

British Standard Aerospace Series : Code of practice for

Installation/repair of aircraft electrical interconnection systems

Série Aérospatiale

Code de bonne pratique pour l'installation et la réparation des réseaux électriques des avions

Luft- und Raumfahrt-Reihe

Leitfaden zum Einbau und zur Reparatur elektrischer Verbindungssysteme in Flugzeugen

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Foreword

This code of practice has been prepared at the request of the aircraft industry under the direction of the Aerospace Standards Policy Committee.

In its present form it applies principally to civil and transport aircraft.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

1 Scope

This code of practice gives the preferred choice of electrical cables, splices, terminations, connectors and accessories and the methods of installing these elements in wiring system form. The guidance given in this document is intended for general applications where design standards are not provided by a recognized design authority. Such design authority may be implied where the design practices of an approved installation are followed in that same installation for the purposes of modifications or repair.

Attention is drawn to clause 3 'Limitations' of this document.

NOTE. The titles of the publications referred to in this code of practice are listed on the inside back page.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 9520 for connectors and British Standard G 230 for electrical cables apply.

3 Limitations

Nothing written or implied in this code of practice should take precedence over any statutory requirement e.g. British Civil Airworthiness Requirements (BCAR) or Joint Airworthiness Requirements (JAR): Part 25 or in any specification which has been approved against such requirements.

4 Sources of supply and user responsibility

Material supplied as conforming to specifications referenced in this British Standard should be verified as meeting the full requirements of the specification. For Civil Aircraft the normal (preferred) system of procurement is by obtaining a certified release (Approved Certificate) from a CAA approved manufacturer. If such a manufacturer holds a CAA Design Approval he will be able to offer a Declaration of Design and Performance (DDP as defined in British Standard 3 G 100: Part 1) and may, additionally, hold an Accessory Approval granted by the CAA certifying the design standard of the product.

For equipment obtained from sources not approved by the CAA the procedure defined in CAA notice number 11 should be observed.

Equipment conforming to an Aerospace British Standard 9000 specification should be obtained using the procedure defined in CAA Notice No. 39.

5 Installation groups

The design, modification and repair of wiring installations are considered for each of the following groups:

- (a) engine harnesses;
- (b) electrical power generation, heavy duty;
- (c) airframe-non pressured SWAMP (severe wind and moisture problem) areas;
- (d) general airframe;
- (e) interconnection of systems;
- (f) equipment wiring;

(g) radio frequency (coaxial);

(h) data bus.

6 Service life

The airframe electrical interconnection system and its components should be selected and installed such that their service life is not less than the aircraft structure. For civil aircraft this would normally be 60 000 flying hours or 15 years.

It should not however, be assumed that all elements of an interconnection system will always achieve this life and installations should be designed, as far as is practicable, to permit a satisfactory level of inspection, test, and repair. Similarly, for engines/power plants the service life should normally be a minimum of 10 000 hours and where, due to their modular construction the interconnection system or parts thereof are required to have greater service lives the system design should permit satisfactory inspection, test and repair.

7 Smoke and fire hazards

Components of the interconnection system defined in this code of practice have been designed with an awareness of the hazards of smoke and toxic products under failure conditions. There are no nationally or internationally agreed methods of test and assessment for these hazards and it has been, and remains, the responsibility of the designers to avoid the use of materials which, in any likely condition of use or abuse could create a known abnormally severe failure condition. The design of installations should recognize the need to provide adequate mechanical protection of cables and included in this code of practice is reference to electrical and mechanical protection systems which should be followed to define the design standard. Flammability requirements have been specified for all the products mentioned in this code of practice and it should be noted that these requirements are intended to minimize, for example, the transmission of fire along cables or the propagation of fire by the release of flaming droplets. Nevertheless the installation of cables should, as far as is practicable, recognize that severe overheating of cables is a possibility, especially at terminations, and the size of cable looms (bundles) and their disposition should be determined with this factor in mind. Where an area of significant risk occurs, such as in bus bar distribution panels within the flight deck or cockpit, then ready access for hand held fire extinguishers should be provided. These should be appropriately identified by the use of a placard.

Due to potential fire hazard, silver plated conductors should not be used in areas where they are subject to contamination by ethylene glycol solutions.

