CIVIL AVIATION PUBLICATION

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INTENSITY LIGHTING FOR AERODROMES

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1.0 Introduction

This Civil Aviation Publication (CAP) is provided for information and guidance purposes as a result of numerous queries from stakeholders looking for guidance on the application of the standard, especially given the increased use of solid-state technology for aerodrome lighting. It may describe an example of an acceptable means, but not the only means, of demonstrating compliance with regulations and standards. This AC on its own does not change, create, amend, or allow deviations from regulatory requirements, nor does it set up standards.

2.0 Purpose

The purpose of this document is to discuss intensity settings associated with brightness steps for aerodrome lighting systems.

3.0 Applicability

This document applies to all airport operators. This information is also available to aerodrome operators and the aviation industry for information purposes.

4.0 References and Requirements

It is intended that the following reference materials be used in conjunction with this document:

- Civil Aviation Act-2021
- Civil Aviation Regulations Aerodrome and Ground Aide one (CAR AGA 1)
- Icao doc 9157 Part 4

By default, it is understood that the publication of a new issue of a document automatically renders any earlier issues of the same document null and void, unless an earlier issue remainsvalid under coming into force provisions by regulation.

5.0 Definitions and Abbreviations

The following **definitions** are used in this document:

Luminous intensity: The measure of the wavelength-weighted power emitted by a lightsource in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. The SI unit of luminous intensityis the candela (cd) or lumen per steradian (lm/sr).
Solid-state technology: Technology using semiconductor devices such as transistors,diodes and integrated circuits (ICs). Examples of solid-state devices are the microprocessor chip, LED lamp, solar cell and semiconductor laser.
Transmissivity: The ratio of the amount light incident on a surface after passing througha unit thickness of the atmosphere to the amount of light that would be incident on the same surface if the flux had passed through a vacuum.

The following **abbreviations** are used in this document:

- **ICAO**: International Civil Aviation Organization
- **LED**: Light Emitting Diodes
- **CAAB**: Civil Aviation Authority Bahamas

6.0 Background

6.1 CAAB has received reports of issues raised with the brightness step settings at aerodromes where the traditional incandescent lighting has been replaced with solid-state technology (LED lighting). The issue stems from perceived brightness of LED installations caused by the differencein color saturation between the two technologies. Detailed guidance is provided in para 6.0 below.

The use of intensity control for aerodrome lighting systems is provided to allow adjustments of the brightness levels so as to not dazzle the pilot during approach and landing in varying visibility conditions.

Guidance for the intensity level to use for the different brightness steps is provided in ICAO document 9157.4 – *Aerodrome Design Manual – Part 4.* Lighting Specifications

6.2 The fundamental concept behind the need to provide different brightness steps for aerodrome lighting is solely based on the need to offer the most suitable level of lighting intensity to the pilot during approach and landing in varying visibility conditions.

6.3 The minimum intensity levels for certification in term of luminous intensity (i.e., candela output) of aerodrome lighting systems is as per Appendix 5B. This minimum standard is to ensure visibility of the lighting system during operations in minimum weather conditions. Hence, the higher step in any step intensity system will always be 100% of that minimum standard value. Anyluminous output less than that minimum standard is purely to accommodate pilots in improved visibility conditions.

6.4 Actual operational conditions will dictate the correct selection of any brightness steps as requested by the pilot using the visual aid, or as required to facilitate aerodrome operations. The imperative is for airport operators to understand that the ultimate aim is to provide the intensity level suiting the pilot's operational needs.

7.0 Intensity Settings

7.1 In order to begin discussion about what intensity should be used for a particular brightness step, it is importance to understand the difference between brightness and luminous intensity and the relation between luminous intensity and the distance at which the human eye will acquire a specific light source in different meteorological conditions.

7.2 Brightness is a relative term. It is how a human eye perceives and interprets a light source in comparison to another light source or the same light source but in different visibility conditions. One person may find a light source "bright" while another may find the same light source having the same luminous intensity from the same distance as not "bright". Most human eyes will find certain light "colors" (i.e., different wavelengths) to have different level of "brightness" because of the relative sensitivity response of the human eye to different wavelengths.

7.3 Luminous intensity, on the other hand, is not relative; it is the amount of light emitted from a light source, measured in candela (cd). For ease of reference, the luminous intensity of a wax candle is roughly one candela. What is generally accepted, however, is that the stronger the luminous intensity of a light, the brighter it will appear to the human eye.

