



The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Équipement de l'Aviation Civile

CERTIFICATION OF AIRCRAFT ELECTRICAL/ELECTRONIC SYSTEMS FOR THE INDIRECT EFFECTS OF LIGHTNING

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Edition 2: Amendment # 1, 26 August 1999 is included in the text

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FOREWORD

1. This document jointly prepared by SAE Committee AE4L and EUROCAE Working Group 31 was accepted by the Council of EUROCAE on April 12, 1996.
2. EUROCAE is an international non-profit making organisation in Europe. Membership is open to users and manufacturers in Europe of equipment for aeronautics, trade associations and, under certain conditions, non-European Members. Its work programme is principally directed to the preparation study of performance specifications and guidance documents for civil aviation equipment, for adoption and use at European and world-wide levels.
3. The findings of EUROCAE are resolved after discussion among its members and in co-operation with the RTCA Inc, Washington D.C., U.S.A and/or the Society of Automotive Engineers (SAE), Warrendale PA, USA, through their appropriate committees.
4. This document was prepared in response to requests from FAA and JAA for technical advice for updating FAA Advisory Circular 20-136 and for formulation of similar advisory and interpretive material for use by JAA. This document has been called "ORANGE BOOK" during its development. It represents the advice of EUROCAE WG-31 and SAE Committee AE4L and does not replace existing FAA or JAA documents such as FAA AC 20-136, unless later adopted by these administrations.
5. This document is compatible with Document EUROCAE ED-14/RTCA DO-160 "Environmental Conditions and Test Procedures for Airborne Equipment, Issue D, Sections 22 and 23 related to Lightning Effects" which is being achieved in co-operation with RTCA SC-135.
6. EUROCAE Performance Specifications and Guidance Documents are recommendations only; EUROCAE is not an official body of the European Governments. Its recommendations therefore are not valid as statements of official policy unless adopted by a particular government or conference of governments.
7. Copies of this document may be obtained from:

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NOTE: *Whenever a reference document appears in this report, it carries the minimum revision level of the reference document acceptable to meet the intended requirements. Later versions of the reference document are also acceptable but earlier versions are not acceptable. In all cases, other documents shown to be equivalent to the referenced document are also acceptable.*

1. PURPOSE

This report provides information and guidance concerning a means, but not the only means, of compliance with Parts 23, 25, 27, and 29 of the Federal Aviation Regulations (FAR) and Joint Airworthiness Requirements (JAR), as applicable for preventing hazards, due to lightning indirect effects, from occurring to electrical/electronic systems.

2. SCOPE

This report provides guidance for a means of showing compliance with the regulations for hazards caused by the lightning environment to electrical/electronic systems installed either on or within aircraft. Equipment hazards addressed include those due to indirect effects on equipment and its associated wiring that is mounted on the aircraft exterior as well as indirect effects on equipment and its associated wiring located within the aircraft interior. This document applies to new aircraft and equipment designs, modifications of existing aircraft or equipment, and applications of existing (off the shelf) equipment on new aircraft.

NOTE: *This report does not address direct effects such as burning, eroding, blasting, of aircraft structure nor does it address fuel ignition hazards (see related reading material in Section 4 of this document). This report does not address lightning zoning methods or lightning test requirements, methods, and techniques. Coverings (fairing, skin, cowl, etc.) should normally prevent direct attachment of the lightning channel to underlying system components. However, if a direct lightning strike attachment to a system component can occur, a complete evaluation of both direct and indirect effects will be necessary.*

It should be noted that electrical/electronic systems or components are sometimes exposed to lightning currents directly conducted from the aircraft exterior, as may happen when an antenna is struck and a portion of lightning current flows in its cable. Care should be taken to identify any such possibilities and either eliminate these situations by design modifications, or address them in the certification plan. No further discussion of these situations is included in this report.

3. RELATED FAR and JAR INFORMATION

A comprehensive discussion on the material in this report, with additional guidance information, is available in the following documents:

