



AEROSPACE RECOMMENDED PRACTICE

ARP6402™

REV. B

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Superseding ARP6402A

(R) LED Landing, Taxiing, Runway Turnoff, and Recognition Lights

RATIONALE

This update includes updated content regarding the spectral content of the white light, icing, warm-up and stabilization, and updated references. The illumination recommendations have been updated to clarify the guidance for smaller aircraft. Additional guidance for lamp aiming and recognition lights has also been added.

FOREWORD

This document provides guidance material for the design, qualification, certification, and use of LED-based landing, taxiing, runway turnoff lights, and recognition lights.

1. SCOPE

This document includes recommendations of installations of adequate landing and taxiing lighting systems in aircraft of the following categories:

- a. Single engine personal and/or liaison type
- b. Light twin engine
- c. Large multiengine propeller
- d. Large multiengine turbojet
- e. Military high-performance fighter and attack
- f. Helicopter
- g. Electric Vertical Takeoff and Landing (EVTOL) and Urban Air Mobility (UAM)

1.1 Purpose

The purpose of this document is to provide certain basic considerations and design criteria for installation of LED landing, runway turnoff, and taxiing light systems for night operation. Criteria for recognition lights are also included.

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2. REFERENCES

2.1 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 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.

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

ARP693	Landing and Taxiing Lights - Design Criteria for Installation
ARP5825	Design Requirements and Test Procedures for Dual Mode Exterior Lights
ARP6161	Flight Compartment Glare
ARP6253	LEDs and Aircraft Applications
ARP6621	Predicting Photometric Degradation of Exterior Aircraft Lights
AS8017	Minimum Performance Standard for Anticollision Light Systems
AS25050	Colors, Aeronautical Lights and Lighting Equipment, General Requirements for
SAE J1330	Photometry Laboratory Accuracy Guidelines

2.1.2 Code of Federal Regulations (CFR) Publications

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

14 CFR Part 23	Airworthiness Standards: Normal Category Airplanes
14 CFR Part 25	Airworthiness Standards: Transport Category Airplanes
14 CFR Part 27	Normal Category Rotorcraft
14 CFR Part 29	Transport Category Rotorcraft
14 CFR Part 121	Operating Requirements: Domestic, Flag, and Supplemental Operations

2.1.3 FAA Publications

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

AC 25-7A 9	Flight Test Guide for Certification of Transport Category Aircrafts
AC 25.981-1A	Guidelines for Substantiating Compliance with the Fuel Tank Temperature Requirements
AC 150	Airport Design

InFO 21003 Issues Related to the Use of Light Emitting Diode (LED) Landing Lights in an Icing Environment

FAA ARAC Rotorcraft Bird Strike Working Group. (2019). *Rotorcraft Bird Strike Working Group Recommendations to the Aviation Rulemaking Advisory Committee (ARAC)*. Federal Aviation Administration, United States Department of Transportation.

2.1.4 FHWA Publications

Available from Federal Highway Administration, 1200 New Jersey Ave, SE, Washington, DC 20590, Tel: 202-366-4000, <https://www.fhwa.dot.gov/>.

FHWA-HRT-15-047 Evaluation of the Impact of Spectral Power Distribution on Driver Performance

2.1.5 U.S. Government Publications

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

MIL-L-6503 Military Specification, Lighting Equipment, Aircraft, General Requirements For

2.1.6 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

CS-23 Normal, Utility, Aerobatic, and Commuter Category Aeroplanes

CS-25 Large Aeroplanes

CS-27 Small Rotorcraft

CS-29 Large Rotorcraft

SC-VTOL-01 Vertical Take-Off and Landing (VTOL) Aircraft

2.1.7 CIE Publications

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

CIE IEC 62471 Photobiological safety of lamps and lamp systems

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

2.1.8 RTCA Publications

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

DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

2.1.9 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 RP-8-18 Roadway Lighting

ANSI/IES TM-30 IES Method for Evaluating Light Source Color Rendition

2.1.10 Other Publications

Sullivan, J.M. and Flannagan, M.J. (2009). *Photometric indicators of headlamp performance* (Report No. UMTRI-2009-18). University of Michigan, Ann Arbor, Transportation Research Institute. <https://deepblue.lib.umich.edu/handle/2027.42/63098>.

