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Interested committees:

Title: BS EN 3197 Aerospace series - Design and installation of aircraft electrical and optical interconnection systems

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Aerospace series - Design and installation of aircraft electrical and optical interconnection systems

Série aérospatiale - Conception et installation de
systèmes d'interconnexion électrique et optique
d'aéronefs

Luft- und Raumfahrt - Konstruktion und Installation
elektrischer und optischer Verkabelung in
Luftfahrzeugen

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee ASD-STAN.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (prEN 3197:2023) has been prepared by the Aerospace and Defence Industries Association of Europe — Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this document has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 3197:2016.

The main changes with respect to the previous edition are listed in Table 1.

Table 1 — Main changes to previous edition

prEN/EN Number	Edition	Publication Date	Modification	Reason and validation
prEN 3179	P1	August 1993	First Issue	
prEN 3179	P2	April 2010	Re write	Addresses Jar 25 requirements
EN 3179	E1	December 2010		
prEN 3179	P3	September 2016	Additional clauses	Update to include lessons learnt replaces EN 3197:2010
prEN 3179	P4		Additional clauses	Additional requirements to address new higher EWIS voltages

1 Scope

This document provides instructions on the methods to be used when designing, selecting, manufacturing, installing, repairing or modifying the aerospace vehicles electrical and optical interconnection networks, now called Electrical Wiring Interconnection System (EWIS), and Optical Fibre Interconnection Systems (OFIS), subject to the limitations defined in Clause 4 of this document. Aerospace Vehicles include manned and unmanned aeroplanes, helicopters, lighter-than-air vehicles, missiles and external pods.

The general content of this document is described in page 2.

A detailed content of this document is given in Annex A.

This document lists all the relevant European standards related to EWIS and OFIS in Annex B.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 2083,¹ *Aerospace series — Copper or copper alloy conductors for electrical cables — Product standard*

EN 2242,² *Aerospace series — Crimping of electric cables with conductors defined by EN 2083, EN 4434 and EN 2346*

EN 2283, *Aerospace series — Testing of aircraft wiring*

EN 2591-601, *Aerospace series — Elements of electrical and optical connection — Test methods — Part 601: Optical elements — Insertion loss*

EN 2812, *Aerospace series — Stripping of electric cables*

EN 2853, *Aerospace series — Current ratings for electrical cables with conductor EN 2083*

EN 3371, *Aerospace series — Electrical bonding — Technical specification*

EN 3373,* *Aerospace series — Terminal lugs and in-line splices for crimping on electric conductors*

EN 3475,* *Aerospace series — Cables, electrical, aircraft use — Test methods*

EN 3719, *Aerospace series — Aluminium or aluminium alloy conductors for electrical cables — Product standard*

EN 3745,* *Aerospace series — Fibres and cables, optical, aircraft use — Test methods*

EN 4434, *Aerospace series — Copper or copper alloy lightweight conductors for electrical cables — Product standard (Normal and tight tolerances)*

EN 4651, *Aerospace series — Copper-clad aluminium alloy conductors for electrical cables — Product standard*

TR 4684,³ *Aerospace series — Electrical technology and component definitions*

¹⁾ Related to EWIS and OFIS, all today's existing ASD Normative references per family of products may be found in Annex B.

²⁾ Published as ASD-STAN Standard at the date of publication of this document by AeroSpace and Defence Industries Association of Europe — Standardization (ASD-STAN), <https://www.asd-stan.org/>.

* All parts quoted in this document.

ASD S1000D, (revision 4.1) International Specification for Technical Publications

ISO 2685,⁴ *Aircraft — Environmental test procedure for airborne equipment — Resistance to fire in designated fire zones*

MIL-STD-202G,⁵ *Test method standard electronic and electrical component parts*

A-A-52080-84,⁵ *Specification tape, lacing and tying*

SAE AS81824/1,⁶ *Splice, electric, permanent, crimp style copper, insulated, environment resistant, class 1*

SAE AS83519/2,⁶ *Shield termination, solder style, insulated, heat-shrinkable, environment resistant with pre-installed leads for cables having tin or silver plated shields (class I)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in TR 4684 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

design authority

in this document, this term covers the Companies in charge of the original design or who give the design agreement for which Certification will be required from the Regulatory Authorities

3.2

regulatory authority

in this document, this term covers the organisations in charge who write rules to satisfy, survey the design and grant Navigability Certificate, e.g., European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA)

3.3

ESN

Electrical Structure Network

use of the aircraft metallic skin or structure as part of the electrical network for bonding purposes and current return

3.4

MBN

Metallic Bonding Network

use of a separate arrangement of metallic parts to act as the electrical network for bonding purposes

4 Limitations

It is recognized that the installation practices contained in this document do not necessarily represent the full requirements for a safe and satisfactory electrical and fibre optic interconnection system.

³⁾ Published as ASD-STAN Technical Report at the date of publication of this document by AeroSpace and Defence industries Association of Europe — Standardization (ASD-STAN), <https://www.asd-stan.org/>.

⁴⁾ Published by: ISO International Organization for Standardization <http://www.iso.ch/>.

⁵⁾ Published by: DoD National (US) Mil. Department of Defense <https://www.defense.gov/>.

⁶⁾ Published by: SAE International (US) Society of Automotive Engineers <https://www.sae.org/>.

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. However, nothing written in this document shall override the specific requirements of a design authority, the airworthiness requirements, applicable laws or any regulation from the regulatory authorities, unless a specific exemption has been obtained.

5 General requirements

5.1 Applicable rulemaking

5.1.1 General

From the EASA European Aviation Safety Agency (IR 21) and the FAR Federal Aviation Regulation (14 CFR, Part 21) — Certification of aircraft and related products, parts and appliances, and of design and production organisations.

5.1.2 Large aeroplanes

The main rulemakings to satisfy for the definitions of the various possible electrical installations on large aeroplanes are derived from:

- Design technical requirements

From the EASA European Aviation Safety Agency Certifications Specification 25 (CS 25) and the FAR Federal Aviation Regulation 14 CFR, Part 25.

5.1.3 Small and medium aeroplanes including unmanned air vehicles

From the EASA European Aviation Safety Agency Certifications Specification 23 (CS 23) and the FAR Federal Aviation Regulation 14 CFR, Part 23.

5.1.4 Rotary craft

The main rulemakings for the definitions of the various possible electrical installations on rotary wing aeroplanes (rotorcraft) are derived from:

- Design technical requirements (Small Rotorcraft)

From the EASA European Aviation Safety Agency Certifications Specification 27 (CS 27) and the FAR Federal Aviation Regulation 14 CFR, Part 27.

- Design technical requirements (Large Rotorcraft)

From the EASA European Aviation Safety Agency Certifications Specification 29 (CS 29) and the FAR Federal Aviation Regulation 14 CFR, Part 29.

5.1.5 Aircraft engines

From the EASA European Aviation Safety Agency Certifications Specification 33 (CS 33) and the FAR Federal Aviation Regulation 14 CFR, Part 33.

