U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

Subject:
Certification of Electrical Wiring Interconnection Systems on Transport Category Airplanes

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1. PURPOSE. This Advisory Circular (AC) provides guidance for certification of electrical wiring interconnection systems (EWIS) on transport category airplanes in accordance with 14 CFR part 25, subpart H, sections §§25.1701 through 25.1739 and sections H25.4 and H25.5 of Appendix H to part 25.

2. APPLICABILITY.

a. The guidance provided in this document is applicable to transport category airplane manufacturers, modifiers, foreign civil aviation authorities, Federal Aviation Administration (FAA) transport airplane type certification engineers, designees, and FAA Flight Standards personnel.

b. This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. We will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

c. This material does not change or create any additional regulatory requirements nor does it authorize changes in or permit deviations from existing regulatory requirements.

d. Terms such as "shall" or "must" are used in this AC only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described herein is used.

3. <u>HOW THIS INFORMATION WAS DERIVED</u>.

a. The National Transportation Safety Board (NTSB) recommended that we address all wiring issues identified in our Aging Systems Plan, either through rulemaking or through other means. To accomplish this we established, in 1998, the Aging Transport Systems Rulemaking Advisory Committee (ATSRAC). The ATSRAC provides a forum for airlines, manufacturers, and other regulatory authorities to make recommendations to us based on the Aging Systems Plan. Recommendations have addressed EWIS certification issues, development of standard wiring practices manuals, enhanced EWIS maintenance requirements, and EWIS training.

b. The guidance in this AC is based on recommendations submitted to us by the ATSRAC and the Aviation Rulemaking Advisory Committee (ARAC). It is derived from best practices identified through extensive research by ATSRAC Industry Working Groups 6, 7, and 9, the ARAC Electrical Systems Harmonization Working Group, United States and European standard aircraft industry practice, and the results of various EWIS-related research and development programs. These recommendations and best practices are based on treating EWIS as an aircraft system, and the belief that EWIS should be designed and installed with the same level of diligence as any other essential or critical system in the aircraft. We endorse these best practices.

4. <u>COMPLIANCE METHODS</u>.

a. The guidance in this AC describes means of compliance with subpart H of part 25 and supplements similar guidance provided in other advisory material and policy memoranda concerning EWIS requirements for airplane systems. A list of related regulations, ACs, and policy memoranda is in Appendix A of this AC.

b. To fully realize the objectives of the guidance contained in this AC, type certificate (TC) holders, supplemental type certificate (STC) holders, maintenance providers, repair stations, and persons performing field modifications or repairs may need to adjust their approach to designing and modifying EWIS. They may need to be aware of the history of the EWIS in a particular aircraft and the role it plays in the safe operation of that aircraft. People who design and modify aircraft EWIS should be aware that it should be designed and installed with the same level of diligence given to any other essential or critical system in the aircraft.

c. The guidance in this AC is organized by subpart H section.

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5. SPECIFIC COMPLIANCE GUIDANCE BY SUBPART H SECTION

a. § 25.1701 DEFINITION.

(1) § 25.1701(a).

(a) Section 25.1701 defines EWIS for the purposes of complying with the subpart H requirements and other EWIS-related requirements of part 25. Section 25.1701 identifies which wires and components these requirements apply to. Although this definition is located in subpart H to part 25, it applies to all EWIS requirements regardless of location within part 25.

(b) Section § 25.1701(a) defines EWIS as any wire, wiring device, or combination of these, including termination devices, installed in any area of the airplane for the purpose of transmitting electrical energy between two or more intended termination points. The term "wire" means bare or insulated wire used for the purpose of electrical energy transmission, grounding, or bonding. This includes electrical cables, coaxial cables, ribbon cables, power feeders, and databuses.

(c) Paragraph (a) of this section provides a listing of the component types that are considered part of the EWIS. These component types are listed as items § 25.1701(a)(1) through § 25.1701(a)(13). While these are the most widely used EWIS components it is not an all inclusive list. There may be components used by an applicant to support transmission of electrical energy that are not listed but meet the EWIS definition. These components will be considered as EWIS components and are subject to EWIS related regulatory requirements.

(2) <u>§ 25.1701(b).</u>

(a) Section § 25.1701(b) says that EWIS components located inside shelves, panels, racks, junction boxes, distribution panels, and back-planes of equipment racks (e.g., circuit board back-planes, wire integration units) are covered by the EWIS definition.

(b) These components are included in the EWIS definition because the equipment they are inside of, or part of, is typically designed and made for a particular airplane model or series of models. So the requirements that apply to airplane EWIS components must be applied to the components inside that equipment. These contrast with avionics components that must be sent back to their manufacturer or a specialized repair shop for service. Components inside shelves, panels, racks, junction boxes, distribution panels, and back-planes of equipment racks are maintained, repaired, and modified by the same personnel who maintain, repair, and modify the EWIS in the rest of the airplane. For example, in an electrical distribution panel system separation must be designed and maintained within the panel just like it must be designed and maintained for the EWIS leading up to that panel. Identification of components inside the panel is just as important as outside the panel since the wiring inside the panel is treated much the same. Also, while this type of equipment is designed for its intended function and is manufactured and installed to the same standards as other EWIS, it is typically not qualified to an environmental standard such as RTCA DO-160.

(3) <u>§ 25.1701(c).</u>

(a) There are some exceptions to the EWIS definitions and those are given in § 25.1701(c). This paragraph excepts EWIS components inside the following equipment, and the external connectors that are part of that equipment:

<u>1</u> Electrical equipment or avionics that are qualified to environmental conditions and testing procedures when those conditions and procedures are –

(aa) appropriate for the intended function and operating environment, and

(bb) acceptable to the FAA.

<u>2</u> Portable electrical devices that are not part of the type design of the airplane including personal entertainment devices and laptop computers.

<u>3</u> Fiber optics.

(b) The first exception means EWIS components located inside avionic or electrical equipment such as flight management system computers, flight data recorders, VHF radios, primary flight displays, navigation displays, generator control units, integrated drive generators, and galley ovens, if this equipment has been tested to industry-accepted environmental testing standards. Examples of acceptable standards are RTCA DO-160 and EUROCAE ED 14, and equipment qualified to an FAA Technical Standard Order (TSO).

(c) An applicant may use any environmental testing standard if the applicant can demonstrate that the testing methods and pass/fail criteria are at least equivalent to the widely accepted standards of DO-160, EUROCAE ED 14, or a specific TSO. Applicants should submit details of the environmental testing standards and results of the testing that demonstrate the equipment is suited for use in the environment in which it will be operated.

b. <u>§ 25.1703 FUNCTION AND INSTALLATION: EWIS.</u> Section 25.1703 requires that applicants select EWIS components that are of a kind and design appropriate to their intended function just as § 25.1301 requires this for other pieces of equipment installed on the airplane. Factors such as component design limitations, functionality, and susceptibility to arc tracking and moisture or other known characteristics of the particular component must be considered. The following paragraphs, 5.b.(1) through 5.b.(7), provide guidance in showing compliance with the specific provisions of § 25.1703 (a) through (d). Paragraph 5.b.(8) deals with EWIS component selection and paragraph 5.b.(9) has specific guidance on wire selection. Paragraph 5.b.(10) discusses EWIS component selection for future modifications.

(1) <u>§ 25.1703(a)(1).</u> This section requires that each EWIS component be of a kind and design appropriate to its intended function. In this context, the requirement means that components must be qualified for airborne use, or otherwise specifically assessed as acceptable for their intended use. To be "appropriate" means that the equipment is used in a manner for which it was designed. For example, a wire rated at 150 degrees Celsius would not be appropriate for installation if that installation would cause the wire to operate at a temperature higher than 150 degrees Celsius. Wire and other components made for household or consumer products use may not be appropriate for airborne use because they are manufactured for the consumer market and not for use in an airborne environment. Other factors that must be considered for EWIS component selection are mechanical strength, voltage drop, required bend radius, and expected service life Refer to paragraph 5.b.(8)(a) for further explanation of "expected service life."

(2) <u>§ 25.1703(a)(2).</u> This section requires that EWIS components be installed according to their limitations. As used here, limitations means the design and installation requirements of the particular EWIS component. Examples of EWIS component limitations are maximum operating temperature, degree of moisture resistance, voltage drop, maximum current-carrying capability, and tensile strength. EWIS component selection and installation design must take into account various environmental factors including, but not limited to, vibration, temperature, moisture, exposure to the elements or chemicals (de-icing fluid, for instance), insulation type, and type of clamp.

(3) <u>§ 25.1703(a)(3).</u> This section requires that EWIS function properly when installed. The key word in understanding the intent of this section is "properly," as that relates to airworthiness of the airplane. For an EWIS component to function properly means that it must be capable of safely performing the function for which it was designed. For example, the fact that an in-flight entertainment (IFE) system fails to deliver satisfactory picture or sound quality is not what the term "properly" refers to, is not a safety issue, and thus not a certification issue. Failure of an EWIS component has the potential for being a safety hazard whether it is part of a safety-related system or an IFE system. Therefore, EWIS components must always function properly (safely) when installed, no matter what system they are part of, and any malfunction of the EWIS must not degrade the airworthiness of the airplane (refer to § 25.1705 for terminology relating to failure classifications).

(4) <u>§ 25.1703(a)(4).</u> This section requires that EWIS components be designed and installed so mechanical strain is minimized. This means the EWIS installation must be designed so that strain on wires would not be so great as to cause the wire or other components to fail. This section requires that adequate consideration be given to mechanical strain when selecting wire and cables, clamps, strain reliefs, stand-offs, and other devices used to route and support the wire bundle when designing the installation of these components.

(5) <u>§ 25.1703(b).</u> This section requires that selection of wires takes into account known characteristics of different wire types in relation to each specific application, to minimize risk of damage. It is important to select the aircraft wire type whose construction matches the application environment. The wire type selected should be constructed for the most severe environment likely to be encountered in service. This means, for example, that insulation types susceptible to arc tracking should not be used in areas exposed to high vibration and constant flexing in a moisture-prone environment.

(6) <u>§ 25.1703(c).</u> This section contains the requirement formerly located in § 25.869(a)(3) that design and installation of the main power cables allow for a reasonable degree of deformation and stretching without failure. Although now located in § 25.1703(c), the meaning of the requirement has not changed. The reason for this requirement is the same as for § 25.993(f), which requires that each fuel line within the fuselage be designed and installed to allow a reasonable degree of deformation and stretching without leakage. The idea is that the fuselage can be damaged with partial separation or other structural damage without the fuel lines or electrical power cables breaking apart. Allowing for a certain amount of stretching will help to minimize the probability of a fuel-fed fire inside the fuselage. As it is used in this requirement, a "reasonable degree of deformation and stretching" should be about 10% of the length of the electrical cable.

(7) § 25.1703(d). This section requires that EWIS components located in areas of known moisture build-up be adequately protected to minimize moisture's hazardous effects. This is to ensure that all practical means are used to ensure damage does not occur from fluid contact with components. Wires routed near a lavatory, galley, hydraulic lines, severe wind and moisture problem areas such as wheel wells and wing trailing edges, and any other area of the airplane where moisture collection could be a concern must be adequately protected from possible adverse effects of exposure to moisture.

