

8.2 If batteries are to be stored in a charged condition, they must be trickle charged periodically in order to balance the inherent self-discharge characteristic. Since this discharge is temperature sensitive, the trickle charge rate is therefore dependent on the storage temperature conditions.

8.3 If it is necessary to return a battery to the manufacturer or to an approved overhaul organisation, it should be discharged, but not drained of electrolyte. It should be packed in its original container, together with its service record (see Paragraph 7) and 'This Way Up' international signs affixed to the outside.

NOTE: If transportation is to be by air, the container must comply with IATA regulations concerning the carriage of batteries containing alkaline electrolyte.

NICKEL-CADMIUM BATTERY SERVICE RECORD

BATTERY AND AIRCRAFT DATA

Manufacturer ……………………Aircraft Type …………………………………

Part No ……………………………

Serial No …………………………..

Rating: Volts ……………Ah …….

Mod. State ………………………..

Registration …………… ……………………

Battery Function (e.g. Standby, APU Starting) ………………………………..

…………………………………………………..

Date Installed ………………………………..

Hours Flown …………………………………

SERVICING DATA

Date Removed …………………..

Date Serviced ……………………

Workshop Ambient Temp ………..

Reason for Removal ………………………

Servicing Instructions Used ………………

Date Released ………………………………

Operation	Results/Comments	Initials	
Details of operations performed and measurements required		Mech	Insp

CELL DATA

Position in Battery	Serial No	Water Added (c.c.)	Voltage	Temperature	Final Voltage	Capacity (Ah)
1						
2						
**						
19						
20						

MAIN TERMINAL VOLTAGE …………………………

I hereby certify that the inspection/overhaul/repair/replacement/modification specified above has been carried out in accordance with the requirements of Chapter A4-3 of British Civil Airworthiness Requirements.

Signed: ………………….

Firm ……………………..

CAA Approval Ref.
or Licence No. …………

Date …………………….

Figure 1

Leaflet 9-8 Use of Electrically Powered Medical Equipment on Aircraft

(Previously issued as AIL/0176)

1 Purpose

This Leaflet provides information and guidance concerning the methods and procedures required to achieve the acceptance for carriage and use of electrically powered medical equipment on board aircraft. This information does not represent the official European Aviation Safety Agency (EASA) policy. However, the information provided in this Leaflet has been used by the UK CAA and is considered to be useful guidance material for the evaluation of electrically powered medical equipment.

2 References

Commission Regulation (EC) No 1702/2003 Annex Part 21 – Certification of aircraft and related products, parts and appliances, and of design and production organisations

CS-23 – Certification Specification for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes

CS-25 – Certification Specification for Large Aeroplanes

CS-27 – Certification Specification for Small Rotorcraft

CS-29 – Certification Specification for Large Rotorcraft

CS-VLA – Certification Specification for Very Light Aeroplanes

CS-VLR – Certification Specification for Very Light Rotorcraft

EUROCAE ED-14, RTCA DO-160 [Applicable Version] – Environmental Conditions and Test Procedures for Airborne Equipment.

BS 2G 239 – Specification for Primary Active Lithium Batteries for use in aircraft

AIC 1/2004 (Pink 62) – Use of Portable Electronic Devices in Aircraft

3 Introduction

This Leaflet provides information and guidance concerning the approval of installations of electrically powered medical equipment and methods of gaining the acceptance to carry and use portable electrically powered medical equipment on board aircraft.

The procedures outlined cover the use of electrically powered medical equipment either installed as part of the cabin equipment or carried on board the aircraft as part of the aircraft emergency equipment.

4 Approval Considerations

An approval assessment will be necessary to demonstrate that the equipment, its installation, and operation will not adversely affect proper functioning of the aeroplane systems and equipment required for type certification or by the operating rules, or whose operation would reduce safety. In addition, it shall not affect the safety of the flight crew, cabin crew or other passengers. It should be noted that the UK CAA or EASA would not endorse any assessment of the functionality of the item of medical equipment.

The approval is therefore based upon a 'no hazard, no credit' assessment in that the equipment is assessed purely on the basis that it introduces no hazard to the aircraft or occupants, but that no credit is given to its functionality.

The procedure to be used for the approval or acceptance of the introduction of electrically powered medical equipment to the aircraft is that which is covered within European Commission Regulation No. 1702/2003 Annex Part 21 by a design change to the aircraft. This is accomplished by the introduction of a change to the aircraft's Type Certificate (TC) by the TC holder, or by the introduction of, or by a change to, a Supplemental Type Certificate (STC).

Equipment is therefore accepted for use on an aircraft using the requirements set out in Part 21 Subparts D or E.

5 No Hazard Aspects

The EASA Certification Specifications for aircraft are used to demonstrate compliance with the Basic Regulation (Regulation 1592/2002) and its implementing rules (Regulation 1702/2003). These include airworthiness codes, which are standard technical interpretations of the airworthiness essential requirements contained in Annex 1 to the Basic Regulation; and acceptable means of compliance, which are non-exclusive means of demonstrating compliance with airworthiness codes or implementing rules.

The Certification Specification for large aeroplanes requires that equipment and systems be designed and installed so that those equipment and systems that are 'required' for type certification or by the operating rules, or whose improper functioning would reduce safety, perform their intended function under all aeroplane operating and environmental conditions. In addition, it requires that all other equipment and systems, within which category electrically powered medical equipment would fall, are not a source of danger in themselves and do not adversely affect the proper functioning of the 'required' equipment, defined above. Similar requirements exist for other aircraft categories, within their respective Certification Specifications.

This requires that it is established by analysis and/or tests that the medical equipment will not present a hazard to the aircraft and its occupants under normal operation or under fault conditions.

The following provides a summary of many of the subjects pertinent to the safety of the aircraft, its occupants and maintenance personnel, which the electrically powered medical equipment manufacturer should consider and the equipment installer needs to address.

5.1 Equipment Evaluation

The installer's evaluation of the electrically powered medical equipment should consider hazards/issues such as flammability, smoke generation, explosion, EMC, magnetic interference, risk of electric shock, risk of burns, safety of cathode-ray tubes, aircraft depressurisation, fluid exposure, electrical bonding, gaseous concentrations, toxicity, battery issues, mechanical integrity etc.

Environmental conditions and test procedures normally specified for airborne equipment are defined in EUROCAE ED-14, RTCA DO-160 [Applicable Version]. This document should therefore be used as guidance material and where possible, compliance with this document should be shown, as applicable.

If items of equipment have previously been tested to an alternative standard, a comparison against the categories in EUROCAE ED-14, RTCA DO-160 [Applicable Version] can be made by the applicant.

Environmental qualification of an item of equipment to a set of categories in EUROCAE ED-14, RTCA DO-160 [Applicable Version] does not imply approval or acceptance for the use of the equipment in a particular aircraft environment. The equipment installer should satisfy himself that the declared equipment environmental standards are appropriate to the environments in the aircraft to which the equipment is to be fitted and operated.

5.1.1 Fire, Smoke, Fumes and Explosion

The risk of the equipment exploding, catching fire or producing noxious or toxic fumes, or smoke, should be reduced to a minimum. It should be noted that even small quantities of smoke can be alarming to passengers and could lead to irrational behaviour. Particular attention should be directed to the design and quality of wire wound components, motors and pressure vessels, so as to minimise the risk of over-heating. Consideration should also be given to the types of protective coatings used on components and assemblies.

It should be established that the stalling of any drive motor would not cause fumes, smoke or overheating.

Materials used in the equipment should meet the applicable fire test criteria defined in the CS equipment requirements or equivalent.

5.1.2 EMC

The levels of Radio Frequency (RF), electrical and magnetic emissions generated by the equipment should not cause an adverse effect to the performance of the required aircraft systems.

It should be demonstrated that the equipment complies with the relevant categories of EUROCAE ED-14, RTCA DO-160 [Applicable Version] or equivalent.

5.1.3 Electric Shock

The risk of electric shock should be reduced to a minimum. Particular attention should be directed to high voltage equipment and to cathode-ray tubes. Where there may be a hazard during maintenance or servicing, equipment operating with voltages above 50 V r.m.s. should be marked with the voltage or suitably placarded with high voltage warnings. Particular care should be taken with defibrillation equipment (Automatic External Defibrillator, etc.), which by its nature, is designed to provide a controlled electric shock to the casualty.

5.1.4 Burns

The risk of burns should be reduced to a minimum. Particular attention should be directed to lamp assemblies and the heatsinks of equipment packages. Hot surfaces should not be exposed where inadvertent contact may be a hazard.

5.1.5 Cathode-Ray Tubes

Equipment containing cathode-ray tubes should be so designed and installed that the risk of harmful exposure to X-rays and to injury as a result of implosion are reduced to a minimum.

5.1.6 Aircraft Depressurisation

Where high voltages are present within the equipment, it should be established that no arcing that would cause a fire risk or unacceptable levels of emission will occur within the equipment when it is subjected to an atmospheric pressure equivalent to the maximum operating altitude of the aircraft. Alternatively, means would have to be provided to automatically disconnect the electrical supply to or of the equipment when the cabin pressure reduces to a level beyond which the safe operation of the equipment is not assured. Particular attention should be paid to hermetically sealed enclosures that may be subjected to differential pressures.

5.1.7 Fluid Exposure

Where the equipment is mounted in a position where exposure to fluid is possible, it should be established that fluid spillage does not cause the equipment to become hazardous. The fluid susceptibility should be declared as part of the general environmental specification of the equipment. EUROCAE ED-14, RTCA DO-160 [Applicable Version] or equivalent would be applicable.

5.1.8 Electrical Bonding

The electrical bonding and protection against static discharge of the equipment should be such as to:

a) Prevent dangerous accumulation of electrostatic charge; and

b) Minimise the risk of electrical shock to crew, passengers and servicing personnel.

The equipment earthing arrangements should be adequate for the conduction of any current, including fault current, and be in accordance with the applicable aircraft standards.

Applicants should adhere to the relevant recommendations for bonding, grounding, shielding and other methods to eliminate and control Electrostatic Discharge (ESD).

5.1.9 Gaseous Equipment

Gaseous equipment should be evaluated in order to check for adequate safety devices such as pressure relief valves etc. Pipes and vessels should be tested to a safety margin of at least 2.5 Proof and 3.0 Ultimate times the normal working pressure. (See CS-25 Appendix K). The build up of gases within the aircraft, as a result of normal operation or equipment fault conditions, should be prevented.

5.1.10 Mechanical Integrity

Equipment, attachments and supporting/stowage structure should be constructed such that the equipment and constituent parts are retained when subjected to the following load factors:

a) Load factors for emergency alighting (Considered as Ultimate) as defined by paragraph 561 in CS codes 23 and 25 for Aeroplanes and 27 and 29 for Rotorcraft. (It should be noted that the load factors specified in CS 23.561 are particularly severe (applicable to Aeroplanes below 5700 kg)).

b) The Ultimate flight inertia factors for the aircraft type considered.

In principle the significant flight cases will be:

i) Vertical gust and Pitch manoeuvres resulting in vertical and drag inertia factors; and

ii) Lateral Gust, Yaw and Roll manoeuvres which result in combined Inertia Factors in the vertical, lateral and drag directions.

5.1.11 **Equipment Location**

The equipment should be located such that it does not present a hazard to evacuating the aircraft under emergency conditions.

5.1.12 **External Surfaces**

The external surface of the equipment should not present a hazard due to sharp corners and rough edges etc.

5.2 **Aircraft Evaluation**

Aircraft tests should be performed on the particular aircraft variant on which the item of medical equipment is to be used. The purpose of the tests is to ensure that the operation of the electrically powered medical equipment does not adversely affect the operation of the aircraft equipment and systems required for the type certification or by the operating rules, or whose improper functioning would reduce safety.

The electrically powered medical equipment should be operated at every likely location and attitude on the aircraft to determine if there is any particular area where the operation of the equipment should be prohibited. Copies of the relevant Test Schedules should be made available for review as required.

5.3 **Acceptance**

Providing that the outcome of the above evaluation and tests is satisfactory and that the requirements of the appropriate EASA CS and relevant subpart of Part 21 are demonstrably complied with, EASA will be requested to accept the use of the particular item of medical equipment on the aircraft subject to any conditions identified during the exercise and providing acceptable operational and maintenance procedures exist.

This acceptance will be for the evaluated and tested item, identified by equipment type, part number and serial number (or controlled standard), for use on the aircraft tested, identified by type.

The applicant will be required to assess the similarity of any aircraft within type, to that of the variant tested, before the use of the medical equipment on other aircraft could be accepted, noting that this may require a further submission to be made to EASA if the intended use is broader than the scope of the certificated design change, i.e. the aircraft identified within the Design Change (TC or STC) certificate.

6 Electrical Power

6.1 **Internally Supplied Power**

The item of medical equipment may be powered by any of the following types of battery:

a) Sealed Lead Acid type, but not including those with electrolyte in liquid form.

b) Sealed Alkaline type, but not including those with electrolyte in liquid form.

c) 'Dry' cell type batteries.

d) Lithium based batteries, provided that the requirements of CAAIP Leaflet 11-22, Appendix 24-6 and BS 2G 239 are complied with.

The charging or re-charging of the equipment batteries should not be permitted within the confines of the aircraft.

Adequate circuit protection should be incorporated to guard against hazardous charge and discharge rates.

The battery should preferably be installed in a container designed to prevent handling damage to the battery itself.

6.2 **Aircraft Supplied Power**

If the item of medical equipment is to use the aircraft's electrical power supply then appropriate steps should be taken to ensure that the safety and integrity of the aircraft electrical system is not compromised.

Adequate circuit protection should be used to protect the aircraft electrical system and the medical equipment power supply cables.

The installer should satisfy himself that the EUROCAE ED-14, RTCA DO-160 [Applicable Version] (or equivalent) categories chosen for the power supply input of the item of electrically powered medical equipment are compatible with those of the relevant aircraft supplies. Both normal and abnormal conditions should be considered.

Attention should be paid to the electrical loads imposed on the aircraft supplies. Provision should be made to allow the flight crew to shed or isolate the aircraft supply to the electrically powered medical equipment in abnormal or emergency conditions to limit the electrical load.

