AEROSPACE RECOMMENDED PRACTICE

ARP5873™ REV. B

Issued 2007-03
Revised 2021-01

Superseding ARP5873A

LED Passenger Reading Light Assembly

RATIONALE

This revision adds square illumination patterns, clarifications for color recommendations, and grammar corrections.

INTRODUCTION

The purpose of this SAE Aerospace Recommended Practice (ARP) is to recommend minimum design criteria which will lead to adequate performance standards for LED passenger reading light assemblies in commercial aircraft. This document recommends design and performance criteria for light emitting diode (LED) reading lights in the passenger cabin of aircraft subject to FAR Part 25 certification. It is intended as guidance for the certifying authority. This document is specific to passenger reading lights using LED technology. Passenger reading lights based on other technologies, such as incandescent or halogen, should be as specified in ARP378. This document includes, but is not limited to, commercial aircraft.

1. SCOPE

This document presents minimum criteria for the design and installation of LED passenger reading light assemblies in commercial aircraft. The use of "shall" in this specification expresses provisions that are binding. Non-mandatory provisions use the term "should."

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 latest 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 +1 724-776-4970 (outside USA), www.sae.org.

ARP378	Passenger Reading Lights
AS8037	Minimum Performance Standard for Aircraft Position Lights
TSB 003	Rules for SAE Use of SI (Metric) Units

2.2 U.S. Government Publications

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

MIL-HDBK-217	Reliability Prediction of Electronic Equipment

2.3 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

Code of Federal Regulations	Title 14, Part 25
Code of Federal Regulations	Title 21, Part 1040, Subpart J
CFR 1040.10	Radiological Health, Performance Standards for Light Emitting Products

2.4 FAR Publications

Available from Federal Aviation Regulations, https://www.faa.gov.

FAR 25.831	Ventilation
FAR 25.853	Compartment Interiors (Flammability)
FAR 25.863	Flammable Fluid Fire Protection
FAR 25.869 (a)(1)	Fire Protection System
FAR 25.1301	Function and Installations
FAR 25.1309	Equipment, Systems, and Installations
FAR 25.1353(a)	Electrical Equipment and Installations (Interference)
FAR 25.1431	Electronic Equipment

2.5 RTCA Publications

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

RTCA DO-160	Environmental Conditions and Test Procedures for Airborne Electronics/Electrical Equipment and Instruments
RTCA DO-178	Software Considerations in Airborne Systems and Equipment Certification

2.6 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60825-1	Safety of Laser Products - Part 1: Equipment Classification and Requirements

2.7 CIE Publications

Available from CIE Central Bureau, Babenbergerstrasse 9/9A, 1010 Vienna, Austria, Tel: +43 1 714 31 87, www.cie.co.at.

Supplement No. 2 to CIE Publication No. 15 Recommendations on Uniform Color Spaces Color Difference Equations - Psychometric Color Terms

CIE 13.3 Method of Measuring and Specifying Colour Rendering Properties of Light Sources

CIE S009/E Photobiological Safety of Lamps and Lamps Systems

2.8 Other Publications

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

IESNA Lighting Handbook

IESNA LM-63 Standard File Format for the Electronic Transfer of Photometric Data and Related Information

MacAdam, D.L., "Journal of the Optical Society of America, Visual Sensitivities to Color Differences in Daylight," May 1942

Rensselaer Lighting Research Center
Passenger Reading Light Study
http://www.lrc.rpi.edu/programs/solidstate/pdf/SAELEDreadinglightstudy4-25-05.pdf

3. DETAILED RECOMMENDATIONS

3.1 Reading Light Design

3.1.1 Illuminance Pattern

The reading light should provide a Gaussian (also known as the "normal" distribution) or a uniform pattern (also known as "top-hat" distribution) of illuminance on a target plane orthogonal to the beam axis per Figure 1. The width of the light pattern and the illuminance within the pattern should be in accordance with either Figures 2, 3, 4, or 5.