2.2 Definitions

COLOR RENDERING: Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant.

ELECTRIC VERTICAL TAKEOFF AND LANDING (E-VTOL): An aircraft that uses electric motors and propellers to take off and land vertically.

GLARE: Light within the visual field that is brighter than the level to which the eyes are adapted, thus reducing visibility, reducing contrast, annoying, causing discomfort, or distracting the observer.

HALATION: Scattering of a light beam beyond its proper boundaries, causing a bright ring or halo surrounding an object or beam of light. Halation causes confusion and disorientation due to the loss of surrounding definition and loss of peripheral detail.

ILLUMINANCE: A measure of power per unit area or flux density on a surface, lumens per unit area; units are lux (lx) or foot-candle (fc). $1.00000 \text{ fc} = 10.7639 \text{ lx}$.

LANDING LIGHT: A light used to illuminate the runway or landing pad for landing or takeoff at night.

LUMINOUS FLUX: The time rate of flow of radiant energy, evaluated in terms of a standardized visual response.

LUMINOUS INTENSITY: The luminous flux per unit solid angle in the direction in question.

POWERED LIFT AIRCRAFT: An aircraft that takes off and lands vertically but uses a fixed wing for horizontal flight.

RECOGNITION LIGHTS: Lights designed to improve the visibility of an aircraft. They are typically mounted on the wings and are often flashed, sometimes in an alternating pattern.

RUNWAY TURNOFF LIGHT: A light used to augment the taxi lights on large aircraft. Directed to illuminate the sides of the runway or taxiway.

TAXI LIGHT: A light used to illuminate the runway or taxiway while an aircraft is moving on the ground.

URBAN AIR MOBILITY (UAM): An air transportation system for passengers and cargo in and around urban environments.

3. GENERAL RECOMMENDATIONS

3.1 Color

Landing and taxi lights are used to illuminate the runway or landing pad and the environment around it. They help detect obstacles, such as animals, vehicles, or debris, that might cause a safety hazard during landing and taxiing. They are also used to illuminate signage along the sides of the runway and painted lines on the runway or landing pad surface. The bright white lights can also be used to signal other aircraft or ground personnel.

CFR and EASA regulations define aviation white but only specifically require it for position lights and anti-collision lights. This allows for some leeway in the color of landing and taxi lights. It is recommended that landing and taxi light specifications define an acceptable white color after considering the following information.

White LEDs are typically designed with high-volume consumer parts in mind, so the white color bins available from the manufacturers may not fit neatly within a particular white specification. LED manufacturers typically offer numerous color bins for white LEDs. The size and shape of these bins varies from one manufacturer to another. While it is not difficult to select a single bin that fits within a desired chromaticity requirement, manufacturers are seldom willing to sell a single bin. Instead, LED manufacturers often select groups of bins to sell as a single part number. This may lead to having some bins that fall outside the color boundary (see Figure 1).