(8) EWIS component selection.

(a) Expected service life. Expected service life should be considered in selecting EWIS components to use. Expected service life means the expected service lifetime of the EWIS. This is not normally less than the expected service life of the aircraft structure. If the expected service life requires that all or some of the EWIS components be replaced at certain intervals, then these intervals must be specified in the ICA as required by § 25.1529.

(b) Qualified components. EWIS components should 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. 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 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 FAA. This is because the manufacturer's technical choice of an EWIS 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.

(c) Mechanical strength. EWIS components should have sufficient mechanical strength for their service conditions.

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

2 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.

3 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.

4 In order to prevent mechanical damage, wires should be supported by suitable clamps or other devices at suitable intervals. 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. In-service experience has revealed abrasion and chafing of wires contained in troughs, ducts, or conduits, so the design should mitigate possibilities for this occurring. This may require additional support or other design strategies.

(d) 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 the European Association of Aerospace Industries' document 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."

(e) 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 minimize 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."

(f) 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.

(g) Wire bundle routing. Following are some considerations that should go into the design of an EWIS installation.

1 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 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 §§ 25.1725 and 25.1727).

2 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, 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.

3 As far as practicable wiring should be routed away from high-temperature equipment and lines to prevent deterioration of insulation (reference § 25.1709(j)).

4 Wiring routed across hinged panels should be routed and clamped so that the bundle will twist, rather than bend, when the panel is moved.

(h) Conduits. Conduits should be designed and manufactured so that potential for chafing between the wiring and the conduit internal walls is minimized.

1 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 should be appropriate for the type of protection the designer intends it to be used for. Additional guidance on the use of tubing or sleeving is given in paragraph 5.(e)(2)(c) of this AC.

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

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

1 Additional scrutiny should be given to any use of components with dissimilar metals, because this may cause electrolytic corrosion.

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

3 You should use sealing plugs and contacts in unused connector cavities. 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 the period of time that the connector is designed to function when exposed to fire.

4 When electromagnetic interference and radio frequency interference (EMI and RFI) protection is required, you should give special attention 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.

(j) 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.

1 Splices in pressurized areas. In pressurized 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. If they are not then you should get approval from your Aircraft Certification Office to use them. In any case, you need to show that the possibility of fluid contamination has been adequately considered.

2 Mechanically protected splices. Mechanical splices give maintenance personnel an alternative to using a heat gun for splices in fuel vapor 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 vapor areas of an aircraft without proper precautions. Mechanical splices are acceptable for use in high temperature and fuel vapor 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 airplane installations.

3 Aluminum wire splice. Splices for aluminum wires should be in accordance with the requirements of the airframe manufacturer's standard practices or SAE AS70991, MS25439, or equivalent specification. You should avoid conditions that result in excessive voltage drop and high resistance at junctions that may ultimately lead to failure of the junction. The preferable location for aluminum splices is in pressurized areas.

Note. To avoid contamination from foreign particles the crimp tool should be dedicated to aluminum wire crimping.

(9) Wire selection.

(a) Installation environment.

1 Careful attention should be applied when deciding on the type of wire needed for a specific application. You should consider whether 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. As examples, 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 in such systems as fire detection, fire extinguishing, fuel shutoff, and fly-by-wire flight control 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, such as wire insulated with aromatic polyimide, are more susceptible to arc tracking than others. Although 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) wire insulated with only aromatic polyimide tape is more susceptible to arc tracking than other types of commonly used wire insulation. Therefore, its use should be limited to applications where it will not be subjected to high moisture, high vibration levels, or abrasion, and where flexing of the wire will not occur.

(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 subjected on the airplane. Generally, conductor wire should be stranded to minimize 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 subjected to during installation into the aircraft.

(e) 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.

(f) 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.

(g) Wire gage selection. To select the correct size of electrical wire, the following 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 wire rating can be found in SAE AS50881 and AECMA EN2853 as well as in AC 43-13.1B.

(h) Wire temperature rating. Selection of a temperature rating for wire should include consideration of the worst-case requirements of the application. You should use caution when locating wires in areas where heat is generated – oxygen generators or lighting ballast units, for example.

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 40^{o}C 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.

(i) 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.

Silverplated 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 airplane 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 would be able to substantiate compliance with the subpart H requirements by using the same or equivalent standards and design practices as those used by the TC holder. If modifiers choose to deviate from those standards and design practices, they would have to substantiate compliance independently. They would also have to consider the standards and design practices used by the TC holder in order to justify their own choice of components.

c. <u>§ 25.1705 SYSTEM SAFETY: EWIS.</u> Section 25.1705 requires applicants to perform a system safety assessment of the EWIS. The analysis required for compliance with § 25.1705 is based on a qualitative *and* quantitative approach to assessing EWIS safety, as opposed to a purely numerical, probability-based quantitative analysis. The safety assessment must consider the effects that both physical and functional failures of EWIS would have on airplane safety. That safety assessment must show that each EWIS failure considered hazardous is extremely remote. It must show that each EWIS failure considered to be catastrophic is extremely improbable and will not result from a single failure.

(1) <u>Objective.</u> The objective of § 25.1705 is to use the concepts of § 25.1309 to provide a thorough and structured analysis of aircraft wiring and its associated components. As in § 25.1309, the fail-safe design concept applies. Any single failure condition, such as an arc fault, should be assumed to occur regardless of probability.

(2) <u>Inadequacies of § 25.1309 in relation to EWIS safety assessments.</u> Section 25.1309 requires the applicant to perform system safety assessments. But current § 25.1309 practice has not led to the type of analysis that fully ensures all EWIS failure conditions affecting airplane level safety are considered. This is because the current § 25.1309(a) only covers systems and equipment that are "required by this subchapter," and wiring for nonrequired systems is sometimes ignored. Even for systems covered by § 25.1309(b) and (d), the safety analysis requirements have not always been applied to the associated wire. When they are, there is evidence of inadequate and inconsistent application. Traditional thinking about nonrequired systems, such as in-flight entertainment systems, has been that, since they are not required, and the function they provide is not necessary for the safety of the airplane, their failure could not affect the safety of the airplane. This is not a valid assumption. Failure of an electrical wire, regardless of the system it is associated with, can cause serious physical and functional damage to the airplane, resulting in hazardous or even catastrophic failure conditions. An example of this is arcing from a shorted wire cutting through and damaging flight control cables. There are more failure modes than have been addressed with traditional analyses. Some further examples are arcing events that occur without tripping circuit breakers, resulting in complete wire bundle failures and fire, or wire bundle failures that lead to structural damage.

(3) <u>Integrated nature of EWIS.</u> The integrated nature of wiring and the potential severity of failures demand a more structured safety analysis approach than that traditionally used in showing compliance with § 25.1309. Section 25.1309 system safety assessments typically evaluate effects of wire failures on system functions. But they have not considered physical wire failure as a cause of the failure of other wires within the EWIS. Traditional assessments look at external factors like rotor burst, lightning, and hydraulic line rupture, but not at internal factors, like a single wire chafing or arcing event, as the cause of the failure of functions supported by the EWIS. Compliance with § 25.1705 requires addressing those failure modes at the airplane level. This means that EWIS failures need to be analyzed to determine what effect they could have on the safe operation of the airplane.

(4) Compliance summary. As specified above, the analysis required for compliance with § 25.1705 is based on a qualitative approach to assessing EWIS safety as opposed to numerical, probability-based quantitative analysis. The intent is not to examine each individual wire and its relation to other wires. Rather, it is to ensure that there are no hazardous combinations. However, in case the "top down" analysis process described in this AC determines that a failure in a given bundle may lead to a catastrophic failure condition, the mitigation process may lead to performing a complete analysis of each wire in the relevant bundle.

(5) Qualitative probability terms. When using qualitative analyses to determine compliance with § 25.1705, the following descriptions of the probability terms have become commonly accepted as aids to engineering judgment:

(a) Extremely remote failure conditions. These are failure conditions that are not anticipated to occur to an individual airplane during its total life but which may occur a few times when considering the total operational life of all airplanes of the type.

(b) Extremely improbable failure conditions. These are failure conditions so unlikely that they are not anticipated to occur during the entire operational life of all airplanes of one type.

(6) Relationship to other part 25 system safety assessments. The analysis described may be accomplished in conjunction with the required aircraft system safety assessments of §§ 25.1309, 25.671, etc.

(7) Classification of failure terms. The classification of failure conditions is given in Table 1. These failure conditions are identical to those proposed by the Aviation Rulemaking Advisory Committee for the draft (Arsenal) version of AC 25.1309-1b, dated June 10th 2002.

Table 1: Classification of Failure Conditions

Term	Explanation
No Safety Effect	Failure conditions that would have no effect on safety, for example failure conditions that would not affect the operational capability of the airplane or increase flightcrew workload.
Minor	Failure conditions that would not significantly reduce airplane safety, and involve flightcrew actions that are well within their capabilities. For example, minor failure conditions may include: • a slight reduction in safety margins or functional capabilities; • a slight increase in flightcrew workload, such as routine flight plan changes; or • some physical discomfort to passengers or cabin crew.

Major	Failure conditions that would reduce the capability of the airplane or the ability of the flightcrew to cope with adverse operating conditions to the extent that there would be, for example: • a significant reduction in safety margins or functional capabilities; • a significant increase in flightcrew workload or in conditions impairing flightcrew efficiency; • discomfort to the flightcrew; or • physical distress to passengers or cabin crew, possibly including injuries.
Hazardous	Failure conditions that would reduce the capability of the airplane or the ability of the flightcrew to cope with adverse operating conditions to the extent that there would be, for example: • a large reduction in safety margins or functional capabilities; • physical distress or excessive workload such that the flightcrew cannot be relied upon to perform their tasks accurately or completely; or • serious or fatal injuries to a relatively small number of persons other than the flightcrew.
Catastrophic	Failure conditions that would result in multiple fatalities, usually with the loss of the airplane. (NOTE: A catastrophic failure condition was defined differently in previous versions of § 25.1309 and in accompanying advisory material as "a failure condition that would prevent continued safe flight and landing.")

(8) Flowcharts depicting the analysis process. Flowcharts 1 and 2 outline one method of complying with the requirements of § 25.1705. The processes in both Flowcharts 1 and 2 identify two aspects of the analysis: physical failures and functional failures. The analysis processes described in both flowcharts begin by using the aircraft level functional hazard analysis developed for demonstrating compliance with § 25.1309 to identify catastrophic and hazardous failure events. A step-by-step explanation of the analysis depicted in the flowcharts is given in this AC in paragraphs 5.c.(11) (for flowchart 1) and 5.c.(12) (for Flowchart 2).

(a) Flowchart 1. This flowchart applies to applicants for pre-TC work and for amended TCs, and STCs when the applicant has all data necessary to perform the analysis per Flowchart 1. If Flowchart 1 is used for post-TC modifications the available data must include identification of the systems in the EWIS under consideration for modification and the system functions associated with that EWIS.

