SAEAerospace	AEROSPACE RECOMMENDED PRACTICE	SAE , ARP5416		REV. A
		Issued Revised	2005-03 2013-01	
	Aircraft Lightning Test Methods	Superseult)

RATIONALE

With the original release of the document, many new test methods were provided to account for aircraft operational experience and changing aircraft technology, including more reliance on electronic data and control systems and increasing use of composite materials in aircraft structures. As experience is gained with these test methods, some changes and clarifications are needed to ensure consistency across test organizations, particularly regarding high voltage tests and integrated system functional upset tests. Also, ignition source detection methods have historically relied upon the use of Polaroid film as the standard. Since this film's source of supply is rapidly disappearing, photographic methods using modern camera technologies needs to be included in the recommended practice.

FOREWORD

This SAE Aerospace Recommended Practice (ARP) has its origins in the SAE AE-4L Committee's "Blue" book issued in 1978 and titled "Lightning Test Waveforms and Techniques for Aerospace Vehicles and Hardware." Subsequent to the issuance of the "Blue" book, the SAE AE-4L developed MIL-STD-1757 for the United States military dated 1981 and titled "Lightning Qualification Techniques for Aerospace Vehicles and Hardware." In MIL-STD-1757, the committee placed the test methodology contained in the "Blue" book into a more formalized format. This ARP is a significant refinement and expansion of the basic material from these sources, providing a more thorough and updated description of the test techniques.

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1. SCOPE

This document is one of a set covering the whole spectrum of aircraft interaction with lightning. This document is intended to describe how to conduct lightning direct effects tests and indirect system upset effects tests. Indirect effects upset and damage tolerance tests for individual equipment items are addressed in DO-160/ED-14. Documents relating to other aspects of the certification process, including definition of the lightning environment, zoning, and indirect effects certification are listed in Section 2.

This document presents test techniques for simulated lightning testing of aircraft and the associated systems. This document does not include design criteria nor does it specify which items should or should not be tested. Acceptable levels of damage and/or pass/fail criteria for the qualification tests must be approved by the cognizant certification authority for each particular case. When lightning tests are a part of a certification plan, the test methods described herein are an acceptable means, but not the only means, of meeting the test requirements of the certification plan.

Each test method is set out in a uniform format, describing the test purpose, test object, test setup, test waveforms (voltage and/or current), measurements and data recording, test procedure and data interpretation. Guidance is provided on how to select the appropriate test or series of tests, and how the test results can be assessed.

Natural lightning is a complex and variable phenomenon and its interaction with different types of vehicles may be manifested in many different ways. It is not intended that every test described herein be applied to every system requiring lightning verification tests. The document is written so that specific aspects of the environment can be called out for each specific program as dictated by the vehicle design, performance and mission constraints.

2. REFERENCES

2.1 Applicable Documents

The documents below provide various sources of information relevant to aircraft lightning testing including descriptions of the external lightning environment applicable to aircraft, methods of determining lightning zoning of aircraft, regulatory requirements, and guidance on certifying aircraft by analysis and test.

NOTE: Whenever a reference document appears in this Recommended Practice, 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.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), <u>www.sae.org</u>.

- ARP4754 Guidelines for Development of Civil Aircraft and Systems
- ARP5412 Aircraft Lightning Environment and Related Test Waveforms
- ARP5414 Aircraft Lightning Zone
- ARP5415 User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
- Report AE4L-76-1 "Lightning Test Waveforms and Techniques for Aerospace Vehicles and Hardware", (Blue Book), dated June 20, 1978
- Report AE4L-81-2 "Test Waveforms and Techniques for Assessing the Effects of Lightning Induced Transients", (Yellow Book), dated December 15, 1981

2.1.2 Federal Aviation Regulations (FAR)

Available from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, <u>www.faa.gov</u>.

US Code of Federal Regulations 14 CFR Parts 21, 23, 25, 27 & 29; Sections x.581, .610, .867, .899, .901, .903, .954, .1301, .1309, .1316, .1431 and .1529 (as applicable)

2.1.3 FAA Advisory Circulars (AC)

Available from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, <u>www.faa.gov</u>.

- AC 20-53A "Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Due to Lightning", dated April 12, 1985, Rev B issued June 5, 2006. Contains zoning definitions and procedures that are used for direct effects protection and is used as a guide to describe zoning as it applies to indirect effects.
- AC 20-136 "Protection of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning", dated March 5, 1990, Rev B issued September, 7, 2011
- AC 21-16D RTCA Document DO-160D, dated July 21, 1998, Rev G issued June 22, 2011
- AC 23.1309-1C "Equipment, Systems, and Installations", dated March 12, 1999, Rev 1E issued November 17, 2011
- AC 25.1309-1A "System Design Analysis", dated June 21, 1988
- AC 27-1B "Certification of Normal Category Rotorcraft", dated September 30, 1999, Change 3 issued September 30, 2008
- AC 29-2C "Certification of Transport Category Rotorcraft", dated September 30, 1999, Change 3 issued September 30, 2008
- 2.1.4 RTCA, Inc. Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA/DO-160D "Environmental Conditions and Test Procedures for Airborne Equipment", dated July 29, 1997, including Change No. 1, dated December, 2000, Change No. 2, dated June, 2001 and Change No. 3, dated December, 2002, Rev G issued December 8, 2010

2.1.5 EASA Publications

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany, Tel: +49-221-8999-000, <u>www.easa.eu.int</u>.

