SAE Aerospace
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AEROSPACE STANDARD

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Superseding AS4914B

(R) Aircraft Fluorescent Lighting Ballast/Fixture Safety Standard

RATIONALE

This document has been revised to provide better guidance in designing failsafe light assemblies. It has also improved defining test requirements along with incorporating lessons learned from industry. Lastly, it has been updated to provide additional testing guidelines.

1. SCOPE

The purpose of this standard is to recommend minimum performance requirements to assist the specification writer in establishing a failsafe airplane interior Fluorescent light assembly design. This standard relates to the design of lamp ballasts, lampholders, fixtures, and installation of the same.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 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), www.sae.org.

ARP4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D495-48T Standard Test Method for High-Voltage, Low-Current Dry Arc Resistance of Electrical Insulation

2.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes, Code of Federal Regulations

AC 25-10 FAA Advisory Circular, Guidance for Installation of Miscellaneous, Non-Required Electrical Equipment

AC 25.1309-1A FAA Advisory Circular, System, Design and Analysis

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2.4 NEMA Publications

Available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Roslyn, VA 22209, Tel: 703-841-3200, www.nema.org.

NEMA_MW-1000 Magnetic Wire Standards

2.5 RTCA Publications

Available from Radio Technical Commission for Aeronautics Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

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

2.6 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-9495, https://assist.daps.dla.mil/quicksearch/.

MIL-HDBK-454 Department of Defense Handbook, General Guidelines for Electronic Equipment.

MIL-HDBK-1547 Department of Defense Handbook, Electronic Parts, Materials, and Processes for Space Vehicles

MIL-STD-889 Military Standards - Dissimilar Metals

MIL-PRF-27 Military Specifications for Transformers and inductors (Audio, Power and High Power Pulse), General Specification for

NAVSO P-3641 More Power for the Dollar (This document is available at the following website http://www.bmpcoe.org/library/books/navso%20p-3641a/index.html)

3. GENERAL DESIGN REQUIREMENTS

Equipment supplied under the requirements of this document shall be designed to the following standards and provide the proper performance operation under the environmental performance levels specified. Requirements include applicable Part 25 Federal Aviation Regulations (FARs). Also as a guide, Advisory Circulars AC 25-10 and AC 25.1309-1A can be used.

The design/construction of all equipment shall incorporate features which allow the equipment to be operated safely. Testing shall be conducted to verify the applicable design standards defined in this document.

3.1 Materials and Finishes

Materials and finishes used in the construction of the ballast/fixture shall be capable of withstanding the airplane environments as specified by RTCA/DO-160 (see Section 4) such as Temperature and Altitude, Temperature Variation, Humidity, Operational and Crash Safety Shocks, Vibration, Fungus Resistance, Sand and Dust, Power Input, Voltage Spike, Audio Frequency Conducted Susceptibility, Induced Signal Susceptibility, Radio Frequency Susceptibility, Radiated and Conducted Emission of Radio Frequency Energy, and Electrostatic Discharge.

a. Metals: All metals shall be of the corrosion resistant type unless suitably protected to resist corrosion during normal service life. Guidance regarding metals in contact with each other shall be selected and protected as defined in MIL-STD-889.

b. Nonmetallic Materials: Materials which are nutrients for fungi shall not be used.

c. Flammable Materials: All nonmetallic/metallic composite materials shall meet Part 25.853 requirements.

d. Electrical wire shall meet the applicable sections of Part 25.869(a)(4), 25.1703 thru 25.1721 and 25.1729 for Electronic Wiring Interconnection Systems (EWIS).