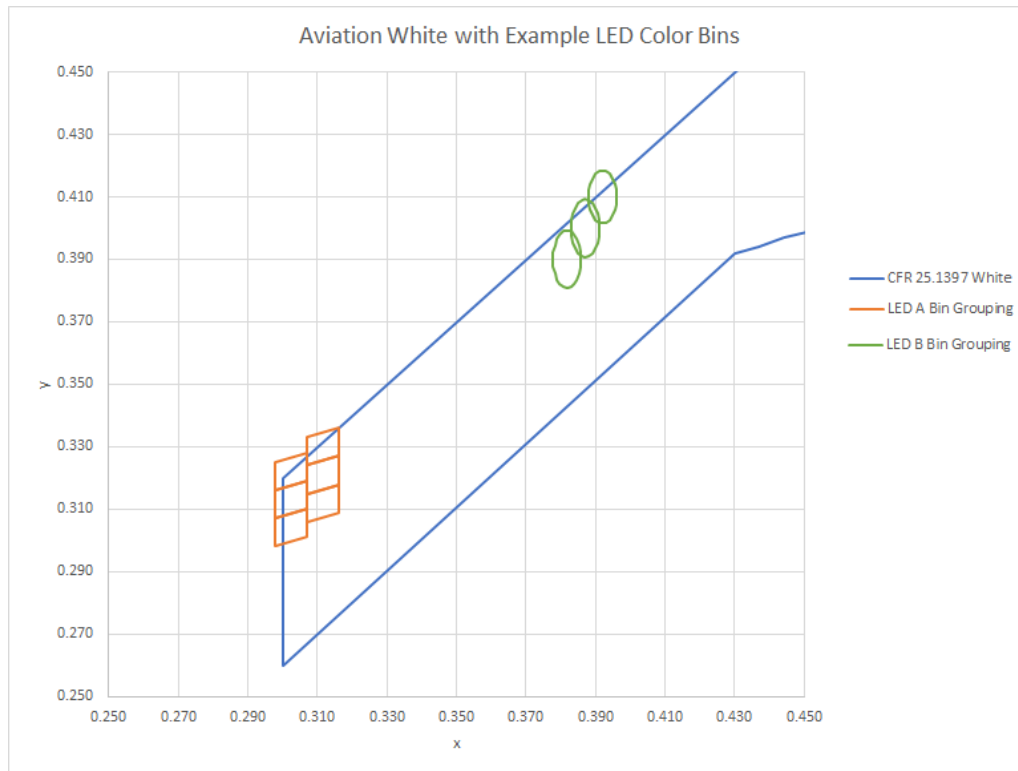


Figure 1 - LED bin groups versus aviation white

AS25050 and AS8017 contain two slightly different definitions of white, used for military aircraft and anti-collision lights (see Figure 2). Any of these may be acceptable for landing and taxi lights. Definitions based on color temperature may also be acceptable.

For lights intended to be used in conjunction with night vision equipment, light at longer wavelengths should be limited to prevent interference with the goggles. Refer to ARP5825 for details.