5.2 EWIS definition

“CS 25.1701 Electrical Wiring Interconnection System Definition

- a) *Electrical wiring interconnection system (EWIS) means any wire, wiring device, or combination of these, including termination devices, installed in any area of the aeroplane for the purpose of transmitting electrical energy between two or more intended termination points. Except as provided for in Subclause (c) of this Subclause, this includes:*

- 1) *Wires and cables.*
- 2) *Bus bars.*
- 3) *The termination point on electrical devices, including those on relays, interrupters, switches, contactors, terminal blocks and circuit breakers, and other circuit protection devices.*
- 4) *Connectors, including feed-through connectors.*
- 5) *Connector accessories.*
- 6) *Electrical grounding and bonding devices and their associated connections.*
- 7) *Electrical splices.*
- 8) *Materials used to provide additional protection for wires, including wire insulation, wire sleeving, and conduits that have electrical termination for the purpose of bonding.*
- 9) *Shields or braids.*
- 10) *Clamps and other devices used to route and support the wire bundle.*
- 11) *Cable tie devices.*
- 12) *Labels or other means of identification.*
- 13) *Pressure seals.*
- b) *(The definition in Subclause (a) of this Subclause covers EWIS components inside shelves, panels, racks, junction boxes, distribution panels, and back-planes of equipment racks, including, but not limited to, circuit board back-planes, wire integration units and external wiring of equipment.*
- c) *Except for the equipment indicated in Subclause (b) of this Subclause, EWIS components inside the following equipment, and the external connectors that are part of that equipment, are excluded from the definition in Subclause (a) of this Subclause:*
 - 1) *Electrical equipment or avionics that is qualified to environmental conditions and testing procedures when those conditions and procedures are:*
 - i. *Appropriate for the intended function and operating environment, and*
 - ii. *Acceptable to the Agency.*
 - 2) *Portable electrical devices that are not part of the type design of the aeroplane. This includes personal entertainment devices and laptop computers.*
 - 3) *Fibre optics.”*

5.3 OFIS definition

The definition of the aircraft fibre optic interconnection network, now called Optical Fibre Interconnection System (OFIS) was created by similarity. The retained text is the following:

“OFIS means any optical fibre or fibre optic cable, including termination devices, installed in any area of the aircraft for the purpose of transmitting optical signals between two or more intended termination points. Except as provided for in Subclause (c) of this Subclause, this includes:

- 1) Fibres and cables.*
- 2) Optical Data buses.*
- 3) The termination point on fibre optic transmitting sources and receiving devices protection devices.*
- 4) Connectors, including feed-through connectors.*
- 5) Connector accessories.*
- 6) Fibre optic splices.*
- 7) Materials used to provide additional protection for fibres and cables, including insulation, and conduit.*
- 8) Clamps and other devices used to route and support the cable bundle.*
- 9) Cable tie devices.*
- 10) Labels or other means of identification.*
- 11) Pressure seals.*
 - a) The definition in Subclause (a) of this Subclause covers OFIS components installed on shelves, panels, racks, and back-planes of equipment racks plus, in , junction boxes and distribution panels*
 - b) Except for the equipment indicated in Subclause (b) of this Subclause, OFIS components inside the following equipment, and the external connectors that are part of that equipment, are excluded from the definition in Subclause (a) of this subclause:*
 - 1) Fibre optic equipment or avionics that is qualified to environmental conditions and testing procedures when those conditions and procedures are:*
 - i. Appropriate for the intended function and operating environment, and*
 - ii. Acceptable to the Agency.”*

Particular information on OFIS may be found in EN 4533-001 to EN 4533-004 (see also particular B.3).

5.4 Design precedence

Design of the EWIS and OFIS shall conform to the following precedence:

- 1st – Safety;*
- 2nd – System requirements;*
- 3rd – The ease of maintenance, removal and replacement of the cabling;*
- 4th – Cost effective aircraft production.*

Cabling shall 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 including cleaning;
- d) prevention of damage.

5.5 Selection considerations

Parts, materials, directives and procedures covered by existing European standards shall be given preference by design authorities for all new European projects wherever suitable.

This document lists all the relevant European standards related to EWIS and OFIS in Annex B.

Otherwise, the parts, materials, directives and procedures shall meet the levels of performance and safety as required by the regulatory authorities.

5.6 Service life

In normal use conditions, the airframe electrical and fibre optic interconnection systems and its EWIS and OFIS components shall be selected and installed so that their service life is not less than that of the aircraft structure, which for a commercial fixed wing large aeroplane is generally 100 000 flying hours or 20 years (whichever comes first), unless otherwise specified.

For military fixed and rotary aircraft the normal service life is dependent upon the type of aircraft and its intended role each aircraft model. For guidance the following groups may be considered

Fixed wing transport aircraft 50 000 flying hours or 20 years

Fixed wing fast jet combat 10 000 hours or 15 years

Rotary wing Helicopters 10 000 h or 12 years

It shall not, however, be assumed that all EWIS and OFIS components will always achieve this life, and installations should be designed to permit a satisfactory level of inspection, test and repair according to rule CS 25.1725.

Similarly, for engines/power plants and undercarriages which normally have a minimum service life of 10 000 hours, but where, due to their modular construction, the interconnection system, or parts thereof, are required to have longer service lives, the system design shall permit satisfactory inspection, test and repair.

For devices and sub-systems which are designed to be disconnected, the number of acceptable mating and unmating operations shall be specified in the relevant technical specifications.

Many component specifications have declared life values specified as given maximum operating conditions or number of operating cycles this information should be considered as guidance only as actual applications vary widely.

5.7 Smoke and fire hazards

Components of the interconnection systems defined in this standard have been designed with an awareness of the hazards of smoke and toxic products under failure conditions. General test requirements may be found in EN 2825 and EN 2826 and dedicated test method may be found in the relevant component specifications (for example: for electrical cables see EN 3475-601 and EN 3475-602 and EN 3745-601 and EN 3745-602 for fibre optic cables).

It is the responsibility of the designer to avoid the use of materials which, in any likely conditions of use or abuse, could create a severe failure condition.

When necessary, the design of EWIS and OFIS installations shall recognize the need to provide adequate protection and separation of cables and cable harnesses by both physical and electrical means.

Flammability and self-extinguishing requirements shall be specified for all EWIS and OFIS components and it shall 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 EWIS and OFIS shall recognize that severe overheating of electrical cables is a possibility, therefore the maximum number and size of cables with associated loads within the cable harness shall be considered, see EN 2853 for calculation.

Care shall be given to the torquing of terminal lug screws.

When considering the acceptability of wire or fibre optic, reference should be made to EN 3475 (electrical) or EN 3745 (fibre optic) respectively, or alternative standards acceptable to the design authority, defining acceptable test methods, including arc-tracking test methods (see next subclause).

Damaged electrical wire and insulation can cause electrical arcing, providing the spark that can cause fire. It should be noted that contamination by materials such as dust, dirt, lint, vapours, etc. can provide fuel for fire.

Owing to potential fire hazard, silver-plating shall not be used in areas where they are subject to contamination by ethylene glycol solutions unless suitable protection features are employed.

USE OF SMALL NON-METALLIC PARTS

Small parts are those that would not contribute significantly to the propagation of a fire as knobs, handles, rollers, fasteners, clips, grommets, rub strips, pulleys, and small electrical parts.

When these parts are grouped together in the same zone, virtual volumes are equivalent and shall be taken into consideration. Verification of flammability behaviour shall be done, for example on a reference homogenous material specimen of 50 mm wide and 30 cm length.

In particular the following shall be taken into account:

- self-extinguishing properties;
- smoke density;
- gas emission toxicity;
- dripping construction materials, insulation etc. must not ignite a flammable product (paper as ISO 4046).

5.8 Short-circuit and arc-tracking

5.8.1 General

Experience has shown that people examining fault damages may confuse these two phenomena. So, the following subclause proposes a means to differentiate both and give technical information to explain the differences.

5.8.2 Short-circuit description

5.8.2.1 Cause

A phenomenon of electrical origin generating an over current (with or without an electric arc), which causes local deterioration of one or more cables (conductor and insulation) by thermal effect. This may be localized. In unprotected cables, if the fault current exceeds the rating of the supply circuits, damage could extend along its length.

The origin of this phenomenon is direct contact:

- between at least two conductors (cable core);

— of a conductor with the structure;
with different electric potentials (voltages).

The over current then appears in the damaged circuit thus causing the protection device located upstream (circuit-breaker, fuse, etc.) to trip.

The duration of the short-circuit is short (a few milliseconds to a few tenths of a second) if the fault is removed by either the operation of protective circuits or vaporization of the shorting link.

“Hard shorts” are normally when the shorting path is sufficiently large in cross section when compared to the supply conductor and if protected are normally short in duration. Such faults in unprotected circuits can cause extensive damage (i.e. low impedance conductor).

