9.3 Mechanical strength. EWIS components should have sufficient mechanical strength for their service conditions.

a. The EWIS should be installed with sufficient slack so that bundles and individual wires are not under undue tension.

b. Wires connected to movable or shock-mounted equipment should have sufficient length to allow full travel without tension on the bundle to the point where failure of the EWIS could occur.

c. Wiring at terminal lugs or connectors should have sufficient slack to allow for two re-terminations without replacement of wires, unless other design considerations apply. This slack should be in addition to the drip loop and the allowance for movable equipment.

d. In order to prevent mechanical damage wires should be supported by suitable clamps or other devices at suitable intervals. The design should be such that the failure of a single clamp will not in itself result in the wire or wire bundle coming into contact with other wires, equipment, structure, fluid lines, control cables, or other items that could cause damage to the wire. Because of in-service experience with abrasion and chafing of wires contained in troughs, ducts, or conduits justification should be given if additional support of the wires will not be used. The supporting devices should be of a suitable size and type, with the wires and cables held securely in place without damage to the insulation as per Society of Automotive Engineers SAE AS50881 or equivalent standard

9.4 Minimum bend radius.

To avoid damage to wire insulation, the minimum radius of bends in single wires or bundles should be in accordance with the wire manufacturer's specifications. Guidance on the minimum bend radius can be found in the manufacturer's standard wiring practices manual. Other industry standards such as AECMA EN3197 or SAE AS50881 also contain guidance on minimum bend radius. For example, SAE AS50881b states: "For wiring groups, bundles, or harnesses, and single wires and electrical cables individually routed and supported, the minimum bend radius shall be ten times the outside diameter of the largest included wire or electrical cable. At the point where wiring breaks out from a group, harness or bundle, the minimum bend radius shall be ten times the diameter of the largest included wire or electrical cable, provided the wiring is suitably supported at the breakout point. If wires used as shield terminators or jumpers are required to reverse direction in a harness, the minimum bend radius of the wire shall be three times the diameter at the point of reversal providing the wire is adequately supported."

9.5 Coaxial cable damage.

Damage to coaxial cable can occur when the cable is clamped too tightly or bent sharply (normally at or near connectors). Damage can also be incurred during unrelated maintenance actions around the coaxial cable. Coaxial cable can be severely damaged on the inside without any evidence of damage on the outside. Installation design should minimise the possibility of such damage. Coaxial cables have a minimum bend radius. SAE AS50881b states: "The minimum radius of bend shall not adversely affect the characteristics of the cable. For flexible type coaxial cables, the radius of bend shall not be less than six times the outside diameter. For semi-rigid types, the radius shall not be less than ten times the outside diameter."

9.6 Wire bundle adhesive clamp selection.

Certain designs use adhesive means to fasten bundle supports to the aircraft structure. Service history shows that these can work loose during aircraft operation, either as a result of improper design or inadequate surface preparation. You should pay particular attention to the selection and methods used for affixing this type of wire bundle support.

9.7 Wire bundle routing.

Following are some considerations that should go into the design of an EWIS installation.

a. Wire bundles should be routed in accessible areas that are protected from damage from personnel, cargo, and maintenance activity. As far as practicable they should not be routed in areas in where they are likely to be used as handholds or as support for personal equipment or where they could become damaged during removal of aircraft equipment (reference CS 25.1719 and 25.1721).

b. Wiring should be clamped so that contact with equipment and structure is avoided. Where this cannot be accomplished, extra protection, in the form of grommets, chafe strips, etc., should be provided. Wherever wires cannot be clamped, protective grommets should be used, wherever wires cannot be clamped, in a way that ensures clearance from structure at penetrations. Wire should not have a preload against the corners or edges of chafing strips or grommets.

c. As far as practicable wiring should be routed away from high-temperature equipment and lines to prevent deterioration of insulation (reference CS 25.1707(j)).

d. Wiring routed across hinged panels, should be routed and clamped so that the bundle will twist, rather than bend, when the panel is moved. When not possible, the bending radius must be in accordance with the acceptable minimum bundle radius.

9.8 Conduits.

Conduits should be designed and manufactured so that potential for chafing between the wiring and the conduit internal walls is minimised.

a. Non-metallic conduit. Insulating tubing (or sleeving) is sometimes used to provide additional electrical, environmental, and limited additional mechanical protection or to increase the external wire dimension. Insulating tubing should not be considered as the sole mechanical protection against external abrasion of wire because it does not prevent external abrasion. At best, it provides only a delaying action against the abrasion. The electrical and mechanical properties of the tubing need to be considered to ensure that it its use is appropriate for the type of protection that the designer intends it to be used for. Additional guidance on the use of insulating tubing or sleeving is given in AMC 25.1707 paragraph (2)(c).

b. Metallic conduit. The ends of metallic conduits should be flared and the interior surface treated to reduce the possibility of abrasion.