7 Design Change Classification

7.1 Changes in type design are classified as minor and major in accordance with Part 21A.91. Examples of how the change classification process might apply to the installation of electrically powered medical equipment are as follows:

a) The initial assessment conducted to demonstrate that the electrically powered medical equipment, its installation, and operation will not adversely affect proper functioning of the aircraft systems and equipment or occupants, as defined in paragraph 2 of this document, will include an equipment and aircraft level evaluation. The considerable extent of new substantiation data generated might result in this change being classified as Major. Major changes will be implemented in accordance with Part 21A.97. It could normally be expected that this be introduced using Part 21 Subpart E, STC process, although Part 21 Subpart D for the TC process would be equally appropriate.

b) The introduction of previously approved electrically powered medical equipment to new aircraft types would require the aircraft level evaluation and this would result in a considerable extent of new substantiation data generated that might also result in this change being classified as Major. It could normally be expected that this be introduced using Part 21 Subpart E, STC process, although Part 21 Subpart D for the TC process would be equally appropriate.

c) Changes or modifications to previously approved electrically powered medical equipment will be assessed in accordance with Part 21A.91. Changes that are classified Minor may be implemented by a Minor design change in accordance with Part 21A.95.

It should be noted that within paragraph c) above, the term “approved” refers to the aircraft level design change that introduces the electrically powered medical equipment to the aircraft. For changes to electrically powered medical equipment that had been issued with a UK CAA BCAR Safety Acceptance (SA) registration certificate by the UK CAA before 28 September 2003, advice should be sought from the UK CAA or EASA.

8 Operating Procedures and Publications

The appropriate members of the crew of the aircraft need to be fully conversant with the operation of the electrically powered medical equipment.

Procedures should be established and stated clearly to control the medical equipment. These should provide as a minimum the following:

a) Procedures to limit the operation of the equipment in certain flight phases (e.g. Take-off and Landing) or during abnormal or emergency conditions, if necessary.

b) Procedures to terminate the operation and/or electrically isolate the system at any time.

c) Procedures for Flight Deck to Cabin co-ordination to ensure all crew are aware of the use of the equipment at all times.

d) Procedures for reporting instances of suspected and confirmed interference with the aircraft systems and equipment.

9 Maintenance Provisions

General procedural instructions for equipment testing should be provided to prevent performance degradation that might become a source of hazard.

Maintenance procedures should be specified and observed, e.g. battery checks etc. The maintenance tasks should be included in the maintenance schedule of the aircraft as appropriate.

10 Equipment Performance

As previously stated, neither the CAA nor EASA will endorse any assessment of the functionality of the item of medical equipment.

The following points should however be noted with regards to the equipment performance:

a) The applicant should ensure by equipment and aircraft evaluation that the item of medical equipment would function as intended in the aircraft environment.

b) The applicant should ensure that the equipment itself operates satisfactorily when subjected to the electromagnetic environment that would typically be present on board the aircraft.

c) All maintenance should be carried out in accordance with the equipment manufacturers' instructions to ensure the continued build standard to prevent performance degradation that may affect the functionality of the equipment.

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Leaflet 9-9 Electrically Powered Aeroplane Passenger Seats

(Previously issued as AIL/0184)

1 Purpose

This Leaflet provides information and guidance for the approval of passenger seats with electrically powered actuators, which are designed to be installed on civil aeroplanes.

NOTE: This information does not represent official European Aviation Safety Agency (EASA) policy. However, the information presented in this Leaflet has been used by the CAA and is considered to be useful guidance material for the evaluation and approval of electrically powered seats.

2 References

Part 21 – Certification of aircraft and related products, parts and appliances, and of design and production organisations

AMC & GM – Acceptable Means of Compliance and Guidance Material for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations to Part 21

CS-23 – Normal, Utility, Aerobatic, and Commuter Category Aeroplanes

CS-25 – Large Aeroplanes

CS-ETSO – European Technical Standard Orders:

TSO/ETSO-C39b – Aircraft Seats and Berths

TSO/ETSO-C127a – Rotorcraft, Transport Aeroplane, and Normal and Utility Aeroplane Seating Systems

JAR-OPS 1 – Commercial Air Transportation (Aeroplanes)

JAA TGL Leaflet No 17 – Passenger Service and In-Flight Entertainment (IFE) Systems

JAA TGM/25/10 – Temporary Guidance Material regarding the Installation of In-Seat Power Supply Systems (ISPSS) for Portable Electronic Devices (PED)

ARINC 628 Part 1&2 – 'Cabin Equipment Interfaces' dated Dec 27 1993

EUROCAE ED-14E, (RTCA DO-160E) – 'Environmental Conditions and Test Procedures for Airborne Equipment'

EUROCAE ED-12B, (RTCA DO-178B) – 'Software considerations in Airborne Systems & Equipment Certification'

RTCA document DO-199 – 'Potential interference to aircraft electronic equipment from devices carried aboard' dated Sept 16th, 1988

FAA AC 21-25A – Approval of Modified Seating Systems Initially Approved Under a Technical Standard Order

3 Introduction

Passenger seats, particularly those in First and Business Class environments, are becoming increasingly complex. In addition to being fitted with Cabin Service and In-Flight Entertainment (IFE) Systems, they may contain a number of electrical actuators and associated control systems to provide such features as powered recline and conversion into beds. Presented in this Leaflet are general criteria for the approval, modification and continued airworthiness of such seats installed in aeroplanes. Although specifically written to address seats with electrical power, many aspects of this Leaflet are applicable to seats that are manually operated. This Leaflet is not applicable to Cabin Service and IFE Systems for which guidance is available in JAA TGL Leaflet No. 17; nor is it applicable to In-Seat Power Supply Systems for which guidance is available in JAA TGM/25/10.

4 Approval Consideration

All seats will need to be approved in accordance with Part 21 Subpart K (Parts and Appliances), in conjunction with the Type Certification procedures of Part 21 Subpart B, D, or E, or alternatively approval may be granted by a European Technical Standard Order Authorisation (ETSO) if the applicant meets the requirements of Part 21 Subpart O. When the equipment has been approved by the CAA, an acceptable installation will be required to be demonstrated by the installer showing that it is in accordance with appropriate Certification Specifications and that proper account has been taken of the equipment manufacturer's Declaration of Design and Performance and installation instructions. Part 21 Subpart O gives guidance for the preparation and format of the Declaration of Design and Performance. Specific guidance on the information to be included in a DDP for an electrically powered passenger seat is included in Section 4.2 of this Leaflet.

It should be noted that the current ETSO C39b and ETSO C127a do not contain electrical requirements. Therefore, for seats that contain electrical in-seat equipment, an ETSO approval alone would not be sufficient to demonstrate suitability for installation on an aeroplane. The electrical aspects of the seat also need to be addressed.

4.1 Applicable Requirements

The following list is for guidance purposes only and is not exhaustive, the applicable airworthiness requirements will depend on the aeroplane in which the passenger seat is to be installed. Where CS 25 has been referenced similar requirements can be generally read across to CS 23.

- JAR-OPS 1.320 Seats, safety belts and harnesses
- JAR-OPS 1.825 Life Jackets
- JAR-OPS 1 Subpart M Aeroplane Maintenance
- CS 25.561 General (Emergency Landing Conditions)
- CS 25.562 Emergency Landing Dynamic Conditions
- CS 25.785 Seats, berths, safety belts and harnesses
- CS 25.787 Stowage compartments
- CS 25.789 Retention of items of mass in passenger and crew compartments and galleys

- CS 25.815 Width of aisle
- CS 25.817 Maximum number of seats abreast
- CS 25.853 Compartment interiors
- CS 25.869 Fire protection: systems
- CS 25.899 Electrical bonding and protection against lightning and static electricity
- CS 25.1301 Function and installation
- CS 25.1309 Equipment, systems and installations
- CS 25.1351 General (Electrical Systems and Equipment)
- CS 25.1353 Electrical equipment and installation
- CS 25.1357 Circuit protective devices
- CS 25.1360 Precaution against injury
- CS 25.1411 General (Safety Equipment)
- CS 25.1431 Electronic Equipment
- CS 25.1501 General (Operating limitations and information)
- CS 25.1529 Instructions for Continued Airworthiness
- CS 25.1541 General (Markings and placards)
- CS 25 Appendix F (Flammability)
- CS 25 Appendix H Instructions for Continued Airworthiness
- CAP 747 Generic Requirement GR No. 2 Minimum Space for Seated Passengers
- CAP 747 Generic Requirement GR No. 3 Access to and Opening of Type III and Type IV Emergency Exits

4.2 **Declaration of Design and Performance (DDP)**

A DDP will need to be produced in accordance with the requirements of Part 21. It is essential to include compliance references to both mechanical and electrical requirements and state limitations and responsibilities. A summary of the key requirements that the DDP will need to address is produced below.

4.2.1 **Electrical**

The DDP will need to define the in-seat electrical equipment by reference to applicable drawings, system analysis and design specifications. The drawings, analysis and specifications should include information such as performance data, dimensions and weight, wiring and connector types, installation methods and wiring routes, seat electrical load, and seat functional hazard analysis.

Electrical equipment and wiring used will need to demonstrate compliance to the applicable airworthiness requirements and their amendments. This may be achieved by making references to test or substantiation reports. Any known operation limitations such as restrictions in mounting attitude or cooling requirements of electronics units and motors will need to be declared.

If the in-seat equipment is not approved as part of the seat, the responsibilities of the seat manufacturer and the in-seat equipment manufacturer will need to be clearly defined in the seat DDP, e.g. the seat manufacturer may be responsible for installation of the in-seat wiring harness and providing suitable mounting provisions (including aspects such as cooling and attachment strength) for the in-seat IFE equipment.

Consideration should be given to the possibility of electrical faults and the method used to isolate an electrical fault. If applicable, consideration should be given to the provision of a facility to isolate an individual seat or a seat row. Such a facility will enable cabin crew to isolate faults locally rather than having to disable other 'healthy' seats. In the event of an emergency, only the faulty seats would require the attention of the cabin crew thereby reducing the emergency drill time.

If the seat control functions are to be integrated into other systems, e.g. IFE system, that are not the responsibility of the seat manufacturer, and are not approved as part of the seat, then the interface requirements between the seat and the seat control functions have to be clearly defined. The seat DDP should also define the limitations and responsibilities of the seat manufacturer and the organisation that designs and manufactures the seat control functions, as well as references to the evidence that demonstrates adequate interface control. An Electrical Interface Control Document (Electrical ICD) should be supplied by both the seat manufacturer and also the supplier of the seat controls (if different), which clearly defines the electrical control aspects of the seat.

A DDP shall declare the flammability characteristics of the electrical items and their performance in various environmental conditions. As with any items installed in aircraft, in-seat electrical items are required to comply with the applicable flammability requirements such as CS 25.853 for large aeroplanes and in addition, to demonstrate acceptable environmental performance. An acceptable means of showing compliance would be to provide compliance statements against EUROCAE ED-14 (RTCA DO-160), 'Environmental Conditions and Test Procedures for Airborne Equipment', Section 4 to Section 25 (inclusive). These statements should include the applicable equipment categories, test levels and test results as defined in the EUROCAE ED-14.

NOTE: New equipment should always be assessed against the latest issue of EUROCAE ED-14.

If applicable, a statement of criticality of software as defined in the latest issue of EUROCAE ED-12 (RTCA DO-178) is required. Any compliance statement will need to be stated with references to test or substantiation reports.

4.2.2 Mechanical override

To aid cabin crew operation, consideration should be given to design features such as a mechanical override mechanism and visible indication for TTL (Taxi, Take-off and Landing) position. The operation of a seat override mechanism should be intuitive and allow the seat to be restored to the TTL position. This should be achievable by the occupant without assistance and with minimal instructions. No special training should be required. Some form of indication (e.g. visible mechanical tab or electrical indication light) to verify that the seat is in a TTL position would provide useful information to the cabin crew. The indication should be clearly visible from the aisle and should provide a definite indication to the cabin crew that the seat is in a TTL position.

5 Installation

It is the Design Organisation that is installing the seat on the aeroplane that is responsible for ensuring that all the declared limitations are complied with. Installation details for the seat should identify fault isolation characteristics and how this relates to the aircraft installation. This may include facilities for isolating an individual seat, group of seats and all seats. Consideration should be given to the effects of fault isolation with respect to cabin crew operating procedures. If the aircraft installation includes a control switch in the flight deck, the flight crew operating procedures should also be considered.

6 Identification and Documentation

Equipment which has been shown to meet the approval requirements of Section 4 has to be so identified. The labelling should be in accordance with the specification of the approval obtained.

A Component Maintenance Manual (CMM) will need to be provided when application for approval is requested. It should provide adequate instructions and information to ensure that the correct replacement equipment and parts are used, and that any maintenance necessary to ensure continued compliance with the safety standards is performed at appropriate intervals.

Adequate documentation should be provided to establish the responsibilities of the seat manufacturer, the in-seat system equipment manufacturer and the seat control equipment manufacturer (if the seat manufacturer is not responsible). The seat manufacturer will need to declare in the seat release documentation that the introduction of the in-seat equipment will not invalidate the seat approval. If applicable, the electrical interface control documentation for the seat and the seat control functions should be provided.

A Functional Hazard Analysis (FHA) should be carried out to identify possible failure modes of any installed electrical apparatus, including required safety objectives. As well as effects on the aeroplane and its system, the analysis should also consider effects on passengers if un-commanded seat movements occur. This information will assist in the preparation of operational procedures for effective fault isolation and to restore an electrically isolated / faulty seat to the TTL position.

7 Operational Procedures

The crew of the aircraft need to be fully conversant with the operation of the seat. Procedures detailing the means by which the seat's electrical system can be shut down and/or electrically isolated will need to be provided to the crew.

Consideration should be given to the need to restore an electrically isolated seat to the TTL position. If a large number of electrically operated seats are installed in the aeroplane, this may require the development of cabin crew procedures to instruct passengers in the use of the manual override in the event of an electrical fault and/or loss of power to the seat. This procedure may be needed in an emergency where there may not be sufficient cabin crew to complete the task in the time given.

7.1 Crew Information

Procedures should be established and stated clearly to ensure that the seat can be correctly configured for taxi, take-off and landing; and electrically isolated if a fault develops. The following procedures should be provided as a minimum:

a) Procedure for normal operation of the seat and restrictions on use, e.g. restrictions depending on phase of flight.

b) Procedure for abnormal operation of the seat in the event of partial or total loss of electrical power, using manual overrides.

c) Procedures to remove electrical power from the seat at any time. If electrical control or indication is provided in the flight deck, the Flight Manual will need to be amended. If the control is via cabin switch(es) only, Operations Manual / Cabin Crew operating procedures should include procedures for cockpit-cabin co-ordination.

d) Where appropriate, oral departure briefings to be given to instruct passengers. Briefings need to be composed to avoid passenger confusion.

