



AEROSPACE RECOMMENDED PRACTICE

ARP6621™

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Predicting Photometric Degradation of Exterior Aircraft Lights

RATIONALE

This document provides guidance in predicting light output degradation of exterior aircraft lighting so that designers can predict the usable life of aircraft lights and ensure that they meet specified performance levels throughout their lifetime.

ARP6621 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This Aerospace Recommended Practice provides guidance for designers and specifiers of aircraft exterior lighting. Typical causes of light degradation and methods of predicting performance degradation in the aircraft environment are given. Although the document considers only exterior lighting, many of the principles and methods discussed apply to interior or flight deck lighting as well.

1.1 Purpose

Although FAA requirements for exterior aircraft lighting, such as CFR 25.1389, state "The intensities prescribed in this section must be provided by new equipment with light covers and color filters in place," other standards and requirements can be interpreted to mean that required light intensities must be met throughout the expected service life of a light. For example, CFR 25.1309 states "The equipment, systems, and installations whose functioning is required by this subchapter, must be designed to ensure that they perform their intended functions under any foreseeable operating condition." The SAE Aerospace standards for position lights and anti-collision lights both define the operating lifetime of a light as "the duration for which the light is expected to meet the minimum intensity requirements." (Refer to AS8017 and AS8037.)

To ensure that an exterior aircraft light meets a specific photometric requirement throughout its operating lifetime, it is important to be aware of the causes of light output degradation and the extent of that degradation over time. One must also take into account the anticipated operating environment of the light. This document provides guidance to help lighting designers and specifiers to be aware of common causes of light degradation and recommended methods of preventing and predicting that degradation.

2. REFERENCES

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 the 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.

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2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AS8017 Minimum Performance Standard for Anticollision Light Systems

AS8037 Minimum Performance Standard for Aircraft Position Lights

2.2 FAA Publications

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

References are taken from Title 14, part 25 of the Code of Federal Regulations. Identical numbered paragraphs in parts 23, 27, and 29 also apply.

14 CFR 25.1301 Function and Installation

14 CFR 25.1309 Equipment, Systems, and Installations

14 CFR 25.1383 Landing Lights

14 CFR 25.1389 Position Light Distribution and Intensities

14 CFR 25.1397 Color Specifications

14 CFR 25.1401 Anticollision Light System

14 CFR 25.1403 Wing Icing Detection Lights

2.3 EASA Publications

Available from European Aviation Safety Agency, Ottoplatz, 1, D-50679 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

CS-25.1309 Equipment, Systems, and Installations

CS-25.1389 Position Light Distribution and Intensities

2.4 IES Publications

Available from Illuminating Engineering Society, 120 Wall Street, Floor 17, New York, NY 10005-4001, Tel: (212) 248-5000, www.ies.org.

ANSI/IES LM-80 Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays, and Modules

IES TM-21 Projecting Long-Term Lumen Maintenance of LED Light Sources

2.5 Lighting Research Center Publications

Available from Rensselaer Polytechnic Institute, Troy, NY 12180, Tel: (518) 687-7100, www.lrc.rpi.edu.

NLPIP Lighting Answers, Volume 7, Issue 3: "What is the life of LEDs?"

2.6 U. S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-DTL-7989	Covers, Light – Transmitting, for Aeronautical Lights, General Specification for
MIL-G-174	Glass, Optical
MIL-PRF-13830	Optical Components for Fire Control Instruments; General Specification Covering the Manufacture, Assembly, and Inspection of

3. UNDERSTANDING THE AIRCRAFT ENVIRONMENT

The aircraft environment has major effects on the life of exterior lights. Designers and specifiers should be aware that the aircraft environment will vary depending on the specific application involved. Three general categories will be listed here as examples.

3.1 Commercial Aircraft

Commercial aircraft are characterized by high usage and multiple cycles per day. The temperature of the lights will cycle from very low temperatures at high altitudes to high temperatures when the aircraft lands in hot environments. The lights will also be exposed to UV radiation and particles in the airstream for long periods of time. Vibration exposure will be nearly constant as the aircraft operates nearly continuously.