9.9 Connector selection.

The connector used for each application should be selected only after a careful determination of the electrical and environmental requirements.

a. Particular attention should be given to any use of components with dissimilar metals, because this may cause electrolytic corrosion.

b. Environment-resistant connectors should be used in applications that will be subject to fluids, vibration, temperature extremes, mechanical shock, corrosive elements, etc.

c. Sealing plugs and contacts should be used in unused connector cavities where necessary. In addition, firewall class connectors incorporating sealing plugs should be able to prevent the penetration of the fire through the aircraft firewall connector opening and continue to function without failure for a specified period of time when exposed to fire.

d. When electromagnetic interference and radio frequency interference (EMI and RFI) protection is required, Special attention should be paid to the termination of individual and overall shields. Back shell adapters designed for shield termination, connectors with conductive finishes, and EMI grounding fingers are available for this purpose.

9.10 Splice selection.

Environmentally sealed splices should be used in accordance with the requirements of the airframe manufacturer's standard wiring practices or SAE AS81824/1, or equivalent specification, particularly in un-pressurized and severe wind and moisture problem (SWAMP) areas. However, the possibility of fluid contamination in any installation needs to be considered.

a. Splices in pressurised areas. In pressurised areas, pre-insulated splices conforming to SAE AS7928, or equivalent specification, may be used if these types of splices are listed as acceptable for use by the manufacturer in their standard wiring practices manual. The possibility of fluid contamination in any installation should also be considered.

b. Mechanically protected splices. Mechanical splices allow maintenance personnel an alternative method to using a heat gun for splices in fuel vapour areas on post-delivery aircraft. The generally available environmental splices use heat shrink material that needs application of heat. Most of these heat sources cannot be used in flammable vapour areas of an aircraft without proper precautions. Mechanical splices are acceptable for use in high temperature and fuel vapour areas, provided the splice is covered with a suitable plastic sleeve, such as a dual wall shrink sleeve or high temperature tape, such as Teflon, wrapped around the splice and tied at both ends. If high temperature tape is used, it should be permanently secured at both ends. Mechanical splices should be installed according to the airframe manufacturer's standard practices, or equivalent specification. The manufacturer's standard wiring practices manual should provide part number detail and best practices procedures for mechanical splices. It should also detail the applicability of each of the recommended splices for all required critical aeroplane installations.

c. Aluminium wire splice. Splices for aluminium wires should be in accordance with the requirements of the airframe manufacturers' standard practices or SAE AS70991, MS25439, or equivalent specification. Conditions that result in excessive voltage drop and high resistance at junctions that may ultimately lead to failure of the junction should be avoided. The preferable location for aluminium splices is in pressurized areas. To avoid contamination from foreign particles the crimp tool should be dedicated to aluminium wire crimping.

9.11 Wire selection.

a. Installation environment.

(1) Careful attention should be applied when deciding on the type of wire needed for a specific application. Due consideration should be given such that the wire's construction properly matches the application environment. For each installation, you should select wire construction type suitable for the most severe environment likely to be encountered in service. For example use a wire type that is suitable for flexing for installations involving movement, use a wire type that has a high temperature rating for higher temperature installations.

(2) When considering the acceptability of wire, you should refer to the industry standards defining acceptable test methods for aircraft wire, including arc tracking test methods. (e.g. EN3475, SAE AS4373, or alternative manufacturer standards)

(3) Wires such as fire detection, fire extinguishing, fuel shutoff, and fly-by-wire / engine control system wiring that must operate during and after a fire must be selected from wire types qualified to provide circuit integrity after exposure to fire for a specified period.

b. Wire insulation selection.

Wire insulation type should be chosen according to the environmental characteristics of wire routing areas. One wire insulation characteristic of particular concern is arc tracking. Arc tracking is a phenomenon in which a conductive carbon path forms across an insulating surface. A breach in the insulation allows arcing and carbonizes the insulation. The resulting carbon residue is electrically conductive. The carbon then provides a short circuit path through which current can flow. This can occur on either dry or wet wires. Certain types of wire insulation are more susceptible to arc tracking than others, and wire insulated with aromatic polyimide is one. Therefore, its use should be limited to applications where it will not be subjected to high moisture, high vibration levels, or abrasion, or where flexing of the wire will occur. There are new types of aromatic polyimide insulated wire, such as hybrid constructions (e.g., the aromatic polyimide tape is the middle layer, and the top and bottom layer is another type of insulation such as Teflon tape) which are less susceptible to arc tracking.

c. Mechanical strength of wire.