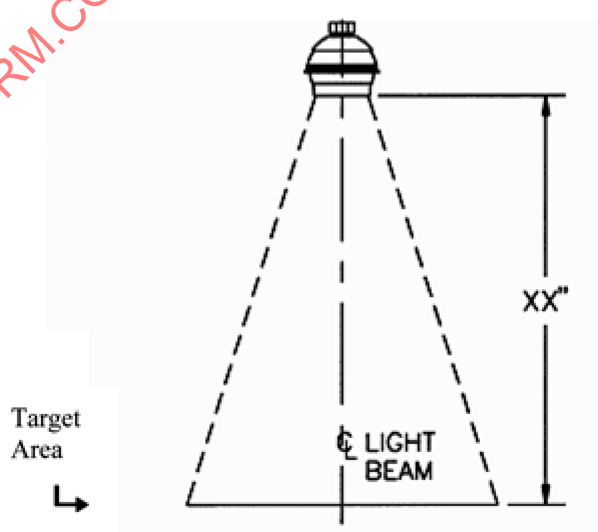
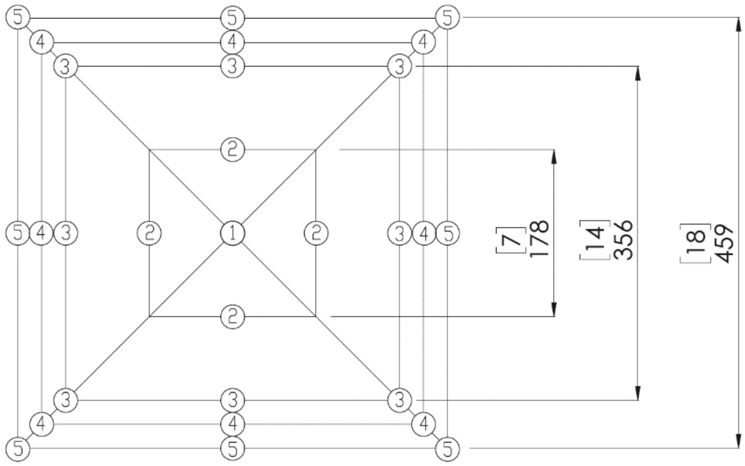
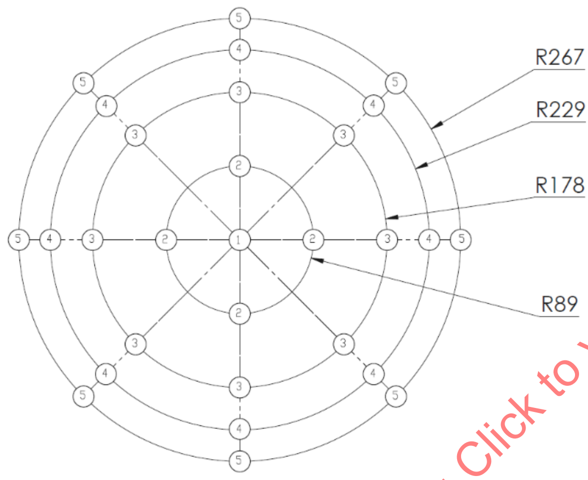


Figure 1 - Target surface is normal to light beam



Measurement Location	Illuminance Recommendations
1	215-410 lx
2	160-300 lx
3	65-118 lx
4	n/a
5	0-16 lx

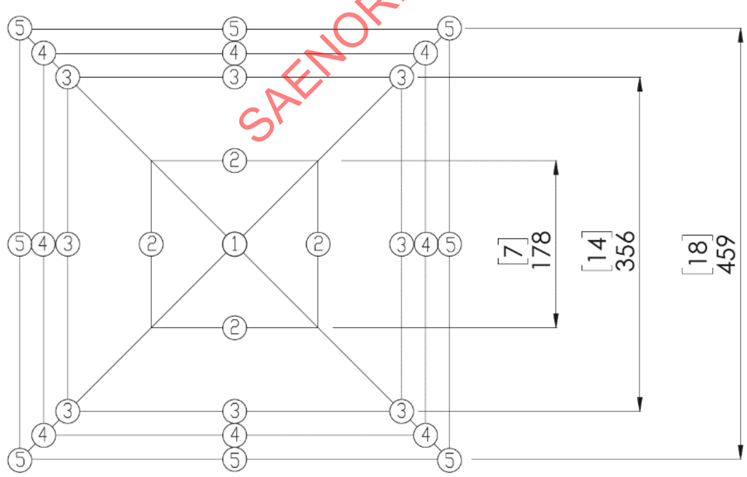
__Figure 2 - Square target with Gaussian illumination pattern__



Measurement Location	Illuminance Recommendations
1	215-410 lx
2	160-410 lx
3	65-118 lx
4	n/a
5	0-16 lx

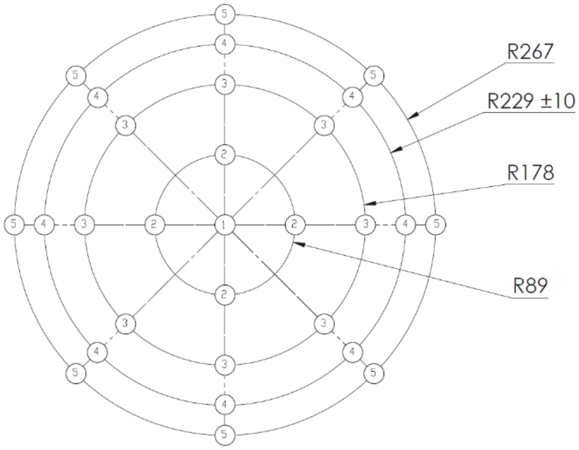
__Figure 3 - Round target with Gaussian illumination pattern__

NOTE: To ensure spot size consistency, the 110 isolux should fall between 219 mm and 239 mm.