(b) Flowchart 2. This flowchart applies to applicants for post-TC modifications when the applicant cannot identify the systems or systems functions contained in EWIS under consideration for modification.

(9) Definitions applicable to § 25.1705. For this discussion the following definitions apply:

(a) Validation. Determination that requirements for a product are sufficiently correct and complete.

(b) Verification. Evaluation to determine that requirements have been met.

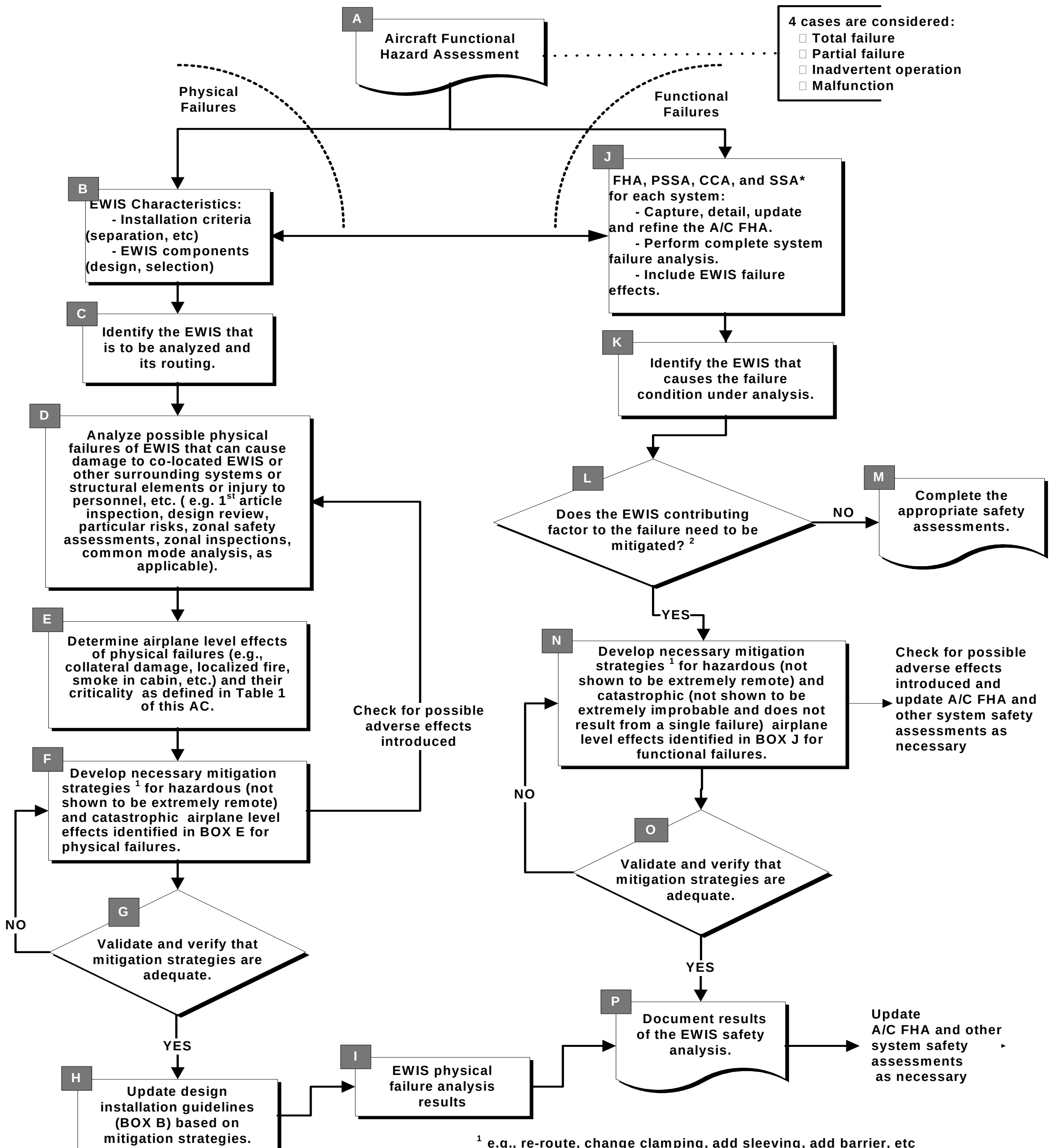
(c) Mitigation. Elimination of the hazard entirely or minimization of its severity and probability to an acceptable level. In the case of this rule, the EWIS failure must be mitigated to a point where the probability of a hazardous failure must be at least extremely remote and the probability of a catastrophic failure at least extremely improbable

(10) Physical failure analysis.

(a) Only single common cause events or failures need to be addressed during the physical failure analysis as described in this AC and shown on the left hand sides of Flowcharts 1 and 2**.** Multiple common cause events or failures need not be addressed.

(b) In relation to physical effects, it should be assumed that wires are carrying electrical energy and that, in the case of an EWIS failure, as defined in paragraph 5.c.(10)(a), this energy may result in hazardous or catastrophic effects directly or when combined with other factors, for example fuel, oxygen, hydraulic fluid, or damage by passengers. These failures may result in fire, smoke, emission of toxic gases, damage to co-located systems and structural elements, or injury to personnel. This analysis considers all EWIS from all systems (autopilot, auto throttle, PA system, IFE systems, etc.) regardless of the system criticality.

Flowchart 1: Pre- and Post-Type Certification Safety Analysis Concept



[1] e.g., re-route, change clamping, add sleeving, add barrier, etc
[2] Contributing means the EWIS causes the failure in whole or in part
* FHA: Functional Hazard Assessment
PSSA: Preliminary System Safety Assessment
CCA: Common Cause Analysis
SSA: System Safety Assessment

Mitigation as used in this flowchart means to eliminate the hazard entirely or minimize its severity and probability to an acceptable level. In the case of this rule, the EWIS failure must be mitigated to a point where the probability of a hazardous failure is at least extremely remote and the probability of a catastrophic failure is at least extremely improbable

(11) Descriptive text for flowchart 1

(a) BOX A Aircraft functional hazard assessment.

1 The functional failure analysis assumes that electrical wires are carrying power, signal, or information data. Failure of EWIS under these circumstances may lead to aircraft system degradation effects.

2 The functional hazard assessment (FHA) referred to in this box is not a stand-alone separate document specifically created to show compliance with § 25.1705. It is the aircraft level FHA that the applicant will have developed in compliance with § 25.1309 to help demonstrate acceptability of a design concept, identify potential problem areas or desirable design changes, or determine the need for and scope of any additional analyses (refer to AC 25.1309-1B).

ANALYSIS OF POSSIBLE PHYSICAL FAILURES

(b) BOX B EWIS characteristics. Use the results of the FHA (BOX A) to identify EWIS installation criteria and definitions of component characteristics. Results from BOX B are fed into the preliminary system safety analysis (PSSA) and system safety analysis (SSA) of BOX J.

(c) BOXES C, D, and E Validation and verification of installation criteria.

1 Ensure that the EWIS component qualification satisfies the design requirements and that components are selected, installed, and used according to their qualification characteristics and the aircraft constraints linked to their location (refer to the requirements of § 25.1703).

2 Use available information (digital mockup, physical mockup, airplane data, historical data) to perform inspections and analyses to validate that design and installation criteria are adequate to the zone/function, including considerations of multi-systems impact. Such inspections and analyses may include a 1st article inspection, design review, particular risk assessment, zonal safety assessment, zonal inspection, and common mode analysis, as applicable. Use such assessments and inspections to ascertain whether design and installation criteria were correctly applied. You should give special consideration to known problem areas identified by service history and historical data (areas of arcing, smoke, loose clamps, chafing, arc tracking, interference with other systems, etc.). Regardless of probability, any single arcing failure should be assumed for any power-carrying wire. The intensity and consequence of the arc and its mitigation should be substantiated. Give special consideration to cases where new (previously unused) material or technologies are used. In any case § 25.1703(b) requires that the selection of wires must take into account known characteristics in relation to each installation and application to minimize the risk of wire damage, including any arc tracking phenomena.

3 You should evaluate deviations from installation and component selection criteria identified by these activities. A determination can then be made about their acceptability. Develop alternative mitigation strategies as necessary.

(d) **BOXES F & G** **Development and validation of mitigation strategy**. Identify and develop a mitigation strategy for the physical failures and their adverse effects identified in Boxes D and E. Validation and verification of the mitigation solution should ensure that:

1 Hazardous failure conditions are extremely remote.

2 Catastrophic failure conditions are extremely improbable and do not result from a single common cause event or failure.

3 This mitigation solution does not introduce any new potential failure conditions.

(e) **BOX H** **Incorporation of applicable mitigation strategies.** Incorporate newly developed mitigation strategies (BOX F) into guidelines (BOX B) for further design and inspection and analysis processes.

(f) **BOX I** **Physical failure analysis results.** From the EWIS physical failure analysis, document:

- Physical failures addressed.
- Effects of those physical failures.
- Mitigation strategies developed.

This information supports the final analysis documentation (BOX P).

ANALYSIS OF POSSIBLE FUNCTIONAL FAILURES

(g) **BOX J** **System safety assessments.** Use the results of the airplane level FHA (BOX A) to guide the system level FHA (BOX J). Incorporate EWIS failures identified by § 25.1705 into the system level and aircraft level FHA, as necessary, the PSSA, the CCA, and the SSA. These analyses are performed to satisfy requirements of § 25.1309. Use results of these analyses to update the EWIS definition (BOX B).

(h) **BOXES K, L, and M** **Hazardous and catastrophic failure conditions.** Use the analyses in BOX J to determine if the EWIS associated with the system under analysis can contribute (in whole or in part) to the failure condition under study. Determine whether the EWIS failure needs to be mitigated. If so, develop, validate, and verify a mitigation strategy. If no mitigation is needed, complete the appropriate safety assessment per § 25.1309, § 25.671, etc..