8 Electrical protection

The cables should be protected from overload by circuit breakers or fuses. The purpose of the circuit protection is to protect the interconnection system rather than the equipment, which should be separately protected if required. The rating of the circuit breaker or fuse should be selected to protect the lowest rated component of the interconnection system. The circuit breaker should be of the 'trip free' type so that no overriding facility exists such

that a circuit overload can be maintained. The rating of a circuit breaker or fuse should not be increased unless the above requirements are met.

9 Cables

9.1 Cable types

Cable types should be selected from table 1 having due regard to the application. The maximum conductor temperature given in the specification for any combination of electrical loading, ambient temperature and loom heating effects should not be exceeded. Factors to be considered in the selection are voltage, current, ambient temperature, mechanical strength, abrasion, flexure, pressure/altitude and the arc tracking test requirements in British Standard G 230. The various types of cables by application are as follows:

(a) *Equipment cables*. Are designed for use within equipment or in areas where total protection from mechanical abuse is afforded.

(b) *Interconnect cables*. Suitable for use in areas with some physical protection such as behind panels or bulkheads and may also be used as the basis for cables having additional protection such as screen and/or jacket. They also have an application for the internal wiring of equipment.

(c) *Airframe cables*. Are of sufficiently robust construction to satisfy the requirements for open aircraft wiring and wiring in engine compartments.

(d) *Fire resistant cables*. Should always be of the airframe cable type with the additional requirement that they will continue to operate, at a reduced performance level, for a period during fire.

(e) *R.F. cables**. Are used to interconnect high frequency circuits. Various types are available dependent on the operating frequency of the circuit e.g. VHF, UHF etc.

(f) *Data bus cables**. Used in the interconnection of data transmission systems.

(g) *Thermocouple**. For interconnecting temperature measuring systems.

Table 1. British Standard cable specifications

Spec.	Conductor	Insulation	Voltage	Temp.	Remarks
			V	°C	
G 177*	Tinned copper or aluminium	PVC/Glass/Nylon	600	105	Airframe, NYVIN
G 221*	Tinned copper	PVC/Glass/Nylon	300	105	Airframe, MINYVIN
G 222	Nickel/copper	PTFE/Glass/PTFE	600	260	Airframe, EFGLAS
G 206*	Nickel/copper	Silicone Rubber/Glass/FEP	600	190	Airframe/fire resistant FEPSIL
G 227	Nickel/copper or aluminium	Silicone Rubber/Glass/PET	600	190	Airframe/fire resistant TERSIL
G 232	Tinned copper	Wrapped insulation	600	135	Airframe or interconnect
G 233	Silver/copper. Copper alloy size 24 and smaller	Extruded insulation	600	135	Airframe or interconnect
G 235	Silver/copper. Copper alloy size 24 and smaller	Wrapped insulation	600	150	Airframe or interconnect
G 236	Nickel/copper. Copper alloy size 24 and smaller	Wrapped insulation	600	200	Airframe or interconnect
G 237	Nickel/copper. Copper alloy size 24 and smaller	Extruded insulation	600	200	Airframe or interconnect
G 238	Nickel/copper. Copper alloy size 24 and smaller	Wrapped insulation	600	260	Airframe or interconnect
G 241	Nickel clad copper alloy	Wrapped insulation	600	260	Airframe/Fireproof
G 210	Silver/copper	PTFE wrapped or extruded	250 500 1000	200 200 200	Equipment cable

* For replacement only. Not to be used on new projects or for modifications to existing aircraft, on which they were not originally specified.

NOTE. For approval of the cables refer to clause 4.

* The installation and repair of these types of cables usually requires specific design authorization and is not therefore covered by this code of practice, except for general guidance given in 9.5.11.3.

9.2 Conductors

For equipment interconnect and airframe cables the conductors are normally of the standard copper type. However for size 24 and smaller conductors these will be of copper alloy on airframe and interconnect cables. Fire resistant cables may also have copper alloy or composite conductors throughout all applicable sizes. Conductor construction should be as given in British Standard G 231. Aluminium cable should be restricted to size 8 and larger. Aluminium cable should neither be directly attached to engine mounted accessories nor installed in other areas of severe vibration.