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3.2 Lampholders

a. The arc resistance time of lampholder insulating materials shall exceed 125 s, when tested per the Arc Resistance Test, ASTM designation D495-48T, Standard Test Method for High-Voltage Low Current Arc Resistance of Electrical Insulation.

b. The lampholders shall be capable of retaining the fluorescent lamp and permit satisfactory lamp operation throughout the specified airplane environment.

c. Gold plated lamp contacts are recommended.

d. Moisture resistant lampholders shall be specified or the fixture design shall provide protection for the lampholder from condensation and moisture accumulation. In- service history has shown that either moisture or condensation dripping onto lampholders may result in an arcing condition during flight which impacts crew workload, operation and could possibly even result in an air turn-back.

e. Lampholders should mechanically lock or have a means to secure the lamp and lamp contacts into position. The goal is to prevent misinstallation of the fluorescent lamp which could result in an arcing condition that may damage the light assembly.

f. Electrical contact Electrical contact resistance between the lamp contacts and lampholder contacts (pin or sockets) should be minimized through maximizing surface area and providing appropriate pressure. Lampholders that only depend on spring pressure tend to arc under intermittent contact during vibration. Contacts should engage at least three quarters of the diameter of the lamp contact.

g. The ballast shall not sustain damage if lamps are removed or installed with power applied.

h. It is recommended that the Fluorescent Lighting Ballast/fixture design include measures that will prevent the following known lampholder failure modes:

1. Lamp Mis-Installation -
   If the lamps are not fully seated and retained in the lamp holder, an intermittent connection can develop. The resulting electrical arc and associated heating can severely damage the lampholder.

2. Use of Broken Lampholders -
   As with a mis-installed lamp, unsecured lamp contacts can result in electrical arcing and lampholder damage.

3. Ground Fault -
   This fault occurs on lampholders where a (conductive) lampholder fastener is attached to the airframe and is relatively close to the lampholder contact. Over time, a conductive path develops between the contact and fastener across the lampholder body. Once initiated, the conductive path increases until a short circuit occurs.

4. End of Life lamps -
   As a fluorescent lamp ages, the cathode filaments deteriorate, ultimately failing as an open circuit. The lamp will continue to operate with the failed filament. However, the remaining elements will reach high temperatures. The heat is transferred to the lamp base which in turn damages the light assembly. A periodic check should be recommended by the manufacturer to detect discoloration and prevent light assembly damage. It is highly recommended that a ballast with the ability to detect fluorescent lamp failures be used in all aircraft interior light assemblies. This will help alleviate failures associated with the End of Life and mis-installation of fluorescent lamps.

5. Overheating Conditions -
   Discoloring marks and lampholder melting may occur as a result of a lamp reaching its end of life while the ballast attempts to illuminate the lamp.

   Light assembly damage may occur as a result of using a non compatible ballast.

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3.3 Ballast/Fixture

When operating in an ambient of 77 °F (25 °C), the exposed surface shall not exceed 160 °F (71 °C) under any conditions of normal, abnormal, overload operations or failure.

All materials used shall be self-extinguishing per Part 25.853. The ballast shall be designed in such a manner to be smoke and fume free when subjected to the conditions called out in RTCA DO-160 as specified in Paragraph 3.1.

Electrical wire shall meet Part 25.869 and applicable sections of 25.1703 thru 25.1721 and 25.1729 for Electronic Wiring Interconnection Systems (EWIS).

The ballast should be designed to have the capability of containing smoke, flame, and arcing when subjected to the test conditions called out in RTCA DO-160 as specified in Section 4 of this document. Ballasts (including those that allow some ventilation) shall:

a. be metallic to provide a barrier for flames to not propagate.

b. have protection features that will not allow hazardous quantities of toxics or smoke to be emitted (see 3.7 and 3.9).

c. have circuit boards that contain fire retardants per Part 25.853 so as not to propagate flame when circuitry has failed.

3.4 Schematic

A schematic shall be affixed to the equipment. The schematic shall clearly show the electrical connections such as input voltage, frequency, dimmer control and lamp load (type or power) and ground plane spacing dimension.

3.5 Ground Plane

If the ballast or integrated light fixture and ballast design approach requires a minimum ground plane spacing, either the airplane lamp installation or the integrated light fixture itself shall provide the proper ground plane spacing.