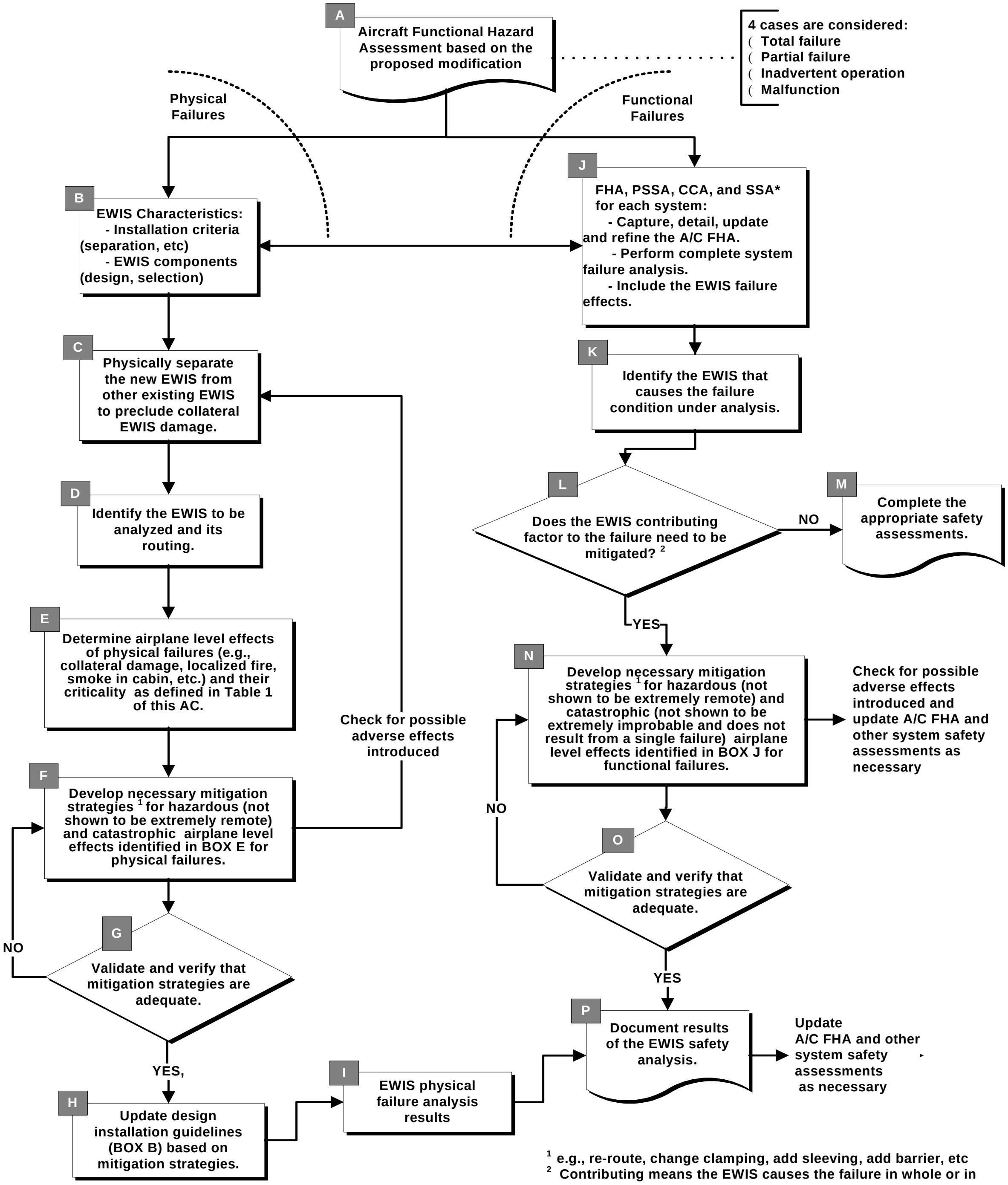
(i) **BOXES N and O** **Development and validation of mitigation strategy.** Identify and develop a mitigation strategy for the functional failures and adverse effects identified in BOX J. Validation and verification of the mitigation solution should -

- Determine if initial objective is fully reached.
- Confirm that this mitigation solution is compatible with existing installations and installation criteria.

If the EWIS was the failure cause, the subsequent mitigation strategy developed may introduce new adverse effects not previously identified by the analysis. Check for any new adverse effects and update the aircraft level FHA and other system safety assessments as necessary.

(j) **BOX P** **Documentation of EWIS safety analysis results.** After mitigation strategies have been validated and verified, document the results of the § 25.1705 analysis. Update as necessary the aircraft level FHA that has been developed in support of certification of the proposed modification, in compliance with § 25.1309 (BOX A).

Flowchart 2: Post-TC Safety Analysis Concept



[1] e.g., re-route, change clamping, add sleeving, add barrier, etc

[2] Contributing means the EWIS causes the failure in whole or in part

* FHA: Functional Hazard Assessment
PSSA: Preliminary System Safety Assessment
CCA: Common Cause Analysis
SSA: System Safety Assessment

Mitigation as used in this flowchart means to eliminate the hazard entirely or minimize its severity and probability to an acceptable level. In the case of this rule, the EWIS failure must be mitigated to a point where the probability of a hazardous failure is at least extremely remote and the probability of a catastrophic failure is at least extremely improbable

(12) DESCRIPTIVE TEXT FOR FLOWCHART 2.

(a) Applicants for post-TC modifications should use the analysis depicted in Flowchart 2 when the applicant cannot identify the systems or systems functions contained in existing aircraft EWIS that may be utilized as part of the modification. An applicant should not add EWIS to an existing EWIS if the systems or systems functions contained in the existing EWIS are unknown. To do so could introduce unacceptable hazards. For example, IFE power wires could inadvertently be routed with aircraft autoland EWIS.

(b) The main objectives are to ensure that the proposed modification –

- Will be correctly designed and installed.
- Will not introduce unacceptable hazards either through its own failure or by adversely affecting existing aircraft systems.

As far as EWIS is concerned, correct incorporation of the modification should be ensured by both good knowledge of original aircraft manufacturer installation practices and their correct implementation or by adequate separation of the added EWIS from existing EWIS. In either case, physical analyses should be performed (similar to the physical failures part of Flowchart 1).

(c) **BOX A** **Aircraft functional hazard assessment.** Airplane level effects must be considered for modified systems or systems added to the aircraft. If the airplane level FHA is available, the applicant should examine it to determine the airplane level effect of the proposed modification. If the airplane level FHA is not available, then the applicant must generate an airplane level FHA based on the proposed modification. This airplane level FHA would be limited to just those airplane systems affected by the proposed modification. If it is determined that no airplane level functional effects are introduced, a statement to this effect and the supporting data is sufficient to satisfy BOX A.

ANALYSIS OF POSSIBLE PHYSICAL FAILURES

(d) **BOX B** **EWIS characteristics.** Use results of the airplane level FHA (BOX A) to identify EWIS installation criteria and definitions of component characteristics. Results of BOX B are fed into the PSSA and SSA of BOX J.

(e) **BOX C** **Physical separation of new EWIS from existing EWIS.**

1 Separate the EWIS to be added from existing airplane EWIS since the systems or system functions contained in the existing EWIS are unknown. Establish physical separation between the new and existing EWIS either by separation distance or by an appropriate barrier or other means shown to be at least equivalent to the physical separation distance when allowed by § 25.1709. Methods given in the advisory material for § 25.1709 provide an acceptable way to determine adequate separation.

2 In cases where separation cannot be maintained because of physical constraints (e.g., terminal strips and connectors), the applicant should accomplish the appropriate analysis to show that no adverse failure conditions result from sharing the common device. This analysis requires knowledge of the systems or system functions sharing the common device (e.g., terminal strips and connectors).

(f) BOX D and E Validation and verification of installation criteria.

1 Ensure that the EWIS component qualification satisfies the design requirements and that components are selected, installed, and used according to their qualification characteristics and the airplane constraints linked to their location.

2 Use available information (digital mockup, physical mockup, airplane data, historical data) to perform inspections and analyses to validate that design and installation criteria are adequate to the zone/function, including considerations of multi-systems impact. Such inspections and analyses may include a 1st article inspection, design review, particular risk assessment, zonal safety assessment, zonal inspection, and common mode analysis, as applicable. Use such assessments and inspections to ascertain whether design and installation criteria were correctly applied. You should give special consideration to known problem areas identified by service history and historical data (areas of arcing, smoke, loose clamps, chafing, arc tracking, interference with other systems, etc.). Regardless of probability, any single arcing failure should be assumed for any power-carrying wire. The intensity and consequence of the arc and its mitigation should be substantiated. You should give special consideration to cases where new (previously unused) material or technologies are used Evaluate deviations from installation and component selection criteria identified by these activities and determine their acceptability.

3 Alternative mitigation strategies should be developed as necessary.

(g) BOXES F & G Development and validation of mitigation strategy. Identify and develop a mitigation strategy for the physical failures identified in BOXES D and E and resulting adverse effects. Validation and verification of a mitigation solution should ensure that:

1 Hazardous failure conditions are extremely remote.

2 Catastrophic failure conditions are extremely improbable and do not result from a single common cause event or failure.

3 This mitigation solution does not introduce any new potential failure conditions.

h) BOX H **Incorporation of Applicable Mitigation Strategies.** Incorporate newly developed mitigation strategies (BOX F) into guidelines (BOX B) for further design and inspection and analysis process.

(i) BOX I **Physical failure analysis documentation.** From the EWIS physical failure analysis, document:

- Physical failures addressed.
- Effects of those physical failures.
- Mitigation strategies developed.

This information supports the final analysis documentation (BOX P).

Analysis of Possible Functional Failures

(j) BOX J **System safety assessments.** Use the results of the airplane level FHA (BOX A) to guide the system level FHA (BOX J). Incorporate EWIS failures identified by § 25.1705 into the system level and aircraft level FHA, as necessary, the PSSA, the CCA, and the SSA. These analyses are performed to satisfy requirements of § 25.1309. Use results of these analyses to update the EWIS definition (BOX B).

(k) BOXES K, L, and M **Hazardous and catastrophic failure conditions.** Use the analyses in BOX J to determine if the EWIS associated with the system under analysis can contribute (in whole or in part) to the failure condition under study. Determine whether the EWIS failure needs to be mitigated. If so, develop, validate, and verify a mitigation strategy. If no mitigation is needed, complete the appropriate safety assessment (e.g., per § 25.1309, § 25.671, etc.).

(l) BOXES N and O **Development and validation of mitigation strategy.** Identify and develop a mitigation strategy for the functional failures and adverse effects identified in BOX J. Validation and verification of the mitigation solution should:

- Determine if initial objective is fully reached.
- Confirm that this mitigation solution is compatible with existing installations and installation criteria.

If the EWIS was the failure cause, the subsequent mitigation strategy developed may introduce new adverse effects not previously identified by the analysis. Check for any new adverse effects and update the aircraft level FHA and other system safety assessments as necessary.

(m) **BOX P** **Documentation of EWIS safety analysis results.** After mitigation strategies have been validated and verified, document the results of the § 25.1705 analysis. Update as necessary the aircraft level FHA that has been developed in support of certification of the proposed modification, in compliance with § 25.1309, (BOX A).

e. § 25.1709 SYSTEM SEPARATION: EWIS.

GENERAL GUIDANCE FOR § 25.1709.

(1) Summary. The continuing safe operation of an airplane depends on the safe transfer of electrical energy by the EWIS. If an EWIS failure occurs, the separation that the EWIS has from other EWIS, systems, or structure plays an important role in assuring the hazardous effects of the failure are mitigated to an acceptable level. Section 25.1709 requires applicants to design EWIS with appropriate separation to minimize the possibility of hazardous effects upon the airplane or its systems. As used in § 25.1709, the term "separation" is a measure of physical distance. The purpose of separation is to prevent hazards of arcing between wires in a single bundle, between two or more bundles, or between an electrical bundle and a non-electrical system or structure.

(2) Separation by physical distances versus separation by barrier. Section 25.1709 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, § 25.1709 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 (or tubing) is used to provide separation, designers 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 airplane model can be unique, and because manufacturers have differing design standards and installation techniques, § 25.1709 does not mandate specific separation distances. Instead it requires that the chosen separation be adequate so that an EWIS component failure will not create hazardous effects on the airplane or its systems. 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 other wire bundle manufacturing variabilities.