- a. Federal Aviation Regulations (FAR). Federal Aviation Regulations 14 CFR Parts 23, 25, 27, 29 and 33; Sections . 901, .903, .1301, .1309, .1316, .1431, and .1529 (as applicable). 14 CFR Part 33, Sections .28 and .91 (as applicable)
- b. FAA Advisor Circulars. The following Advisory Circulars (AC) may provide additional information.
 - (1) AC23.1309-1C, System and Equipment Installations in Part 23 Airplanes, dated March 12, 1999.
 - (2) AC 25.1309-1A, System Design and Analysis, dated June 21, 1988.
 - (3) AC 27-1A, Certification of Normal Category Rotorcraft, dated August 8, 1985, including to Change 4 dated August 18, 1995.
 - (4) AC 29-2A, Certification of Transport Category Rotorcraft, dated September 16, 1987, including to Change 3 dated February 14, 1995.
 - (5) AC 21-16C, Radio Technical Commission for Aeronautics Document DO-160C, dated February 14, 1990.
- c. Joint Airworthiness Requirements (JAR). Joint Airworthiness Requirements Parts 23.1309, 25X899, 25.1431, 27.610, 27.1309, 29.610, 29.1431, JAR E AMJ 20X-1.
- d. JAA Advisory and Interpretive Material.
 - (1) ACJ 25X899, Electrical Bonding and Protection Against Lightning and Static Electricity (Interpretive Material and Acceptable Means of Compliance).
 - (2) ACJ 29.610, Lightning and Static Electricity Protection (Interpretive Material and Acceptable Means of Compliance).
 - (3) AMJ 20X-1, Certification of Aircraft Propulsion Systems Equipped with Electronic Controls.
 - (4) AMJ 25.1309, System Design and Analysis.
 - (5) AMJ 29.1309, Equipment System Installation.

4. RELATED READING MATERIAL

A comprehensive discussion on the material in this report, with additional guidance information, is available in the following documents:

a. EUROCAE Documents.

These documents are available from EUROCAE, 17 rue Hamelin , 75783 Paris Cedex 16, France.

EUROCAE ED-14D, Environmental Conditions and Test Procedures for Airborne Equipment, dated July 1997.

b. EUROCAE/SAE Joint Documents.

(1) User's Manual for ED-81/ARP-5413 (in development).

(2) Aircraft External Lightning Environment and test Waveform ED-84 (ARP-5412).

(3) Aircraft Lightning Zoning ED-91 (ARP-5414).

(4) Aircraft Lightning Testing Methods (in development).

(5) EUROCAE ED-79/SAE ARP-4754, Certification Considerations for highly Integrated or Complex Aircraft Systems.

Fault/Failure analysis Procedure.

SAE Documents are available from Society of Automotive Engineers Inc, 400 Commonwealth Drive, Warrendale PA 15096, USA.

5 BACKGROUND

- a. Aircraft electrical/electronic systems may be vulnerable to lightning hazards. Aircraft which utilize an increasing number of electrical/electronic systems are currently being and will continue to be certified.
- b. Lightning indirect effects may result when the electromagnetic fields produced by a direct strike to the aircraft induce voltage and current transients into the electrical/electronic equipment or components. These transients can be produced by electromagnetic field penetration into the aircraft interior or by structural IR (current times resistance) voltage rises due to current flow on the aircraft. Physical damage (direct effects) can also result from a direct lightning attachment to the aircraft.
- c. The trend toward increased reliance on electrical/electronic systems for flight and engine control functions, navigation, and instrumentation requires that effective protection against lightning induced transients be designed and incorporated into these systems. Reliance upon redundancy as a sole means of protection against lightning indirect effects is generally not adequate because the electromagnetic fields and structural IR voltages can interact concurrently with all electrical wiring aboard an aircraft.

6 DEFINITIONS AND ABBREVIATIONS

See Appendix 1 for Glossary of Terms, and Appendix 2 for Abbreviations.

7. APPROACHES TO COMPLIANCE

The following seven (7) activities are elements of an iterative process for certification of aircraft electrical/electronic systems with respect to the indirect effects of lightning. The particular order of activities addressed, and the iterative application of the elements appropriate for a particular situation, are left to the applicant and strict adherence to the particular ordering of the elements in the list is not intended.

Review the safety analysis with respect to the indirect effects of lightning on the aircraft.

Determine the lightning strike zones for the aircraft.

Establish the airframe lightning current paths for the zones.

Establish the effects of the internal environment.

Establish Transient Control Levels (TCL) and Equipment Transient Design Levels (ETDL).

Verify Compliance.

Corrective Measures.

The elements are described in more detail in paragraphs (a) through (g).

a. Review the safety analysis with respect to the indirect effects of lightning

A Functional Hazard Assessment (FHA) is conducted to identify all failures and classify them in functional and operational terms. The results of the FHA should be reviewed to ensure that any unique indirect effects of lightning have been identified, such as common mode failures. Airworthiness requirements for classifying these functions are based on Section .1309 of FAR/JAR Parts 23, 25, 27, and 29. FAA advisory circulars which provide guidance in classifying these failure conditions according to their severity are as follows: AC 23.1309-1C, 25.1309-1A, 27-1A and 29-2B, AMJ 1309, ACJ 29 1301.