CS Parts 21, 23, 25, 27 & 29; Sections x.581, .610, .867, .899, .901, .903, .954, .1301, .1309, .1316, .1431 and .1529 (Parts and Sections as applicable)

2.1.6 EUROCAE Publications

Available from EUROCAE, 102, rue Etienne Dolet, 92240 Malakoff, France, Tel: +33.1.40.92.79.30, www.eurocae.net.

- EUROCAE ED-14D "Environmental Conditions and Test Procedures for Airborne Equipment", dated July, 1997, including Change No. 1, dated December, 2000, and Change No. 2, dated June, 2001 and Change No. 3, dated December, 2002, Rev G issued May, 2011
- EUROCAE ED-79 "Certification Considerations for Highly Integrated or Complex Aircraft Systems", dated April, 1997, Rev A issued December, 2010
- EUROCAE ED-81 "Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning", dated May, 1996, including Amendment No. 1, dated August 26, 1999
- EUROCAE ED-84 "Aircraft Lightning Environment and Related Test Waveforms Standard", dated August, 1997, including Amendment No. 1, dated October 19, 1999, including Amendment No. 2, dated May, 2001, including Amendment No. 3, dated June, 2006
- EUROCAE ED-91 "Aircraft Lightning Zoning Standard", dated July, 1998, including Amendment No. 1, dated September 6, 1999, including Amendment No. 2, dated June, 2006
- 2.1.7 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, <u>www.ansi.org</u>.

ANSI Z540.1 "General Requirements for Calibration Laboratories and Measuring and Test Equipment", dated 1994

2.1.8 IEC Publications

Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112.

IEC 60060-2 "High-Voltage Test Techniques - Part 2: Measuring Systems", dated November, 1994

- 2.2 Definitions, Abbreviations, and Acronyms
- 2.2.1 Definitions

ACTION INTEGRAL: The integral of the square of the time varying current over its time of duration. It is usually expressed in units of ampere squared seconds (A²s).

ACTUAL TRANSIENT LEVEL (ATL): The level of transient voltage and/or current that appears at the equipment interfaces as a result of the external environment. This level may be less than or equal to the transient control level but should not be greater.

APERTURE: An electromagnetically transparent opening.

ARC ROOT: The location on the surface of a conducting body at which the lightning channel is attached while high current flows.

ATTACHMENT POINT: A point of contact of the lightning flash with the aircraft.

CABLE (WIRE) BUNDLE: A group of wires and/or cables bound or routed together that connect two pieces of equipment.

CORONA: A luminous discharge that occurs as a result of an electrical potential difference between the aircraft and the surrounding atmosphere.

DIRECT EFFECTS: Any physical effects to the aircraft and or equipment due to the direct attachment of the lightning channel and/or conduction of lightning current. This includes dielectric puncture, blasting, bending, melting, burning and vaporization of aircraft or equipment surfaces and structures. It also includes directly injected voltages and current in associated wiring, plumbing, and other conductive components. Direct effects also include shock and flash blindness to personnel.

DISCHARGE: Relative to High Voltage (HV) or High Current (HC) impulse generators, the transfer of charge from the storage capacitors. This action may or may not cause an electrical breakdown of the gap between the electrodes connected to the output terminals of the generator.

EQUIPMENT INTERFACE: A location on an equipment boundary where connection is made to the other components of the system of which it is part. It may be an individual wire connection to an electrical item, or wire bundles that interconnect equipment.

EQUIPMENT TRANSIENT DESIGN LEVEL (ETDL): The peak amplitude of transients to which the equipment is qualified.

EXTERNAL ENVIRONMENT: Characterization of the natural lightning environment for design and certification purposes as defined in ARP5412/ED-84.

FACILITY GROUND: Reference ground plane (electrical) for the experiment or test configuration.

FLASHOVER: The condition when the arc produced by a gap breakdown passes over or close to a dielectric surface without puncture.

GAP BREAKDOWN: The electrical breakdown of the gap between the electrodes connected to the generator output terminals. This breakdown is caused by the discharge of the capacitors of an HV or HC impulse generator.

GENERATOR: A set of equipment (waveform synthesizer amplifiers, couplers, etc.) that delivers a voltage or current waveform, via direct or indirect coupling to the equipment under test (EUT).

HOT SPOT: A surface in contact with fuel/air mixtures that is heated by the conduction of lightning currents to a temperature which will ignite the mixtures.

INDIRECT EFFECTS: Electrical transients induced by lightning in aircraft electric circuits.

INTERNAL ENVIRONMENT: The fields and structural IR potentials inside the aircraft produced by the external environment.

LIGHTNING FLASH: The total lightning event. It may occur within a cloud, between two clouds, or between cloud and ground. It can consist of one or more return strokes, plus intermediate or continuing currents.