If the circuit is protected, “hard shorts” are normally short in duration.

5.8.2.2 Effects on electric cable looms

In unprotected circuits (incorrect compatibility between the cable cross section and the rating of the protection device) “hard shorts” can cause extensive damage effects on electric cable looms.

The deterioration depends on the power flowing in the circuit.

With high short circuit current, deterioration of collateral cables may occur.

Cable damage generally does not exceed 70 mm length).

Where solid state circuit breakers are used there may be minimal signs of damage and it can be difficult to locate the location of the fault.

5.8.3 Arc-tracking description

5.8.3.1 Cause

The origin of this phenomenon is contact between at least two conductors (cable core) with different electric voltages which initiates the event either due to a wet initiated arc (electrolyte liquid and damaged insulation) or dry arc (chafing on structure or between cables) “resistive” circuit.

This results in the appearance of electric arcs limiting the current in the circuit(s) to an integrated value below the tripping threshold of the thermal circuit breaker located upstream.

In returning to the source, the electric arc causes cable deterioration (conductor and insulation) by thermal effect.

As the protection devices do not trip immediately the duration of the arc-tracking phenomenon is relatively longer than that of a short-circuit and can last for several seconds.

The phenomenon stops when:

- direct ‘hard’ contact occurs between adjacent conductors (short-circuit). The over current then appears in the damaged circuit thus causing the protection device located upstream (circuit-breaker, fuse, ...) to trip;
- current flows stop due to separation of cores (lack of maintaining, blow effect, ...).

Reduce the possibility of this phenomenon by:

- using cables that are arc-tracking resistant, (combinations of materials may be employed to optimise the performance of an insulating system);
- fitting specific device to accelerate tripping from the very beginning of the arc appearance.

EXAMPLE The use of arc fault protection, such as AFCB (Arc Fault Circuit-Breaker), is another solution. It can be used to accelerate tripping from the very beginning of an arc's appearance, thus limiting collateral damage.

Providing physical separation or additional protection between cables if they are not deemed arc resistant at the circuit voltages being operated could mitigate this phenomenon.

Particular care needs to be taken with DC applications as arc resistance thresholds are often lower than for AC applications.

5.8.3.2 Effects on electric cable looms

Arc-tracking can be differentiated from a short-circuit mainly through the following indications:

- the cable insulation is partly or fully transformed into blackish carbonized residue;
- the cable damage is always located between the initial defect and the supply source;
- deterioration of collateral cables may occur.

Where solid state circuit breakers are used there may be minimal signs of damage.

5.8.4 Arc-tracking phenomenon

5.8.4.1 General — Initiation of arc phenomenon for test purposes

This phenomenon is basically a thermal effect resulting in the conversion of some particular insulating polymer into an electrically conducting material.

This is mainly the root cause for networks carrying 115 V a.c./230 V a.c. Where higher voltages are considered, the tracking is becoming less dependent of the cable insulation.

There are various ways to initiate this degradation of the insulation; nevertheless, once a power arc is produced the resultant reaction is the same.

Traditional test methodologies are carried out with 115 V a.c. in order to cover all present existing voltage sources (115/200 V a.c. and 28 V d.c.) used on aircraft, three main ways exist, classified as wet test, dry test or wet short circuit test.

The arc phenomenon may occur with 28 V d.c. power system, but it does not evolve to a sustained arc, so it was not found necessary to conduct separate DC arc resistance tests.

Revised test methods have been developed to assess a cables resistance to arc tracking when used in power systems operating at ac voltages up to 230 V phase to neutral 400 V phase to phase.

Current test methods do not cover voltages above 28 V d.c. or 230/400 V a.c. For these higher voltages, the arc tracking resistance cannot only be demonstrated by the cable insulation performance. The protection device shall play an essential role: system design rules shall define a minimum threshold of short circuit current enabling short tripping times so that damaged harness length is limited and demonstrates arc tracking resistance.

5.8.4.2 Wet arc tracking — Moisture or electrolyte-initiated tracking

This is a surface phenomenon that can act over a significant distance.

When failure occurs the conversion proceeds through the bulk of the insulation and results in more extensive damage (see note below). A continuing supply of electrolyte is required over the polymer surface, bridging points at different electrical potential typically exposed by some form of damage. When the supply of electrolyte is at a suitable rate multiple random dry spots on the surface, due to heating in the electrolyte, lead to very small low current, short duration arcs (scintillation). These arcs have a temperature of 1 000 + degrees acting over a very tiny area and, in a tracking material, gradually

produce a characteristic “treeing” pattern on the surface of the insulation. When a branch (or branches) of the “tree” eventually forms a complete path between the electrodes a sustained high temperature power arc is established. This can lead to an avalanche effect where the resultant high energy and temperature convert adjacent insulating material, that was not initially involved, into a thermally and mechanically stable, electrically conducting graphitic material.

The concerned test method is EN 3475-603. (This method includes options for both the traditional 115/200 V ac as well as an option to test 230/400 V a.c.). Pass/fail criteria used for this test is normally based on the number of insulation failures to the collateral damage cables within the test loom (115 V only) as well as the distance the arc travels along the test loom (115 V, 230 V and higher voltages).

Rationale: Harnesses that contain 115 V a.c. power supplies may also contain signal cables where EMI compatibility is demonstrated. In case of short circuit, damage to the signals shall be minimized. In that case, pass/fail criteria considering collateral damage is appropriate. For higher voltage, harnesses are only constituted of power supply lines. Therefore, in case of short circuit the amount of produced energy is “significant” and collateral cables are damaged. The loss of the complete harness shall be considered during the design phase and the consequences shall be mitigated according to system requirements and safety objectives. Thus, collateral cables damaged are not considered.

The test was designed to simulate the effect of moisture creating an electrical path between insulation damage on adjacent cables. This damage may come from insulation ageing or from possible mechanical aggression for example from chafing or bad hot stamp markings.

5.8.4.3 Electrical erosion

Where a material does not produce conductive surface spots the scintillation may lead to the loss, by evaporation or de-polymerisation, of tiny amounts of insulation whilst leaving the surface chemically unaltered. In tests for wet tracking, it is important that the pass/fail criteria be set to discriminate between violent tracking failure and the longer term, relatively benign effects resulting from extreme erosion in materials prone to this effect.

Cable insulations that erode causing collateral damage failures, under standard 115/200 V a.c. EN 3475-603 test conditions, are not normally considered acceptable for use on aircraft for power distribution applications.

It is important to note that all insulating systems subjected to long term electrical erosion will fail, even cables subject to collateral damage. It is just a question of time.

So, visual examination of test samples is an important way of discriminating between the arc-tracking and electro erosion phenomena (see 5.8.3.2).

5.8.4.4 Dry tracking

This is a bulk rather than a surface effect. No electrolyte or moisture is required. This phenomenon is historically the most common form of arc track seen on aircraft.

Very localized heating occurs over the cross section of the insulation at the “fault” point. The heating results from tiny, intermittent, short duration sparks from the bridging of exposed conductors that do not trip a conventional circuit breaker. Such faults are known as “splashing” or “ticking” faults and may be caused in service by a vibrating conductor to structure contact or flexing of wire with broken conductor strands. Such sparks act in a similar manner to scintillation and gradually, pyrolysis the entire bulk of the insulation material will occur. This results in, for a tracking polymer, a conducting graphitic structure with the potential for avalanche failure within a bundle (as is the case with wet arc tracking described above).

Typically, in tests for dry tracking the initiation is via a vibrating metal edge which bridges power carrying conductors at points having different electrical potential.

The concerned test method is EN 3475-604. This test method simulates the most common cause of arc track events that has historically been seen on aircraft. (The method includes options for both the traditional 115/200 V a.c. testing as well as an option to test 230/400 V a.c.). Pass/fail criteria used for this test is normally based on the number of insulation failures to the collateral damage cables within the test loom as well as the distance the arc travels along the test loom.