Measurement Location	Illuminance Recommendations
1	180-410 lx
2	180-410 lx
3	180-410 lx
4	n/a
5	0-16 lx

__Figure 4 - Square target uniform illumination pattern__



Measurement Location	Illuminance Recommendations
1	180-410 lx
2	180-410 lx
3	180-410 lx
4	110 lx
5	0-16 lx

Figure 5 - Round target with uniform illumination pattern

NOTE: To ensure spot size consistency, the 110 isolux should fall between 219 mm and 239 mm.

3.1.1.1 Illuminance Gradient

The LED passenger reading light assembly shall meet the illuminance requirements as specified in Figures 2 or 3 (Gaussian distribution) or in Figures 4 or 5 (uniform distribution).

3.1.2 Optics

The LED passenger reading light assembly optics shall be designed to meet the illuminance pattern requirements as specified in 3.1.1 when mounted at the installation height of the application. All illuminance measurements shall be made with a cosine-corrected illuminance meter that is orthogonal to the beam axis.

3.1.2.1 Optical Components Quality

The optical components (lens, reflector, etc.) should minimize defects such as scratches, chips, and air bubbles, etc., so that they do not cause noticeable non-uniformity on the illuminated surface. Resistance to environments such as UV should be considered.

3.1.2.2 LED Considerations

The optical performance of a lighting assembly can be significantly affected by the LED selection and how this device affects the fundamental performance and architecture of the overall lighting system. It should be understood that these aspects of LED lighting and their design from the component level on through to the system design have significant impact on the electronic circuit design and complexity; the mechanical, environmental and thermal design, choice and implementation of the optical design, and a variety of performance considerations, including long term intensity, color performance, and lifetime. Some examples of these impacts are:

a. Light assembly designs that utilize red-green-blue (RGB) or similar color mixing architectures experience color shift over time because the different color LEDs degrade in intensity and/or shift wavelength at various rates. Since the requisite color relies on the correct combination and ratio of light intensity from each contributing color, electronic control circuitry that utilizes color sensing feedback and independent led drive control such that each LED can be adjusted individually is prudent for many applications.

b. Light assembly designs with commonly utilized LED materials in white, blue, or ultra-violet (UV) LEDs may experience component and materials degradation that is normally experienced with UV light exposure. Discoloration and embrittlement of the light source and optical components are some of the impacts.

c. Light assembly designs that utilize white (photo-conversion) LEDs (such as yellow phosphor coated blue die that produce white colors) can experience a reduction in the phosphor conversion efficiency over operational time. A conversion efficiency loss can be accelerated by exposure to heat from higher temperatures. This can result in a color shifting as well as light intensity reduction.

d. There is significant variability within each part number for every LED device. These manufacturer variations can be minimized through careful scrutiny of the specific vendors and their products. The resulting LED assembly product designs should account for the variations in intensity, forward bias voltage, color, etc., that will be experienced. The lot to lot variability of a single manufacturer or between multiple manufacturers of equivalent LEDs should be accounted for.

e. The luminous intensity of an LED is inversely related to its ambient environment temperature. Because of this, the illuminance requirements and performance need to be considered over the expected operating temperature range.

f. The luminous intensity of an LED is inversely related to operational usage time. End of useful life for LEDs is predominantly a result of reduced intensity and not of catastrophic failure like in incandescent or halogen reading light sources. Because of this, the illuminance requirements and performance need to be considered over the expected life per 3.1.5.

The long-term performance of the LED device type(s) and the fundamental light source architecture(s) should be well understood before making a LED design selection. The light assembly design should be developed with regard for these characteristics to ensure acceptable optical performance of each light assembly over the expected life and utilization environment.