LIGHTNING HIGH VOLTAGE WAVEFORMS (A, B, C, AND D): Different standardized high voltage waveforms. For details refer ARP5412/ED-84.

LIGHTNING STRIKE: Any attachment of the lightning flash to the aircraft.

LIGHTNING STRIKE ZONES: Aircraft surface areas and structures classified according to the possibility of lightning attachment, dwell time and current conduction. See ARP5414/ED-91 for reference.

LIGHTNING STROKE (RETURN STROKE): A lightning current surge that occurs when the lightning leader makes contact with the ground or another charge center.

LOCAL GROUND: Any ground strap or conductor that is connected to the equipment and the same part of airframe structure in which that equipment is installed. The ground strap or conductor would, therefore, be bonded to the same ground plane that the equipment is mounted to and, during a lightning strike, would be at the same potential as the equipment.

MULTIPLE BURST: A randomly spaced series of bursts of short duration, low amplitude current pulses, with each pulse characterized by rapidly changing currents (i.e., high dl/dt). These bursts may result from lightning leader progression or branching, and are associated with the cloud-to-cloud and intra-cloud flashes. The multiple bursts appear to be most intense at the time of initial leader attachment to the aircraft.

MULTIPLE STROKE: Two or more lightning return strokes occurring during a single lightning flash.

PUNCTURE: Localized irreversible breakdown of insulation properties of a solid dielectric material.

SHIELD: A conductor that is grounded to an equipment case or aircraft structure at both ends and is routed in parallel with and bound within a wire bundle. It usually is a wire braid around some of the wires or cables in the wire bundle or may be a metallic conduit, channel or wire grounded at both ends within the wire bundle. The effect of the shield is to provide a low resistance path between equipment so connected.

SHIELDED CABLE (WIRE) BUNDLE: A wire bundle that contains one or more shields. Such wire bundles may include SOME unshielded wires.

STREAMER: Branch-like ionized paths that occur in the presence of a direct stroke or under conditions when lightning strokes are imminent.

STRUCTURAL IR VOLTAGE: The portion of the induced voltage resulting from the product of the distributed lightning current (I) and the resistance (R) of the aircraft skin or structure.

SYSTEM: A combination of two or more parts or equipment, generally physically separated when in operation, and such other units, assemblies, and basic parts necessary to perform an operational function or functions.

SYSTEM FUNCTIONAL UPSET: An impairment of system operation, either permanent or momentary (e.g., a change of digital or analog state) which may or may not require manual reset.

THERMAL SPARKS: Burning particles emitted by rapid melting and vaporization of conductive materials carrying current through a point contact.

TRANSIENT CONTROL LEVEL (TCL): The maximum allowable level of transients appearing at the equipment interfaces as a result of the defined external environment.

UNSHIELDED CABLE (WIRE) BUNDLE: A wire bundle that contains no shields.

UPSET: (See System Functional Upset).

 V_{OC} AND I_{SC} : Open circuit voltage and short circuit current from a test generator for a particular primary excitation of the generator. The ratio (V_{OC}/I_{SC}) of the two quantities denotes the source impedance (see ARP5415 for reference).

VOLTAGE AND CURRENT TEST/LIMIT LEVELS (V_T , I_T , V_L AND I_L): Voltage and current excitation thresholds for generators used for testing of systems and equipment. For details, refer to ARP5412/ED-84, ARP5415, and DO-160/ED-14.

VOLTAGE SPARK: An electrical breakdown of a gaseous dielectric between two separated conductors.

ZONING (1A, 1B, 1C, 2A, 2B, AND 3): The process (or end result of the process) of determining the location on an aircraft to which the components of the external environment are applied. For details, refer to ARP5414/ED-91.

2.2.2 Abbreviations

А	amperes
AC	alternating current
С	CAPACITANCE
cm	centimeters
d or D	distance or diameter
dB	decibel
DC	direct current
f or F	frequency
ft	feet
GΩ	gigaohms
Hg	mercury
Ηž	hertz
i or l	current
Κ	constant
kA	kiloamperes
kHz	kilohertz
kV	kilovolts
L	inductance
m	meter
mA	milliamperes
MHz	megahertz
υH	microhenries
u.J	microioules
us	microseconds
mm	millimeters
mmHa	millimeters of mercury
MO	megohms
nH	nanohenries
n	pressure
P	power
pF	picofarad
p: ps	picoseconds
0	ohms
0	resonance characteristics
R	resistance
s	seconds
v	voltage or volts
Ŵ	watts
7	impedance
-	inipoddiloo
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AC	Advisory Circular
ANSI	American National Standards Institute
AOA	Angle-Of-Attack
ARP	Aerospace Recommended Practice
ATI	Actual Transient Level
CEC	Carbon Fiber Composite
CER	Code of Federal Regulations
CERP	Carbon Fiber Reinforced Plastic
CN	Coupling Network
CS	Certification Specification
CW/	Continuous Wave
FFD	Electro-Explosive Device
	European Aviation Safety Agency