(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 airplane manufacturer's standard wiring practices manual and the ICA required by § 25.1529 and § 25.1739.

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

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

(4) <u>Cases of inadequate separation.</u> Some areas of an airplane may have localized areas where maintaining the minimum physical separation distance is not feasible. This is especially true in smaller transport category airplanes. In those cases, other means of ensuring equivalent minimum physical separation may be acceptable, if testing or analysis demonstrates that safe operation of the airplane is not jeopardized. The testing or analysis program should be conservative and consider the worst possible condition not shown to be extremely improbable. The applicant should substantiate to the ACO that the means to achieve the necessary separation provides the necessary level of protection for wire related failures. Electro-magnetic interference (EMI) protection must also be verified.

(5) <u>Meaning of the term "hazardous condition" as used in § 25.1709</u>. The term "hazardous condition" in § 25.1709 is used in a different context than it is used in § 25.1705, System safety: EWIS. Section 25.1705 uses the term "hazardous failure condition" in the context of assigning a numerical probability to failures that can cause the type of hazards as defined in Table 1: Classification of Failure Conditions, of this AC. As used in § 25.1709, the term means that the applicant must perform a qualitative design assessment of the installed EWIS. 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 airplane's ability to continue safe operation. However, the requirements of § 25.1709 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 FAA from requiring such an analysis if the applicant cannot adequately demonstrate that hazardous conditions will be prevented solely by using the qualitative design assessment. Also note that a numerical probability assessment may still be required under the requirements of § 25.1705 if the airplane level functional hazard assessment identifies EWIS failures that could affect safe operation of the airplane.

To illustrate the type of assessment required by § 25.1709, consider the following simple example involving the use of wire bundle clamps. Clamps are used to secure a wire bundle to structure in order to hold the bundle in place and route it from one location to another along a predetermined path. An airplane manufacturer, using the criteria contained in paragraph 5.e.(3) above, determines that a 2-inch separation between a certain wire bundle and some hydraulic lines is necessary. The manufacturer further decides that one clamp every 10 inches is needed to maintain that separation. However, there is one localized area where a single clamp failure would potentially create a hazard. This is because the area in question is a high vibration, high temperature area, subject to exposure to moisture. So the clamp in this particular area is exposed to severe environmental conditions that could lead to accelerated degradation. The manufacturer decides that using just a single clamp every 10 inches in this area would not suffice to preclude a hazardous event. The manufacturer prescribes use of double clamps every 10 inches in that area.

(6) Specific guidance by section of § 25.1709

(a) § 25.1709(a).

1 The requirements of § 25.1709(a) were derived from § 25.1353(a). It requires that EWIS associated with any system on the airplane 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. The failure conditions referred to in the paragraph are those defined by § 25.1309(b)(1) and (b)(2).

2 Paragraph 25.1709(a) also requires that adequate physical separation be achieved by separation distance or by a barrier that provides protection equivalent to that separation distance. Refer to paragraphs 5.(e)(2), (3), and (4) for further guidance regarding separation distances and the use of barriers.

(b) § 25.1709(b).

1 This section requires that each EWIS be designed and installed so that any electrical interference likely to be present in the airplane will not result in hazardous effects on the airplane or its systems.

2 One type of electrical interference is electromagnetic interference (EMI). Electromagnetic interference can be introduced into airplane systems and wiring by coupling between electrical cables or between cables and coaxial lines or other airplane systems. System function should not be affected by EMI generated by adjacent wire. EMI between its source wiring and wire susceptible to it increases in proportion to the length of parallel runs. It decreases with greater separation. Wiring of sensitive circuits that may be affected by EMI should be routed away from other wiring interference, or provided with sufficient shielding to avoid system malfunctions under operating conditions. EMI should be limited to negligible levels in wiring related to systems necessary for continued safe flight, landing, and egress. The following sources of interference should be considered:

(aa) Conducted and radiated interference caused by electrical noise generation from apparatus connected to the busbars.

(bb) Coupling between electrical cables or between cables and aerial feeders.

(cc) Malfunctioning of electrically-powered apparatus.

(dd) Parasitic currents and voltages in the electrical distribution and grounding systems, including the effects of lightning currents or static discharge.

(ee) Different frequencies between electrical generating systems and other systems.

(c) **<u>§ 25.1709(c).</u>** This section contains the wire-related requirements formerly located in § 25.1353(b). Coverage is expanded beyond wires and cable carrying heavy current to include their associated EWIS components as well. This means that all EWIS components, as defined by § 25.1701, that are associated with wires and cables carrying heavy current must be installed in the airplane so damage to essential circuits will be minimized under fault conditions.

(d) **<u>§ 25.1709(d).</u>** Section 25.1709(d) contains wire-related requirements from §§ 25.1351(b)(1) and (b)(2) and introduces additional requirements.

<u>1</u> Paragraph (d) requires that EWIS components associated with the generating system receive the same degree of attention as other components of the system, such as the electrical generators.

<u>2</u> Paragraph (d)(1) prohibits airplane independent electrical power sources from sharing a common ground terminating location. Paragraph (d)(2) prohibits airplane static grounds from sharing a common ground terminating location with any airplane independent electrical power sources. The reason for these paragraphs is twofold:

- to help ensure the independence of separate electrical power sources so that a single ground failure will not disable multiple power sources; and
- to prevent introduction of unwanted interference into airplane electrical power systems from other airplane systems.

(e) **<u>§§ 25.1709(e), (f), (g), (h).</u>** These paragraphs contain specific separation requirements for the fuel, hydraulic, oxygen, and waste/water systems. They require adequate EWIS separation from those systems except to the extent necessary to provide any required electrical connection to them. EWIS must be designed and installed with adequate separation so a failure of an EWIS component will not create a hazardous condition and any leakage from those systems (i.e., fuel, hydraulic, oxygen, waste/water) onto EWIS components will not create a hazardous situation.

1 Under fault conditions and without adequate EWIS separation a potential catastrophic hazard could occur should an arcing fault ignite a flammable fluid like fuel or hydraulic fluid. Also an arcing fault has the potential to puncture a line associated with those systems if adequate separation is not maintained. If there is leakage from one of those systems and an arcing event occurs, fire or explosion could result. Similarly, leakage from the water/waste system can cause damage to EWIS components and adversely affect their integrity. An EWIS arcing event that punctures a water or waste line could also introduce fluids into other airplane systems and create a hazardous condition.

2 In addition to the required separation distance, the use of other protection means such as drip shields should be considered to prevent fluids fromleaking onto EWIS.

(f) § 25.1709(i). To prevent chafing, jamming, or other types of interference, or other failures that may lead to loss of control of the airplane, EWIS in general and wiring in particular must be physically separated from flight control or other types of control cables. Mechanical cables have the potential to cause chafing of electrical wire if the two come into contact. This can occur either through vibration of the EWIS and/or mechanical cable or because of cable movement in response to a system command. A mechanical cable could also damage other EWIS components, such as a wire bundle support, in a way that would cause failure of that component. Also, if not properly designed and installed, a wire bundle or other EWIS component could interfere with movement of a mechanical control cable by jamming or otherwise restricting the cable's movement. Without adequate separation, an arcing fault could damage or sever a control cable. A control cable failure could damage EWIS. Therefore, paragraph (i) requires an adequate separation distance or barrier between EWIS and flight or other mechanical control systems cables and their associated system components. It also requires that failure of an EWIS component must not create a hazardous condition and that the failure of any flight or other mechanical control systems cables or systems components must not damage EWIS and create a hazardous condition. Clamps for wires routed near moveable flight controls should be attached and spaced so that failure of a single attachment point cannot interfere with flight controls or their cables, components, or other moveable flight control surfaces or moveable equipment.

(g) § 25.1709(j). This section requires that EWIS design and installation provide adequate physical separation between the EWIS components and heated equipment, hot air ducts, and lines. Adequate separation distance is necessary to prevent EWIS damage from extreme temperatures and to prevent an EWIS failure from damaging equipment, ducts, or lines. High temperatures can deteriorate wire insulation and other parts of EWIS components, and if the wire or component type is not carefully selected, this deterioration could lead to wire or component failure. Similarly, should an arcing event occur, the arc could penetrate a hot air duct or line and allow the release of high pressure, high temperature air. Such a release could damage surrounding components associated with various airplane systems and potentially lead to a hazardous situation.

(h) <u>§ 25.1709(k).</u> Reliability for some airplane systems is so critical that independent, redundant systems are required. The autoland system is an example. If one channel of a redundant autoland system is lost, the airplane can continue to operate safely. But if both channels of a two-channel system were lost because of a common failure, the results could be catastrophic. To maintain the independence of redundant systems and equipment so that safety functions are maintained, adequate separation and electrical isolation between these systems must be ensured. Paragraph (k) requires that EWIS associated with any system requiring redundancy to meet certification requirements have an adequate separation distance or barrier.

<u>1</u> EWIS of redundant aircraft systems should be routed in separate bundles and through separate connectors to prevent a single fault from disabling multiple redundant systems. Separation of functionally similar EWIS components is necessary to prevent degradation of their ability to perform their required functions.

<u>2</u> Power feeders from separate power sources should be routed in bundles separate from each other and from other aircraft wiring in order to prevent a single fault from disabling more than one power source.

<u>3</u> Wiring that is part of electro-explosive subsystems, such as cartridge-actuated fire extinguishers and emergency jettison devices, should be routed in shielded and jacketed twisted-pair cables, shielded without discontinuities, and kept separate from other wiring at connectors.

(i) <u>§ 25.1709(l).</u> This section requires that EWIS be designed and installed so they are adequately separated from aircraft structure and protected from sharp edges and corners. This is to minimize the potential for abrasion and chafing, vibration damage, and other types of mechanical damage. This protection is necessary because over time the insulation on a wire that is touching a rigid object, such as an equipment support bracket, will fail and expose bare wire. This can lead to arcing that could destroy that wire and other wires in its bundle. Structural damage could also occur depending on the amount of electrical energy the failed wire carries.

f. <u>§ 25.1711 COMPONENT IDENTIFICATION: EWIS.</u> Section § 25.1711 requires applicants to identify EWIS components using consistent methods that facilitate easy identification of the component, its function, and its design limitations. For EWIS associated with flight-essential functions where specific certification requirements are met by redundancy, identification of the EWIS must also include separation requirements. This section requires that the identifying markings remain legible throughout the expected service life of the EWIS component, and that the method used to identify components have no adverse effect on their performance.

(1) <u>§ 25.1711(a).</u> This section requires a consistent method of EWIS identification to avoid confusion and mistakes during airplane manufacturing, modification, and maintenance. This means we expect airplane manufacturers to develop an EWIS identification method that facilitates easy identification of the systems that any specific EWIS component supports and use that identification method in a consistent manner throughout the airplane. This consistent identification method must be used for new type certifications and changes to those designs.