3.6 Connector/Contacts

Connectors with gold plated or Berryllium-Copper (BeCu) contacts are recommended for the power input and product-to-product electrical connections. If it is probable that an incorrect connection between various light assemblies or ballasts could cause a catastrophic failure, keyed connectors, mounting hole or foot print variations or other mechanical means shall be used to prevent incorrect connections.

Plastic shell connectors are preferable to metal shell connectors or terminal boards (open terminals).

Ballasts using open terminals are not preferred due to their lack of protection and their susceptibility for collecting dust. If open terminals are to be used, the terminals should be covered or sealed after making the connections.

The connector's moisture resistance level category shall be consistent with the lampholder, light fixture and ballast design and the environmental requirements listed in Section 4.

Arcing of contacts should not occur because of vibration.

3.7 Thermal Protection

The equipment shall be protected against overheating by thermal protective devices. The rated trip temperature of these thermal protective devices must be lower than that of the rated temperature of the material that is being protected. It is recommended that verification tests be conducted to ensure the effectiveness of these thermal protective devices when tested in their actual product locations. See Section 4.1.1.

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3.8 Electrical Grounding and Bonding

The equipment shall provide a grounding system capability that is compatible with the grounding within the aircraft and all other equipment which is used with or which interfaces with the equipment.

3.9 Electrical Protection

The input power circuit of the electrical equipment shall contain a fuse or circuit breaker with a current rating of at least 50% over the product's maximum input current under worst case voltage and environment conditions. See Section 4. The fuse part number shall be marked adjacent to the fuse on external replaceable fuses. External replaceable fuses are optional. Where possible, output short circuit protection is desirable to prevent smoke or fire.

It is recommended that ballast designs contain circuitry that provides overvoltage protection and detects electrical arcing, ground faults, open filaments, and lamp open circuits to prevent overheating and improve safety.

3.10 Standard Parts

Guidance on the selection of electrical/electronic components can be found in MIL-HDBK-454. Particular consideration shall be given to the part's environmental limits, electrical characteristics and limits, power ratings, and materials used. All parts shall be suitably derated to ensure safety. Recommended derating guidelines can be found in NAVSO P-3641 or in MIL-HDBK-1547.

Note that the use of high voltage capacitors and inductors/transformers in the ballast, when they fail short, can cause catastrophic failure to the ballast. Circuit designs should therefore have provisions to mitigate such potential failures. Additionally, there shall be sufficient safety margins regarding temperature and voltage ratings.

For capacitors, the temperature rating shall be greater than the ambient temperature adjacent to the capacitor when the ballast is operated at a temperature of 71 °C ambient. Oil filled or oil-bath type capacitors should not be used in aircraft ballast designs.

For inductors and transformers, the devices should meet the requirements of MIL-PRF-27, Class V, where possible. Magnet wire used in these devices should conform to the requirements of NEMA MW-1000, class MW-35C (heavy) [supersedes J-W-1177/14 and MIL-W-583 Class 200 Type K2].

3.11 Starting

The use of long lamps requires the need for high starting voltages from the ballast. For this reason, the ballast should be located close to the lamps to minimize high voltage exposure.

The instant starting of cold cathode starting systems should be avoided. Rapid Start and Pre-Heat lamps shall be used whenever possible.

3.12 Flickering

Lamps that flicker or are erratic, when powered by magnetic ballasts should require prompt maintenance.

Flickering light may be the result of:

a. A Loose wire in the light assembly installation.

b. Mis-installation of the fluorescent lamp in conjunction with airplane vibration.

c. Flourescent lamps reaching the end of their life.

d. Mismatch between a ballast's output and the required drive characteristics for a particular lamp.

A periodic check should be recommended by the manufacturer to inspect for discoloration on the lamp or lamp holders and provide specific detailed corrective action instructions for these conditions.

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3.13 Thermal Environment

A good ballast design must consider the application's expected thermal environment.

Heat dissipation presents more of a problem in electronic ballasts so the proper thermal management of this product is necessary. Where feasible, maximum heatsinking is required. Mounting on metal surfaces is preferred, and the proper bonding practices are necessary.