7.2 Passenger Information

7.2.1 A comprehensive set of instructions on the operation of the seat needs to be available to passengers. These instructions should contain:

a) Warnings.

b) Limitations and restrictions.

c) Normal operating procedures and advice.

d) Emergency operating procedures, i.e. crash or evacuation.

7.2.2 Instructions should be presented in a clear and unambiguous manner. Printed material may be appropriately furnished in the form of a dedicated:

a) Hand-held card.

b) Placard.

c) Engraving.

d) Booklet.

8 Maintenance Provisions

Maintenance checks should be scheduled where in-seat system degradation may be a source of hazard, especially hazards such as explosion, fire, fumes and smoke. The extent of maintenance tasks required will depend on the extent of monitoring built into the system or equipment.

General procedural instructions for in-seat system testing should be provided.

Maintenance procedures will need to be specified and observed. Consideration should be given to inspection of seat wiring harnesses that may be vulnerable to damage induced by passengers and cabin configuration changes, seat equipment checks, fixtures and fittings.

9 Modifications (Electrical) to Approved Seats

9.1 Modifications (Electrical) as proposed by the Original Design Organisation

Minor modifications that do not affect previously approved airworthiness data may be accepted without investigation provided they are carried out under the auspices of the seat manufacturer’s design approval. They would normally be sanctioned by the issue of a Service Bulletin.

Major modifications need to be approved by an organisation with an appropriate design approval to Part 21 Subpart J.

Any in-seat equipment changes should be assessed and demonstrated to maintain compliance with the applicable airworthiness requirements. For in-seat equipment that is not the responsibility of the seat manufacturer, e.g. IFE equipment, the seat manufacturer will need to demonstrate that the provision made for such in-seat equipment is still applicable to the new equipment. Particular attention should be paid to equipment cooling requirements, in-seat wiring and connector rating etc.

Where seat control functions are integrated into other systems, e.g. IFE, it is the seat manufacturer's responsibility to ensure that any changes to that system do not affect the safe operation of the seat and compliance with the applicable airworthiness requirements is maintained.

9.2 **Modifications (Electrical) as performed by a Design Organisation other than the Original Design Organisation**

Seats that are modified by other approved organisations may invalidate the ETSO seat approval. Such modified seats may be approved for use on an aeroplane under a major modification. However, the modified seats can no longer claim to be ETSO approved. Re-approval (ETSO) of such seats can only be achieved under the auspices of the seat manufacturer's design approval.

For modification to the in-seat equipment that is not the responsibility of the seat manufacturer, e.g. IFE equipment, the seat manufacturer should be consulted to ensure that the provision made for such in-seat equipment is still adequate for the new equipment. If the seat provision can be demonstrated to be applicable to the new equipment, the seat approval may be maintained.

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Leaflet 9-10 Aircraft Security, Flight Crew Compartment Monitoring Systems

(Previously issued as AIL/0191)

1 Purpose

This Leaflet provides guidance for approval where cabin mounted video cameras in conjunction with flight deck displays are used.

NOTE: This Leaflet does not cover the Performance and Operational aspects of the monitoring systems. The CAA Flight Operations Department will address these aspects by installation appraisal and via a 'Special Communication'.

2 References

The following list is for guidance purposes only. The applicable requirements will depend upon the aircraft in which monitoring systems are to be installed. Although EASA CS-25 has been referenced for large public transport aircraft similar requirements can be read across to EASA CS-23 for smaller aircraft.

CS 25.561 – Emergency Landing Conditions – General

CS 25.773 – Pilot compartment view

CS 25.777 – Cockpit controls

CS 25.785 – Seats, berths, safety belts and harnesses

CS 25.789 – Retention of items of mass in passenger and crew compartments and galleys

CS 25.803 – Emergency Evacuation

CS 25.853 – Compartment Interiors

CS 25.869 – Fire Protection Systems

CS 25.1301 – Function and installation

CS 25.1309 – Equipment, systems and installations

CS 25.1333 – Instrument systems

CS 25.1351 – General

CS 25.1353 – Electrical equipment and installations

CS 25.1357 – Circuit protective devices

CS 25.1360 – Precaution against injury

CS 25.1523 – Minimum flight crew

CS 25.1529 – Instructions for Continued Airworthiness

CS 25.1555 – Control markings

TGM/21/07 – Electrical Wiring Policy

3 Introduction

3.1 ICAO Annex 6 Chapter 13 now includes a requirement such that appropriate means shall be provided for monitoring from either pilot's station the area outside the flight crew compartment so as to identify persons requesting entry and to detect suspicious behaviour or potential threat.

3.2 This Leaflet provides a summary of policy and advisory material that should be applied when certifying the installation aspects of monitoring systems with flight deck display on aircraft. This policy has been derived from FAA policy as stated in FAA memorandum 01-111-196 dated October 5 2001.

3.3 Monitoring systems equipment is to be qualified approved as part of the overall modification to the aircraft in which it is to be installed.

4 Electrical Installation Considerations

The key aspects for the installation are as follows:

a) In accordance with CS 25.1301, the monitoring system should be of a kind and design appropriate to its intended function, and should function properly when installed. The key words to understand the intent of this regulation are "appropriate" and "properly", as they relate to airworthiness. To be "appropriate" means that the equipment is used in a manner for which it was designed. To function "properly" means that the monitoring system should not interfere with the ability of the aeroplane and flight crew to continue safe flight, landing, and egress.

b) The monitoring system components and wiring should meet the flammability requirements of CS 25.853 and 25.869.

c) Monitoring system wire should be installed in accordance with the wiring standards established by the original aeroplane manufacturer and in accordance with the JAA/EASA Guidance Material TGM/21/07.

d) An electrical load analysis, based on the most recent electrical load configuration for the aeroplane should be accomplished in accordance with CS 25.1351(a).

e) Monitoring system wiring should be protected by appropriately rated circuit breakers in accordance with CS 25.1357.

f) System separation should not be compromised by the installation of the monitoring system (reference CS 25.1353(a)).

g) Required instrument systems should not be compromised by the installation of the monitoring system (reference CS 25.1333(c)).

h) Laboratory, ground and flight testing for electromagnetic interference should be accomplished, as appropriate.

i) The monitoring system should be connected to an electrical bus that **does not** supply power to aeroplane systems that are necessary for continued safe flight and landing. System designers should be encouraged to select lower level electrical buses (e.g. utility, galley, ground service bus, etc.).

j) A means should be provided for the flight crew to manually disconnect the monitoring system from its source of power. The removal of power should occur as close to the bus supplying power as possible. The disabling/deactivating of component outputs is not considered an acceptable means to remove power (i.e., disabling/deactivating the output as opposed to removing input power to the system).

NOTE: The ability to remove monitoring system power should not be provided outside of the flight deck (i.e., no control of the monitoring system within the passenger cabin).

k) Reliance on pulling system circuit breakers (CBs) as the sole means to remove monitoring system power is not acceptable. The use of a CB as a switch will degrade the CB's ability to trip at its rated current trip point.

l) The design and installation of the monitoring system should be such that impact upon operational procedures is minimised. However, the Aeroplane Flight Manual (AFM) must address any changes to normal, abnormal, and emergency procedures that are due to the installation of the monitoring system.

m) CS 25.1529, Instructions for Continued Airworthiness, and any information and instructions to be contained in the MMEL should be addressed.

5 Construction and Attachment Strength Considerations

Monitoring equipment, attachments and supporting structure should be constructed such that the constituent parts do not break loose when subjected to the loads (both flight and emergency alighting) prescribed in the appropriate sections of the Certification Specifications. Commercial equipment may not comply with these requirements and may need to be strengthened before being installed in an aircraft.

The monitoring equipment has, as far as is practicable, to be so positioned that, if it should break loose, it will be unlikely to cause injury or nullify escape facilities provided for use after an emergency landing or alighting on water. When such positioning is not practicable each such item of equipment shall be restrained under all loads up to the prescribed ultimate inertia forces for the flight and emergency landing conditions.

NOTE 1: The structural requirements applicable to equipment can vary dependent upon the type and size of the aircraft in which it is to be installed. If the equipment is designed to be installed in any aircraft then all the relevant airworthiness codes will need to be consulted and an envelope of conditions determined for design purposes.

NOTE 2: The installer will need to consult the original aeroplane manufacturer to obtain data on the vertical acceleration factors (resulting from gusts and aircraft manoeuvres) applicable to the aircraft type and the proposed equipment location.

6 Flight Deck Human Factors Issues Associated with Installation of Monitoring System (To Allow Viewing of Cabin by Flight Crew)

The primary issue is to ensure that installation does not compromise usability of existing systems. The use of the monitoring system, in accordance with the proposed operating procedures, should not result in pilot distraction or workload that may unacceptably compromise pilot performance of other required tasks. If the system provides audio in addition to video, that audio should not interfere with required pilot communication, nor should it interfere with the detection and identification of aural alerts. The monitoring system should be de-activated during take-off, approach and landing conditions.

There are two categories of installations to be considered:

a) **Standalone**

The first category is a separate video display that is not integrated with existing approved, essential flight deck display systems. This category also includes installations that use the video display unit associated with other non-required, non-safety-related displays (e.g. maintenance displays).

Issues associated with standalone installations: These issues result from the installation of new controls and displays in the flight deck.

i) Ensure that the video display unit does not produce unacceptable glare or reflections on the existing essential/critical displays or on the flight deck windows, under all expected lighting conditions. See also CS 25.773(a)(2);

ii) Ensure that the installation does not place the controls for the camera system in locations that may result in inadvertent operation of other controls (i.e. when the pilot reaches for the camera control it is likely that some other control may be "bumped" and repositioned). See also CS 25.777(a);

iii) Since this system is likely to be needed a number of times during a flight, ensure that the pilots can operate/view any controls and displays (that are to be used in flight) from their normally seated positions. See also CS 25.785(g);

iv) Ensure that any cockpit mounted video display unit would not hinder crew emergency escape provisions. See also CS 25.803.

b) **Integrated**

Systems in which the video from the cabin camera is routed to existing approved, essential/critical displays (e.g. main panel multifunction displays, Flight Management System (FMS) control/display units) and/or the audio system.

Issues associated with integrated installations: In such installations, it is expected that the issues above will be less significant (even though they are applicable), because such an installation is likely to use previously approved controls and/or displays. In addition, the following issues should be considered:

i) The camera system and its use should not interfere with the intended function and use of other essential/critical functions with which it shares displays and/or controls (e.g. viewing the video from the camera should not prevent or unacceptably interfere with the display of other required information, such as flight or navigation data). See also CS 25.1301(a);

ii) Integration of the camera system controls and displays should not result in confusion in the labelling or operation of other required systems (e.g. the nomenclature of control functions should not be similar to existing nomenclature to the extent that confusion could result). See also CS 25.777(a), CS 25.1555(a).

7 Further Information

For Airworthiness Certification aspects further information may be obtained from:

Engineering Department
Safety Regulation Group
Aviation House
Gatwick Airport South
West Sussex
RH6 0YR
Tel: +44 (0)1293 573134

Leaflet 9-11 Protection from the Effects of HIRF (High Intensity Radiated Fields) Aircraft Modifications

(Previously issued as AIL/0192)

1 Purpose

This Leaflet provides information on the issues to be considered when reviewing the HIRF requirement aspects of aircraft modifications.

NOTE: This information does not represent official European Aviation Safety Agency (EASA) policy. However, the information presented is the policy adopted by the CAA and JAA Certification Standardisation Panel. The EASA policy will supersede this Leaflet when available.

2 References

AC/AMJ 20.1317 – Final Draft Issue (EEHWG Document WG327 dated November 98)

EUROCAE ED107/SAE ARP 5583 – HIRF Users Guide – March 2001

EUROCAE ED-14D (RTCA DO-160D) – Environmental Conditions and Test Procedures for Airborne Equipment

EUROCAE ED-90A – Radio Frequency Susceptibility Test Procedures - Users Guide to ED-14D Change 1 Section 20

NOTE: Although current versions of the above guidance and advisory material are quoted, the latest version of the above documents should always be applied where applicable.

3 Introduction

The current JAA/EASA HIRF Interim Policies are listed below:

INT/POL/25/2	Issue 2
INT/POL/27, 29/1	Issue 3 Draft
INT/POL/23/1	Issue 1

The threat levels and applicability dates for each of the above are varied but generally aircraft have been required to comply with HIRF requirements since early 1992.

Aircraft have therefore been certificated to various HIRF standards, which range from no requirement through to the current policies and standards.

JAR21.101 (a)/Part 21.A101 (a) requires that an applicant for a change to a Type Certificate (Changed Product Rule, CPR) must show that the changed product complies with the applicable airworthiness requirements that are in effect at the date of the application, unless the applicant can demonstrate that certain exemptions exist, 21.101 (b)/21.A101 (b).

The basic concern for better identification and protection from High Intensity Radiated Fields arose for the following reasons:

a) Operation of modern aeroplanes is increasingly dependent upon electrical/ electronic systems, which can be susceptible to electromagnetic interference.

b) The increasing use of non-metallic materials like carbon or glass fibre in the construction of the aeroplane reduces their basic shielding capability against the effects of radiation from external emitters.

c) Emitters are increasing in number and in power. They include ground-based systems (military systems, communication, television, radio, radars and satellite uplink transmitters) as well as emitters on ships or other aircraft.

Changes/modifications to equipment and systems that could be susceptible to the effects of HIRF are not specifically mentioned in 21.101/21.A101; however, such changes could contribute materially to the level of safety. These changes should therefore be considered as 'HIRF significant' in the first instance.

Modifications (STCs and Amended STCs) to aircraft should therefore be assessed for the effects that could be caused by exposure to HIRF, irrespective of the original certification basis.

This document therefore provides advice on the certification activities to be undertaken in this respect for modifications to aircraft for the various original aircraft HIRF certification standards.

NOTE: The approach is scaled dependent on the functional criticality levels (safety levels) determined in the Aircraft/System Hazard Assessment.

4 Advice

CAUTION

In addition to the certification activities that are described below, all modifications should, irrespective of their functional failure classification, be assessed for their effect and impact on existing installed system functions throughout the aircraft. There should be no adverse effect (introduced by wiring installation changes for example) on existing system functions as a result of the modification.

4.1 Aircraft certificated to the latest/current HIRF Policies

Modifications that involve electrical or electronic equipment changes should be assessed for full compliance with the latest HIRF Interim Policy to the level appropriate to the system functional criticality.