9.3 Conductor platings

Various platings are used on the copper and copper alloy conductors to improve corrosion resistance and the electrical resistance of terminations. The platings can themselves limit the conductor operating temperature but although these maximum continuous temperatures are given below, in practice they may be further reduced by the type of insulating material used.

The most common platings are:

- (a) *Tin plate.* Up to a continuous temperature of 135 °C.
- (b) *Silver plate.* Up to a continuous temperature of 190 °C (see clause 7 regarding proximity of ethylene glycol).
- (c) *Nickel plate.* Up to a continuous temperature of 260 °C.

Fire resistant cable conductors are normally nickel clad to enable sufficient cross section of nickel to be deposited.

9.4 Insulating materials

9.4.1 General. The insulations should be suitable for the application for which they are designed and may consist of dielectric and sheath. The dielectric is the material surrounding the conductor which provides the essential electrical characteristics of the cables and is referred to as the core. The sheath is a protective covering applied to the core, which may be of a different material to the dielectric, to improve the cables' mechanical and/or fluid resistive properties. The sheath should form an integral part of the insulation.

9.4.2 Equipment cables. The insulation on equipment cables is designed to be of minimum size and weight and may consist of dielectric only.

9.4.3 Interconnect cables. The insulation on interconnect cables will normally consist of dielectric and sheath, but be of minimum dimensions to comply with the physical protection requirements given in the individual cable specifications.

9.4.4 Airframe cables. The insulation for this type should always be of multilayer construction such that physical damage to the sheath will not progress into the dielectric. Airframe cables may also be designated 'fire resistant' or 'abrasion resistant' by altering the insulation construction to incorporate materials enabling such properties to be achieved.

9.4.5 Screen. The screen should give 85 % minimum physical coverage.

9.4.6 Cable sealing. Where the construction of the cable presents anything other than a smooth circular surface, precautions should be taken to ensure a satisfactory seal through bulkheads and at terminating devices. The cables should be installed so that transverse loads will not destroy the integrity of the sealing features of the grommet.

Cabling should be handled, stripped and installed so as not to distort, roughen or damage the insulation on which sealing is to be effected. Methods of marking and identification should be applied so as not to provide a track for moisture entry (see clause 11). The impression left on the insulation of shielded and twisted cables can also cause unacceptable degradation of the insulation in relation to the elastomer seal. Caution should be taken to avoid this condition.

9.5 General requirements

9.5.1 Selection of parts and materials. Parts and materials covered by standards listed in this code of practice are preferred and should be used whenever they are suitable for the purpose. Parts and materials should be procured from approved sources when they exist. Non-standard parts and materials should be equivalent to or better than similar standard parts and materials. When this code of practice fails to provide an applicable specification or standard, the user should use other established specifications or standards. Parts and materials selected from other than this code of practice are not standard. Approval should be obtained from the relevant agency given in clause 4 for each vendor source of non-standard parts or material prior to use in an aerospace vehicle.

When a non-standard part is used where a suitable standard part exists, the contractor should reference the standard part on the drawing, parts lists, or data package, and the installation should provide for replacement with the standard part.

9.5.2 Contractor's specification. Cabling and cabling devices conforming to contractor's specifications may be used, provided each contractor's specification is approved by the constructor and provided no acceptable specification as defined in clause 4 exists.

9.5.3 Commonality. An objective in the selection of parts should be to maximize commonality and minimize the variety of cabling components and related servicing tools required in the construction, installation and maintenance of the electrical cabling system.

9.5.4 Metals. Metals used in the installation of interconnect systems should be corrosion resistant or should be suitably protected to resist corrosion and electrolytic action during normal service life.

9.5.5 Non-metals. Non-metals used, including plastics, fabrics, and protective finishes should be moisture and flame resistant, should not support fungus growth, should meet the relevant flammability requirements, and should not be adversely affected by weathering, applicable fluids and propellants, or temperature and ambient conditions encountered during operation of the vehicle. Materials

which give off a minimum amount of noxious gases should be selected. Non-metals may be treated to conform to this requirement.

9.5.6 Component selection and installation. Cable and cabling devices should be selected and installed so as not to be subject to conditions exceeding the limits specified in the applicable cabling component specification.