3.14 EMI: Electromagnetic Radiation

Any electric arc is a source of EMI. For the operation of any fluorescent lamp, there is an arc at either end of the lamp. These arcs are capable of causing serious interference with radio communication and navigation systems in the airplane.

Extreme care must be taken when designing lamp fixtures, ballasts and interconnecting wiring so that conducted or radiated EMI effects to the airplane's electrical system from the lighting systems are minimized.

4. TEST REQUIREMENTS

In this section, regarding photometric performance, the meaning of "no significant lighting degradation" or "no significant change(s)" means that the Aircraft Fluorescent Ballast/Fixture must operate properly (including no flickering) without suffering any significant visually detectable loss of intensity during and following the tests, as applicable. Note: these characteristics apply primarily to the ballast & lamp holder hardware and may exclude typical and expected lamp failures.

4.1 Operational Tests

The system shall perform within operational requirements during and after exposure to the following environmental tests.

4.1.1 Temperature and Temperature Variation Tests

The equipment shall be subjected to thermal testing per Temperature, Section 4, Category A2 and Thermal Variation, Section 5, Category C as defined in RTCA/DO-160, or as defined by the customer specification without suffering significant lighting degradation.

4.1.2 Altitude Test

The equipment shall be subjected to Altitude testing in accordance with RTCA/DO-160, Altitude, Section 4.0, Category A2 or as defined by the customer specification without suffering significant lighting degradation.

4.1.3 Vibration Test

The equipment shall be subjected to vibration testing in accordance with RTCA/DO-160, Paragraph 8.0, Category S or S2, Sine or Random. During the test, any signs of arcing, flame, smoke emission, intermittent contact (lamp flickering) shall constitute a failure of the test article. After testing inspect the lamp and lampholder contacts for signs of arcing or lampholder contact displacement and/or wear. Any signs of arcing, lamp or lampholder contact displacement shall constitute a failure of the fixture.

4.1.4 Operational Shock Test

The equipment shall be subjected to operational shock testing in accordance with RTCA/DO-160, Operational Shock, Section 7.0, paragraph 7.2, Category A, 6.0 g's. After testing inspect the lamp and lampholder contacts for signs of arcing and lampholder contact displacement. Any signs of arcing, flame, smoke emission, intermittent contact (lamp flickering) shall constitute a failure of the test article.

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4.1.5 Waterproofness Tests

The equipment shall be subjected to the Waterproofness test specified in RTCA/DO-160, Section 10, Category W under the following conditions:

a. The equipment shall be tested in the normal aircraft installation orientation with droplets falling from above.

b. A standing water requirement of 0.2 inches will be imposed (Note: while being subjected to falling water, the test article is placed into a container that is capable of containing 0.2" of water).

c. The test solution shall be a 5% Sodium Chloride solution.

d. The equipment shall be operated during the test.

e. Fuse opening or temporary shutdown shall not constitute failure or rejection of the test article.

f. Failure of the test article shall consist of a permanent malfunction (not including fuse opening), flame or smoke emission, arcing, or other signs of catastrophic failure and without significant lighting degradation.

4.1.6 Power Input and Voltage Spike Tests

The Test Article shall be tested to verify compliance with its Power Input and Voltage Spike performance requirements when supplied with power, having normal and abnormal operating characteristic as specified in Power Input Section 16, of RTCA/DO-160, for Category E equipment or as specified by the customer's specification without suffering significant lighting degradation. When electrical power with an abnormal steady state and transient characteristic is applied, the Test Article shall meet the following requirements:

a. Sustain no damage and remain safe.

b. Reliability and life shall not be affected.

c. Automatically recover full performance capability when power with normal characteristics is re-established.

d. The article shall not cause interference to other aircraft equipment or systems based upon compliance to Induced Signal Susceptibility, RF Susceptibility and Lightning Induced Transients test requirements (see later sections).

4.1.7 Electromagnetic Interference (EMI) (Emissions and Susceptibility) Tests

The location of the equipment in the aircraft and its wiring have a major impact on the significance of the product's EMI emissions and susceptibility performance. The system level EMI requirements should be considered when writing the equipment EMI specification. It is required that the ballast, fixture and lamp be tested to show that they meet the requirements of RTCA/DO-160 Sections 17 through 21 without suffering significant lighting degradation.