3.2 Business and General Aviation

Business and general aviation aircraft typically operate for far fewer hours than commercial aircraft. Although the lights still experience extremes of temperature, as well as exposure to UV and vibration, the number of cycles will normally be far lower. These aircraft may experience long periods of storage and may not receive maintenance as regularly.

3.3 Military

Military aircraft can endure conditions not frequently seen by other aircraft, such as use in carrier operations with high exposure to salt water. They may also experience harsh vibration and shock environments as well as high levels of dust, dirt, and debris.

4. CONSIDERING MANUFACTURING VARIATIONS AND TOLERANCES

There are many possible sources of variation during manufacturing which can create variability in a light's operational lifetime. Some examples to consider:

- Protective coatings are applied in many components of a light. Some examples include abrasion resistant coatings on lenses, corrosion resistant coatings on metals, and humidity/moisture resistant coatings on circuit board components. The impact of failure from these coatings can range from degraded thermal performance to light transmission. Application of these coatings can vary in thickness and uniformity from batch to batch, affecting lifetime and resistance.
- For LED applications, LEDs are binned by voltage, flux, and color. Degradation calculations should consider the range of performance the selected LED will provide. For example, data sheets from three high powered LEDs from three of the major LED manufacturers list flux bin sizes from 3 to 13% of the total flux.
- Incandescent and halogen light sources typically have flux tolerances of ± 20 to $\pm 25\%$ of the total flux.
- Electrical components such as sensors can vary in sensitivity from batch to batch, which can impact performance or functionality of end of life detection.
- Thermal interface materials can degrade at an accelerated rate if applied incorrectly, causing degraded thermal performance and reduced light output and lifetime.

5. CAUSES OF LIGHT PERFORMANCE DEGRADATION

Lights and light sources degrade in a number of ways as they age. The luminous flux or brightness of the light will decrease, the color of the light may change, and the angular distribution of light intensity and/or color may change. There are a large number of possible causes of light degradation. The following list covers some of the most common causes, but is not comprehensive.

5.1 Contamination or Dirt

While dirt or other contamination of the lens will certainly cause a degradation in the light output of a light, contaminants can be cleaned off. This document will only consider causes of degradation that permanently impact light performance.

5.2 Lens Degradation

5.2.1 Lens Yellowing (For Lenses Made of Polycarbonate or Other Plastics)

Lenses or covers made of plastic may darken or turn yellow due to exposure to high temperatures or ultraviolet light. UV protective additives and coatings are available that can reduce this effect. A lens which has yellowed can impact both the light intensity and the color of the light passing through it.

5.2.2 Lens Erosion

Aircraft cover lenses degrade with typical use, which affects their performance. The effect of this degradation on optical performance is reduced light transmission and light scattered in unwanted directions. The amount of light loss will vary according to the material used and its level of exposure to various environmental factors. The effect of degradation on mechanical performance is a reduction in the physical integrity of the cover lens. Surface degradation is allowable so long as testing (or other acceptable methods) demonstrates that the lens still performs in a manner that maintains regulatory compliance.

Degradation in aircraft cover lenses is due to environmental factors which include, but are not limited to, the following:

- Wind erosion
- Rain or ice erosion
- Particulate erosion
- Impact
- Cleaning or handling
- Chemical exposure

The types of surface degradation of aircraft cover lenses include, but are not limited to, the following:

- Scratched surfaces – If the cover lens comes into contact with sharp or abrasive objects, such as metals, ceramics, rocks, or ice, it can become scratched. This is seen as a rough groove on the lens surface. Scratches are most likely to occur during installation or ground operations. Coarse or deep scratches can affect the physical integrity of the cover lens and are unacceptable. These are defined for glass and plastic materials as scratches exceeding 160 as per MIL-PRF-13830. Minor scratches are acceptable so long as the length of the scratch does not exceed 25% of the largest dimension of the lens, and so long as the light output is not reduced below required levels.