9.5.7 Current carrying capacity. A guideline for the continuous current in each cable is given in table 2. The use of this tabulation should not eliminate other requirements for cable selection. The current ratings were derived for cable application only, and cannot be applied directly to associated cable termination devices (e.g. connector contacts, relays, circuit breakers, switches). The current ratings of these devices are dependent on inherent thermal and physical properties, and are limited by the design characteristics of the device. Care should be taken to ensure that the continuous current value chosen for a particular system circuit should not create hot spots within any circuit element which leads to premature failure. Acceptable temperature levels of circuit components should be those defined by the particular circuit component specification.

9.5.8 Ambient temperature. The contractor should ensure that the maximum ambient temperature to which the cable bundles will be subjected plus the temperature rise due to the cable current loads does not exceed the maximum conductor temperature rating found in table 1.

9.5.9 Voltage drop. For power distribution circuits, the total impedance of supply and return paths should be such that the voltage at the load equipment terminals is within the limits of British Standard 3G 100: Part 3.

Table 2. Nominal current ratings of cables*

Conductor material	Cable size	Current rating
Copper alloy	26	3.5
Copper alloy	24	5
Copper	22	6.5
Copper	20	8.5
Copper	18	11.5
Copper	16	15
Copper	14	18.5
Copper	12	26
Copper	10	37

* The nominal current rating is based on the continuous current which will raise the conductor temperature by a maximum of 40 °C for a bunch of three cables in free air, e.g. for a cable rated at 260 °C the maximum ambient temperature without current derating is 260 °C – 40 °C = 220 °C. Currents above those specified in table 2 may raise the conductor temperature above the 40 °C allowable temperature rise and cause insulation damage. For ratings of particular cables and for sizes above 10 the applicable British Standard should be consulted. For ratings applicable to the selection of circuit breakers refer to the 1 min ratings of the applicable cable specification.

9.5.10 Cable size colour code system. When approved by the procuring activity, a cable size colour code system as specified below may be used to facilitate recognition of the cable size. When a cable size colour code is used, the cable insulation should be identified with the appropriate colour by one of the following methods:

- (a) solid coloured;
- (b) distinctively colour banded;
- (c) distinctively striped.

The cable size colour code should be as follows.

Size	Colour
26	Black
24	Blue
22	Green
20	Red
18	White

9.5.11 Installation

9.5.11.1 General. The ease of maintenance, removal and replacement of cabling should take precedence in the original installation. Cabling should be fabricated and installed so as to achieve the following:

- (a) maximum reliability;
- (b) minimum interference and coupling between systems;
- (c) accessibility for inspection and maintenance;
- (d) circuit segregation;
- (e) prevention of damage caused by:
 - (1) chafing;
 - (2) use as handholds or as support for personal equipment;
 - (3) personnel moving within the vehicle;
 - (4) stowage or shifting of cargo;
 - (5) battery fluid or acid fumes;
 - (6) abrasion in wheel wells where exposed to stones, ice, mud, etc.;
 - (7) combat (to the maximum extent practicable);
 - (8) moving parts;
 - (9) moisture and fluids;
 - (10) localized high temperatures.

9.5.11.2 Arrangement of cabling. Cables should be arranged in looms and bundles to facilitate installation and maintenance. Individual looms should be spot tied, and when these looms are bundled lacing spot ties need not be removed, unless they are underneath a clipping point. Mechanically applied ties should be removed in all cases.

9.5.11.3 Radius of bend

9.5.11.3.1 Single or multicore cables. For single or multicore cables individually routed and supported, the minimum bend radius should be ten times the outside diameter of the cable. At the point where an individual cable breaks out from a harness or bundle, the minimum bend radius of the cable should be ten times the outside diameter of the cable, provided the cable is suitably supported at the break out point. If cables used as shield

terminators or jumpers are required to reverse direction in a harness, the minimum bend radius of the cable should be three times the diameter at the point of reversal providing the cable is adequately supported.

9.5.11.3.2 Bundles or harnesses. The minimum bend radius of a cable bundle or harness should be six times the outside diameter of the bundle or harness. In no case should the bend radius of the bundle be less than 10 times the diameter of the largest included single cable.

9.5.11.3.3 Coaxial cables. The minimum radius of bend should not adversely affect the characteristics of the cable. For flexible type coaxial cables, the radius of bend should not be less than six times the outside diameter. For semi-rigid types, the radius should be not less than ten times the outside diameter.