(2) <u>§ 25.1711(b).</u> Certain airplane systems are installed with redundancy because of certification rules or operating rules or in order to meet the reliability requirements of § 25.1705. For EWIS components associated with these systems, paragraph (b) requires specific identification indicating component part number, function, and separation requirement. This is necessary to prevent modifiers from unintentionally introducing unsafe design or installation features on previously certified airplanes when they install new or modified systems. Such identification will aid the designers and installers of the new system by alerting them to the presence of the critical system. It will enable them to make appropriate design and installation decisions. Component identification will also make those performing maintenance and inspections more aware of what systems are associated with specific EWIS in the areas undergoing maintenance or inspection.

(3) <u>§ 25.1711(c).</u> Paragraph (c) requires that identifying markings required by §25.1711(a) and (b) remain legible throughout the design life of the component. As most wire installations are designed to remain on the airplane throughout the airplane's service life, this means the identification marks must be able to be read for the life of the airplane. The method of marking must take into account the environment in which the EWIS component will be installed. The Society of Automotive Engineers (SAE) documents ARP 5607, "Legibility of Print on Aerospace Wire and Cables," and AS 5942, "Marking of Electrical Insulating Materials," provide guidance on this subject. Dot matrix and ink-jet marking should only be used when there is no strong need for chemical or mechanical resistance of the ink. The color used for identification should contrast with the wire insulation, sleeve, support material, or other EWIS components.

(4) <u>§ 25.1711(d).</u> Paragraph (d) requires that the means used to identify an EWIS component may not have an adverse effect on component performance throughout its design life. The preferred method of EWIS component identification is with dot matrix, ink-jet, or laser marking.

(a) Certain wire marking methods have potential to damage wire insulation. Hot-stamp marking is one such method. According to SAE aerospace information report AIR5575, "Hot Stamp Wire Marking Concerns for Aerospace Vehicle Applications," the hot-stamp marking method is not well suited for today's generation of aircraft wiring. As noted in that document, wire insulation has become markedly thinner over the years since the procedure was first introduced in the 1940s. Because of this, problems have arisen over wire damage from excessive penetration by the hot stamp process. The document further states: "The frequent need for adjustments in temperature, pressure, and dwell time inherent to achieving legible hot stamp wire marking provides many opportunities for error. The controls, methods, and guidance necessary to achieve satisfactory performance with hot stamp marking are often not made available to operators in smaller wire shops."

(b) If damage to the insulation occurs during the marking process, it may fail later in service after exposure to the sometimes-harsh environmental conditions of aircraft use. While § 25.1711(d) does not prohibit use of hot-stamp marking, its use is not encouraged. To comply with this paragraph, if the hot-stamp marking process is used, the guidelines of SAE recommended practice ARP5369, "Guidelines for Wire Identification Marking Using the Hot Stamp Process" or equivalent should be followed. Other information related to the use of the hot-stamp marking process can be found in SAE AIR 5575 and AECMA EN3197.

(c) In some cases it may not be practicable to mark an EWIS component directly because of component size or identification requirements. In this case other methods of identification such as a label or sleeve should be used.

(5) <u>§ 25.1711(e)</u>. Paragraph (e) requires that EWIS modifications to the type design take into consideration the identification scheme of the original type design. This is to ensure that the consistency required by § 25.1711(a) is maintained when a modification is installed. The intent of this requirement is to provide continuity for EWIS identification on a particular model. It is not the intent of the requirement to impose on the modifier the exact wire identification methods of the airplane manufacturer. However, since the purpose of § 25.1711 is to make it easy to identify those airplane systems essential to safe operation of the airplane, it is in the best interest of safety that designers of any modifications to the original design consider the approved type design identification methods. For example it would not be appropriate for a modifier to use purple wire to identify a specific flight critical system when the approved type design used the color green, especially if the type design already uses purple wire to identify non-essential systems. Such a scheme could cause confusion and lead future modifiers or maintainers to believe that the routing of purple wires with green wires (and thus critical systems with non-essential systems) is acceptable. The regulation does not prescribe a particular method for identification but is meant to ensure that consistent identification is maintained throughout the life of the airplane.

(6) <u>Visible Identification of Critical Design Configuration Limitations.</u> Section 25.981(b) states that "...visible means to identify critical features of the design must be placed in areas of the airplane where maintenance actions, repairs, or alterations may be apt to violate the critical design configuration limitations (e.g., color-coding of wire to identify separation limitation)." The design approval holder should define a method of ensuring that this essential information will:

- be communicated by statements in appropriate manuals, such as wiring diagram manuals, and
- be evident to those who may perform and approve such repairs and alterations.

An example of a critical design configuration control limitation that would result in a requirement for visible identification means would be a requirement to maintain wire separation between FQIS (fuel quantity indication system) wiring and other electrical circuits that could introduce unsafe levels of energy into the FQIS wires. Acceptable means of providing visible identification means for this limitation would include color-coding of the wiring or, for retrofit, placement of identification tabs at specific intervals along the wiring.

(7) <u>Types of EWIS component identification.</u> There are at least four types of EWIS component identification which are accomplished at different stages. They are listed and described below.

(a) <u>Component manufacturer part number</u>. EWIS components should be identified by their manufacturer in accordance with the International Organization for Standardization document ISO 2574, “Aircraft – Electrical Cables – Identification Marking,” or similar specifications. This identification comprises product part number, manufacturer identification, and, when possible or specifically required, batch identification or year of manufacture. This helps ensure:

- Identification and traceability of the component.
- Verification of compliance with the aircraft certification basis.
- Accuracy in manufacture, maintenance, quality control, storage, and delivery.

- Verification of the use of approved/qualified sourcing.
- Monitoring of the aircraft configuration during the aircraft life.

1 EWIS component manufacturer identification. It is common practice to use the five-digit/letter C.A.G.E. (commercial and government entity) code for manufacturer identification, particularly for wires. Alternatively, for small components whose size may make it difficult to use other forms of clear identification, a logo may be used.

2 Identification intervals. Wires and cables should be identified at intervals of not more than 15 inches (380mm). Exceptions can be made for short runs of wires or cables or when the majority of the wire or cable is installed in a manner that facilitates easy reading of the identification markings.

3 Manufacturer markings. Wire manufacturer markings should generally be green to differentiate them from the black marking typically used by the airplane manufacturer, but other contrasting colors are also acceptable.

4 The component technical specification should include methods used for identification and legibility during the design life of the component.

(b) Airframe manufacturer component function identification number. In addition to the type identification imprinted by the original wire manufacturer, aircraft wire should also contain a unique circuit identification coding that is accomplished at time of harness assembly. This allows existing installed wire to be identified as to its performance capabilities when considering replacement. Inadvertent use of a lower performance and unsuitable replacement wire can thus be avoided. Identification of EWIS components by the airframe manufacturer helps ensure:

- Identification and inspection of cable runs.
- Accuracy of manufacture, maintenance, quality control, storage and delivery.
- Verification of the system to which the component belongs.
- Identification of components related to systems required for safe flight, landing, or egress or that have the potential to impact the flightcrew's ability to cope with adverse operating conditions.

1 Identification intervals. Wires and cables should be identified at intervals of preferably not more than 18 inches (460mm) and should not obscure the identification markings of the EWIS component manufacturer or the routing identification markings described in paragraphs 5.f.(1)(a)2 and 5.f.(1)(c)3. Exceptions can be made for short runs of wires or cables or when the majority of the wire or cable is installed in a manner that facilitates easy reading of the identification markings.

2 Identification of EWIS components should clearly correspond to aircraft wiring manuals.

(c) Airframe manufacturer routing identification and modification. Electrical drawings should describe wire routings through the entire airplane indicating, for example, incompatibility between routes, minimum distance between routes, absolute ban of combining bundles, and be available in the maintenance documentation as required by paragraph H25.5 of Appendix H to part 25. This information ensures that modification designers and maintenance personnel are aware of the defined physical separation of the different routes of the aircraft model they are working on. Coding for identification of routes or bundles used on aircraft should be displayed by adequate means such as labels, tags, placards, colored ties, or bar-codes. This type of component identification helps insure:

- Identification and inspection of bundles.
- Accuracy of manufacture, maintenance, quality control, storage and delivery.
- Determination of the type of route, or route function, (feeder power, radio etc.).
- Clear identification of systems that require physical separation (to detect the possible mix of different routes/bundles, the misrouting of a system in an area, etc.).
- Identification of routes taken by systems that are required for safe flight, landing, egress, or have the potential to impact the ability of the flightcrew to cope with adverse operating conditions.

1 Modification and repairs identification, in a form that helps ensure the original airplane manufacturer's identification scheme, should be maintained throughout the service life of the airplane.

2 Wires and cables should be identified at intervals of preferably not more than 18 inches (460mm) and should not obscure the identification markings of the EWIS component manufacturer or airframe manufacturer component function identification number described in paragraphs 5.f.(1)(a)2 and 5.f.(1)(b)1. Also, exceptions can be made for short runs of wires or cables or when the majority of the wire or cable is installed in a manner that facilitates easy reading of the identification markings.

(d) Identification of user EWIS modification or repair (operator's identification coding). Repairs or modifications to EWIS should follow the identification guidance given in the above paragraphs for airplane manufacturers. This helps ensure that the original airplane manufacturer's identification scheme is not compromised by future modifications or repairs and is maintained throughout the service life of the airplane. A temporary repair identification with a non-hydraulic-resistant material could remain in a hydraulic bay for some days, but such material would not be a suitable marking method for the long term.

g. § 25.1713 FIRE PROTECTION: EWIS. The intent of this requirement is to help ensure that the EWIS does not propagate fire and produce hazardous quantities of smoke and toxic fumes.

(1) § 25.1713(a). This paragraph requires that all EWIS components meet the applicable fire and smoke protection requirements of § 25.831(c), a requirement that was formerly located in § 25.869(a)(1). After reasonably probable failures or malfunctions, EWIS components should not cause harmful or hazardous concentrations of gases or vapors in excess of the levels prescribed in § 25.831(b)(1) and (2).

(2) § 25.1713(b). This requirement was formerly located in § 25. 869(a)(2). It requires that EWIS components that are located in designated fire zones and used during emergency procedures must be at least fire resistant. This requirement is intended to help ensure that emergency services are available in the event of a fire.

(a) The definition of "fire resistant" is found in § 1.1 *General definitions*. As applied to EWIS components it means:

To be fire resistant means that EWIS components must have the capacity to perform the intended functions under the heat and other conditions likely to occur when there is a fire at the place concerned.

(b) EWIS components in regions immediately outside fire zones and in engine pod attachment structures should be made of such materials and installed at such a distance from the firewall that they will not suffer damage that could hazard the airplane if the surface of the firewall adjacent to the fire is heated to 1100° C (2012° F) for 15 minutes.

(3) § 25.1713(c). This section was formerly located in § 25.869(a)(4). It requires that insulation on electrical wire and electrical cable installed anywhere in the airplane be self-extinguishing when tested in accordance with the applicable portions of part I appendix F of part 25.

(a) In addition, to protect against propagation of a fire, EWIS components other than wire and cable should be designed using non-flammable and self-extinguishing materials as tested to the equivalent of Part 1 appendix F or equivalent.