The failure condition classifications listed below are derived from this guidance material and are included to assist in the use of this document. The classifications are:

- (1) Catastrophic: Failure conditions which would prevent continued safe flight and landing
- (2) Hazardous/Severe-Major: Failure conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be:
 - (i) A large reduction in safety margins or functional capabilities.
 - (ii) Physical distress or higher workload such that the flight crew could not be relied on to perform their tasks accurately or completely, or
 - (iii) Serious (or fatal*) injury to a relatively small number of the occupants.

* JAA only
- (3) Major: Failure conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety

that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew work load or in conditions impairing crew efficiency, or discomfort to occupants, possibly including injuries.

- (4) Minor: Failure conditions which would not significantly reduce aircraft safety, and which involve crew actions that are well within their capabilities. Minor failure conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some inconvenience to occupants.
- (5) No Effects: Failure conditions which do not affect the operational capability of the aircraft or increase crew workload.

The system development assurance level would also be assessed when performing the FHA and would be approved by the cognizant aviation certification authority. Guidance for selecting the system development assurance level is provided in draft SAE ARP 4754/EUROCAE ED-79.

The following development assurance levels are related to the failure condition classifications.

Level A: Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a catastrophic failure condition for the aircraft.

Level B: Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a hazardous/severe-major failure condition for the aircraft.

Level C: Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a major failure condition for the aircraft.

Level D: Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a minor failure condition for the aircraft. Once a system has been confirmed, by the cognizant aviation certification authority, as being Level D, no further application of this regulation is required.

Level E: Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in no effect on aircraft operational capability or crew workload. Once a system has been confirmed, by the cognizant aviation certification authority, as being Level E, no further application of this regulation is required.

b. Determine the lightning strike zones for the aircraft

The characteristics of currents entering the aircraft vary according to attachment point locations on the aircraft. To establish the lightning characteristics appropriate for different portions of the aircraft, lightning strike zones have been defined in the **Aircraft Lightning Zoning Standard**.

Zones are the means by which the external environment is applied to the aircraft. **The locations of these zones on any aircraft are dependent on the aircraft's geometry, materials, and operational factors, and often vary from one**

aircraft type to another; therefore, a determination must be made for each aircraft configuration. Guidance for location of the strike zones on particular aircraft is given in the **Aircraft Lightning Zoning Standard**.

c. Establish the airframe lightning current paths for the zones

The external lightning environment is a consequence of the interaction of the lightning flash with the exterior of the aircraft. The external environment is represented by the lightning current components at the aircraft surface as defined by the synthesized waveforms in the **Aircraft External Lightning Environment and Test Waveform Standard**. Application of the various current waveforms with respect to the zones is described in the **Aircraft Lightning Zoning Standard**.

Zones 1 and 2 define where lightning is likely to attach, and, as a result, the entrance and exit points for current flow through the vehicle. By definition, Zone 3 areas carry lightning current flow between pairs of direct or swept stroke lightning attachment points. Therefore, design and analysis using Zone 3 current levels as the external environment is generally acceptable.

d. Establish the effects of the internal environment

The internal lightning environment consists of the electromagnetic fields and structural IR voltages, which are produced by the external environment, as a result of current flow through the airframe and the penetration of electromagnetic fields. The fields and structural IR voltages cause voltages and currents on interconnecting wiring which in turn appear at equipment interfaces. In some cases, electromagnetic fields within the aircraft may penetrate equipment enclosures and compromise system operation.

For each system to be qualified, determine the lightning induced voltage and current waveforms and actual transient levels (ATL) that can appear at the electrical/electronic equipment interfaces. In many cases, the induced transients will be defined in terms of the open circuit voltage (voc) and the short circuit current (isc) appearing at wiring/equipment interfaces. The "v" and "i" will be related by the source impedances (i.e., loop impedance) of interconnecting wiring, and there may be different levels determined for different circuit functions or operating voltages.

e. Establish Transient Control Levels (TCL) And Equipment Transient Design Levels (ETDL)

The ETDLs represent the amplitude of voltage and/or current that the equipment is required to withstand or tolerate and remain operational (e.g., no damage or system functional upset). The TCLs, in turn, are set equal to or higher than the maximum ATL. The difference between ETDL and TCL is the margin. The equipment transient susceptibility level (ETSL) is the amplitude of voltage or current which, when applied to the equipment, will result in damage to components, or upset such that the equipment can no longer perform its intended function. The relationship between ATLs, TCLs, ETDLs, and ETSLs is illustrated in Figure 1. The ETDL is usually stated in the specifications for electrical/electronic equipment and constitutes a qualification test level for this equipment. Since ETDLs are typically represented by these standardized requirements, their use greatly simplifies compliance evaluation. Normally, the TCLs and ETDLs will be established by the airframe manufacturer or system