Wires should be sufficiently robust to withstand all movement, flexing, vibration, abrasion and other mechanical hazards to which they may be reasonably subjected on the aeroplane. Generally, conductor wire should be stranded to minimise fatigue breakage. Refer to AS50881 and AECMA EN3197 for additional guidance. Additionally, wires should be robust enough to withstand the mechanical hazards they may be reasonably subjected to during installation into the aircraft.

d. Mixing of different wire insulation types.

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

e. Tin plated conductors.

Tin plated conductors may be difficult to solder if not treated properly, so preparation of the conductor is necessary to ensure a good connection is made.

(f) Wire gauge selection.

To select the correct size of electrical wire, the following requirements should be considered:

(1) The wire size should be matched with the circuit protective device with regard to the required current.

(2) The wire size should be sufficient to carry the required current without overheating.

(3) The wire size should be sufficient to carry the required current over the required distance without excessive voltage drop (based on system requirements).

(4) Particular attention should be given to the mechanical strength and installation handling of wire sizes smaller than AWG 22 (e.g., consideration of vibration, flexing, and termination.) Use of high-strength alloy conductors should be considered in small gauge wires to increase mechanical strength.

Note: Additional guidance for selecting wires and other EWIS components can be found in SAE AS50881 and EN2853.

g. Wire temperature rating.

Selection of a temperature rating for wire should include consideration of the worst-case requirements of the application. Caution should be used when locating wires in areas where heat is generated, for example where oxygen generators or lighting ballast units are located.

(1) Wires have a specified maximum continuous operating temperature. For many types, this may be reached by any combination of maximum ambient temperature and the temperature rise due to current flow.

(2) In general, it is undesirable to contribute more than 40oC rise to the operating temperature by electrical heating.

(3) Other factors to be considered are altitude de-rating, bundle size de-rating, and use of conduits and other enclosures.

(4) Particular note should be taken of the specified voltage of any wire where higher than normal potentials may be used. Examples are discharge lamp circuits and windscreen heating systems.

h. EWIS components in moisture areas.

(1) Severe wind and moisture problem.

Areas designated as severe wind and moisture problem (SWAMP) areas are different from aircraft to aircraft but they generally are considered to be such areas as wheel wells, wing folds, pylons, areas near wing flaps, and other exterior areas that may have a harsh environment. Wires for these applications should incorporate design features that address these severe environments.

(2) Silver plated conductors.

Many high strength copper alloy conductors and coaxial cables use silver plating. Contamination of silver-plated conductors with glycol (de-icing fluid) can result in electrical fire. Accordingly, you should not use silver plated conductors in areas where de-icing fluid can be present unless suitable protection features are employed. Silver plated conductors and shields can exhibit a corrosive condition (also known as 'Red Plague') if the plating is damaged or of poor quality and is exposed to moisture. Designers should be aware of these conditions.

(3) Fluid contamination of EWIS components.

Fluid contamination of EWIS components should be avoided as far as practicable. But EWIS components should be designed and installed with the appropriate assumptions about fluid contamination, either from the normal environment or from accidental leaks or spills. Industry standards, such as RTCA DO-160/EUROCAE ED-14, contain information regarding typical aircraft fluids. It is particularly important to appreciate that certain contaminants, notably from toilet waste systems, galleys, and fluids containing sugar, such as sweetened drinks, can induce electrical tracking in already degraded electrical wires and unsealed electrical components. The only cleaning fluids that should be used are those recommended by the aeroplane manufacturer in its standard practices manual.

10 EWIS component selection for future modifications

If a TC includes subpart H in its certification basis, future modifiers of those TCs should comply with the subpart H requirements by using the same or equivalent standards / design practices as those used by the TC holder. If modifiers choose to deviate from those standards / design practices, they should have to substantiate compliance independently. The standards / design practices used by the TC holder in order to justify their own choice of components should also be considered.

[Amdt 25/5]

CS 25.1705 Systems and Functions; EWIS

ED Decision 2008/006/R

(a) EWIS associated with systems required for type certification or by operating rules must be considered an integral part of that system and must be considered in showing compliance with the applicable requirements for that system.

(b) For systems to which the following rules apply, the components of EWIS associated with those systems must be considered an integral part of that system or systems and must be considered in showing compliance with the applicable requirements for that system.

(1) CS 25.773(b)(2) Pilot compartment view.

(2) CS 25.854 Lavatory fire protection

(3) CS 25.858 Cargo compartment fire detection systems

(4) CS 25.981 Fuel tank ignition prevention.