4.2 Aircraft certificated to an earlier/intermediate HIRF Policy

Following the original introduction of the JAR HIRF Policies (JAR 25 1992, JAR 27/29 1997) there have been iterations of the associated field strengths and test criteria. Aircraft were certificated to different standards deemed to be current at the time of aircraft certification. The actual values used were recorded in Certification Review Items (CRIs), which formed part of the aircraft certification basis. The field strengths used for the various frequency ranges could therefore be higher or lower than current values, dependent on the frequency band.

For aircraft certificated in this period, any future modifications that involve electrical or electronic equipment changes should be assessed for compliance with the HIRF requirements appropriate to the system function criticality level. The field strengths and test criteria to be used can either be based on the original standard at the time of certification or the latest standards, depending on the available equipment or aircraft test data available.

4.3 Aircraft certificated prior to the introduction of the HIRF Policy

As stated above, the HIRF requirements/policies were first introduced in 1992 to address concerns associated with the increasing use of electrical/electronic systems, non-metallic structures and the proliferation of RF transmitters.

When considering modifications to aircraft certificated prior to the introduction of the HIRF requirements the concerns regarding the use of electrical/electronic systems and the proliferation of RF transmitters are still valid if the modification involves changes to electrical or electronic equipment.

Therefore, modifications on this standard of aircraft that involve changes to electrical or electronic equipment should still address the issue of HIRF.

The consideration of HIRF should primarily focus on system functions, the failure of which would prevent the continued safe flight and landing of the aircraft. Consideration should also be given to those system functions the failure of which would cause large reductions in the capability of the aircraft or the ability of the crew to cope with adverse operating conditions. This will require an assessment of the criticality of the functions of the modified/changed equipment.

Compliance with HIRF requirements typically involves aircraft tests, equipment tests, analogy or similarity or any combination. As part of the normal equipment qualification process the equipment may have been tested to levels commensurate with the intended environment, i.e. the equipment would have been assessed as ‘fit for its intended environment’. It is therefore possible that compliance with the HIRF requirements could be demonstrated by a review and analysis of the equipment and/or aircraft test data, without further equipment or aircraft testing.

Note that changes to Control Systems, the failure of which would prevent the safe flight and landing, require compliance to be based on actual aircraft testing or by similarity to other comparable aircraft tests.

5 Additional Points

The certification requirements for the HIRF aspects of any modification should be discussed with the Civil Aviation Authority at an early stage.

The acceptance of a modification from an applicant is predicated on the availability of the necessary original aircraft and equipment design data on which to base the HIRF assessment.

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Leaflet 9-12 Lightning Strike Hazards on Light Aeroplanes and Gliders

(Previously issued as AIL/0014)

1 Purpose

The purpose of this Leaflet is to provide technical information that may be useful when considering lightning protection for light aeroplanes. The information contained in this Leaflet is based on CAA (UK) experience with light aeroplanes. The implementation of this Leaflet alone may not be sufficient to meet the applicable lightning requirements. The users of this Leaflet are advised to identify the applicable lightning requirements and the acceptable means of compliance for the aeroplanes in consideration. Enquiries should be directed to the responsible Airworthiness Authority.

2 Introduction

The information given in this Leaflet outlines the problems which may be encountered on aeroplanes fitted with metallic or non-metallic tip tanks or other external non-metallic components and gives information on methods of reducing their vulnerability to lightning strikes.

Further information or assistance can be obtained from:

Engineering Department
Safety Regulation Group
Civil Aviation Authority
Aviation House
Floor 2E
Gatwick Airport South
Gatwick
West Sussex
RH6 OYR

3 Lightning - What Is It?

In order to appreciate the problems of lightning strikes it is felt that a short description of the differences between static electrical charging and lightning associated with aircraft would be useful. Basically they fall into three categories:

a) Precipitation Static is the build up of charging on the aircraft by its passage through charged particles in the air. It is unlikely to cause damage to the aircraft but does interfere with radio, especially HF and ADF frequencies, and can cause serious navigation and communication problems. It can be attenuated by fitting static dischargers on the aircraft wing tips and empennage.

b) St. Elmo's Fire is the visible corona of static discharge when passing through densely charged conditions, and is a very clear indication that the local areas are intensely charged and lightning may occur.

c) Lightning Strikes. Natural lightning flashes usually originate from charge centres in a cloud. The positive and negative charges in clouds are produced by complex processes of freezing and melting and by movements of raindrops and ice crystals involving collisions and splintering. The strong electric fields can initiate discharges, called lightning flashes, which may be of three types, namely:

i) Flashes between regions of opposite polarity within a cloud (intra cloud discharges),

ii) Flashes between regions of opposite polarity in different clouds (inter cloud charges), and

iii) Flashes from clouds to ground and from ground to clouds of either polarity. Ground to cloud flashes, however, become only relevant to taller objects, e.g. towers and mountains.

A lightning strike to an aircraft will either be triggered (i.e. initiated) by the presence of the aircraft in a strong electric field and will originate at the aircraft, or will occur as a result of encounter with a naturally occurring discharge path. The result of a lightning strike is voltages and currents of an extremely high order passing through the aircraft structure which are capable of damaging component assemblies or destroying wiring and equipment if not adequately protected. System operational upsetting may also occur.

4 Lightning Protection

When an aeroplane is struck the discharge will most probably enter and leave by the wing tips, nose or empennage and it is therefore these components that require special protection. All should be adequately bonded to each other through the aircraft's metallic structure or, in the case of non-metallic aircraft, by bonding links throughout the complete structure.

Wing and empennage tips (see Figure 1) can be protected by fitting copper straps either solid or a woven sheath of at least an equivalent to 1" x 26 SWG cross sectional area attached to the component to form a complete cage, and bonded to the structure at the nearest joint. However this is not always practical on existing parts and as an alternative metallic foil tapes can be glued on the exterior, but again should be bonded to the airframe, and routine inspections should be carried out to check against damage by erosion. It should also be noted that should the tape be struck it will burn away probably without damage to the airframe.

Wing tip fuel tanks made from non-metallic materials (see Figures 2, 4 and 5) should be given special attention and only external bonding may be used. This may be similar to that used on wing tips but in addition it is vital to ensure that the navigation lamp plus its earth return cable and associated duct is bonded to the airframe as near the wing tip as possible. Where the tanks are of all metal construction (see Figure 3) it is necessary to ensure that the nose and tail are not less than 0.080" thick in order to reduce the danger of being punctured by the lightning strike. The safest tank design is one with an air space at either end thus eliminating any fuel vapours from the most dangerous areas.

Where loss of or damage to a non-metallic nose cone can hazard the aeroplane it can be protected by a suitable cage (see Figure 6) in the shape of a cruciform fitted either inside or outside and made from similar materials as the wing tip protection. If radar is fitted (see Figure 7) fingers should be brought as far forward as possible without affecting the radar efficiency.

5 Gliders

Attention should be given to these aircraft, especially those of non-metallic structure, and bonding straps should be installed between the extremities to conduct any strike away from the flying controls. A point to remember is that bonding should be run as straight as possible avoiding loops formed by excess lengths at, for example, transport joints, since a lightning strike will jump across any sharp loops or bends.

6 Illustrations

The illustrations shown in this section are for information only and do not represent every aeroplane or their variants or the type of bonding that may be used.

LIGHTNING PROTECTION ILLUSTRATIONS

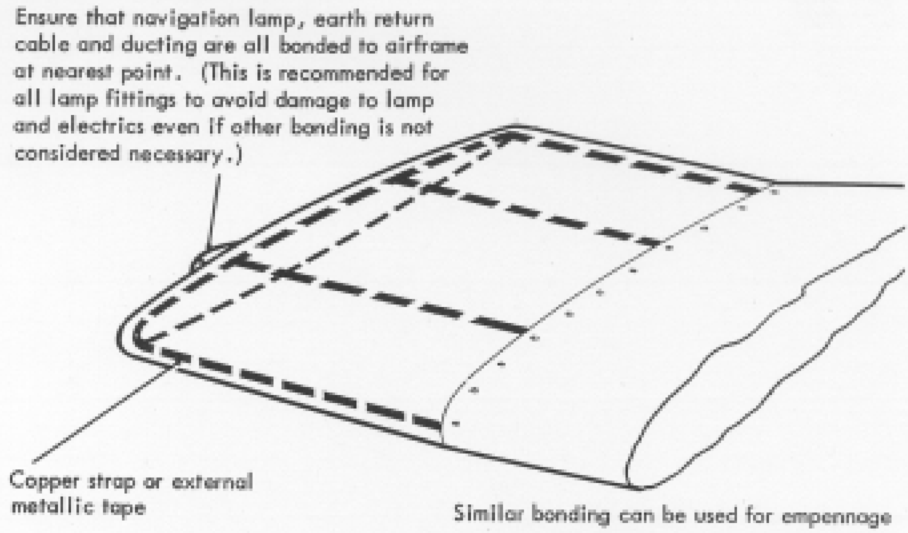

Figure 1 WING TIP (NON-METALLIC)

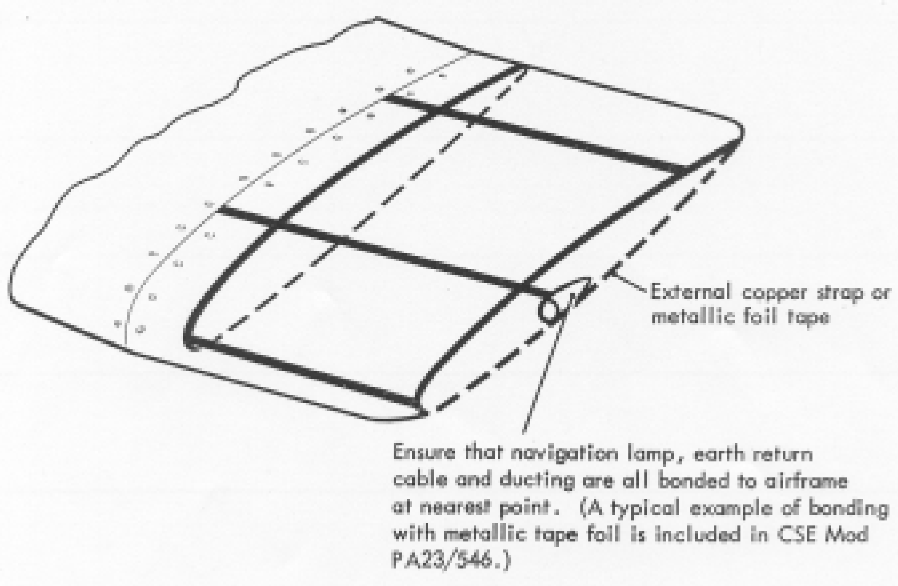

Figure 2 WING TIP TANK (NON-METALLIC)

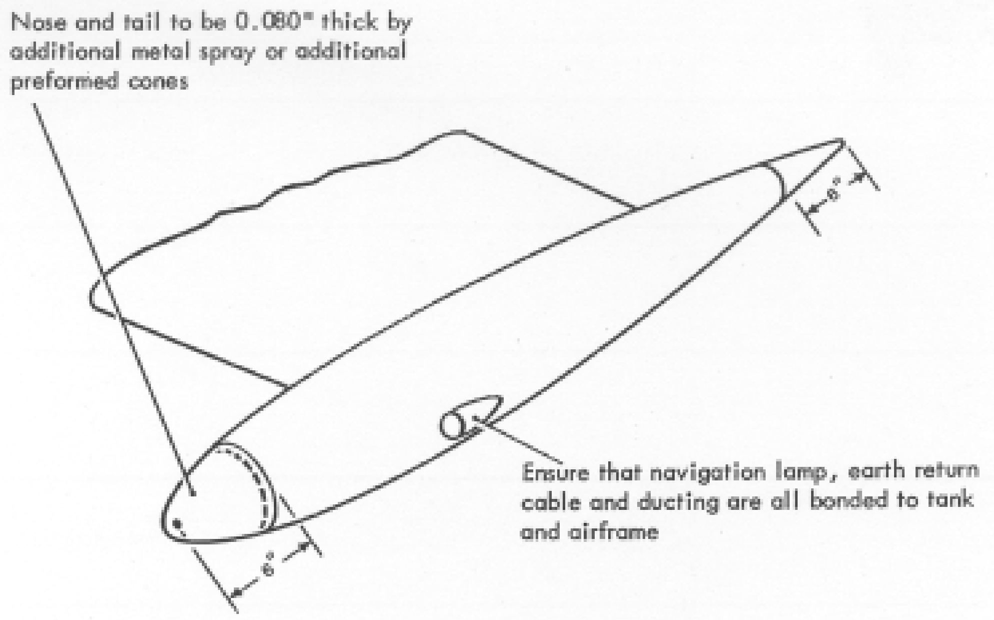

Figure 3 WING TIP TANK (ALL METAL)

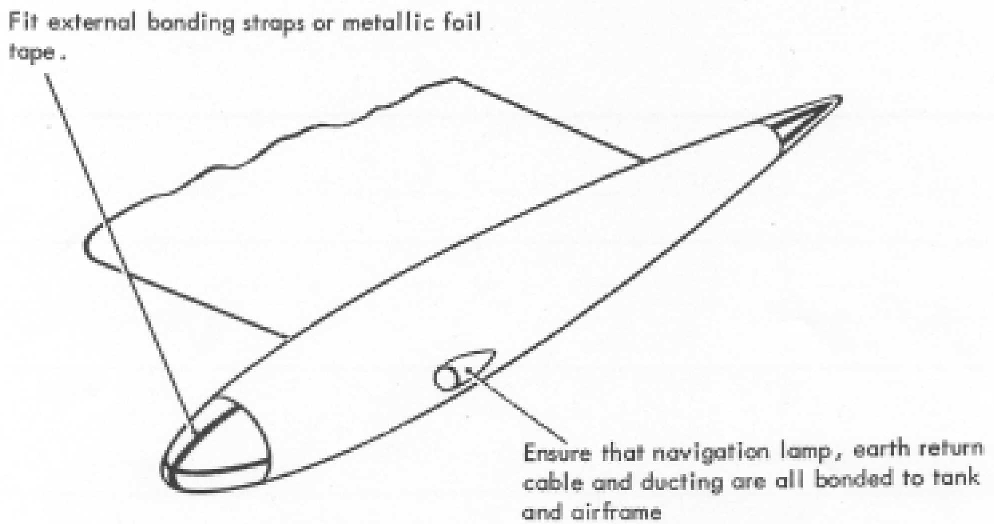

Figure 4 WING TIP TANK (NON-METALLIC ENDS)