The test was designed to simulate the effect of chaffing against structure creating an electrical path between insulation damage on adjacent cables.

5.8.4.5 Wet short-circuit test

This involves the simultaneous shorting, by drops of electrolyte that run down the insulation and across the exposed flush cut ends of conductors in a wire bundle. The conductors are energised at different potentials and because of the small inter-conductor distances vigorous arcing is quickly established on all wires. There is a combination of some surface scintillation between the electrolyte drip point and the conductors but primarily vigorous arcing over the short distance of the insulation cross section. In a tracking insulation there is rapid conversion into a graphitic structure and rapid “burn back” towards the electrical source. In a non-tracking system, the conductor itself is gradually eroded within the insulation. The insulation remains as a tube and the path length between conductors slowly increases to the point where the short circuit ‘self-extinguishes’ and activity ceases.

The concerned test method is EN 3475-605. (The method includes options for both the traditional 115/200 V a.c. testing as well as an option to test 230/400 V a.c.). Pass/fail criteria used for this test is normally based on distance the arc travels along the test loom.

The test was designed to simulate the effect of moisture ingress into a connector back shell in which bung sealing is faulty and can lead to shorting between rear parts of pins via wire insulation and/or across the surface of the sealing bung.

Care should be taken when assessing the results of this test as the burn back length can be limited by the creation of a hard short between conductors due to molten conductor bridging the gap and artificially removing the power and giving miss leading test results.

5.8.4.6 Notes on arc characteristics

Metal-to-metal arcs are of high-current density and relatively unstable; as such they tend to “cut” conductors rapidly and thus limit damage to the faulted wire. Graphite-to-metal and particularly graphite-to-graphite arcs are low-current density, stable, and spread over a large area so that circuit interruption is delayed; this delay gives time, in tracking materials (only a few milliseconds are required), for the conversion of adjacent insulation to conducting material and the potential avalanche effects.

5.9 Installation groups

The design, modification and repair of EWIS and OFIS need to be considered for each of the following groups according to their specific requirements. Zoning references for military aircraft are based on ASD-STAN S1000D Chap.3.4 “Zoning and access”:

- fire and high temp zones (engine bays): engine cable harnesses;
- essential equipment and systems fuel zones and fuel systems/management wiring;
- electrical power generation and distribution - heavy duty; and/or high voltage;
- airframe non-pressurized SWAMP (Severe Wind And Moisture Problems) areas;
- undercarriage areas;

- general airframe;
- equipment cabling (line replaceable unit boxes, panels and racks, etc.);
- radio- and/or video frequency;
- data bus and/or video digital links;
- optical fibre link.

5.10 Maintenance considerations

The maintainability of EWIS and OFIS including cleaning, inspection and test shall be a prime consideration in the selection, design, installation and identification of harnesses, electrical/optical cable assemblies and wiring system components. All cabling should be accessible, repairable and/or replaceable at the maintenance level specified by the design authority. Other specific requirements concerning maintenance, such as cleaning methods, are specified in the appropriate subclause on the subject.

It shall be noted that EWIS and OFIS of some particular systems or parts may require particular maintenance considerations, examples: engines, landing gears, fly-by-wire, shielded bundles, weapons and defensive aids subsystems.

When performing maintenance on certain parts of the aircraft such as engines, wings etc. there may be additional considerations such as flammable liquids that may prohibit some operations such as the use of heat guns.

5.11 Materials and parts considerations

5.11.1 General

As a minimum, the selection of EWIS and OFIS materials shall take into account requirements of rule CS 25.603.

Parts and materials listed within this document are to be used wherever they are qualified and suitable for the purpose and must be procured from qualified, traceable sources. If non-standard parts and materials shall be used, they shall be qualified and equivalent to or better than similar standard parts or materials and shall also be procured from qualified traceable sources. If a non-standard part is used where a suitable standard part exists or not, the Original Equipment Manufacturer (OEM) and/or final user shall ensure qualification and interchangeability conformities to seek approval as substitution.

(Hence manufacturers shall be qualified and demonstrate traceable sources before manufacture or supply commences).

However, OEM shall reference the standard part on the drawing or parts list and clearly manage and trace any substitution lists versus to the standard parts to make provision for substitution the applicable standard, when applicable; otherwise, a specified parts or materials must be qualified and be referenced on the drawings.

5.11.2 Environmental directives

Directives, such as EU (RoHS-REACH), relative to electrical components or equipment's have evolved and now call for the prohibition of the use of substances considered to be hazardous, such as lead, cadmium, mercury and hexavalent chromium, contained in these components or equipment. For particular cases where no substitutive solution exists, derogation shall be obtained from the authorities.

The following technical reports apply to the aerospace and defence industries and their supply chains:

- TR 9535, *Aerospace series — Substance declaration*;
- TR 9536, *Aerospace series — Declarable Substances Recommended Practice*.

During the life of the airframe the above may render existing components obsolete and care shall be taken when selecting replacement items that they are compatible with and maintain the performance of the existing system components.

5.11.3 Metals

The metals used shall be corrosion-resistant or suitably protected for resistance to corrosion throughout the expected service-life. The maximum potential difference between any two metals in mutual contact should be 300 mV to minimize the risk of electrolytic corrosion unless the junction shall be protected to avoid electrolyte presence. See Annex C for potential differences between common metals.

5.11.4 Dissimilar metals

Dissimilar metals used shall conform to the requirements of Table 2. The requirements shall be established for the selection and protection of dissimilar metal combinations and other significant corrosion behaviour factors.

5.11.5 Non-metals

All non-metals used, including plastics, fabrics and protective finishes, shall not support micro-organic or fungus growth, and should not be adversely affected by weathering, applicable fluids, temperature and ambient conditions encountered while the aircraft is in service.

So as to avoid any hazards to the occupants, they shall:

- meet the relevant flammability requirements of the Design Authority including the requirements of JAR 25 CS Appendix F;
- not emit, when burning, a smoke density higher than a specified limit;
- not emit toxic gases with a concentration exceeding specified values;
- not allow the build-up of static when installed in a fire zone.

Cable insulation and protective parts using PVC (polyvinyl chloride) are absolutely prohibited.

Polyamide materials can be used for cable ties and fitting parts provided that they are not used in applications which exceed the devices environmental ratings.

Attention is brought on some fluoroelastomers for which decomposition residues, after fire for example, can be hazardous.

Wire insulation shall have an arc resistance capability as defined in their own standard.

5.12 Quality

5.12.1 Components qualification

EWIS and OFIS components shall be qualified for airborne use or specifically assessed as acceptable for the intended use and be appropriate for the environment in which they are installed, through for example the ASD quality management systems and qualification procedures defined in EN 9133.

Aircraft manufacturers list approved components in their manuals, such as the standard wiring practices manual (ATA Chapter 20). Only the components listed in the applicable manual or approved

substitutes should be used for the maintenance, repair, or modification of the aircraft. EWIS and OFIS modifications to the original type design should be designed and installed to the same standards used by the original aircraft manufacturer or other equivalent standards acceptable to the Authorities. This is because the manufacturer's technical choice of an EWIS and OFIS component is not always driven by regulatory requirements alone. In some cases, specific technical constraints would result in the choice of a component that exceeds the minimum level required by the regulations.

5.12.2 Processes qualification

All processes, used for production shall be qualified for airborne use or specifically assessed as acceptable for the intended use, when available through standards such as:

- EN 2812 for stripping of electric cables, or;
- EN 2242 for crimping of electric contacts;
- EN 3373 for terminal lugs for crimping;
- EN 2283 for testing of aircraft wirings.

During maintenance, repair or modification, processes must come from the same standards used by the original aircraft manufacturer or from other equivalent standards acceptable to the authorities.

Some particular processes may require qualified operators and this qualification shall be periodically re-validated.

When performing maintenance on certain zones of the aircraft such as engines, wings etc. there may be additional considerations such as flammable liquids or gases that may prohibit some operations such as the use of heat guns.