(5) CS 25.1165 Engine ignition systems.

(6) CS 25.1203 Fire-detector systems

(7) CS 25.1303(b) Flight and Navigation Instruments

(8) CS 25.1310 Power source Capacity and Distribution

(9) CS 25.1316 System lightning protection

(10) CS 25.1331(a)(2) Instruments using a power supply

(11) CS 25.1351 General.

(12) CS 25.1355 Distribution system.

(13) CS 25.1360 Precautions against injury.

(14) CS 25.1362 Electrical supplies for emergency conditions.

(15) CS 25.1365 Electrical appliances, motors, and transformers.

(16) CS 25.1431(c) and (d) Electronic equipment.

[Amdt 25/5]

CS 25.1707 System Separation; EWIS

ED Decision 2008/006/R

(See AMC 25.1707)

(a) Each EWIS must be designed and installed with adequate physical separation from other EWIS and aeroplane systems so that an EWIS component failure will not create a hazardous condition. Unless otherwise stated, for the purposes of this paragraph, adequate physical separation must be achieved by separation distance or by a barrier that provides protection equivalent to that separation distance.

(b) Each EWIS must be designed and installed such that any electrical interference likely to be present in the aeroplane will not result in hazardous effects upon the aeroplane or its systems except under extremely remote conditions.

(c) Wires and cables carrying heavy current and their associated EWIS components must be designed and installed to ensure adequate physical separation and electrical isolation, so that damage to essential circuits will be minimised under fault conditions.

(d) Each EWIS associated with independent aeroplane power sources or power sources connected in combination must be designed and installed to ensure adequate physical separation and electrical isolation so that a fault in any one aeroplane power source EWIS will not adversely affect any other independent power sources. In addition:

(1) Aeroplane independent electrical power sources must not share a common ground terminating location, and

(2) Aeroplane system's static grounds must not share a common ground terminating location with any of the aeroplane independent electrical power sources.

(e) Except to the extent necessary to provide electrical connection to the fuel systems components the EWIS must be designed and installed with adequate physical separation from fuel lines and other fuel system components, such that

(1) An EWIS component failure will not create a hazardous condition, and

(2) Fuel leakage onto EWIS components will not create a hazardous condition.

(f) Except to the extent necessary to provide electrical connection to the hydraulic systems components the EWIS must be designed and installed with adequate physical separation from hydraulic lines and other hydraulic system components, such that

(1) An EWIS component failure will not create a hazardous condition, and

(2) Hydraulic fluid leakage onto EWIS components will not create a hazardous condition.

(g) Except to the extent necessary to provide electrical connection to the oxygen systems components the EWIS must be designed and installed with adequate physical separation from oxygen lines and other oxygen system components, such that an EWIS component failure will not create a hazardous condition.

(h) Except to the extent necessary to provide electrical connection to the water/waste systems components the EWIS must be designed and installed with adequate physical separation from water/waste lines and other water/waste system components, such that

(1) An EWIS component failure will not create a hazardous condition, and

(2) Water/waste leakage onto EWIS components will not create a hazardous condition.

(i) Electrical wiring interconnection systems must be designed and installed with adequate physical separation between the EWIS and flight or other mechanical control systems cables, and associated system components such that,

(1) Chafing, jamming, or other interference are prevented, and

(2) An EWIS component failure will not create a hazardous condition, and

(3) Failure of any flight or other mechanical control systems cables or systems components will not damage EWIS and create a hazardous condition.

(j) Electrical wiring interconnection systems must be designed and installed with adequate physical separation between the EWIS components and heated equipment, hot air ducts, and lines such that;

(1) An EWIS component failure will not create a hazardous condition, and

(2) Hot air leakage or generated heat onto EWIS components will not create a hazardous condition.

(k) For systems for which redundancy is required either by specific certification requirements, operating rules or by CS 25.1709, each applicable EWIS must be designed and installed with adequate physical separation.

(l) Each EWIS must be designed and installed so there is adequate physical separation between it and other aeroplane components and structure, and so that the EWIS is protected from sharp edges and corners, in order to minimise potential for abrasion/chafing, vibration damage, and other types of mechanical damage.

[Amdt 25/5]

AMC 25.1707 System separation; EWIS

ED Decision 2008/006/R

1 Summary

The continuing safe operation of an aeroplane depends on the safe transfer of electrical energy by the EWIS. If an EWIS failure occurs, its separation from other EWIS and from other systems and structures plays an important role in ensuring that hazardous effects of the failure are mitigated to an acceptable level. CS 25.1707 requires applicants to design EWIS with appropriate separation to minimise the possibility of hazardous conditions that may be caused by an EWIS interfering with other EWIS, other aeroplane systems, or structure.