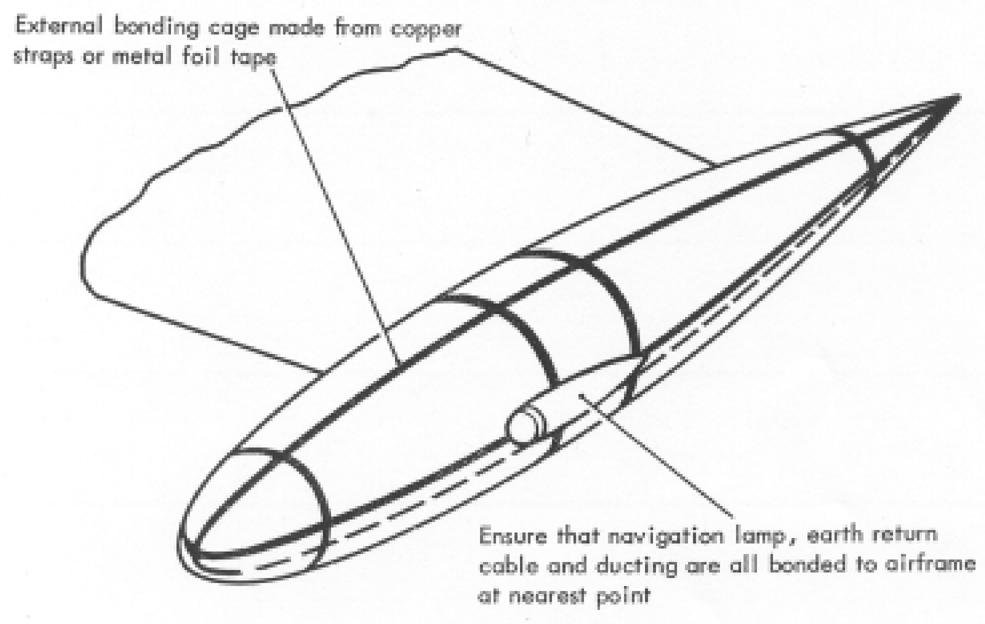

Figure 5 WING TIP TANK (NON–METALLIC)

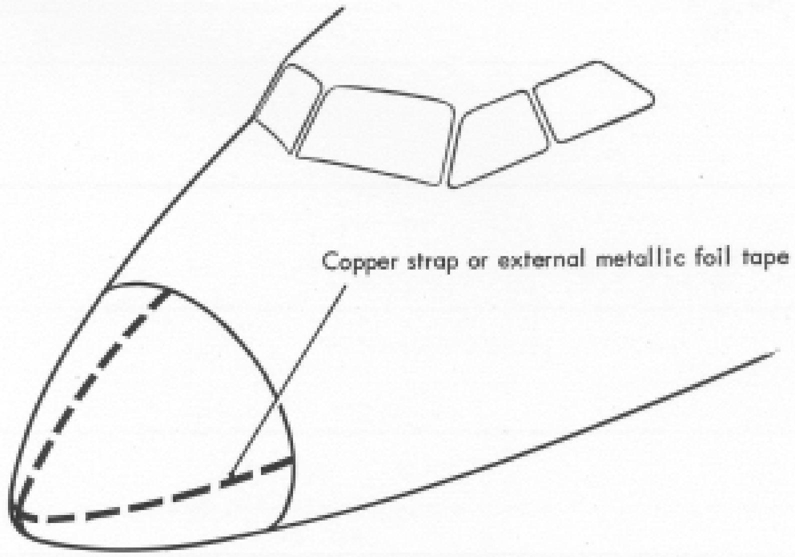

Figure 6 NOSE CONE (NON-METALLIC)

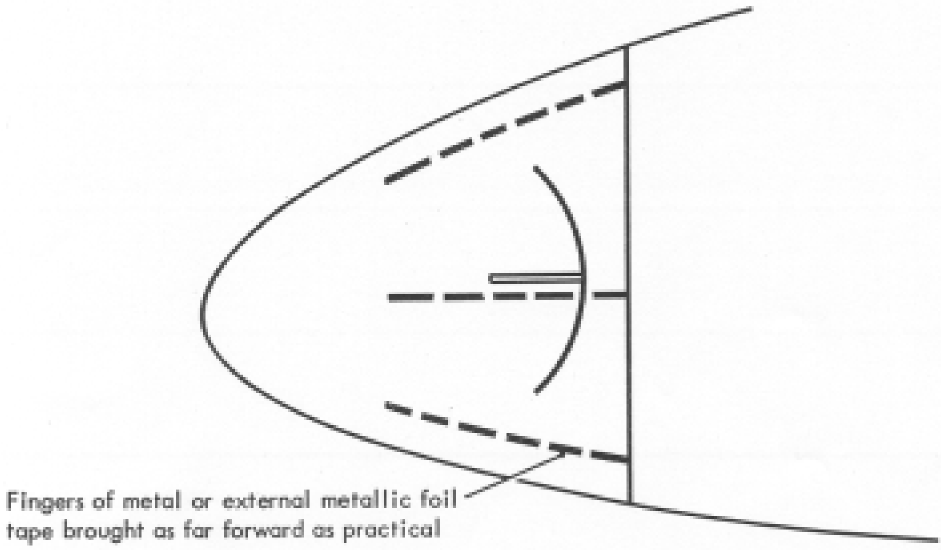

Figure 7 RADOME

Leaflet 9-13 Aircraft Electrical Load and Power Source Capacity Analysis

(Previously issued as AIL/0194)

1 Purpose

The purpose of this Leaflet is to provide guidance material on the preparation of an Electrical Load and Power Source Capacity Analysis as required by Civil Aviation Requirements.

2 References

2.1 **Applicable Certification Specifications and Acceptable Means of Compliance**

The following references to Certification Specifications (CS) and Acceptable Means of Compliance (AMC) are for guidance purposes only. The applicable Certification Specifications will depend upon the type of aircraft for which the Electrical Load Analysis (ELA) is to be compiled. Although CS-25 has been referenced for large public transport aircraft, similar requirements are contained in CS-VLA and 23 for smaller aircraft and CS-VLR, 27 and 29 for Rotorcraft.

CS 25.1165 (b)	Engine Ignition Systems
CS 25.1310 (a), (b)	Power source capacity and distribution
CS 25.1351 (a), (b), (d)	Electrical Systems and Equipment – General
CS 25.1355 (b)(6)	Distribution System
CS 25.1585	Operating procedures
AMC 25.1351 (d)	
AMC-20	General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances.

2.2 **Historical References**

British Civil Airworthiness Requirements – Section J (Electrical) (CAP 466)
Military Specification MIL-E-7016F (Electric Load and Power Source Capacity, Aircraft, Analysis of).

2.3 **Other References**

EUROCAE ED-14D, RTCA DO-160D 'Environmental Conditions and Test Procedures for Airborne Equipment' Section 16 (Power Input).

3 Introduction

3.1 In order to show compliance to CS 25.1351 (a) (CS-25 Certification Specifications at 17 October 2003), a determination has to be made of the electrical system capacity, which is typically demonstrated by the compilation and submission of an 'Electrical Load Analysis'.

CS 25.1351(a)(17 October 2003)

"a) *Electrical system capacity.* The required generating capacity, and number and kinds of power sources must -

1 Be determined by an electrical load analysis; and

2 Meet the requirements of CS 25.1309. "

NOTE: The above Certification Specification is for CS-25 (Large Aeroplanes), however this requirement is similar to that contained in other CS Certification Specifications such as CS-23.

3.2 The main purpose of the Electrical Load Analysis (ELA) and Power Source Capacity analysis is to estimate the system capacity (including generating sources, converters, contactors, busbars etc.) needed to supply the worst-case combinations of electrical loads. This is achieved by evaluating the average demand and maximum demands under all of the applicable flight conditions.

3.3 A summary can then be used to relate the ELA to the system capacity and can establish the adequacy of the power sources under normal, abnormal and emergency conditions.

NOTE: It is important to note that the Electrical Load Analysis is a 'living' document and as such should be maintained throughout the life of the aircraft to record changes to the connected loads, which may be added or removed by modification.

3.4 The Electrical Load Analysis that is produced for Aircraft Type Certification should be used as the baseline document for any subsequent changes. If possible, the basic format for the ELA should be maintained to ensure consistency in the methodology and approach.

3.5 In some cases, the original ELA may be lacking in certain information, for instance, 'time available on emergency battery', and as such, it may be necessary to update the ELA using the guidance material contained in this Leaflet.

4 Electrical Load Analysis - Basic Principles

4.1 The principle of an Electrical Load Analysis demands the listing of each item or circuit of electrically powered equipment and the associated power requirement. The power requirement for a piece of equipment or circuit may have several values depending on the utilisation for each phase of aircraft operation.

4.2 In order to arrive at an overall evaluation of electrical power requirement, it is necessary to give adequate consideration to transient demand requirements which are of orders of magnitude or duration to impair system voltage and/or frequency stability, or to exceed short-time ratings of power sources (i.e. intermittent/ momentary and cyclic loads). This is essential, since the ultimate use of an aircraft's ELA is for the proper selection of characteristics and capacity of power-source components and resulting assurance of satisfactory performance of equipment, under normal, abnormal and emergency operating power conditions.

5 Content of Electrical Load Analysis

The Load and Power Source Capacity Analysis report should include sections as follows:

a) Introduction

b) Assumptions and Criteria

c) AC and DC Load Analysis – Tabulation of Values

d) Emergency and Standby Power Operation

e) Summary and Conclusions

a) **Introduction**

It is suggested that the introduction to the 'Load and Power Source Capacity Analysis' report include the following information in order to assist the reader in understanding the function of the electrical system with respect to the operational aspects of the aircraft.

Typically, the introduction to the ELA would contain details of the following:

i) Brief description of aircraft type, which may also include the expected operating role for the aircraft;

ii) Electrical system operation, which describes primary and secondary power sources, bus configuration with circuit breakers and connected loads for each bus. A copy of the bus wiring diagram or electrical schematic should also be considered for inclusion in the report;

iii) Generator and other power source description and related data (including such items as battery discharge curves, TRU, Inverter, APU, Ram Air Turbine, etc.).

Typical data supplied for power sources would be as follows:

IDENTIFICATION	1	2	3
ITEM	**DC Starter-Generator**	**Inverter**	**Battery**
No of Units	2	1	1
Continuous Rating (Nameplate) 5 second Rating 2 minute Rating	250A 400A 300A	300VA (Total)	35Ah
Voltage	30V	115VAC	24VDC
Frequency	-	400Hz	-
Power Factor	-	0.8	-
Manufacturer	ABC	XYZ	ABC
Model No	123	456	789
Voltage Regulation	+/- 0.6V	+/-2%	-
Frequency Regulation	-	400Hz +/-1%	-

iv) Operating logic of system (e.g. automatic switching, loading shedding etc.);

v) List of installed equipment.

b) **Assumptions and Criteria**

All assumptions and design criteria used for the analysis should be stated in this section of the load analysis.

For example, typical assumptions for the analysis may be identified as follows:

- Most severe loading conditions and operational environment in which the aeroplane will be expected to operate are assumed to be night and in icing conditions.

- Momentary/intermittent loads, such as electrically operated valves, which open and close in a few seconds are not included in the calculations.
- Galley utilisation.
- Motor load demands are shown for steady-state operation and do not include starting inrush power. The overload ratings of the power sources should be shown to be adequate to provide motor starting inrush requirements.
- Intermittent loads such as communications equipment (radios e.g. VHF/HF comms.), which may have different current consumption depending on operating mode (i.e. transmit or receive).
- Cyclic loads such as heaters, pumps etc. (duty cycle).
- Estimation of load current, assuming a voltage drop between busbar and load.
- Power factors would need to be estimated for equipment, if unknown.

c) **AC and DC Load Analysis – Tabulation of Values**

A typical 'Load and Power Source Analysis' would identify the following details in tabular form:

Connected Load Table:

i) **Aircraft Busbar, Circuit description and Circuit code**

ii) **Load at Circuit Breaker.** Ampere loading for DC circuits and Watts/VA, VARs, power factor for AC circuits.

iii) **Operating Time.** Usually expressed as a period of time (seconds/minutes) or may be continuous, as appropriate. Equipment operating time is often related to the average operating time of the aircraft. If the 'on' time of the equipment is the same or close to the average operating time of the aircraft, then it could be considered that the equipment is operating continuously for all flight phases.

In such cases, where suitable provision has been made to ensure that certain loads cannot operate simultaneously or where there is reason for assuming certain combinations of load will not occur, appropriate allowances may be made. Adequate explanation should be given in the summary.

In some instances, it may be useful to tabulate the data using a specified range for equipment operating times, such as follows:

- 5-second analysis - All loads that last longer than 0.3 seconds should be entered in this column.
- 5-minute analysis - All loads that last longer than 5 seconds should be entered in this column.
- Continuous analysis - All loads that last longer than five minutes should be entered in this column.

Alternatively, the equipment operating times could be expressed as follows:

- Actual operating time of equipment, in seconds or minutes; or
- Continuous operation.

In the examples given in Appendices 1 and 2, the approach taken is to show either continuous operation or to identify a specific operating time in seconds/ minutes.

iv) **Condition of aircraft operation.** Phase of pre-flight and flight (such as ground operation and loading, taxi, take-off, cruise, land).

For commercial aircraft, the following conditions could be considered:

• Ground Operation and Loading	(30 mins – typically)
• Engine Start	(5 mins – typically)
• Taxi	(10 mins - typically)
• Take-off and Climb	(30 mins – typically to optimum cruise height)
• Cruise	(as appropriate for aircraft type)
• Landing	(30 mins - typically)

The following conditions could be used for a typical helicopter operation:

• Engine Start and warm-up (night)	(10 mins - typically)
• Take-off and climb (night)	(10 mins - typically)
• Cruise (night)	(30 mins - typically)
• Cruise (day)	(30 mins - typically)
• Landing (night)	(10 mins - typically)
• Emergency Landing (night)	(5 mins - typically)[1]
• One Generator Cruise (night)	(10 mins - typically)[2]

1. Considers the failure of all generated power (i.e. Emergency Operation).
2. Considers the loss of a single generator (assuming two generators) (i.e. Abnormal Operation).