3.1.3 White Light Color Definition

The LED passenger reading light assembly target area for correlated color temperature (CCT) shall be within 3400 to 5600 K. Figure 4 herein illustrates the recommended color range. For example, a 4300 K color temperature corresponds to u’=0.220 and v’=0.496 (x=0.368 and y=0.369 on the CIE 1931 chromaticity diagram). A human factors LED reading light study suggests that a range of 3600 to 5200 K is preferred. Some factors influencing these preferences are skin tone appearance, and tasks such as computer typing, reading, and color discrimination. A single color point should be selected within the range and designated as the reading light’s designed or nominal color point. Aesthetically, the tolerance of the LED reading light assemblies should be within a 0.004 u', v' color target radius. Within this tolerance, variations between LED reading light assemblies will not be conspicuous to most observers. LED reading light assemblies within this tolerance are classified as Group A. However, at the time of publication of this document, high flux white LEDs are not readily available within these tolerances. Therefore, this ARP also provides for a less restrictive tolerance, classified as Group B. Group B LED passenger reading light assemblies should have a color tolerance radius within 0.012 u', v' about the target. This corresponds approximately to a seven step MacAdam ellipse, indicating that a majority of the population will discern a color difference. A wide color range could result in a noticeable difference in color appearance from light to light. It should be noted the Lighting Research Center was used to support the above lighting criteria. LED readings lights should meet the color recommendations through all temperature ranges encountered in the installation environment.

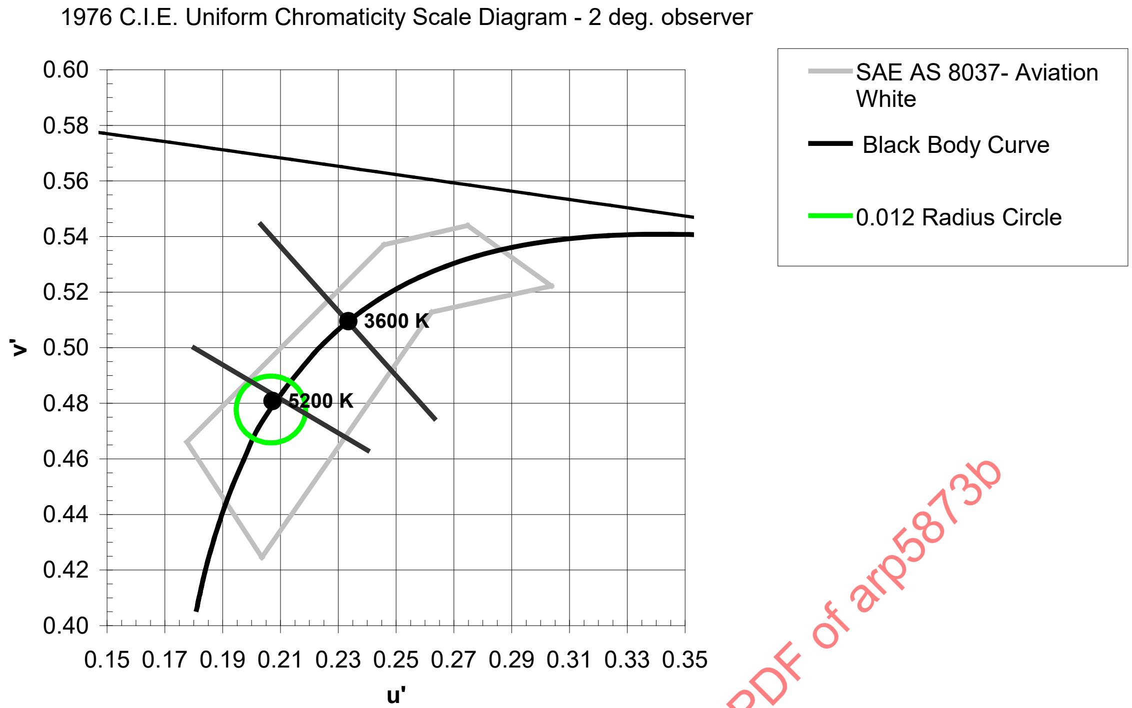


Figure 6 - Recommended color tolerance for LED reading lights in Group B

3.1.3.1 Color Rendering Properties

The LED passenger reading light assembly should have a minimum Color Rendering Index (CRI) of 80 in addition to having an R9 value above 80. Measurements shall be in accordance with CIE 13.3-1995.

3.1.3.2 Color Uniformity

The LED passenger reading light assembly shall meet the color temperature and color coordinate requirements for any point within the illuminance pattern. There should not be visible color fringing, halo, or other noticeable change in color.

3.1.4 Warm Up and Stabilization

For purposes of demonstrating compliance with this specification, all photometric and color measurements shall be made after 30 minutes or after the lamp has reached thermal stabilization, whichever is longer. Thermal stabilization shall be defined as the point in which light output does not change by more than 3% over a 15 minute period.