The purpose of separation is to prevent hazards of interference between wires in a single bundle, between two or more bundles, or between an electrical bundle and a non-electrical system or structure. Such interference could take the form of mechanical and or electrical interference (EMI for example). Mechanical interference examples include chafing between electrical cables or pipes or structure and may lead to fluid leakage such as galley water waste systems.

2 Separation by physical distances versus separation by barrier.

CS 25.1707 states that adequate physical separation must be achieved by separation distance or by a barrier that provides protection equivalent to that separation distance. The following should be considered when designing and installing an EWIS:

a. In most cases, physical distance is the preferred method of achieving the required separation. This is because barriers themselves can be the cause of EWIS component damage (e.g., chafing inside of conduits) and can lead to maintenance errors such as barriers removed during maintenance and inadvertently left off. They can also interfere with visual inspections of the EWIS.

b. If a barrier is used to achieve the required separation, CS 25.1707 requires that it provide at least the same level of protection that would be achieved with physical distance. That means that when deciding on the choice of the barrier, factors such as dielectric strength, maximum and minimum operating temperatures, chemical resistivity, and mechanical strength should be taken into account.

c. In addition to the considerations given in paragraph (b) above, when wire bundle sleeving is used to provide separation, applicants should consider that the sleeving itself is susceptible to the same types of damage as wire insulation. The appropriate type of sleeving must be selected for each specific application and design consideration must be given to ensuring that the sleeving is not subjected to damage that would reduce the separation it provides.

3 Determination of separation.

Determining the necessary amount of physical separation distance is essential. But because each system design and aeroplane model can be unique, and because manufacturers have differing design standards and installation techniques, CS 25.1707 does not mandate specific separation distances. Instead it requires that the chosen separation be adequate so that an EWIS component failure will not create a hazardous condition. The following factors should be considered when determining the separation distance:

a. The electrical characteristics, amount of power, and severity of failure condition of the system functions performed by the signals in the EWIS and adjacent EWIS.

b. Installation design features, including the number, type, and location of support devices along the wire path.

c. The maximum amount of slack wire resulting from wire bundle build tolerances and the variability of wire bundle manufacturing

d. Probable variations in the installation of the wiring and adjacent wiring, including position of wire support devices and amount of wire slack possible.

e. The intended operating environment, including amount of deflection or relative movement possible and the effect of failure of a wire support or other separation means.

f. Maintenance practices as defined by the aeroplane manufacturer's standard wiring practices manual and the ICA required by CS 25.1529 and CS 25.1729.

g. The maximum temperature generated by adjacent wire/wire bundles during normal and fault conditions.

h. Possible EMI, HIRF, or induced lightning effects.

4 Cases of inadequate separation.

Some areas of an aeroplane may have localized areas where maintaining the minimum physical separation distance is not feasible. This is especially true in smaller aeroplanes. In those cases, other means of ensuring equivalent minimum physical separation may be acceptable, if testing or analysis demonstrates that safe operation of the aeroplane is not jeopardized. The applicant should substantiate to the Agency that the means to achieve the required separation provides the necessary level of protection for wire related failures. Electro-magnetic interference (EMI) protection must also be verified.

5 Meaning of the term "hazardous condition" as used in CS 25.1707.

The term "hazardous condition" in CS 25.1707 has the same meaning as the one used in CS 25.1309 or CS 25.1709. Unlike CS 25.1309 or CS 25.1709, no probability objectives are required for compliance. The intent of CS 25.1707, is that the applicant must perform a qualitative design assessment of the installed EWIS and the physical separation to guard against hazardous conditions

This assessment involves the use of reasonable engineering and manufacturing judgment and assessment of relevant service history to decide whether an EWIS, system, or structural component could fail in such a way as to create a condition that would affect the aeroplane's ability to continue safe operation. However, the requirements of CS 25.1707 do not preclude the use of valid component failure rates if the applicant chooses to use a probability argument in addition to the design assessment to demonstrate compliance. It also does not preclude the agency from requiring such an analysis if the applicant cannot adequately demonstrate that hazardous conditions will be prevented solely by using the qualitative design assessment.

6 Subparagraph CS 25.1707(a) requires that EWIS associated with any system on the aeroplane be designed and installed so that under normal conditions and failure conditions, it will not adversely affect the simultaneous operation of any other systems necessary for continued safe flight, landing, and egress. CS 25.1707(a) also requires that adequate physical separation be achieved by separation distance or by a barrier that provides protection equivalent to that separation distance.