In some cases, the helicopter operations may be utilised in a specialised role (e.g. search and rescue, North sea operations etc.). The ELA should be reviewed and revised accordingly to take into account any significant changes to the conditions or operating times that were specified in the original ELA.

v) **Condition of Power Sources.** Normal, Abnormal (Abnormal conditions to be specified e.g. one generator inoperative, two generators inoperative etc.) and Emergency.

The following Aircraft Operating Phases should be considered for the Electrical Load Analysis and would typically assume 'night' conditions as being the worst-case scenario.

In addition, icing conditions should also be considered for worst-case scenario. However, it should be noted that in some cases, the icing system is de-energised to operate and so icing may not always be the worst-case.

The analysis should also identify permissible unserviceabilities likely to be authorised in the Master Minimum Equipment List (MMEL) during the Certification of the aeroplane and should include calculations appropriate to these cases.

The following definitions are used when considering Normal, Abnormal and Emergency Electrical Power Operation:

Normal Electrical Power Operation. Normal operating conditions assumes that all of the available electrical power systems are functioning correctly within MMEL limitations (e.g. AC and/or DC Generators, Transformer Rectifier Units, Inverters, Main Batteries, Auxiliary Power Unit etc.).

Abnormal Electrical Power Operation (or Abnormal Operation). Abnormal operation occurs when a malfunction or failure in the electric system has taken place and the protective devices of the system are operating to remove the malfunction or the failure from the remainder of the system before the limits of abnormal operation are exceeded. The power source may operate in a degraded mode on a continuous basis where the power characteristics supplied to the utilisation equipment exceed normal operation limits but remain within the limits for abnormal operation (e.g. a single generator failure on an aircraft with two electrical generators).

Emergency Electrical Power Operation (or Emergency Operation). Emergency operation is a condition that occurs following a loss of all normal electrical generating power sources or other malfunction that results in operation on standby power (batteries and/or other emergency generating sources such as an APU or Ram Air Turbine) only. Also identified as 'operation without normal electrical power' – CS 25.1351(d) and AMC.

In some cases, the ELA will include a specific section covering Extended Range Operations requirements (Reference AMC-20) and will address 'total loss of normal generated electrical power' for the extended range conditions specified.

Typical phases of Normal Aircraft Operation are identified and defined as follows: Ground and Loading, Engine Start, Taxi, Take-off and Climb, Cruise and Land.

Ground Operation and Loading. Preparation of aircraft prior to aircraft engine start. During this period, power is supplied by APU, internal batteries or an external power source.

Taxi. Taxi is the condition from the aircraft’s first movement under its own power to the start of the take-off run, and from completion of landing rollout to engine shutdown.

Take-off and Climb. Take-off and climb is that condition commencing with the take-off run and ending with the aircraft levelled-off and set for optimum cruising.

Cruise. Cruise is that condition during which the aircraft is in level flight.

Landing. Landing is that condition commencing with the operation of navigational and indication equipment specific to the landing approach and following to the completion of the rollout.

vi) **Calculations.** The following calculations can be used to estimate total current, maximum demand and average demand for each of the aircraft operating phases (Ground Operation and Loading, Engine Start, Taxi, Take-off and Climb, Cruise and Landing):

Total Current (Amps) = Number of Units Operating Simultaneously x (multiplied by) Current per Unit (Amps);

or

Total Current (Amp-Min) = Number of Units Operating Simultaneously x (multiplied by) Current per Unit (Amps) x Operating time (Min)

Volt-amperes (VA or kVA) = Voltage x Current

Maximum Demand or Maximum Load (Amps) = Number of Units Operating Simultaneously x (multiplied by) Current per Unit (Amps);

or

Maximum Demand or Maximum Load (Volt-Amps, VA or kVA) = Number of Units Operating Simultaneously x Current per Unit (Amps) x (multiplied by) Supply Voltage (Volts)

It should be noted that the addition of AC load using kVA and Power Factor is a vector addition and is not an algebraic addition.

kW is the effective power

kVA is the apparent power

kVAR is the reactive power

NOTE: Volt-amperes (VA) = $(\text{watts}^2 + \text{vars}^2)^{1/2}$

Power Factor (PF) = W/VA, W = watts

Power = Voltage x Current x Power Factor (in watts)

For sinusoidal supplies a convenient form is

Power Factor = $\cos \Phi$

Where Φ is the angle of lag or lead between V and I.

$\cos \Phi$ = kW/kVA therefore kVA = kW/$\cos \Phi$

kVAR = kVA $\sin \Phi$

Total kVA = $\sqrt{(\text{kW}^2 + \text{kVAR}^2)}$

Power Factor of total load = kW/kVA

Worked Example for addition of AC loads with varying Power Factors:

Cabin Lighting (capacitive) 20 kW at p.f of 0.92 leading
Flap Motor (inductive) 75 kW at p.f of 0.7 lagging
Heater (resistive) 45 kW at p.f of 1.0

Cabin Lighting	kVA_1	=	20/0.92	=	21.74 kVA
Flap Motor	kVA_2	=	75/0.7	=	107.2 kVA
Heater	kVA_3	=	45/1	=	45.0 kVA

$\cos \Phi_1$ = 0.92 therefore Φ_1 = 23°4′

$\cos \Phi_2$ = 0.7 therefore Φ_2 = 45°34′

$kVAR_1$ = $kVA_1 \sin \Phi_1$ = 21.74 x 0.3919 = 8.520 kVAR

$kVAR_2$ = $kVA_2 \sin \Phi_2$ = 107.2 x –0.7141 = –76.52 kVAR

Total kVAR = –68.00 kVAR

Total kW = 20 + 75 + 45 = 140 kW

Total kVA = $\sqrt{(\text{kW}^2 + \text{kVAR}^2)} = \sqrt{(140^2 + (-68.00)^2)}$ = 155.64 kVA

Power factor of total load = kW/kVA = 140/155.64 = 0.899520 lagging

Average Demand or Average Load (Amps) = Total Current (Amps-Minute) (divided by) Duration of Ground or Flight Phase (Minutes);

or

Average Demand or Average Load (Volt-Amps, VA or kVA) = Total Current (Amps-Minute) (divided by) Duration of Ground or Flight Phase (Minutes) x Supply Voltage (Volts)

It can be considered that at the start of each operating period (e.g. taxi, take-off, etc.), all equipment that operates during that phase is considered to be switched 'On', with intermittent loads gradually being switched 'Off'.

Intermittent Loads. For intermittent peak loads, root mean square (RMS) values of current should be calculated. Where the currents are continuous, the RMS and the average values will be the same, however, where several intermittent peak loads are spread over a period of time, the RMS value will be more accurate than the average.

Additional Considerations:

Non-Ohmic or constant power devices (e.g. Inverters). In some cases, the currents drawn at battery voltage (e.g. 20-24VDC) are higher than at the generated voltage (e.g. 28VDC) and will influence the emergency flight conditions on battery. However, for resistive loads, the current drawn will be reduced due to the lower battery voltage.

NOTE: Where the currents are continuous, the RMS and average values will be the same. However, where several intermittent peak loads are spread over a period, the RMS value will be more accurate than the average.

System Regulation

The system voltage and frequency should be regulated to ensure reliable and continued safe operation of all essential equipment while operating under the normal and emergency conditions, taking into account the voltage drops which occur in the cables and connections to the equipment.

The following definitions are provided in ED-14D (16.5.2.1) for maximum, nominal, minimum and emergency operations (28VDC System):

Maximum	30.3 volts
Nominal	27.5 volts
Minimum	22.0 volts
Emergency	18.0 volts

The defined voltages are those supplied at the equipment terminals and allows for variation in the output of the supply equipment (e.g. generators, batteries etc.) as well as voltage drops due to cable and connection resistance.

NOTE: Voltage drop between busbar and equipment should be considered in conjunction with busbar voltages under normal, abnormal and emergency operating conditions in the estimation of the terminal voltage at the equipment i.e. reduced busbar voltage in conjunction with cable volt drop could lead to malfunction or shutdown of equipment.

Load Shedding

Following the loss of a power source or sources it is considered that a 5 minute period will elapse prior to any manual load shedding by the flight crew, provided that the failure warning system has clear and unambiguous attention-getting characteristics (refer to AMC 25.1351(d)). However, any automatic load shedding can be assumed to take place immediately.

NOTE: 10 minutes should be used where no flashing warning is provided to the flight crew.

Where automatic load shedding is provided, a description of the load(s) that will be shed should be provided with any specific sequencing, if applicable.

d) Emergency or Standby Power Operations

Where standby power is provided by non-time limited sources such as a Ram Air Turbine (RAT), Auxiliary Power Unit (APU), pneumatic or hydraulic motor, the emergency loads should be listed and evaluated such that the demand does not exceed emergency generator capacity.

Where batteries may be used to provide a time limited emergency supply for certain phases of flight e.g. landing, an analysis of battery capacity should be undertaken. This should be compared with the time necessary for the particular phase (e.g. from slat extension to landing including rollout) of flight where batteries may be utilised in lieu of non-time limited sources.

Battery Condition Calculations

Battery Duration. Battery endurance can be estimated from either a practical test, which involves applying typical aircraft loads for a period of time, or by calculation. It is important that considerations be given to the initial conditions of the aircraft (e.g. condition and state of charge of battery).

Using the material of AMC 25.1351 (d) (17 October 2003), the required duration of a time limited power source (e.g. battery), which is used as an alternative to the normal power sources, will depend on the type and role of the aircraft. Unless it can be shown that a lesser time is adequate, such a power source should have an endurance of at least 60 minutes, at least 30 minutes of which is available under IMC. The endurances of the time limited power source, with any associated procedures, should be specified in the Flight Manual.

Calculation

An accurate theoretical assessment of the battery performance requires a load analysis to be compiled and the discharge figures checked against the battery manufacturer's discharge curves and data sheets.

The capacity of a battery is:

Rate of discharge (amps) x Time to discharge

Normally expressed in ampere-hours, but for a typical load analysis, calculations are usually expressed in amp-mins (i.e. amp-hours x 60). However, this is not a linear function for with heavier discharge currents the discharge time decreases more rapidly so that the power available is less (i.e. reduced efficiency).

Therefore, in order to make an accurate assessment of battery duration, reference should be made to the manufacturer's discharge curves. However, it is recognised that these may not be available and certain assumptions and approximations are provided in the following paragraphs to allow for this case.

Because of the problem of definition of capacity it is first necessary to ensure that all calculations are based on the one-hour rate. Some manufacturers however do not give this on the nameplate and quote the five-hour rate. For these calculations, as a general rule, it may be assumed that the one-hour rate is 85% of the quoted five-hour rate.

Following the generator system failure and before the pilot has completed the load shedding drills the battery may be subjected to high discharge currents with a resultant loss of efficiency and capacity on the principle explained in the previous paragraph.

To make allowance for such losses, the calculated power consumed during the pre-load shed period should be factored by an additional 20% if the average discharge current in amps is numerically more than twice the one-hour rating of the battery.

It should be noted that the discharge rate of a lead-acid battery is different than that of a nickel cadmium battery. The following graph shows a typical discharge curve for lead-acid and nickel-cadmium battery at a 5 amp discharge rate.

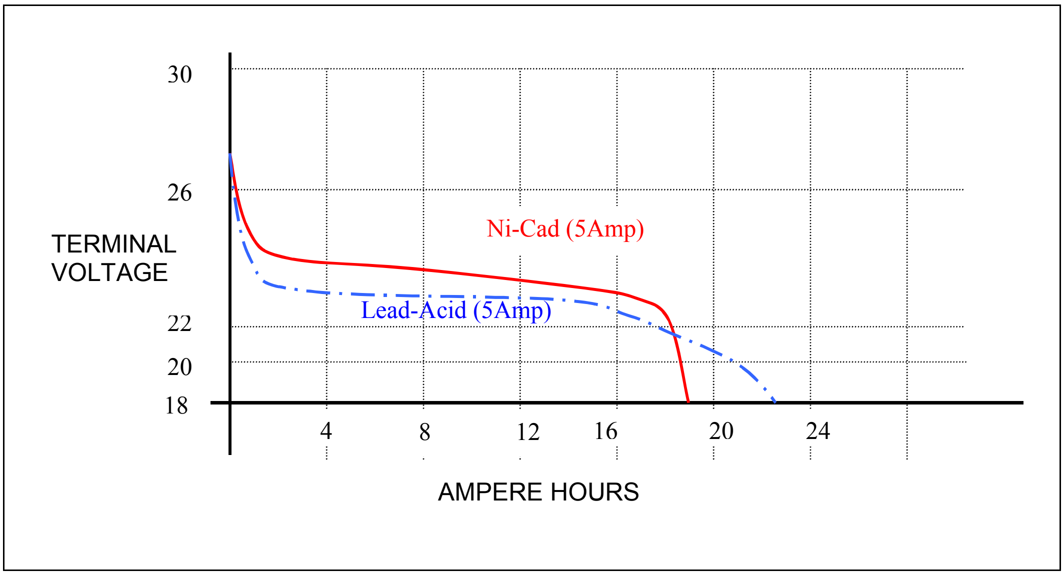

Figure 1 Typical discharge rates of lead-acid and nickel-cadmium batteries

AMC 25.1351(d)(6.1)(b) (17 October 2003) states:

"Unless otherwise agreed, for the purpose of this calculation, a battery capacity at normal ambient conditions of 80% of the nameplate rated capacity, at the one-hour rate, and a 90% state of charge, may be assumed (i.e. 72% of nominal demonstrated rated capacity at +20°C). The allowance for battery endurance presumes that adequate requirements for periodic battery maintenance have been agreed."

Battery-Charging Current Analysis

The charging current for any aircraft battery is based on the total elapsed time from the beginning of the charge, and is calculated using the following formula:

I = A x C where,

I is the average charging current in Amperes.

A is the Ampere-hour capacity of the battery, based on the one-hour discharge rate.

C is the battery-charging factor taken from the battery-charging curve supplied with battery data (graphical data).

An example of how to calculate the battery duration is given below:

i) Check the nameplate capacity of the battery and assume 72% is available e.g. 12 amp-hour = 720 amp-mins.

Therefore, 72% is equal to 518.4 amp-mins.

ii) Estimate the normal or pre-load shed cruise consumption (assume worst-case cruise at night). For example, 15 amps (15 amps x 5 mins = 75 amp-mins).