5.12.3 Test methods

Test methods used for qualification, validation, expertise, technical comparison should come from recognized standards and particularly when available from European standards such as EN 2591, EN 3475, etc.

(See list of existing standards in Annex B).

5.13 Specific requirements

5.13.1 Advice

In this particular paragraph, only requirements specific to power plants, helicopters and light planes are highlighted. All other requirements are in accordance with this document.

5.13.2 Power plant

5.13.2.1 General

Engines have no pressurized zones, but normally operate below an altitude of 50 000 feet for civil aircraft or 100 000 feet for military aircraft.

Engines are generally equipped with several harnesses which can be removed separately and are considered as equipment. Each harness is serialised.

Cables or wires encased in some form of overprotection are not individually identified, although at single wire terminations identification is required to prevent cross connection.

Each harness and each connector on the harness is identified with a functional identification number.

5.13.2.2 Connectors

a) Selection

Sealed version of connectors and connecting devices are required.

b) Sealing

Contacts shall be fitted in all cavities at firewalls. All cavities in the rear grommet shall be filled with either a wire, a filler plug or a wire stub.

c) Mechanical locking

Connectors that have a self-locking device are preferred if these are not available an alternative method shall be used.

5.13.2.3 Wiring and fastening

a) Minimum bend radius recommended

For solid harness (when cables are strongly clamped together) and interconnection harnesses, minimum bend radius recommended are:

1) electrical harnesses :

- 5 times to 10 times the diameter of assembly depending on harness technology (for example heat shrinkable tubing or over-braiding of the harness);
- the minimum bend radius of any of individual cable shall not be exceeded;

2) data harnesses, fibre optic bundles and hybrid harnesses:

- the recommended bend radius of these cables is given in 9.5.4, Table 2;

b) Harness clamps

Generally, harnesses shall be fixed on engine by means of locked attachment devices (P clamp types) or unlocked attachment devices (omega type).

It is recommended to use a locked attachment device when there is a risk of accidental unclipping of the harness in case of shocks, or during interventions on LRU equipment and between two mobile points (harness installed on a hinged door).

It is recommended to alternate the orientation (up and down) of the unlocked attachment device, to avoid accidental unclipping of whole harness. The use of the omega clips is not recommended in abrupt bending areas (90°) in order to avoid unclipping or damaging the harness branch.

5.13.2.4 Installation

Electrical harnesses and fibre optic bundles should be installed so that they can be removed and refitted without the need to remove other engine components, such as brackets, pipes, etc.

Where a harness or bundle crosses butting flanges in hot area of engine main casings, sufficient care shall be brought such that no possible hot gas leakage can damage cable insulation.

The harness or bundle shall not be routed parallel to and on top of engine main flanges junction where a hot gas leakage may destroy the electrical cable insulation or compromise the outer jacket of fibre optic cables.

Consideration shall be given to the following when deciding a cable route:

- a) avoidance of, or protection from, damage during engine installation and maintenance;
- b) avoidance of areas where crash-landing damage would constitute a hazard;
- c) accessibility for maintenance testing, inspection and repair;
- d) avoidance of any position and/or shape which would encourage the use of the harness for handholds or footrests;
- e) common mode failure of duplicated functions;
- f) minimise physical damage that may result from fire, turbine burst, starter burst, duct burst or fluid contamination;
- g) Failure Mode Effect Analysis (FMEA) on signal separation;
- h) removal of harness without disturbance to another system that would necessitate a re-test to that system;
- i) removal of LRU accessories with minimal harness disturbance;
- j) relative movement between connectors/terminations and fixed points, such as clipping points, terminal blocks, etc.

In the area of fan blade-out containment, special attention shall be taken for the minimum clearance in order to avoid any hazardous damage.

The connections to accessories which are mounted on vibration isolators shall be carefully considered. The clipping and harness shall not add loads to the installed accessory outside of defined limits. The accessory manufacturer shall take into account the connecting hardware (harness and associated clipping) and its spring rate for the requirements of the anti-vibration system.

The relevant movement between the engine and the pylon shall be taken into account for items that connect to the pylon interface.

5.13.2.5 Separation

On dual channel, electronically controlled engines, harnesses for the two separate channels shall be allocated to different connectors and the separation shall comply with the following:

- a) whenever possible, the maximum lane separation shall be maintained for the entire harness run;
- b) for civil extended twin operations (ETOPS), a lane-to-lane separation shall be maintained in those areas designated “cross-engine debris areas”, where uncontained debris from one engine can impact the remaining engine;
- c) lane-to-lane separation may be relaxed outside “cross engine debris areas” providing there is no risk of common mode failure. The minimum segregation distance allowed shall be conform to airworthiness requirements and should be quoted in the relevant specification. If the requirement of the relevant specification is not achievable due to space restraints, agreement shall be obtained from the relevant authority.

In order to minimize the transmission of radio frequency interference from the High Energy (HE) igniter leads to the engine harness, cables shall not be run parallel with the HE leads closer than 100 mm (4.00 ins). Where cables have to cross HE leads this shall be done as near 90° as possible with a

minimum air gap of 10 mm (0.39 ins). If the above two conditions cannot be met, then a HF shield shall be interposed between the HE lead and the cable or the HE-leads shall be shielded.

5.13.3 Rotorcraft

5.13.3.1 General

Rotorcraft may be manned or unmanned, military or civil and is typically designated as being a helicopter, but can also include tilt rotor platforms.

A helicopter is a type of aircraft which derives both lift and propulsion from horizontally mounted overhead revolving rotors with a tail rotor, ducted fan or NOTAR (no tail rotor). It is capable of moving vertically and horizontally, the direction of motion being controlled by the pitch of the rotor blades.

Due to rotating masses of flight surfaces helicopters, can exhibit high levels of vibration in normal flight modes. These vibration curves are usually defined within general specification requirement documents per Design Authority platform. It is the Design Authority responsibility to ensure that EWIS and OFIS consider vibration curves and ensure that selection of components and installation procedures are not compromised by vibration factors.

It should be considered that helicopters have restricted absolute service ceiling height in comparison to fixed wing platforms. This in general precludes the assessment of wiring harness power de-rating. If the Helicopter design exceeds recognized ceiling heights, it will be the design authorities responsibility to assess and maintain correct parameters in accordance with de-rating tables.

Tilt rotor designs are hybrid Helicopter/Fixed Wing aircraft and may contain pressurized zones. Design authorities should therefore consider both Helicopter and fixed wing requirements where appropriate.

Helicopters in certain roles, will operate in heavy salt spray laden environments. Design authorities shall consider selection of components and installations to ensure optimum protection from those environments.

Helicopters in a military role will need to conform to the requirements of the mandating military authority with respect to armament installations. These requirements will take precedence over requirements specified in EN 3197.

Consideration shall be made to weight saving by use of optimized:

- 1) equipment locations;
- 2) electrical harness routing between equipment;
- 3) selection of wire/cable types and gauges;
- 4) use of composite connection devices and accessories satisfying lightning strike exposure, temperature exposure and environmental exposure (plating finish);
- 5) electric harness/fibre optic bundle component parts;
- 6) attachments and cable supports.

5.13.3.2 Connectors

a) Selection

Where practical environmentally sealed connectors and connecting devices incorporating interfacial and rear grommet seals are preferred. Selection of connector types where practical shall conform to recognized aerospace connectors and connector standards. Where aerospace standards do not exist, it is the design authorities responsibility to authorize usage.

b) Sealing

Unused cavities of environmentally sealed connectors shall be populated and sealed at the rear grommet side to maintain the environmental sealing of the connector.

For electrical connectors the cavities shall be populated with non-terminated contacts and sealed at the rear grommet side using filler plugs or contacts with stub wires.

For fibre optic connectors the cavities shall be populated with sealing plugs. The sealing plugs shall conform to the sealing requirements of the fibre optic terminus and have a protruding extension at the rear of the connector body to allow ease of insertion and extraction, and to act as an indicator that a sealing plug is installed.