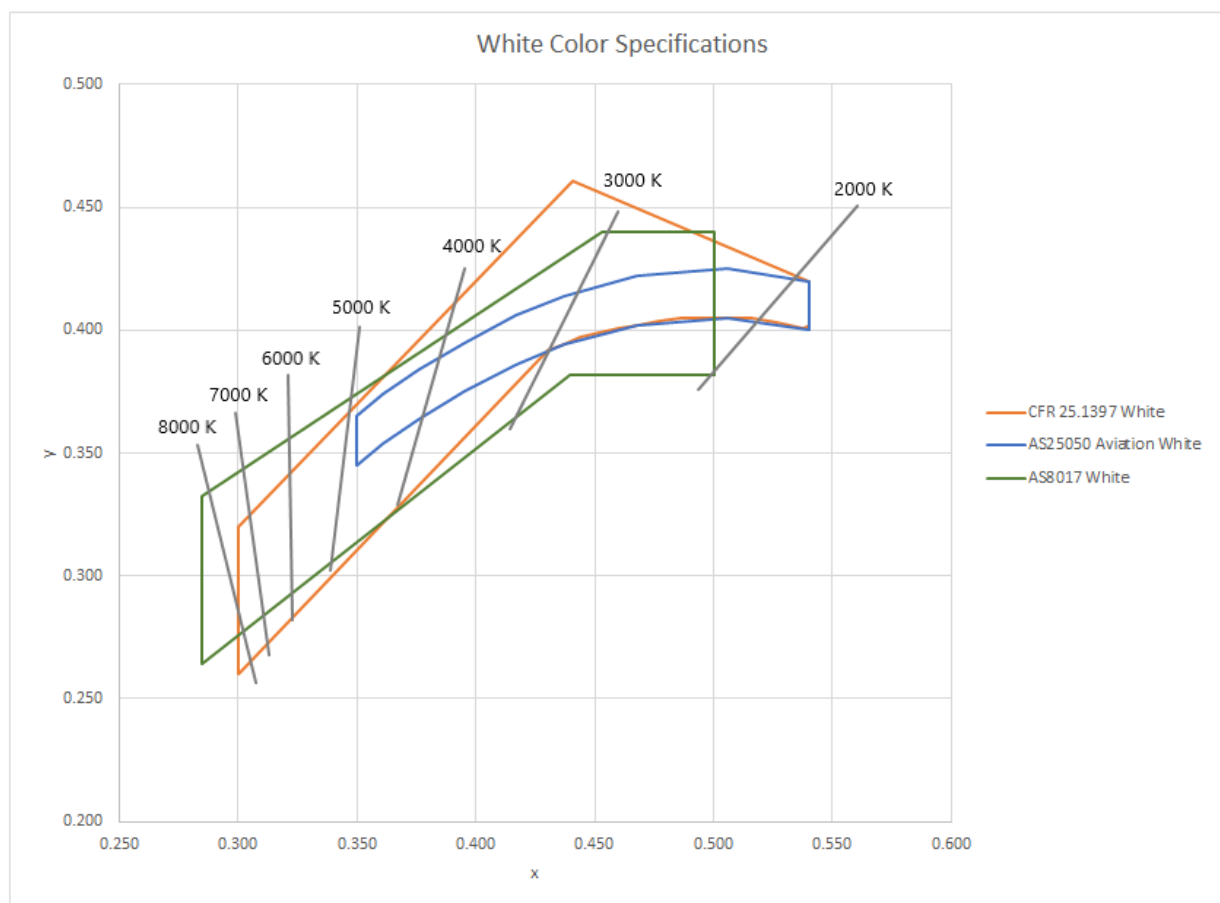


Figure 2 - White color specifications

3.2 Spectral Content

While obstacle detection is the most important function of landing and taxi lights, the spectral content of the lights can influence the ability to see certain colors and needs to be considered when designing LED landing and taxi lights. LED manufacturers can provide LEDs with different spectral content and color rendering capability. Figure 3 gives an example of the spectral content of two typical white LEDs. The cool white LEDs in this example will be brighter and look more like daylight than the warm white LEDs, but the warm white LEDs might help red colors stand out more than the cool white LEDs.