This assumes 5 minutes for pilot to shed non-essential loads following a low voltage warning. Any automatic load shedding can be assumed to be immediate and need not be considered in the pre-load shed calculations.

iii) Estimate the minimum cruise load necessary to maintain flight after the generator/alternator has failed e.g. 10 amps.

iv) Estimate the consumption required during the landing approach e.g. 20 amps for 5 minutes (100 amp-mins).

The cruise duration is therefore:

$$\frac{\text{Battery Capacity (i)} - [\text{Pre-Load Shed (ii)} + \text{Landing Load (iv)}]}{\text{Cruise Load (iii)}} = \frac{\text{(i)} - [\text{(ii)} + \text{(iv)}]}{\text{(iii)}}$$

$$= \frac{518.4 - (75 + 100)}{10} = \frac{343.4}{10} = 34 \text{ mins}$$

Total Duration = Pre-Load Shed Cruise Time + Cruise Duration + Landing Time

Total Duration = 5 + 34 + 5 = 44 minutes.

e) Summary and Conclusions

Summary

The Electrical Load Analysis summary should provide evidence that for each operating condition, the available power can meet the loading requirements with adequate margin for both peak loads and maximum continuous loads. This should take into account both the normal and abnormal (including emergency) operating conditions.

For AC systems, these summaries should include power factor and phase loadings.

Conclusions

The conclusions should include statements that confirm that the various power sources can satisfactorily supply electrical power to necessary equipment during normal and abnormal operation under the most severe operating conditions as identified in the analysis. It should be confirmed that the limits of the power supplies are not exceeded.

6 Example of AC and DC Electrical Load Analysis

6.1 As stated previously, the Electrical Load Analysis is designed to show capability of the electrical system under various ground and flight operating conditions. The analysis should verify that the electrical power sources would provide power to each circuit essential for the safe operation of the aircraft.

6.2 The examples provided are intentionally over-simplified to clarify the process involved. The applicable design organisation is responsible for the selection of the method of analysis.

6.3 A typical electrical load utilisation and analysis for an AC and DC aircraft is provided in Appendices 1 (DC analysis) and 2 (AC analysis) of this document.

In addition, Appendix 3 provides an analysis (DC and AC) derived from BCAR Section J (historical data), which provides a more detailed analysis.

7 Practical Test (Ground or Air)

Practical testing may be used as an expedient method of verifying certain loads and would be used as supporting data in the compilation of the Electrical Load Analysis.

8 Definitions

The following definitions are applicable to this Leaflet:

An **Electrical System** consists of an electrical power source, its power distribution system and the electrical load connected to that system.

An **Electrical Source** is the electrical equipment which produces, converts, or transforms electrical power. Some common AC sources are identified as follows: AC Generators, inverters, transformers and frequency changers. Some common DC sources are DC Generators, converters and batteries. In practice an electrical source could be a combination of these units connected in parallel e.g. a typical AC bus may have both AC Generators and inverters connected in parallel.

A **Primary** source is equipment that generates electrical power from energy other than electrical, and is independent of any other electrical source. For example, the Primary source of an AC electric system may be the main engine-driven generator(s) or Auxiliary Power Unit-driven generator(s). The Primary source of a DC electrical system may be a battery, main engine-driven generator(s) or Auxiliary Power Unit-driven generator(s). There may be both AC and DC Primary power sources in the same aircraft.

A **Secondary** source is equipment that transforms and/or converts Primary source power to supply electrical power to either AC or DC powered equipment. A Secondary source is entirely dependent upon the Primary source and is considered part of the load of the Primary source. There may be both an AC and DC Secondary source in the same aircraft.

The **Normal** source is that source which provides electrical power throughout the routine aircraft operation.

An **Alternate** source is a second power source, which may be used in lieu of the Normal source, usually upon failure of the Normal source. The use of alternate sources creates a new load and power configuration, and therefore a new electrical system, which may require separate source capacity analysis.

The **Nominal Rating** of a unit power source is its nameplate rating. This rating is usually a continuous duty rating for specified operating conditions.

The **Growth Capacity** is a measure of the power source capacity available to the aircraft electrical system to supply future load equipment. This value is expressed in terms of percent of source capacity.

Grounding Operation and Loading. Preparation of aircraft prior to aircraft engine start. During this period power is supplied by APU, internal batteries or an external power source.

Taxi. Taxi is the condition from the aircraft's first movement under its own power to the start of the take-off run and from completion of landing rollout to engine shutdown.

Take-off and Climb. Take-off and climb is that condition commencing with the take-off run and ending with the aircraft levelled-off and set for cruising.

Cruise. Cruise is that condition during which the aircraft is in level flight.

Landing. Landing is that condition commencing with the operation of navigational and indication equipment specific to the landing approach and following to the completion of the rollout.

Normal Electrical Power Operation (or Normal Operation). Normal Operating conditions assumes that all of the available electrical power system is functioning correctly within MMEL limitations (e.g. AC and/or DC Generators, Transformer Rectifier Units, Inverters, Main Batteries, Auxiliary Power Unit etc.).

Abnormal Electrical Power Operation (or Abnormal Operation). Abnormal operation occurs when a malfunction or failure in the electric system has taken place and the protective devices of the system are operating to remove the malfunction or the failure from the remainder of the system before the limits of abnormal operation are exceeded. The power source may operate in a degraded mode on a continuous basis where the power characteristics supplied to the utilisation equipment exceed normal operation limits but remain within the limits for abnormal operation.

Emergency Electrical Power Operation (or Emergency Operation). Emergency operation is a condition that occurs following a loss of all normal electrical generating power sources or other malfunction that results in operation on standby power (batteries and/or other emergency generating sources such as an APU or Ram Air Turbine) only. Also identified as 'operation without normal electrical power' – CS 25.1351(d) and AMC.

Power Factor. The ratio of real power (measured in watts) to apparent power (measured in volt-amperes).

APPENDIX 1

Typical DC Electrical Load Analysis (Normal and Emergency)

Table 1 Electrical Load Analysis (DC – Current) – Normal Operating Conditions

	BUS – DC1					**NORMAL CONDITIONS**					
CIRCUIT/SERVICE	**CB**	**LOAD AT CCT BREAKER**	**OP TIME**	**APPROPRIATE CONDITIONS**	**NOTES**	**TAXIING (NIGHT) 30 MINS**		**TAKE OFF & LAND (NIGHT) 10 MINS**		**CRUISE (NIGHT) 60 MINS**	
		AMPS	**MINS**			**AMPS**	**AMP-MINS**	**AMPS**	**AMP-MINS**	**AMPS**	**AMP-MINS**
AIR CONDITIONING											
DUMP DITCH MOTORS	AB1	0.90	0.1	A,B,C	a,b,c	-	-	-	-	-	-
CABIN ALT WARNING	AB2	0.04	CONT	A,B,C	a,b,c	0.04	1.2	0.04	0.4	0.04	2.4
MAN. PRESSURE CONTROL	AB3	0.60	CONT	A,B,C	a,b	-	-	-	-	-	-
COMMUNICATIONS											
ACARS MEMORY	BC1	0.08	CONT	A,B,C	a,c	0.08	2.4	0.08	0.8	0.08	4.8
ELECTRICAL POWER											
BATTERY 1 CHARGE	CD1	3.50	CONT	A,B,C	a,b	3.50	105.0	3.50	35.0	3.50	210.0
**	**	**	**	**	a,c	**	**	**	**	**	**
**	**	**	**	**	a,b,c	**	**	**	**	**	**
**	**	**	**	**	a,b,c	**	**	**	**	**	**
**	**	**	**	**	a,b,c	**	**	**	**	**	**
BATTERY 1 TEMP PROT	CD2	0.04	CONT	A,B,C	a,b	0.04	1.2	0.04	0.4	0.04	2.4
		TOTALS	TOTAL (AMP-MINS)				200		100		300
			MAXIMUM DEMAND (AMPS)			15		24		12	
			AVERAGE DEMAND (AMPS)			6.7		10		5	

Table 2 Electrical Load Analysis (DC – Current) – Emergency Operating Conditions

	BUS – DC1					EMERGENCY (Failure of one power-unit or generator)					
CIRCUIT/SERVICE	**CB**	**LOAD AT CCT BREAKER**	**OP TIME**	**APPROPRIATE CONDITIONS**	**NOTES**	**CRUISE (NIGHT) PRIOR TO LOAD SHED 5 MINS**		**CRUISE (NIGHT) AFTER LOAD SHEDDING 60 MINS**		**LAND (NIGHT) 10 MINS**	
		AMPS	**MINS**			**AMPS**	**AMP-MINS**	**AMPS**	**AMP-MINS**	**AMPS**	**AMP-MINS**
AIR CONDITIONING											
DUMP DITCH MOTORS	AB1	0.90	0.1	A,B,C	a,b,c	-	-	-	-	-	
CABIN ALT WARNING	AB2	0.04	CONT	A,B,C	a,b,c	0.04	0.2	0.04	2.4	0.04	0.4
MAN. PRESSURE CONTROL	AB3	0.60	CONT	A,B,C	a,b	-	-	-	-	-	-
COMMUNICATIONS											
ACARS MEMORY	BC1	0.08	CONT	A,B,C	a,c	0.08	0.4	0.08	4.8	0.08	0.8
ELECTRICAL POWER											
BATTERY 1 CHARGE	CD1	3.50	CONT	A,B,C	a,b	3.50	17.5.0	3.50	210	3.50	35.0
**	**	**	**	**	a,c	**	**	**	**	**	**
**	**	**	**	**	a,b,c	**	**	**	**	**	**
**	**	**	**	**	a,b,c	**	**	**	**	**	**
**	**	**	**	**	a,b,c	**	**	**	**	**	**
BATTERY 1 TEMP PROT	CD2	0.04	CONT	A,B,C	a,b	0.04	0.2	0.04	2.4	0.04	0.4
		TOTALS	TOTAL (AMP-MINS)				50		300		100
			MAXIMUM DEMAND (AMPS)			15		24		12	
			AVERAGE DEMAND (AMPS)			10		5		10	

APPENDIX 2

Table 3 Electrical Load Analysis (AC – Current) – Normal Operating Conditions

	BUS – AC1							**NORMAL CONDITIONS**				
CIRCUIT/SERVICE	**CB**	**LOAD AT CCT BREAKER**		**OP TIME**	**APPROPRIATE CONDITIONS**	**NOTES**	**TAXIING (NIGHT) 30 MINS**		**TAKE OFF & LAND (NIGHT) 10 MINS**		**CRUISE (NIGHT) 60 MINS**	
		WATTS	**VARS**	**MINS**			**WATTS**	**VARS**	**WATTS**	**VARS**	**WATTS**	**VARS**
AIR CONDITIONING												
AUTO TEMP FLT DECK	AB1	33.0	17.0	CONT	A,B,C	a,b, c	33.0	17.0	33.0	17.0	33.0	17.0
AUTO PRESS CONT	AB2	30.0		CONT	A,B,C	a,b,c	30.0		30.0		30.0	
MAN. TEMP CTL	AB3	11.0	7.0	CONT	A,B,C	a,b	11.0	7.0	11.0	7.0	11.0	7.0
COMMUNICATIONS												
ACARS PRINTER	BC1	60.0		CONT	A,B,C	a,c	60.0		60.0		60.0	
ELECTRICAL POWER												
AC1 BUS FAIL	CD1	4.0		CONT	A,B,C	a,b	4.0		4.0		4.0	
**	**			**	**	a,c	**	**	**	**	**	**
**	**			**	**	a,b,c	**	**	**	**	**	**
**	**			**	**	a,b,c	**	**	**	**	**	**
**	**			**	**	a,b,c	**	**	**	**	**	**
ESS BUS FAIL	CD2	8.0		CONT	A,B,C	a,b	8.0		8.0		8.0	
		TOTALS		BUS TOTAL KW / KVAR			400	50	400	50	400	50

Table 4 Electrical Load Analysis (AC – Current) – Abnormal Operating Conditions (Failure Of One Generator)

	BUS – AC1						EMERGENCY (Failure of one power-unit or generator)					
CIRCUIT/SERVICE	**CB**	**LOAD AT CCT BREAKER**		**OP TIME**	**APPROPRIATE CONDITIONS**	**NOTES**			**CRUISE (NIGHT)**		**LAND (NIGHT)**	
		WATTS	**VARS**	**MINS**					**WATTS**	**VARS**	**WATTS**	**VARS**
AIR CONDITIONING												
AUTO TEMP FLT DECK	AB1	33.0	17.0	CONT	A,B,C	a,b, c			33.0	17.0	33.0	17.0
AUTO PRESS CONT	AB2	30.0		CONT	A,B,C	a,b,c			30.0		30.0	
MAN. TEMP CTL	AB3	11.0	7.0	CONT	A,B,C	a,b			11.0	7.0	11.0	7.0
COMMUNICATIONS												
ACARS PRINTER	BC1	60.0		CONT	A,B,C	a,c			60.0		60.0	
ELECTRICAL POWER												
AC1 BUS FAIL	CD1	4.0		CONT	A,B,C	a,b			4.0		4.0	
**	**			**	**	a,c			**	**	**	**
**	**			**	**	a,b,c			**	**	**	**
**	**			**	**	a,b,c			**	**	**	**
**	**			**	**	a,b,c			**	**	**	**
ESS BUS FAIL	CD2	8.0		CONT	A,B,C	a,b			8.0		8.0	
		TOTALS		BUS TOTAL KW / KVAR					400	50	400	50