Before installing a wire/cable into a connector, reference shall be made to the product standard for that connector, to ensure that the outside diameter of the cable outer jacket outside diameter is compatible with the connector grommet seal. If the diameter is below the size authorized by the product standard, it shall be increased by sleeving as specified by the design authority.

c) Polarization

The polarization master key should be situated at the top of receptacle (front view of equipment).

Intermediate airframe plug breaks -The polarization master key should be situated at the top of receptacle breaks. If mounted horizontally (not preferred) the master key should face forward.

Electrical connectors shall be angularly indexed especially when elbowed rear connector accessory is used.

5.13.3.3 Components

Electrical and fibre optic components selected shall conform where practical to recognized aerospace standards. Where aerospace standards do not exist, it is the design authorities' responsibility to authorize usage.

5.13.3.4 Wiring and fastening

Electrical wires and fibre optic cables selected for helicopter wiring harnesses shall conform where practical to recognized aerospace standards. Where aerospace standards do not exist, it is the design authorities' responsibility to authorize usage.

EWIS and OFIS should be installed in such a way that the airframe or localized structure affords natural protection for wiring harnesses and fibre optic bundles. Where the airframe or localized structure does not afford suitable protection, additional protective means should be used, or suitable mechanical guard introduced.

Harnesses and bundles should be routed in such a way that they are not capable of being damaged by external forces e.g. cargo, used as hand or footholds and protected against crushing e.g. being stepped on, other considerations should be taken into account, including:

- routing along heavier structural members whenever possible;
- routing within Severe Wind and Moisture Prone (SWAMP) areas should be kept to a minimum;
- sharp edges must be protected by suitable protective edging or grommets to prevent chafing;
- avoid routing under fluid carrying pipes;
- avoid routing between aircraft skin and fuel lines. Where deemed necessary the route should be at an angle to the pipe not parallel;

- avoid running wire harnesses and fibre optic bundles along the bottom of the fuselage or within 150 mm of the bilge;
- avoid routing over landing gear, or adjacent to flammable fluid or fuel lines or fuel tanks;
- ensure no interference of harnesses or bundles with rotating or moving parts by suitable routing or fastening;
- ensure failure of a fastener does not allow a harness or bundle to interfere with rotating or moving parts;
- EWIS and OFIS components installed in the passenger cabin are located to prevent, or protected from possible damage by passengers;
- harnesses and bundles routed to, and on seats should be routed to prevent, or protected from damage by external effects e.g. luggage, feet, etc.

Separation distances of wires to other (or equivalent barriers) should be determined considering the factors listed above.

When necessary, electrical wiring, fibre optic cables or buffered optical fibres inside panels, boxes, racks shall be installed in such way that distance between the various routes shall ensure the required separation (as defined by the design authority). Where this is not practically achievable consideration should be given to system content within the enclosure to EMC coupling and/or physical damage and their implications to helicopter safety and mission.

Where helicopters utilize a single engine, with dual redundant channels within the engine control architecture or the helicopter has multiple engines with/without dual redundant channels lane segregation is applicable.

5.13.4 Light aircraft

Reserved.

5.13.5 APU

See 5.13.2 on power plants.

5.13.6 Composite structures

5.13.6.1 Electrical implication

Metallic fuselage inherently supports the following functions:

- 1) signal and power current return (grounding);
- 2) fault current return path (bonding);
- 3) signal electrical reference (low impedance ground plane);
- 4) lightning protection: systems, structure, passengers;
- 5) electro-magnetic field protection (HIRF);
- 6) antenna ground plane.

Composite materials do not satisfy any of these without the addition of metallic components or systems for example:

Composite structures can provide support to:

- functions 1, 2 and 3 with the implementation of a single metallic Electrical Structural Network (ESN) or Metallic Bonding Network (MBN);
- function 4 with the implementation of metallic foil or mesh to the outer surface structure;
- functions 5 and 6 with the implementation of metallic foil on the inside of the structure. Special attention shall be given to wiring adjacent to composite structure containing carbon, this can increase the secondary (indirect) effects of lightning.

Adequate protection must be provided for wiring in composite structures to resist the effects of lightning strike.

Special provision shall be made to protect wiring in fuel tank areas.

Measures shall be taken to prevent the build of electrostatic charge on composite structures, especially any air washed surfaces. Adequate electrical bonding provision must be provided.

5.13.6.2 Thermal implication

Thermal characteristics of composite structures are different to those of metal structures. So particular care shall be taken to avoid:

- 1) current injection as a result of an abrasion between an electrical harness and composite part causing a thermal effect of a short circuit in the immediate vicinity;
- 2) reduced capability for heat sinking properties for structurally attached components.

Such failure modes can generate localized hot spots, leading to overheating, fire, smoke, current injection and arcing.

5.13.6.3 Installation considerations

From the failure modes detailed above, the following requirements should be applied as a minimum:

- routings of cables or harnesses should be defined so as to take advantage of protection provided by any surrounding metallic structures;
- any contact between electrical cables or harnesses and carbon fibre-composite panels, structure, surface, conductive or non-conductive shall be prohibited. A minimum specified clearance must be maintained to avoid any reciprocal damage. If this clearance cannot be maintained, additional protection shall be provided on the harness or on the conductive composite part.

5.13.6.4 Electrical structure network (ESN)

The ESN integrity shall be maintained during the service life of the platform. For this the maintaining of the electrical resistance value between any two points of the ESN shall be guaranteed.

6 Selection of EWIS and OFIS components

6.1 Applicable rulemaking

As a minimum, the selection of EWIS and OFIS components shall take into account EASA Certification requirements.

6.2 Special requirements

6.2.1 Commonality

An objective in the selection of parts shall be to maximize commonality and minimize the variety of components and related servicing tools required for the construction, installation and maintenance of the interconnection system.

6.2.2 Maintenance, repair or modification

EWIS and OFIS components shall be chosen according to requirements given in 5.12.

6.2.3 Materials

Materials used for EWIS and OFIS components shall take into account materials consideration from 5.11. Pig tails and flying leads attached or integral with components shall conform to the general wire requirements for cables within the aircraft zone that they are being fitted.

6.3 Electrical and fibre optic cable selection

6.3.1 Environment

Careful attention should be applied when deciding on the type of cable needed for a specific application. Consideration should be given whether the construction of the wires and cables are suitable for the application environment. For each installation select cable construction type suitable for the most severe environment likely to be encountered in service. As examples, use a cable type that is suitable for flexing for installations involving movement; use a cable type that has a high temperature rating for higher temperature installations.

When considering the acceptability of cable refer to the industry standards defining acceptable test methods for aircraft cable (e.g. EN 3475/EN 3745 or alternative manufacturer standards).

Cables in systems that must operate during and after a fire, such as fire detection, fire extinguishing, fuel shutoff, and fly-by-cable flight control, must be selected from cable types qualified to provide circuit integrity after exposure to fire for a specified period.

In addition to the necessary flammability requirement of EN 3475-407 (self-extinguishing test), the selection of electrical and optical cables must take into account known characteristics in relation to particular installation and application so as to minimize the risk of cable damage including any arc-tracking phenomena.

For use in pressurized zones, smoke and toxicity characteristics of the insulation must be taken into account.

Cable shall be selected so that the rated maximum temperature is not exceeded for any combination of electrical loading, ambient temperature, and heating effects of bundles, conduit and other enclosures. Typical factors to be considered in the selection are voltage, current, ambient temperature, mechanical strength, abrasion, flexure and pressure altitude requirements, and extreme environments such as Severe Wind and Moisture Problem (SWAMP) areas or locations susceptible to significant fluid concentrations.

Different cable types installed in the same bundle should withstand the cable-to-cable abrasion to which they will be subjected. Consideration should be given to the types of insulation mixed within cable bundles, especially if mixing a hard insulation type with a relatively softer type, and particularly when relative motion could occur between the cables. Such relative motion between varying cable insulation types could lead to accelerated abrasion and subsequent cable failure.