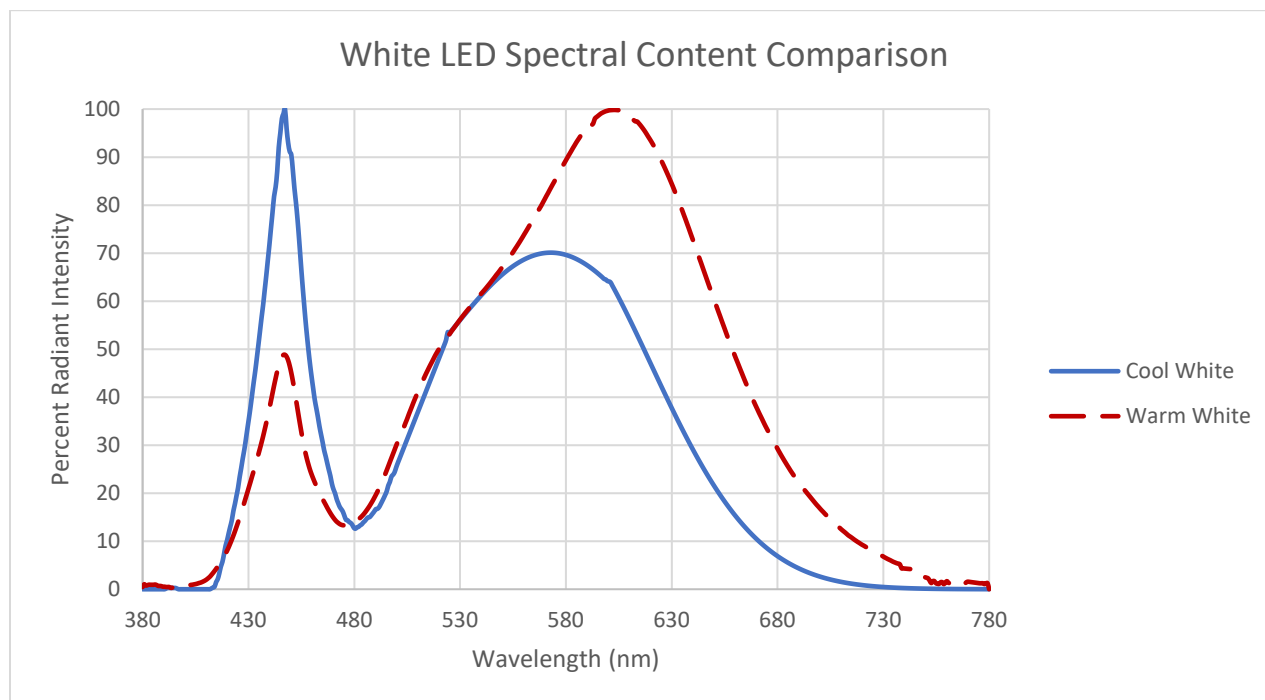


Figure 3 - Example spectra of two white LEDs

Color rendering is the effect that a light source has on the color appearance of objects.

Adequate color rendering is needed to ensure that tasks such as detecting obstacles, reading taxi runway signage, and interpreting runway markings can be accomplished by the pilot.

There is no one metric or measure that can accurately quantify all subjective perceptions of color rendition or identify the most desirable light source for every application.

The CIE 13.3 General Color Rendering Index, R_a , which is the average of nine special color-rendering indices, has been used for some time to quantify the color rendering ability of light sources. One method to ensure adequate color rendering of landing and taxi lighting is to specify a minimum color-rendering index value.

The Illuminating Engineering Society (IES) has recently made improvements to the CIE color rendering index in ANSI/IES TM-30. One significant IES color rendering improvement is that it considers and is more accurate for solid-state LED light sources. The color fidelity and color gamut scores from this standard could also be considered when specifying landing and taxi light color. For reference, color fidelity and color gamut scores from LED landing lights from five different manufacturers as well as the example LEDs in Figure 3 are shown in Table 1.

Table 1 - Example color scores

Lamp Manufacturer	A	B	C	D	E	Figure 3 Cool White	Figure 3 Warm White
Rf (color fidelity)	66	74	73	68	65	72	83
Rg (color gamut)	95	94	94	97	97	94	98

3.3 Related Lighting Spectrum Research

Human factors research has been performed for ground vehicle lighting, which has many similarities to aircraft lighting, especially when taxiing. The IES, based on research performed for the U.S. Federal Highway Administration, concluded that “varying spectral content of overhead luminaires does not affect driver performance, as represented by detection of potential hazards” (refer to ANSI/IES RP-8-18).

The study mentioned was carried out by the Virginia Tech Transportation Institute. It mentioned that broad-spectrum light sources were preferred for user comfort and acceptance, and specifically stated that “LED lighting is the optimal broad-spectrum source for roadway lighting” (refer to FWHA-HRT-15-047). Broad-spectrum lighting had greater, though not statistically significant, color-recognition distances for off-axis pedestrians.

The airport environment has some significant differences from the roadway environment in the above study. Aircraft can land with much higher speeds than typical ground vehicles, and airports are more highly controlled environments where pedestrians are less likely to be present. Those pedestrians who are present are typically trained personnel who often wear high-visibility clothing.

Based on all these factors, no recommendation is made for a specific color rendering index or color fidelity score, other than to recommend that the spectral content of the lights be considered during design and that a visual evaluation of those lights be made.

3.4 Eye Safety

Extremely bright light emitted from a small area has a small possibility of causing eye injury, especially for people who may be exposed for long periods of time while testing or maintaining the light. Light beyond the visible range, such as IR radiation used in night vision lighting, has a greater potential to cause an unsafe condition. An eye safety analysis should be performed for landing and taxi lights, especially those that emit non-visible radiation. The international standard for lamp safety is CIE IEC 62471.