9.5.11.3.4 Shipping, handling and storage. These requirements also apply during shipping, handling and storage.

9.5.11.3.5 Storage and ultimate storage life. Cables should be stored in their original packages in areas where the conditions are clean, temperature controlled between 15 °C and 30 °C and a relative humidity of 50 % to 80 %. The exposed cable ends should be sealed.

Under these conditions table 3 gives the ultimate storage life for the cables listed in table 1.

The ultimate storage life given is subject to the cables being inspected at 5 yearly intervals in accordance with the requirements laid down by the cable manufacturer.

Table 3. Ultimate storage life

Specification	Ultimate storage life
	Years
BS G 177	15
BS G 210	15
BS G 221	15
BS G 222	Indefinite
BS G 206	15
BS G 227	15
BS G 232	Indefinite
BS G 233	Indefinite
BS G 235	20
BS G 236	Indefinite
BS G 237	Indefinite
BS G 238	Indefinite
BS G 241 (Fireproof)	Indefinite

9.5.11.4 Bundle and loom size. As a design objective, bundles and looms within clamps should be no more than 50 mm in diameter.

9.5.11.5 Inspection and maintenance. In open cabling, looms should be installed to permit inspection and replacement of the loom without removal of the bundle.

9.5.11.6 Dead ending. Each undesignated cable end should be dead ended with caps or with insulation in a manner

acceptable to the design authority. Dead ending should take place within 100 mm to 150 mm of connectors or feed through bushings.

9.5.11.7 Drip loop and slack in cabling

9.5.11.7.1 General. Where wiring is dressed downward to a connector, terminal block, panel or junction box a trap or drip loop should be provided in the cabling to prevent fluids or condensate from running into the devices. Potted connectors are exempt from this requirement. In addition to slack provided for drip loops, slack should also be provided to meet the requirements of **9.5.11.7.2**

to **9.5.11.7.6**. Slack requirements should be met on every production vehicle as well as experimental models. In production cable harness fabrication, provisions should be incorporated into the harness design and fabrication process to ensure that the installed harness meets these requirements without the need for straining, forcing or modifying the harness.

9.5.11.7.2 When cabling is terminated in a connector (excluding RF connectors) a minimum of 50 mm of slack for complete connector replacement should be provided. This slack should be between the connector and the second cabling support clamp. The 50 mm slack requirement should be interpreted to mean, that with the connector unmated and the first cabling support clamp loosened, the cabling will permit the front end of the connector shell to extend 50 mm beyond the point normally required to properly mate the connector.

9.5.11.7.3 At each end of a cable terminated by a lug, a minimum length of slack equal to twice the barrel length of the lug should be provided. For copper wire, size 2 and larger, and aluminium wire, size 4 and larger, the minimum length of slack should be equal to one barrel length of the lug. The slack should be in the vicinity of the lug and available for replacement of the lug by maintenance personnel.

9.5.11.7.4 To prevent strain on cables, junctions and supports.

9.5.11.7.5 To permit free movement of shock and vibration mounted equipment.

9.5.11.7.6 To permit shifting of cabling and equipment required to perform maintenance within the vehicle.

9.5.11.8 Pipelines carrying fluid. Wiring should be supported independent of, and with the maximum practicable separation from, all pipes carrying fluid. Wiring should be routed above rather than below pipes carrying fluid to prevent contamination or saturation of the wiring in the event of a leakage. Where this routing is not practicable, the wiring should pass below the pipes at an angle rather than parallel to the pipes. Terminating devices should not be placed under any pipes. Wiring should not be attached to pipes carrying fluid unless they require electrical connections. Where pipes and wiring are installed such that they are separated by rigid nonmetallic conduit, metal conduit, ribs, webs, frames, channels, extrusions, stringers, or other suitable barriers, the above requirements do not apply.

9.5.11.9 Ground return. The electrical power source ground terminals should be connected to the primary metallic structure of the vehicle. The vehicle structure should serve as the ground return circuit unless system considerations require separate ground return wiring. Equipment which incorporates a ground terminal should be grounded by the shortest suitable ground wire. Equipment which is internally grounded and which does not incorporate a ground terminal should be grounded by the shortest practicable ground wire if suitable grounding is not provided by the equipment mounts, or if corrosion of the mounts is likely to occur.