The marking process used to add a "Function Identification Number" must take into account the thickness and the notch propagation characteristic of the insulation or outer jacket. The process used to

apply user marking to the insulation or outer jacket shall not degrade the insulation or outer jacket. Marking of cables by the hot stamp cable marking processes is not allowed.

6.3.2 Type of cable

The type of electrical and optical cable used should meet the requirements of the relevant ISO standard or European standard aerospace series or any other Aerospace standard deemed acceptable by the aircraft design authority.

The type of cable selected will depend upon the application. For existing European standards, see B.2 of Annex B.

Cable termination in devices which require an environment resisting seal shall have jacket materials compatible with the sealing feature of the device. Where the outer diameter of the cable is smaller than the minimum allowable diameter of the sealing feature, sleeving to EN 4530, EN 4708 or similar methods shall be selected to provide effective environmental sealing of the device.

The various types of cable by application shall be as described in 6.3.6 to 6.3.12.

6.3.3 Electrical cables

6.3.3.1 Conductors

6.3.3.1.1 General

For equipment cables, the conductors shall be copper, including size 002 (24 AWG) and smaller.

For airframe cables the conductors shall be copper or nickel-plated copper clad aluminium. Size 002 (24 AWG) and smaller sizes shall be a high-strength copper alloy or reinforced construction.

For feeder cables, the conductors shall be copper or aluminium or copper clad aluminium.

Fire-proof and fire-resistant cables, such as in EN 2346, shall have nickel clad copper alloy conductors throughout all the applicable sizes.

The construction of copper and copper alloy conductors shall be as defined in EN 2083 or EN 4434.

The construction of aluminium conductors shall be as defined in EN 3719.

The construction of copper clad aluminium conductors shall be as defined in EN 4651.

Aluminium and copper clad aluminium conductors need specific connection devices. Smaller sizes should be restricted in high vibration Aluminium material has less flexibility and a reduced flexible endurance compared to copper material.

Small size aluminium cable shall not be attached to engine mounted accessories or installed in other areas of vibration or flexing.

Aluminium cables shall not normally be used where the length of run is less than 1 m or in areas where corrosive fumes may exist.

The mechanical strength of aluminium conductors is reduced when subject to temperatures above 180 °C and the use of smaller sizes above this temperature is not recommended.

6.3.3.1.2 Conductor platings

Various plating's are used on the conductors to improve corrosion resistance, temperature rating and the electrical resistance of terminations.

The plating's can themselves limit the conductor operating temperature but although these maximum continuous operating temperatures are given below, it shall be understood that they may be further reduced by the type of insulating or conductor material used:

Tinplate: maximum temperature of 150 °C;(continuous rating). The solder ability of tinplate copper conductors degrades significantly 6 months to a year after production and soldering of these conductors should be avoided unless mitigating processes are used (retinning, activated flux use, etc.).

Silver plate: up to a continuous temperature of 200 °C, this temperature may be reduced by the temperature properties of the insulation materials used (see limitations regarding proximity of ethylene glycol).

NOTE Tin- and silver-plated copper conductors will degrade when exposed to operation beyond their stated continuous rating. These platings are non-preferred on military aircraft for general purpose and power applications.

a) nickel plate: up to a continuous temperature of 260 °C;

b) nickel cladding: up to 315 °C.

Aluminium or aluminium alloy cable conductors, without plating, shall be limited to 180 °C.

Silver- or nickel-plated aluminium or copper clad aluminium cable conductors shall be limited to 180 °C as the conductor material tends to loss tensile strength above this temperature. Copper clad aluminium and aluminium conductors shall only be used when the termination method incorporates environmental sealing, due to the possibility of corrosion caused by dissimilar metals (Annex C).

6.3.3.2 Insulating materials

The insulation of electrical cables shall be suitable for the applications for which they are designed and may consist of one or more layers or coatings. Addition of a special sheath is sometime necessary for particular purpose.

Insulating materials shall have an arc resistance capability which will meet the intended usage.

The dielectric is that part of the insulating material surrounding the conductor and provides the essential electrical characteristics of the cables. The sheath is an integral part of the insulation applied as a protective covering over the whole cable. It may be of a different material from the dielectric to improve the mechanical and/or fluid-resistant properties and may be used to identify the cables.

The temperature rating of the insulation may be the limiting factor rather than the conductor material for some cable types.

6.3.3.3 Screen

Braided screens give normally 85 % minimum optical coverage, unless otherwise specified in the relevant product standard. Spiral screens give normally 90 % minimum optical coverage, unless otherwise specified in the relevant product standard.

Particular screen construction, such as double braids, special tape, may be used to obtain necessary surface transfer impedance (Zt).

For screen plating's may be used for braid screens Tin, Silver, Nickel.

6.3.3.4 Jacket

The outer jacket of electrical cables shall be suitable for the applications for which they are designed and may consist of one or more specific materials or coatings.

The jacket may be used for facilitation of marking, environmental or mechanical protection, electrical insulation of screen or colour coding.

Cable jackets using PVC (polyvinyl chloride) are absolutely prohibited for new designs or installations.

Hybrid polyimide jacketing/insulation materials may be used when approved by the relevant design authority.

6.3.4 Voltage and current ratings

6.3.4.1 Voltage rating

Insulation systems used in aerospace applications have the majority of tests and ac applications performed up to 115 volts (Phase to neutral, 400 Hertz AC and 28 Volts DC. Verification of the suitability of this product for use in other electrical system configurations is the responsibility of the design authority. In all cases the dielectric strength of the insulation shall be at least 3 times the working voltage.

Voltage rating shall take into account the effects of low air pressure. Where voltages greater than 300 V are used the effects of corona shall also be considered.

Designers should also take into account application specific factors such as peak voltages, switching transient voltages and other voltage conditions particularly in circuits attached to reactive loads which may be switched whilst under load. These may be increased where solid state circuit breakers are implemented as the protection device.

6.3.4.2 Current ratings

EN 2853 gives directives for the continuous current in each electrical cable. This does not justify disregarding other requirements for the selection of cables (see 7.5.2.4 Rating choice).

Cable should be sized so that all wires distributing current from a circuit protective device shall have a capacity which is at least equal to or greater than the rating of the protective device under all operating conditions. Power feeder wires shall be sized for the rated capacity of the power source.

The effects of altitude (reduced cooling effect), bundling environmental temperature and the thermal insulating properties of any cable protection systems see AS50881 de-rating curves.

6.3.5 Equipment cable

These cables are designed for use within equipment or in areas where total protection from mechanical abuse is ensured.

6.3.6 Airframe cable

Copper EN 2267, EN 2266, EN 2854, EN 2713, EN 2714, EN 4611 and EN 4612

Aluminium EN 4681, EN 4682

These cables are of sufficiently robust construction to satisfy the requirements for open aircraft cabling and cabling nonessential systems within engine compartments.

Cable sizes smaller than 002 (24 AWG) are not generally for use as single wires without additional support. Size, 002 (24 AWG) and smaller wires should always be high strength copper alloy conductors.

6.3.7 Fireproof and fire-resistant cable

(EN 2346, EN 4608)

Wires routed in fire zones for fire detection, fire extinguishing, fuel shutoff, and fly-by-wire flight control systems that are required to operate during and after a fire, shall be selected from types that are qualified to provide circuit integrity during exposure to fire for a specified period.

The use of standard airframe cables with additional protection that achieves the equivalent fire performance may be considered.

These cables shall always be of the "airframe" type with the additional requirement that they continue to operate, at a reduced performance level, for a period during fire as defined in ISO 2685 (fireproof 15 minutes. and fire resistant 5 minutes.).

6.3.8 Coaxial cable

(EN 4604)

These radio-frequency cables are used to connect high frequency circuits. Various types are available according to the operating frequency of the circuit, e.g. VHF, UHF, etc.

6.3.9 Data bus cable

(EN 3375)

These data bus cables are used in the interconnecting of data transmission systems.