(b) Maximum physical or spatial separation is especially important above the component, or downstream of any consistent, known airflow. See paragraph 5.e**.**, System Separation EWIS of this advisory circular for guidance on demonstrating compliance with the separation requirements of § 25.1709.

h. <u>§ 25.1717 ELECTRICAL BONDING AND PROTECTION AGAINST STATIC ELECTRICITY: EWIS.</u> The build-up and subsequent discharge of static electricity has the potential to create hazardous conditions for both airplane systems and people. It can injure people, interfere with installed electrical/electronic equipment, and cause ignition of flammable vapors. All EWIS components used for bonding and protection against static electricity play a vital role in ensuring the integrity of the bonds.

(1) <u>§ 25.1717(a).</u> This section requires that EWIS used for electrical bonding and protection against static electricity meet the requirements of § 25.899. To minimize the hazardous effects of static discharge, EWIS components should be selected, designed, and installed so that the cross-sectional area of bonding paths used for primary and secondary bonding ensure that an appropriately low electrical impedance is obtained and maintained throughout the expected service life of the components.

(a) The maximum resistance for electrical bonds varies depending on the type of bond, e.g., ground stud, between connector shell and structure. A typical value is 1 milliohm, but this can vary from .01 milliohms to 3 milliohms. The airplane manufacturer's standard wiring practices manual (SWPM) provides guidance on maximum bonding resistance.

(b) The airplane manufacturer's SWPM provides guidance on proper surface preparation, materials, tooling, maximum torque values and other variables important to ensuring an adequate bond One airplane manufacturer's SWPM for example states that steel washers, dyed washers, and other washers with a non-conductive surface should not be used in the conductive path of a bond.

(2) <u>§ 25.1717(b).</u> This section requires that EWIS components used for any electrical bonding purposes (not just those used for protection against static electricity) provide an adequate electrical return path under both normal and fault conditions. EWIS components should be selected, designed, and installed so that the cross-sectional area of bonding paths used for primary and secondary bonding paths ensure that an appropriately low electrical impedance is obtained and maintained throughout the expected service life of the components.

i. <u>§ 25.1719 SYSTEMS AND FUNCTIONS: EWIS.</u> This section requires consideration of EWIS components in showing compliance with the certification requirements for specific airplane systems. Although not all part 25 certification requirements directly address EWIS, many address EWIS in an indirect way. The EWIS associated with such systems play an integral role in ensuring the safe operation of the system and of the airplane. If a system is required by type certification or by operating rules, EWIS associated with that system must be evaluated as part of showing compliance of the system. Section 25.1719(a) and (b) may seem redundant. Section 25.1719(a) has the general requirement. Section 25.1719(b) identifies specific regulations to which this requirement applies. These specific sections contain requirements that do not lend themselves to creating a separate EWIS-based subpart H requirement. But this is not an exclusive list. If a regulation is absent from 25.1719(b) it must still be considered under the general terms of 25.179(a), The general requirement of (a) is necessary because there may be other regulations where EWIS must be considered. It also ensures that EWIS is given full consideration for any system-related regulation adopted in the future.

j. <u>§ 25.1721 CIRCUIT PROTECTIVE DEVICES: EWIS.</u> This section requires that electrical wires and cable be compatible with the circuit protective devices required by § 25.1357. This means that when selecting wire and cables for a specific application, care must be taken to ensure selection of the proper type and rating of the circuit protective device (e.g., circuit breaker) so that the wire and cables are adequately protected from over-current situations. This section is based on the requirements that formerly resided in § 25.1353(d)(1).

<u>NOTE:</u> Section 25.1353(d)(1) only referred to "cables." Section 25.1721 adds the word "wire" to expand the requirement to all sizes of wire, not just heavy-current-carrying cables.

k. <u>§ 25.1723 INSTRUMENTS USING A POWER SUPPLY: EWIS.</u> This section requires that EWIS components associated with flight and navigation instruments using a power supply be designed and installed so that compliance with § 25.1331 is ensured. This means that EWIS associated with these systems must be considered part of those systems and given the same design and installation considerations as the rest of the system.

l. <u>§ 25.1725 ACCESSIBILITY PROVISIONS: EWIS.</u> This section requires that means be provided to allow for inspection of EWIS and replacement of their components as necessary for continued airworthiness.

(1) The intent of § 25.1725 is to ensure that EWIS components are installed so that inspections, tests, repairs, and replacements can be undertaken with a minimum of aircraft disassembly. When adjacent structures and aircraft systems components must be removed to allow access to wire installations, new possibilities for contamination, chafing, and other types of damage are introduced.

(2) As far as practicable, EWIS components should be installed so that inspections, tests, repair, and replacements can be done without undue disturbance to the EWIS installation or to surrounding aircraft systems. During the design phase, consider minimizing the amount of aircraft disassembly required to perform such tasks. For example, wiring inside conduit may incur damage from chafing against the sides of the conduit. If failure of wiring inside a conduit can lead to a hazardous or catastrophic condition, a means should be provided for inspection of those wires. Inspection may be by testing or other means acceptable to the Administrator and should be included in the maintenance requirements that are part of the Instructions for Continued Airworthiness.

m. <u>§ 25.1727 PROTECTION OF EWIS</u>. The requirements of this section are intended to prevent damage to EWIS by passenger, crew members, baggage or cargo handlers, or maintenance and service personnel, or by movement of cargo or baggage. Section 25.1727(a) is applicable to EWIS located in cargo or baggage compartments, and §§ 25.1727(b) and (c) apply to EWIS located anywhere in the airplane.

(1) <u>§ 25.1727(a).</u> The requirements of this paragraph, as they pertain to EWIS, were formerly located in § 25.855(e). Under section 25.1727(a), EWIS cannot be located in cargo or baggage compartments if its damage or failure may affect safe operation unless it cannot be damaged by movement of cargo or baggage in the compartment and unless its breakage or failure will not create a fire hazard. This means that any EWIS located in a cargo or baggage compartment must be protected against damage. It further means that EWIS must be designed and installed so that if it fails or breaks, for whatever reason, such as failed wire bundle support devices, damage to cargo liners, or chafed wires, such failure will not create a fire hazard.

It does not matter if the EWIS located in the compartment is associated with a flight critical or essential system or a passenger convenience system, such as an IFE system. Failure of an EWIS component, no matter what system it is associated with, could cause a fire or other type of damage to aircraft systems or structure. EWIS in general and wiring in particular should be installed so the structure affords protection against its use as a handhold and damage from cargo. Wires and wire bundles should be routed or otherwise protected to minimize the potential for maintenance personnel stepping, walking, or climbing on them. Wire bundles should be routed along heavier structural members whenever possible. If the structure does not afford adequate protection, other protection means such as a mechanical guard should be provided. When EWIS is close to sharp metal edges, the edges should be protected by grommets to prevent chafing. Additionally, wires should not be routed between aircraft skin and fuel lines.

(2) **<u>§ 25.1727(b).</u>** This paragraph requires that EWIS be designed and installed to minimize its damage and risk of damage by movement of people in the airplane during all phases of flight, maintenance, and servicing. Some examples of areas of concern are the flight deck, passenger compartment, crew rest area, wheel wells, and wing leading and trailing edges.

(a) Special consideration should be given to EWIS that are routed to and on passenger seats. It should be protected so that passengers cannot damage it with their feet or access it with their hands.

(b) EWIS located in the lavatories should not be readily accessible by passengers or aircraft cleaners. It should be designed and installed so that it cannot be damaged by the removal and replacement of items such as trash containers.

(c) EWIS located in the galleys should not be readily accessible by cabin crew, aircraft cleaners, or passengers. It should be designed and installed so that galley equipment, including galley carts, cannot come into contact with it and cause damage. The design and installation of EWIS around and in galley areas should be such that galley equipment, such as chiller units, can be removed and reinstalled without coming into contact with EWIS components and damaging them.

(d) As with EWIS located in baggage and cargo compartments, EWIS in areas such as landing gear bays, the APU compartment, and electrical and electronic bays should be designed and installed to minimize potential for maintenance personnel stepping, walking, or climbing on them. Where the structure does not afford adequate protection, other protection such as a mechanical guard should be provided.

(3) **<u>§ 25.1727(c).</u>** This paragraph requires that EWIS be designed and installed to minimize its damage and risk of damage by items carried onto the aircraft by passengers or cabin crew. This is intended to protect EWIS from items such as baggage that is carried on board by passengers and cabin crew and stowed beneath passenger seats or other places where luggage is likely to be stowed.

<u>n. § 25.1729 FLAMMABLE FLUID FIRE PROTECTION: EWIS.</u> This section requires that EWIS located in areas where flammable fluid or vapors might escape must be considered to be a potential ignition source. As a result, these EWIS components must meet the requirements of §25.863. Section 25.863 requires that efforts be made to minimize the probability of ignition of fluids and vapors, and the hazards if ignition does occur. See § 25.1709 for the separation requirements between EWIS and flammable fluids. Paragraph 5e of this AC contains the advisory material for § 25.1709.

The airplane manufacturer defines fuel vapor zones. EWIS components located in fuel vapor zones should be qualified as explosion proof in accordance with Section 9 of RTCA Document DO160 or EUROCAE ED-14, "Environmental Conditions and Test Procedures for Airborne Equipment," latest approved revision or other equivalent approved industry standard. The possibility of contamination with flammable fluids due to spillage during maintenance action should also be considered.

o. § 25.1731 Powerplants: EWIS.

(1) § 25.1731(a). This paragraph requires that the failure of EWIS components must be considered when demonstrating compliance with the requirements of § 25.903(b). That means that when a powerplant fails or malfunctions, an EWIS component may not fail in such a way as to prevent continued safe operation of the remaining powerplants or require immediate action by any crewmember for continued safe operation.

(2) § 25.1731(b). This paragraph requires that design of EWIS must take into account damage to them from a powerplant rotor failure or from a fire originating in the powerplant that burns through the powerplant case. The design of EWIS must minimize hazards to the airplane when these events occur.

p. § 25.1733 Flammable fluid shutoff means: EWIS. This section requires that EWIS associated with each flammable fluid shutoff means and control be fireproof or be located and protected so that any fire in a fire zone will not affect operation of the flammable fluid shutoff means, in accordance with the requirements of § 25.1189.

q. § 25.1735 FIRE DETECTOR SYSTEMS, GENERAL: EWIS. The environmental qualification of the system components should include the use of fire resistant EWIS components and/or design to ensure that the system will detect fire if exposed to it.

r. § 25.1737 POWER PLANT AND APU FIRE DETECTOR SYSTEMS: EWIS. To minimize occurrences of nuisance fire warnings, consider separately routing fire detection system wiring within the fire zone to allow optimal routing and ease of replacement. Exercise particular care regarding the environmental qualification of the system connectors (fire resistance, resistance to moisture and fluids etc.).

s. § 25.1739 INSTRUCTIONS FOR CONTINUED AIRWORTHINESS: EWIS. Section 25.1739 requires applicants to prepare Instructions for Continued Airworthiness (ICA) in accordance with sections H25.4(a)(3) and H25.5. The guidance for those sections of Appendix H applicable to EWIS ICA are contained in paragraph 5.t. of this AC.

t. APPENDIX H TO PART 25 INSTRUCTIONS FOR CONTINUED AIRWORTHINESS REQUIREMENTS FOR EWIS. The following discusses the requirements for including EWIS component information in the ICA for aircraft. Including EWIS in the ICA will promote proper maintenance, repair and modifications of EWIS components. Improper maintenance, repair, and modifications often hasten the "aging" of EWIS. To properly maintain, repair, and modify airplane EWIS, certain information needs to be available to people who design, modify, install, and maintain it. Sections H25.4(a)(3) and H25.5 require applicants for both type certificates and supplemental type certificates to prepare ICA for EWIS. The EWIS-related ICA must be approved by the cognizant FAA office and be in the form of a document easily recognizable as EWIS ICA. The following paragraphs, 5.t.(1) through 5.t.(7), provide specific guidance on acceptable compliance methods for EWIS ICA.