When tested to the methods of RTCA/DO-160 the following shall apply;

The ballast, lamp and fixture shall not be harmed when subjected to the following susceptibility requirements:

a. Voltage Spikes, Sections 17, for Category A equipment,

b. Audio Frequency Conducted Susceptibility, Section 18, category per customer's specification,

c. Induced Signal Susceptibility, Section 19, for Category A equipment or per customer's specification and,

d. Radio Frequency Susceptibility, Section 20, for Category T equipment. or per customer's specification

The ballast, lamp and fixture shall be designed to meet the Radiated Emissions requirements of Section 21, for Category B equipment.

NOTE: When the installation requires a discrete ballast located remotely from the light fixture assembly, the Radiated Emissions and Susceptibility tests shall be set up with a distance of 1 m between the ballast and light assembly.

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4.1.8 Electrostatic Discharge Tests

Electrostatic Discharge (ESD): The system shall be tested in accordance with the electrostatic Discharge requirements of DO-160, Section 25.0, without suffering permananet damage and without significant lighting degradation.

4.2 Non-operational Tests

4.2.1 Acceleration and Crash Safety

The equipment shall be subjected to crash safety testing in accordance with RTCA/DO-160, Crash Safety Shock, Section 7.0, paragraph 7.3 - except the force shall be 9.0 g's in each axis.

4.2.2 Humidity

The equipment shall operate normally and without suffering any significant lighting degradation after exposure to relative humidity up to 100% with temperature and altitude cycling between 20 to 130 °F (-6.7 to 54.5 °C) and -1000 to 20 000 ft mean sea level (MSL), including conditions where condensation occurs on the equipment as described in RTCA/DO-160, Humidity, Section 6, for Category B equipment – Severe Humidity Environment.

4.2.3 Sand and Dust

The equipment shall operate normally and without suffering any significant lighting degradation after exposure to Sand and Dust testing per RTCA/DO-160, Section 12.0, Category D.

4.2.4 Insulation Resistance Test

The insulation resistance between electrically isolated circuit elements and between those elements and the housing shall be measured at 500 V DC minimum (with lamps removed). The minimum insulation resistance shall be 100 Meg Ω. This test shall be performed prior to and following the dielectric withstanding voltage test.

4.2.5 Dielectric Withstanding Test

Apply a test voltage of 1500 V rms at 60 Hz for 1 minute between mutually insulated conductive paths. The test voltage shall be applied and removed at a uniform rate of 250 to 500 V/s. Any arcing as evidenced by flashover, sparkover, (or) breakdown, or leakage current exceeding 2 mA shall constitute a failure. Capacitors, diodes, and other electronic devices susceptible to damage may be disconnected from the equipment or short circuited for these tests.

4.2.6 Fungus Test

The equipment must be tested or an analysis performed in accordance with the Fungus Resistance test, Section 13.0 of DO-160. Following testing, the ballast, lamp and fixtures shall not be harmed such that their is no significant lighting degradation.

4.3 Flammability Test

All nonmetallic/metallic composite materials shall meet the requirements of Part 25.853. All electrical wire shall meet the requirements of FAR 25.869 and applicable sections of 25.1703 thru 25.1721 and 25.1729 for Electronic Wiring Interconnection Systems (EWIS).

4.4 Failsafe Verification Testing

Catastrophic failure is defined as a failure or malfunction that emits smoke, noxious gas, or causes a flame, arc, fire, explosion, damage to adjacent aircraft structure, components, equipment or system, or interfere with an essential or critical aircraft equipment or system(s).

The ballast and fixture shall be designed so that when a failure occurs due to any normal or abnormal conditions and/or operation, this failure shall not be catastrophic. Testing (at least under the following conditions and when the unit is powered) shall be performed to verify that the Ballast and fixture fail in fail/safe mode:

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