3.5 Life

LEDs generally do not fail catastrophically but experience gradual degradation in light output over time. The rate of degradation is dependent upon many factors, including the LED component materials, drive current, operating environment, and LED junction temperature. Due to the lack of a hard failure point, it is desirable to define the photometric end of life (EoL). EoL can be defined as a percentage of initial output (70% for many applications), or the length of operational time until the light no longer meets defined minimum intensities. Because photometric margin and life can be impacted by adjusting package size, weight, power, and cost, establishing specific values/requirements for life is not appropriate, as these requirements can be market/platform/installation specific. An appropriate EoL requirement does, however, need to be considered during the design/installation process to ensure that the lights will meet their intended function for the duration of their rated life. Refer to ARP6621 for specific guidance on life calculations.

LED EoL calculations can be used to recommend replacement of LED landing and taxi lights after a set number of hours. Another approach to determining EoL of an LED light is to add electronics to monitor the intensity or other parameters, and then signal the user when the parameter goes out of specification. Any monitoring method should be as simple as possible to avoid added complexity leading to additional failure modes for the light. EoL determinations can also be made via direct observation of the landing light beam by the pilot.

LED life can be shortened if the LEDs are exposed to high currents, high temperatures, or incompatible chemicals. Care should be taken in the design of LED lights to minimize exposure to these conditions.

3.6 Thermal Considerations

3.6.1 Icing, Humidity, and Condensation

Icing, humidity, and condensation should be considered in the design of the lighting system due to effects on system performance. Appropriate draining and/or venting are recommended. In some icing conditions, pilots have noted that retractable LED landing lights take longer to melt the ice than equivalent halogen lights (refer to InFO 21003). While all lights may experience conditions that degrade performance, such as icing, dirt buildup, or etching of lenses, LED lights may require different procedures, such as longer warm-up times, due to their lower power and lower heat generation.

3.6.2 High Temperature Operation

The expected operating temperature must be considered in designs using LEDs because LED brightness reduces with increasing temperature. The design of the light should include adequate heat sinking or other methods of limiting the LED junction temperature to acceptable levels. Calculations of photometric performance should take into account the highest expected LED junction temperature.

3.6.3 Warm Up and Stabilization

Depending on the thermal design of the landing or taxi light, it may take a significant time for these lights to reach a stable temperature after activation. While it is common practice for photometric measurements to be made after a lamp has stabilized, measuring a landing light after a very long stabilization period may not be practical. The lights should be designed so that they will meet their illuminance requirements under any reasonably expected condition. Photometric measurements can be made after a designated warm-up time or after complete stabilization. An analysis should be done to evaluate the photometric performance during the expected flight profile of the light.

4. DETAILED RECOMMENDATIONS

4.1 Landing Lights

Landing lights are used primarily to see the runway when landing. They provide ground reference information during final approach, touchdown, ground roll, and takeoff, and they illuminate any major obstructions in the aircraft approach glide path or on runway at night. See Appendix A for recommendations on calculating the runway areas to be illuminated.

Landing lights may also be used for signaling purposes in flight and on the ground. The landing lights may be turned “on” when:

- a. Operating within 10 miles of any airport, day or night.
- b. Operating in conditions of reduced visibility, i.e., haze, dust, etc.
- c. Operating under special visual flight rules (SVFR) conditions.
- d. Operating where flocks of birds may be expected (coastal area, swamp lands, migratory areas, etc.). This requires that all or some landing lights are functional when gear and slats/flaps are retracted.
- e. Landing lights may have a “flashing” or “wig-wag” function where they are turned on and off at a certain rate to increase visibility to other planes and airports. The Rotorcraft Bird Strike Working Group recommends that rotorcraft operators “use landing and/or taxi lights in continuous mode during sunny conditions and at night when practical and use a 2 Hz pulsed mode during partly cloudy conditions, and/or install lighting systems that provide the equivalent” (refer to FAA ARAC Rotorcraft Bird Strike Working Group, 2019).