APPENDIX 3

Table 5 DC System : 28 V

Aircraft –Two Power Units Flight Duration : 3 Hours Electrical System : Earth Return DC 28 V; 2 Generators 3kW at Cruise, 1.5 kW at taxiing; 1 battery 37 Ah (Ten-Hour Rate)								**Conditions of Aircraft operation**													
								Normal								**Abnormal (Failure of one power-unit or generator)**					
1	2	3	4	5	6	7	8	9		10		11		12		13		14		15	
Item	Service	Units per A/C	Units op simult	Current at 95% volts (amp)	Drop in line volts (volt)	Op Time (min or sec)	No of times ON	Taxi (night) 30 mins		Take-off and land (night) 10 mins		Cruise (day) 60 mins		Cruise (night) 60 mins		Cruise (night) prior to load shed 5 mins		Cruise (night) after load shed 60 mins		Land (night) 10 mins	
								amp	amp-min	amp	amp-min	amp	amp-min	amp	amp-min	amp	amp-min	amp	amp-min	amp	amp-min
1	Motor, Flaps	1	1	120	6	15s	1	120	30	120	30	-	-	-	-	-	-	-	-	120	30
2	Prop, feather	2	1	100	5	15s	1	-	-	100	25	-	-	-	-	100	25	-	-	-	-
3	Motor, U/C	1	1	160	8	30s	1	-	-	160	80	-	-	-	-	-	-	-	-	160	80
4	Trim tab motor	3	1	4	1	1	3	4	12	4	12	4	36	4	36	4	12	4	36	4	12
5	Cowl flaps	2	2	10	2	3	2	20	60	20	60	20	60	20	60	20	60	20	60	20	60
6	Water heater	1	1	25	2	10	2	-	-	-	-	25	500	25	500	25	125	-	-	-	-
7	Galley	1	1	40	2	15	1	-	-	-	-	40	600	40	600	40	200	-	-	-	-
8	Radio Trans.	1	1	20	2	15	1	20	300	20	200	20	300	20	300	20	100	20	300	20	200
9	Fuel Trans. pump	2	1	10	2	15	1	-	-	-	-	10	150	-	150	10	-	10	150	-	-
10	Motor de-icing	1	1	5	1	15	1	-	-	5	50	5	75	5	75	5	25	5	75	5	50
11	Prop. Auto Ctl	2	2	5	1.5	Cont	Cont	10	300	10	100	10	600	10	600	10	50	10	600	10	100
12	Fuel Boost pump	2	2	10	2	Cont	Cont	-	-	20	200	20	1200	20	1200	20	100	20	1200	20	200
13	Engine Inst.	12	12	1	0.5	Cont	Cont	12	360	12	120	12	720	12	720	12	60	12	720	12	120
14(a)	Int. light (Ess)	5	5	1	0.5	Cont	Cont	5	150	5	50	-	-	5	300	5	25	5	300	5	50
14(b)	Int. Lights (non-essential)	10	10	1	0.5	Cont	Cont	10	300	10	100	-	-	10	600	10	50	-	-	-	-
15	Nav. Lights	5	5	1	0.5	Cont	Cont	5	150	5	50	-	-	5	300	5	25	5	300	5	50
16	Vent Fans	6	6	5	1.5	Cont	Cont	30	900	5	50	5	300	5	300	5	25	-	-	-	-
17	Refrigerator	1	1	15	2	Cont	Cont	15	450	15	150	15	900	15	900	15	75	-	-	-	-
18	Autopilot Inv.	1	1	5	1	Cont	Cont	-	-	-	-	5	300	5	300	5	25	-	-	-	-
19	Inst. (flight) inv.	1	1	5	1	Cont	Cont	5	150	5	50	5	300	5	300	5	25	5	300	5	50
20	Radio Receiver	1	1	5	1	Cont	Cont	5	150	5	50	5	300	5	300	5	25	5	300	5	50
21	Intercomm.	1	1	5	1	Cont	Cont	5	150	5	50	5	300	5	300	5	25	5	300	5	50
					Total (amp-min)				3462		1427		6641		7841		1057		4641		1102
					Maximum Demand (amp)			266		526		206		226		316		126		396	
					Average Demand (amp)			115		143		111		131		211		77		110	

Table 5 considers a two-engined aircraft of medium range with a DC generator driven by each engine. The headings of each column are self-explanatory in general, but where explanation is considered necessary it is given below.

Column 5 – For column 5, it is necessary to choose an arbitrary value of voltage for the estimation of current consumption. For this case a value of 95% E_{max} has been used.

Column 6 – Column 6 gives the drop in line voltage between the busbar and the equipment, assuming the current consumption shown in column 5. This voltage drop should be considered in conjunction with busbar voltages under normal and emergency conditions in the estimation of the terminal voltage at the equipment.

Column 10 – Column 10 gives the loading conditions immediately following a power-unit failure during take-off. This condition is assumed to persist for 10 minutes. This could be considered as an abnormal operating condition.

Table 6 Battery Capacity Analysis

1	2	3	4	5	6	7
Item No	**Equipment**	**Units**	**Total Demand per unit (amp)**	**Time (mins or secs)**	**Amp-min in 20 min period**	**Simultaneous demand (amp)**
1	Motor, Flaps	1	120	0-15 secs	30	120
2	Prop, feather	2	100	0-15 secs	50	100
3	Motor, U/C	1	160	0-30 secs	80	160
4	Trim tab motor	3	4	1	12	4
5	Cowl flaps	2	10	3	60	20
8	Radio Trans.	1	15	15	225	15
9	Fuel Trans. pump	2	-	-	-	-
10	Motor de-icing	-	-	-	-	-
11	Prop. Auto Ctl	2	-	-	-	-
12	Fuel Boost pump	2	-	-	-	-
13	Engine Inst.	12	-	-	-	-
15	Nav. Lights	5	1	Cont	100	5
19	Inst. (flight) inv.	1	5	Cont	100	5
20	Radio Receiver	1	5	Cont	100	5
21	Intercomm.	1	5	Cont	100	5
	Totals				857	439

This table refers to the loading in the case of a forced descent and landing, with all power-units inoperative and the battery supplying power for the electrical loads essential during this period, which is assumed to be 20 minutes.

Column 7 gives the maximum demand which the battery must be capable of meeting while maintaining an adequate voltage at any time within the 20 minutes.

The summation of Column 6 gives a total consumption of 857 amp-min (i.e. 14 amp-hour).

Table 7 Electrical System : 200 volt 3-phase, 400 Hz (Nominal)

Item No	Service	No of Units	Units Op Simult.	Volt-amp per Unit		Op. Time (min)	Load Dist.			Normal Operation								
				Peak	Normal		Normal supply	Standby Supplies		Engine Start	Taxi (night)			Take-off or Land (night)			Cruise (night)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
								1st	2nd	A	P	S	A	P	S	A	P	S
1	Starter Motors	2	1	7000	600	0-10sec	A	-	-	7000	-	-	-	-	-	-	-	-
2	Propeller-Feathering (P)	1	1	2300	200	0-15sec	A	S	-	-	-	-	-	-	-	-	-	-
3	Propeller-Feathering (S)	1	1	2300	2000	0-15sec	A	P	-	-	-	-	-	-	-	-	-	-
4	Cowl Gill Motor (P)	1	1	150	150	0-20sec	P	A	S	-	150	-	-	-	-	-	-	-
5	Cowl Gill Motor (S)	1	1	150	150	0-20sec	S	A	P	-	-	150	-	-	-	-	-	-
6	Main Undercarriage (P)	1	1	4000	4000	0-10sec	P	A	-	-	-	-	-	4000	-	-	-	-
7	Main Undercarriage (S)	1	1	4000	4000	0-10sec	S	A	-	-	-	-	-	-	4000	-	-	-
8	Tail Wheel	1	1	500	500	0-10sec	S	A	-	-	-	-	-	-	500	-	-	-
9	Wing Flaps	1	1	500	500	0-20sec	P	A	-	-	500	-	-	500	-	-	-	-
10	Landing Lamps	2	2	200	200	10	P	A	S	-	400	-	-	400	-	-	-	-
11	Interior Lights A	Total	Total	100	100	C	P	A	S	100	100	-	-	100	-	-	100	-
12	Interior Lights B	Total	Total	300	300	C	S	A	P	-	-	300	-	-	300	-	-	300
13	Heating Load A	Total	Total	1000	1000	C	P	A	-	-	1000	-	-	1000	-	-	1000	-
14	Heating Load B	Total	Total	1000	1000	C	S	A	-	-	-	1000	-	-	1000	-	-	1000
15	Frequency Changer	1	1	2000	2000	C	S	A	P	-	-	2000	-	-	2000	-	-	2000
16	Frequency Compensator	1	1	2400	2400	C	P	A	S	1800	2400	-	-	2400	-	-	2400	-
17	Pressure Head Heater	1	1	100	100	C	S	A	P	-	-	-	-	-	-	-	-	100
18	Engine Controls (P)	Set	Set	200	200	C	P	A	S	200	200	-	-	200	-	-	200	-
19	Engine Controls (S)	Set	Set	200	200	C	S	A	P	200	-	200	-	-	200	-	-	200
20	Fuel Boost Pump (P)	1	1	150	150	C	P	A	S	150	150	-	-	150	-	-	150	-
21	Fuel Boost Pump (S)	1	1	150	150	C	S	A	P	150	-	150	-	-	150	-	-	150
22	Fuel Valves (P)	3	1	50	50	0-10sec	P	A	S	-	50	-	-	50	-	-	50	-
23	Fuel Valves (S)	3	1	50	50	0-10sec	S	A	P	-	-	50	-	-	50	-	-	50
24	Flying Control Servo	3	3	200	200	C & Int	P	A	S	-	600	-	-	600	-	-	600	-
25	Motor de-ice	1	1	150	150	C	S	A	P	-	-	-	-	-	-	-	-	150
26	Refrigerator	1	1	250	250	C	S	A	P	-	-	250	-	-	250	-	-	250
27	Navigation Lights	3	3	25	25	C	P	A	S	-	75	-	-	75	-	-	75	-
28	Windscreen Wiper	1	1	60	60	C	S	A	P	60	-	60	-	-	60	-	-	60
29										-	-	-	-	-	-	-	-	-
30										-	-	-	-	-	-	-	-	-
			Totals	10 seconds Peak Maximum Load (VA)						9660	5625	4160	0	8475	7510	0	4575	4260
				30 seconds Peak Maximum Load (VA)						2660	5575	4110	0	5425	3960	0	4525	4210
				Continuous Maximum Load (VA)						2660	4425	3960	0	4425	3960	0	4025	4210

Table 8 Electrical System : 200 volt 3-phase , 400 Hz (Nominal)

Item No	Service	No of Units	Units Op Simult.	Volt-amp per Unit		Op. Time (min)	Load Distribution			Abnormal Operation										Emergency Operation
										Port power-unit and alternator off			Starboard power-unit and alternator off			Auxiliary Power Unit (APU)				Both power units off
				Peak	Normal		Normal supply	Standby Supplies		Take off or land (night)		Cruise (night)	Take off and land (night)		Cruise (night)	Taxi (night)		Take-off or land (night)		Forced descent (night) and land
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
								1st	2nd	S	A	S	P	A	P	P	S	P	S	A
1	Starter Motors	2	1	7000	600	0-10sec	A	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Propeller-Feathering (P)	1	1	2300	200	0-15sec	A	S	-	-	2300	-	-	-	-	-	-	-	-	-
3	Propeller-Feathering (S)	1	1	2300	2000	0-15sec	A	P	-	-	-	-	-	2300	2300	-	-	-	-	-
4	Cowl Gill Motor (P)	1	1	150	150	0-20sec	P	A	S	-	-	-	-	-	-	150	-	-	-	-
5	Cowl Gill Motor (S)	1	1	150	150	0-20sec	S	A	P	-	-	-	-	-	-	-	150	-	-	-
6	Main Undercarriage (P)	1	1	4000	4000	0-10sec	P	A	-	-	4000	-	4000	-	-	-	-	4000	-	-
7	Main Undercarriage (S)	1	1	4000	4000	0-10sec	S	A	-	4000	-	-	-	4000	-	-	-	-	4000	-
8	Tail Wheel	1	1	500	500	0-10sec	S	A	-	500	-	-	-	500	-	-	-	-	500	-
9	Wing Flaps	1	1	500	500	0-20sec	P	A	-	-	500	-	500	-	-	500	-	500	-	500
10	Landing Lamps	2	2	200	200	10	P	A	S	-	400	-	400	-	-	400	-	400	-	400
11	Interior Lights A	Total	Total	100	100	C	P	A	S	-	100	100	100	-	100	100	-	100	-	100
12	Interior Lights B	Total	Total	300	300	C	S	A	P	300	-	300	-	300	300	-	300	-	300	-
13	Heating Load A	Total	Total	1000	1000	C	P	A	-	-	1000	-	1000	-	1000	1000	-	1000	-	-
14	Heating Load B	Total	Total	1000	1000	C	S	A	-	1000	-	1000	-	1000	-	-	1000	-	1000	-
15	Frequency Changer	1	1	2000	2000	C	S	A	P	2000	-	2000	-	2000	2000	-	2000	-	2000	2000
16	Frequency Compensator	1	1	2400	2400	C	P	A	S	-	1800	2400	2400	-	2400	2400	-	2400	-	1800
17	Pressure Head Heater	1	1	100	100	C	S	A	P	-	-	100	-	-	100	-	-	-	-	100
18	Engine Controls (P)	Set	Set	200	200	C	P	A	S	-	-	-	200	-	200	200	-	200	-	200
19	Engine Controls (S)	Set	Set	200	200	C	S	A	P	200	-	200	-	-	-	-	200	-	200	200
20	Fuel Boost Pump (P)	1	1	150	150	C	P	A	S	-	-	-	150	-	150	150	-	150	-	150
21	Fuel Boost Pump (S)	1	1	150	150	C	S	A	P	150	-	150	-	-	-	-	150	-	150	150
22	Fuel Valves (P)	3	1	50	50	0-10sec	P	A	S	-	50	50	50	-	50	50	-	50	-	50
23	Fuel Valves (S)	3	1	50	50	0-10sec	S	A	P	50	-	50	-	50	50	-	50	-	50	50
24	Flying Control Servo	3	3	200	200	C & Int	P	A	S	-	600	600	600	-	600	600	-	600	-	600
25	Motor de-ice	1	1	150	150	C	S	A	P	-	-	150	-	-	150	-	-	-	-	150
26	Refrigerator	1	1	250	250	C	S	A	P	250	-	250	-	250	250	-	250	-	250	-
27	Navigation Lights	3	3	25	25	C	P	A	S	-	75	75	75	-	75	75	-	75	-	75
28	Windscreen Wiper	1	1	60	60	C	S	A	P	60	-	60	-	60	60	-	60	-	60	60
29										-	-	-	-	-	-	-	-	-	-	-
				Totals	10 seconds Peak Maximum Load (VA)					7510	9825	9785	8475	9460	9785	5625	4160	8475	7510	6585
					30 seconds Peak Maximum Load (VA)					3960	6775	9685	5425	5910	9685	5575	4110	5425	3960	6485
					Continuous Maximum Load (VA)					3960	3475	6885	4425	3610	6885	4425	3960	4425	3960	5485

Tables 7 and 8 consider an aircraft with two power-units carrying one alternator per power-unit and an Auxiliary Power Unit (APU), the latter being primarily for use at low altitudes. The determination of the alternator capacity needed to supply the most onerous probable combination of loads is illustrated for the following conditions, Normal, Abnormal and Emergency (forced descent and land – night).