(1) H25.4(a)(3). This section requires the applicant to include in the Airworthiness Limitations section of the Instructions for Continued Airworthiness any mandatory replacement times for EWIS components. EWIS components are those defined by § 25.1701. Generally, EWIS components are designed and selected to last for the service life of the airplane. Any EWIS component that must be replaced at regular intervals to maintain the airworthiness of the associated system or airplane must be specified, with its required replacement interval, in the Airworthiness Limitations section of the ICA.

(2) H25.5(a). This section requires applicants to prepare ICA applicable to EWIS. The ICA must cover all EWIS components as defined in § 25.1701. The rule requires that the FAA approve the EWIS ICA.

(3) H25.5(a)(1). This paragraph requires applicants to prepare EWIS maintenance and inspection requirements using an enhanced zonal analysis procedure (EZAP). An EZAP is a specifically wire-focused version of the zonal analysis procedure widely used to analyze an airplane's physical areas or zones. It is used for developing maintenance tasks. One version of an EZAP is described in AC 120-XX, "Program to Enhance Aircraft Electrical Wiring Interconnection System Maintenance."

(4) H25.5(a)(2). This paragraph requires applicants to document EWIS maintenance practices in a standard format. This is typically accomplished with publication of a standard wiring practices manual (SWPM). The rule is not intended to require that every manufacturer's SWPM be identical. The intent is to enable people performing EWIS maintenance and repairs to find needed information in the SWPM more quickly and easily, regardless of what airplane model they are currently working on. Standard wiring practices include procedures and practices for the installation, repair, and removal of EWIS components, including information about wire splices, methods of bundle attachment, connectors and electrical terminal connections, bonding, and grounding. A SWPM is not a design manual, and designers of EWIS modifications for specific airplane models should not use it as such. But it does provide the designer with insight into the types of EWIS components used by the TC holder and the procedures recommended by the manufacturer for maintenance or repair that supports continued airworthiness of the components. Advisory Circular 25-XX, "Development of Standard Wiring Practices Documentation," provides guidance on how to comply with the requirements of paragraph H25.5(a)(2) of Appendix H to part 25.

(5) H25.5(a)(3). This section requires applicants to include EWIS separation requirements in the ICA. EWIS separation guidelines are important for maintaining the safe operation of the airplane. Maintenance and repair personnel need to be aware of the type certificate holder's separation requirements so they do not compromise separation in previously certified systems. This requirement will help maintenance, repair, and modification personnel easily determine EWIS separation requirements.

(a) Determination of EWIS separation requirements is required by § 25.1709. To comply with H25.5(a)(3), the applicant needs to develop a way to convey these separation requirements and place them in the ICA. For example, if an airplane has a fly-by-wire flight control system and a minimum of 2 inches of physical separation is needed between the EWIS associated with the flight control system and other EWIS, this information must to be available in the ICA. Similarly, the separation of certain wires in fuel tank systems may be critical design configuration control items and therefore qualify as an airworthiness limitation. Maintenance personnel need these guidelines and limitations because many times wire bundles must be moved or removed to perform maintenance.

(b) The separation data included in the ICA can take many forms. If a particular airplane model has fly-by-wire flight controls, the manufacturer may designate the EWIS associated with the flight control systems by a certain identification scheme (as required by § 25.1711), and in the ICA state that EWIS so designated must be maintained with XX amount of separation from all other EWIS and YY amount of separation from other airplane systems and structure. The manufacturer can then repeat this information for other EWIS associated with other airplane systems. The ICA could indicate how EWIS associated with IFE and other passenger convenience systems is identified, and that this EWIS must be maintained XX inches from other categories of EWIS or structure.

(c) It is not the intent of the regulation to require a design approval holder or an applicant to divulge proprietary information in order to comply. Certain information, however, needs to be made available to modifiers and maintainers to ensure that future modifications and repairs do not invalidate previously certified designs.

(6) **<u>H25.5(a)(4).</u>** This paragraph requires that the ICA contain information explaining the EWIS identification method and requirements for identifying any changes to EWIS. This requirement is intended to ensure that future modifications that add EWIS identify the added EWIS with the same type of identification scheme used by the original airplane manufacturer. This information will help modification designers and modification personnel avoid improper modification and repair of existing EWIS or improper installation of new EWIS. These personnel need to review the applicable standard wiring practices, EWIS identification requirements, and electrical load data for the airplane they are modifying.

(7) **<u>H25.5(a)(5).</u>** This paragraph requires that the ICA contain electrical load data and instructions for updating that data. Electrical load data and the instructions for updating it are necessary to help ensure that future modifications or additions of equipment that consume electrical power do not exceed the generating capacity of the onboard electrical generation and distribution system. Maintaining a record of actual airplane electrical loads is important to ensure that modifications to the original design do not impose electrical loads on the electrical generating system in excess of the system's capability to provide the necessary power and maintain necessary margins. To comply with the requirements of this paragraph applicants need to provide:

(a) Electrical generating capacity of each source of normal electrical power generation.
(b) Electrical generating capacity of each source of emergency power generation.
(c) Electrical load capacity of each electrical bus.
(d) Actual electrical loading of each electrical bus.

APPENDIX
RELATED REGULATIONS AND DOUCMENTS

RELATED SECTIONS OF TITLE 14, CODE OF FEDERAL REGULATIONS (CFR), PART 25

§ 25.773 Pilot compartment view.
§ 25.831 Ventilation.
§ 25.863 Flammable fluid fire protection.
§ 25.869 Fire protection: systems.
§ 25.899 Electrical bonding and protection against static electricity.
§ 25.903 Engines.
§ 25.981 Fuel tank ignition prevention.
§ 25.1165 Engine ignition systems.
§ 25.1189 Shutoff means.
§ 25.1203 Fire detector system.
§ 25.1301 Function and installation.
§ 25.1303 Flight and navigation instruments.
§ 25.1309 Equipment, systems, and installations.
§ 25.1310 Power source capacity and distribution.
§ 25.1316 System lightning protection.
§ 25.1331 Instruments using a power supply.
§ 25.1351 General.
§ 25.1353 Electrical equipment and installations.
§ 25.1355 Distribution system.
§ 25.1357 Circuit protective devices.
§ 25.1360 Precautions against injury.
§ 25.1362 Electrical supplies for emergency conditions.
§ 25.1365 Electrical appliances, motors, and transformers.
§ 25.1431 Electronic equipment.
§ 25.1529 Instructions for Continued Airworthiness.

OTHER RELATED CFR PARTS

Part 21 Certification Procedures for Products and Parts

Part 43 Maintenance, Preventive Maintenance, Rebuilding, and Alteration

Part 91 General Operating and Flight Rules

Part 121 Operating Requirements: Domestic, Flag, and Supplemental Operations

Part 125	Certification and Operations: Airplanes having a Seating Capacity of 20 or More Passengers or a Maximum Payload Capacity of 6,000 Pounds or More: and Rules Governing Persons on Board Such Aircraft
Part 129	Operations: Foreign Air Carriers and Foreign Operators of U.S.-Registered Aircraft Engaged in Common Carriage
Part 145	Repair Stations

ADVISORY CIRCULARS

AC 25-10	Guidance for Installation of Miscellaneous, Nonrequired Electrical Equipment
AC 25-16	Electrical Fault and Fire Protection and Prevention
AC 43-13.1B	Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair
AC 25.773-1	Pilot Compartment View Design Considerations
AC 25-869-1	Electrical Smoke and Fire Protection
AC 25.981-1B	Fuel Tank Ignition Source Prevention Guidelines
AC 25.1309-1A	System Design and Analysis
AC 25.1310-1	Power Source Capacity and Distribution
AC 25.1353-1	Electrical Requirements and Installations
AC 25-1357-1	Circuit Protective Device Accessibility
AC 25-1360-1	Electric Shock and Burns
AC 25-1362	Electrical Supply for Emergency Service
AC 25.1363-1	Electrical System Tests
AC 25.1365-1	Electrical Appliances, Motors, and Transformers
AC 25.17XX-1	Development of Standard Wiring Practices Documentation

AC 25.17YY-1 Program To Enhance Aircraft Electrical WiringInterconnection System Maintenance

POLICY MEMORANDA

PS-ANM100-1999-0021 Requirements of FAR 25.1357(e)

PS-ANM100-2000-00105 Interim Policy Guidance for Certification of In-Flight Entertainment Systems on Title 14 CFR Part 25 Aircraft

PS-ANM100-2001-00113 Interim Summary of Policy and Advisory Material Available for Use in the Certification of Cabin Mounted Video Camera Systems with Flight Deck Displays on Title 14 CFR Part 25 Aircraft

PS-ANM111-2002-01-04 System Wiring Policy for Certification of Part 25 Airplanes

REPORTS

"Task 6 Final Report" Aging Transport Systems Rulemaking Advisory Committee, dated October 29, 2002.

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) DOCUMENTS

Note: AS = Aerospace Standard
AIR = Aerospace Information Report
ARP = Aerospace Recommended Practice

AS4373 Test Methods for Insulated Electric Wire

AS50881 Wiring Aerospace Vehicle

AS70991 Terminals: Lug and Splice, Crimp Style, Aluminum, For Aluminum Aircraft Wire

AS7928 Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification For

AS81824 Splices, Electric, Permanent, Crimp Style Copper, Insulated, Environment Resistant

AIR5575 Hot Stamp Wire Marking Concerns for Aerospace Vehicle Applications

ARP5369 Guidelines for Wire Identification Marking Using the Hot Stamp Process

ARP4404 Aircraft Electrical Installations

EUROPEAN NORMS

EN 34375 Aerospace Series – Cables, Electrical, Aircraft Use

prEN 2853 Current Ratings for Electrical Cables to be Installed on Aircraft (in development)

prEN 3197 Aerospace Series – Installation of Aircraft Electrical and Optical Interconnection Systems (in development)

OTHER DOCUMENTS

RTCA DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

Eurocae ED-14 Environmental Conditions and Test Procedures for Airborne Equipment

International Organization for Standardization Document ISO 2574 Aircraft – Electrical Cables – Identification Marking