They can be of twin or quadrax construction.

Splices on databus cables are not permitted on Military aircraft without express permission of the design authority and pre-acceptance by the end user.

6.3.10 Thermocouple or extension cable

(EN 4049)

These cables are used for interconnecting temperature measuring systems.

Environmentally sealed connections should be used for the transition from thermocouple cable to copper. Crimp terminations are preferred.

Care should be taken to ensure both the ambient temperature conductor and internal hot junction conductor are at the same ambient temperature at any interconnect point.

Splices on thermocouple cables are not permitted on military aircraft without express permission of the design authority and pre-acceptance by the end user.

6.3.11 Fibre optic cables

6.3.11.1 General

Fibre optic cables and optical fibres have a number of distinct transmission capabilities and advantages over electrical wiring. Examples of advantages include:

- a) safety – Optical fibres are passive and do not carry any electrical current. Therefore, should the cable be damaged and the core exposed, there is no risk of a short circuit generating a spark that may ignite explosive gasses or fluids;
- b) high bandwidth – High data rate transfer than conventional electrical systems;
- c) size and weight – FO cables are typically 70 % to 80% lighter than their copper counterparts;
- d) FO cables are unaffected by external interference including Electro-magnetic Interference (EMI), they are also non-emitting eliminating signals that can cause interference. Therefore, they can be routed alongside power and signal cables without any risk of crosstalk;
- e) signal loss – FO cables have very low rates of attenuation allowing for reliable data transmission with very low BIT rates;
- f) security – FO cable does not radiate a signal as the optical signal is a passive light wave therefore, they cannot be accessed by non-intrusive means.

When considering the acceptability of wire refer to the industry standards defining acceptable test methods for aircraft wire e.g. EN 3745 or alternative manufacturer standards.

6.3.11.2 Construction

A fibre optic cable comprises of an optical fibre with additional protective layers. This section provides details of the fibre optic cable construction

Optical fibre

An optical fibre comprises of two elements:

- core – The central element of the optical fibre that carries the transmitted light. The core is usually made of silica which has dopants added during the manufacturing process to raise its refractive index above that of pure silica;
- cladding – The cladding surrounds the core and is typically made from pure silica with a lower refractive index than the core to allow total internal reflection to take place.

The core and cladding are an integral part of an optical fibre construction produced when the fibre is drawn as a solid filament and cannot be physically separated from each other.

The size of an optical fibre is determined by the core diameter followed by the cladding outside diameter in microns e.g. 50 µm/125 µm.

6.3.11.2.1 Protective layers

Primary coating/buffer

The primary coating/buffer is a material applied to the optical fibre to provide protection from external shock, temperature effects and moisture. This coating/buffer can be an extrusion or wrap comprising of silicone, polyimide or high temperature acrylates.

Secondary coating/buffer

A secondary extruded coating/buffer is also applied to provide protection to the optical fibre at elevated temperatures. Materials used for this coating/buffer are typically materials such as silicon, acrylate or manufacturers proprietary materials that conform to the defined qualification requirements.

Strength member

To protect the optical fibre from longitudinal loads and any external stress from bending or compression a strength member is woven or laid onto the secondary layer. A strength member can be made from an aramid yarn or aramid yarn/fibreglass mix. The strength member also provides a coupling mechanism between the fibre optic cable and fibre optic terminus to prevent axial loads being applied directly to the optical fibre core.

6.3.11.2.2 Outer jacket

A fluoropolymer extrusion applied over the strength member to provide an external protective barrier against external forces e.g. scraping, fluids and moisture. It also allows application of identification marking of the cable using laser marking equipment.

The outer jacket shall be violet in colour to identify it as a fibre optic cable. The material may be translucent to allow inclusion of a visible identification tape beneath the outer jacket.

The use of hot stamping is forbidden on fibre optic cables.

6.3.11.2.3 Bandwidth and transmission performance

Fibre optic cables are categorized by size, bandwidth and transmission performance with categories defined for multimode and single mode fibre optic cables. For details of these categories refer to ISO/IEC 11801 and BS EN 50173. Table 2 provides a summary of these categories 'OM*' for Multi-mode and 'OS*' for Single mode.

Table 2 — Bandwidth and transmission performance of optical cables

Fibre category	Fibre size (µm)	Min. bandwidth (MHz.km)		Attenuation (dB/km)		Max. length (1 GB)	Max. length (10 GB)
Multimode		850 nm	1 300 nm	850 nm	1 300 nm	850 nm	1 300 nm
OM1	62,5/125	200	500	4 dB/km	2dB/km	275 m	33 m
OM2	50/125 or 62,5/125	500	500			550 m	82 m
OM3	50/125	1 500	500			550 m	300 m
OM4	50/125	3 500	500			550 m	550 m
Single mode				1 310 nm	1 550 nm		
OS1	—	—	—	1 dB/km	1 dB/km		10 000

6.3.11.3 Special Installation requirements

Where electrical and fibre optic cables are routed in the same bundle e.g. hybrid cable harnesses attention should be taken to ensure that:

- materials used for the outer jacketing of electrical and fibre optic cables are compatible;
- heat generated by power cables does not exceed the maximum operating temperature of the fibre optic cables;
- bend radii of mixed or hybrid cable harnesses shall take account of the minimum permitted by the fibre optic cable manufacturer.

If these criteria cannot be met, then the fibre optic cables shall be routed separately.

Splices on fibre optic cables are not permitted on military aircraft without express permission of the design authority and pre-acceptance by the end user.

For existing standards, see B.2 of Annex B.

6.3.12 Special cable types

Some particular needs call for special assembly of various types of cables. Conditions of qualification for such cables must follow requirements given in 5.12.

6.3.12.1 Armament and electro explosive cables

When required by the contract armaments and electro-explosive cables and wiring shall be routed as twisted pair wiring and shall be separately marked. The use of red cables or those with a red stripe are recommended. Electro-explosive and armaments wiring shall be shielded and kept separated as far as practicable throughout its length and shall be shielded and kept separated from other circuit wiring at junctions and interconnects.

Splices on electro-explosive and armaments cables are not permitted on military aircraft without express permission of the design authority and pre-acceptance by the end user.

6.3.12.2 Fuel probe wiring

Fuel probe wiring shall be separated as far as practicable from power systems wiring throughout its length.

6.3.12.3 Signal wiring and other low power sensitive circuit wiring

Signal wiring and other low power sensitive circuit wiring shall be kept separate from other circuits at junctions and interconnects.

6.3.12.4 Primary electrical power systems wiring

Primary electrical power systems wiring shall not be grouped or bundled with distribution circuit wiring. Wiring from two or more power sources shall not be in the same harness or bundle to prevent single event failure affecting multiple power sources.

6.3.12.5 Other special cable types

Depending on system requirements, special cable types have to be used they shall satisfy the system performances and be installed in compliance with their particularities.

Example of special cables:

- low noise transmission cable (for accelerometer probes);
- filter cables;
- hyper-frequency (for warfare systems).

6.4 Connector selection

6.4.1 Environment

Connectors are classified according to the environmental conditions in which they are to be located, taking account of materials, plating, surface finish, the design of sealing, etc.

6.4.2 Types of connectors

Various types of connectors, both circular and rectangular, are available. They can be sealed, unsealed or hermetic (for the receptacle only). The type selected and the method of installation shall depend on its intended function and its location and shall, where possible, be selected from relevant ISO standards or from the aerospace series of existing European standards. For existing European standards, see B.4 of Annex B.

6.4.2.1 Circular types

Circular connectors are available in various formats as follows:

- a) arrangements including electrical contacts for power, signal, coaxial, twinax, triaxial, quadrax and fibre optic termini;
- b) various coupling devices (bayonet, threaded, push pull, ...);
- c) high temperature, fire wall and fire resistant for engine applications;
- d) single way coaxial; twin-axial, tri-axial and quad-axial;
- e) multi way coaxial; twin-axial, tri-axial and quad-axial;