9.5.11.10 Shielded wire grounding. Unless otherwise specified by the detail installation specification for the equipment involved, shielded wires should have the shields adequately grounded.

9.5.11.11 Electromagnetic compatibility. Cable shall be routed so as to minimize electromagnetic interference.

9.5.11.12 Ignition

9.5.11.12.1 Magneto type. Flexible metallic conduit of a type specifically approved by the procuring authority should be used for magneto cable circuits. Magneto ground cables (except the induction vibrator output cable) should not run through conduit or junction boxes containing other cables.

9.5.11.12.2 Ignition HE/HT. Flexible convoluted metallic conduit incorporating a single braided metallic screen should be used for HE/HT cable assemblies. They should not be run parallel with engine harness cables when closer than 100 mm or cross them within 10 mm. Any crossing should be as near to 90° as possible.

9.5.11.13 Compass deviation. Cabling and ground return paths should be installed so as not to cause a compass deviation exceeding that allowed by British Standard G 229. Each wire carrying direct current in the area of compasses or the sensitive pick up elements of compasses should have a corresponding ground return wire twisted with it to neutralize the magnetic field.

9.5.11.14 Engine mounted accessories. For direct attachment to engine mounted accessories, cable smaller than size 20 should not be used. When size 20 cables are used, they should be high strength alloy conductors and when terminated in connectors the connector should provide support and prevent strain on terminations. The cables should be adequately grouped, spot tied and supported.

9.5.11.15 Wheel well areas. Conduit or other mechanical protection should be provided for all cables in wheel well areas. Drain holes should be positioned at all trap points unless the system is fully sealed.

9.5.12 Support and protection

9.5.12.1 General. Wiring should be supported and protected to meet the following requirements.

- (a) To prevent chafing. Where physical separation of at least 10 mm cannot be maintained the edges should be covered with suitable protection strips or grommets. Grommets and protection strips should be securely fastened in place with an adhesive bond or other

suitable means.

- (b) Secure wiring where routed through bulkheads and structural members.
- (c) Properly group, support and route wiring in junction boxes, panels and bundles.
- (d) Prevent mechanical strain or workhardening that would tend to break conductors or connections. Cables which are required to move should be installed so that the loom or bundle will twist axially with movement rather than bend.
- (e) Prevent arcing or overheated wiring from causing damage to mechanical control cables and associated moving equipment.
- (f) Facilitate reassembly to equipment terminal boards.
- (g) Prevent interference between wiring and other equipment.
- (h) To prevent excessive movement in areas of high vibration.
- (i) Dress the wiring at connectors and terminating devices in the direction of the run without deformation of grommet seals.

9.5.12.2 Primary support. Primary support of wiring should be provided by cushion clamps and plastic clamps in accordance with 17.1 spaced at intervals not exceeding 300 mm. In addition where wiring is routed through cutouts in any aircraft structure clamps should be installed as necessary to meet the protection and anti-chafing requirements of this code of practice. Open wiring contained in troughs, ducts or conduits is exempt from this requirement. Rigid portions of harnesses should be supported by clamps spaced at intervals not exceeding 1100 mm. Clamps for harnesses other than round should be shaped to fit the contour of the harness and should provide a snug fit. Plastic clamps should not be used to support rigid portions of harnesses. Plastic cable straps should not be used as primary supporting devices unless specifically approved by the design authority and then they should be subject to the restrictions on plastic clamps. The primary support of wiring should not be attached to adjacent wiring.

9.5.12.3 Support at connectors. Cables terminating in connectors should be supported to dress the wiring in the direction of the run. This may be accomplished by adaptors, clamps, potting, wire guides, or other means in accordance with 15.1.5.

9.5.13 Secondary support. Secondary support of cabling (support between primary support) should be provided by the devices selected from (a) to (c).

- (a) Lacing tapes.
- (b) Plastic cable ties in accordance with clause 13.
- (c) Binding sleeves in accordance with clause 12.

9.5.14 Limitations on support

9.5.14.1 Continuous lacing should not be used, except in panels and junction boxes where this practice is optional.

9.5.14.2 The use of insulating sleeving for the protection of cabling should be kept to a minimum. Provisions should be included to eliminate the possibility of entrapment of liquids.