3.1.5 Lumen Maintenance

The LED passenger reading light assembly shall be capable of meeting its illuminance over its useful life as specified by the purchasing authority. Lumen maintenance and useful lifetime, as used herein, shall be time until the LED passenger reading light assembly is no longer capable of meeting the requirements of this specification.

3.1.6 Dimming

The LED passenger reading light assembly may be stepped or continuously dimmable. If it is dimmable, perceived brightness changes should vary linearly with the input control, and the color temperature, color coordinates, beam pattern geometry and illuminance distribution should not change appreciably over the dimming range. The LED passenger reading light shall be capable of being turned completely off.

3.1.7 Light Trespass

The reading light shall be designed in such a manner so that when the reading plane is orthogonal to the beam, the intensity of the light falling outside the pattern, the peripheral area beginning at a radius of 267 mm (10.5 inches) from the beam center and beyond the specified pattern (Figures 2, 3, 4, and 5), shall not exceed 16.1 lx (1.5 ft-c).

3.1.8 Glare

To minimize glare, the LED light source should not produce luminous intensity in excess of 5 cd over an angle of 70 to 90 degrees from the beam centerline. Adjustability, aiming, and placement with respect to the illuminated surface of the light source should be considered.

3.1.9 Input Power

The reading light should operate from one of the industry standard aircraft power buses. Some common power buses are shown below. Care should be taken that the reading light will provide rated operation over the entire operating voltage range.

28 VDC
28 VAC, 400 Hz
115 VAC, 400 Hz
115 VAC, variable frequency
12 VDC

3.1.10 Abnormal Conditions

The LED passenger reading light assembly shall meet all the performance requirements as specified herein, except for abnormal conditions of voltage and temperature. For abnormal conditions, some degradation of light output may be permissible. However, no damage to the LED light assembly shall occur and the light assembly shall recover and provide rated operation when normal conditions recover.

3.1.11 Environmental Requirements

It is recommended the reading light should meet the RTCA DO-160 environmental requirements of Table 1. Following these requirements facilitates showing compliance to the applicable CFRs.

Table 1 - RTCA DO-160 environmental requirements

Requirement	Test Level*
Temperature and Altitude	Category A1.
Temperature Variation	Category C.
Humidity	Category A.
Operational Shocks and Crash Safety	Category A.
Vibration	Category S or S2 test curves B or B2.
Waterproofness	Category W; use 5% NaCl in water sample for this test.
Power Input	Category B or Z (for 28 VDC applications). Category A(CF) (for VAC applications; single phase). Category A(WF or NF) (for 115 VAC variable frequency, single phase). For voltages other than 115 VAC, the tests shall scale the RTCA 115 VAC voltage requirements by the same proportion as the nominal operating voltage to 115 VAC (for example, 28 VAC would scale the RTCA requirements for maximum voltages, voltage surges, etc., by a factor of 28/115).
Voltage Spike	Category A.
Audio Frequency Conducted - Power Inputs	Category B (for 28 VDC applications). Category R(NF) (for 28 VAC applications). Test shall scale the 115 to 28 VAC or use a 115 to 28 VAC transformer.
Induced Signal Susceptibility	Category B.
Radio Frequency Susceptibility (Radiated and Conducted)	Category S.
Emission of Radio Frequency Energy	Category B.
Electrostatic Discharge	Category A.

* The categories and paragraphs noted in this table were specified from RTCA DO-160.

3.1.12 Software Requirements

Reading light assemblies using software shall comply with RTCA DO-178.

3.1.13 Voltage Polarity

The reading light shall not be damaged by reverse polarity. Polarity shall be clearly indicated.

3.1.14 Reliability

The LED passenger reading light assembly shall meet reliability requirements as set forth by the purchasing authority. Reliability calculations should be computed in accordance with MIL-HDBK-217 for airborne, inhabited, cargo environments.

3.1.14.1 Environmental Stress Screening (ESS) or Burn-In

LED passenger reading light manufacturers should consider methods of achieving or exceeding reliability requirements, such as ESS or burn-in.

3.1.15 Safety

During normal operation or any failure mode, the reading light or cabin light installations that use LED technology shall not impose any high intensity light hazard to flight crew, maintenance personnel, or passengers. Failure modes should be considered in the design such that in the event of a failure, the illuminance does not create an unsafe condition. The LED reading light assembly shall comply with Code of Federal Regulations Title 21, Part 1040, Subpart J, DFR 1040.10 Radiological Health, and Performance Standards for Light Emitting Products.