7.4 The relationship between the luminous intensity of an aerodrome light source and the distance of the pilot's eye from that light source through the atmosphere is crucial in understanding perceived "brightness" in different visibility conditions. Most importantly, the relationship is non-linear. The intensity of a light source, and by default its perceived brightness, is proportional to the transmissivity of the atmosphere and is inversely proportional to the square distance from the light source. In other words, the further you are and the worst the visibility, the less "bright" the light will appear, however, doubling the intensity will not suffice to maintain the same perceived "brightness" at twice the distance. The relationship bet ween atmospheric transmissivity and visibility is also non-linear. Furthermore, background luminance affects the acquisition of given light intensities depending on atmospheric and sunlight conditions.

What the previous paragraph indicates is that a variable step intensity lighting system cannot have a linear relationship (i.e., equal increments) between the steps and their associated intensity levels. If step 5 of a five-step system is set at the default 100% of the minimum standard requirement of 10,000 cd for a high intensity precision runway edge light, setting the intensity for step 4 at 8,000 cd (80%) will have little effect on the perceived brightness by the pilot. What it also means is the human eye cannot easily detect the difference in perceived brightness levels within a certain percentage of a specific luminous intensity, i.e., 5,000 cd +/- 1,000 cd.

7.5 The best approach is to determine what is the lowest acceptable level of luminous intensity required for aerodrome lighting systems in the most favorable visibility condition (ie night, very low background luminance, high visibility) and make that the intensity setting for the lowest step (step 1). Then, it is simply a matter of figuring out the intervals in between. There is plenty of guidance available as to what recommended intensity settings should be for each brightness step of both three-step and five-step systems, typically associated with medium and high intensity system respectively. ICAO Doc 9157.4 recommends using 5% of the minimum requirement for step 1, based on an approximate 50% step-to-step reduction, starting with step 5 (100%) for a five-step system. The UK recommends 1% for step 1, based on an approximate 66% (2/3rd.) step- to-step reduction. The FAA specifies 0.15% for step 1, based on an approximate 75% step-to- step reduction. In Canada, TP312, 4th edition used 0.2% for step 1 of a five-step system based on an approximate 75% step-to-step reduction.

7.6 Generally, the guidance for a five-step system suggests stepping the intensity down in increments of somewhere between 50%-75% from one step to the next, ie the intensity of step 4 is 25%-50% of step 5, the intensity of step 3 is 25%-50% of step 4 (or 6.25%-25% of step 5), etc. Canada and the United States are some of the States with the most aggressive reductions at approximately 75%. This provides a broader range of intensity settings to accommodate pilots. Guidance for three-step systems is generally accepted worldwide as adequate for using approximately 30% step-to-step reduction (i.e., 100%, 30% and 10%).

With the above considerations in mind, the recommended settings for the aerodrome lighting systems in Table 1 below. A tolerance of +/- 20% of the stated percentages listed for each step is deemed to be acceptable (e.g., the setting for step 3 for a five-step system would be 5% +/- 20%, or somewhere between 4%-6%.)

Table 1 – Recommended Brightness Step Intensity Settings			
Five-step systems		Three-Step systems	
Step	Intensity	Step	Intensity
5	100%	3	100%
4	25%	2	30%
3	5%	1	10%
2	1%		
1	0.2%		

8.0 Incandescent vs solid-state lighting systems

8.1 The concept of "perceived" brightness is reinforced when comparing incandescent and solid-state technologies, especially at lower intensity settings. From paragraph 5.0(2) above, we can recall that many factors affect how the human eye perceives brightness of lights; one of these factors isthe color or chromaticity of the light. Incandescent technology works on the principle of heating anelement (filament) in order to generate light by running an electrical current through the filament to heat it up. When a filament is "heated", its correlated color temperature (CCT) properties are such that the filament goes from" warm" yellow to "cool" white as the current increases. When thecurrent through a white incandescent light bulb of an aerodrome lighting system is reduced to accommodate the lower brightness steps, the color of the emitted light therefore tends to shift from white to yellow.

8.2 On the other hand, solid-state lighting systems (LED) work on a completely different principle. Instead of running high current through a filament, LED devices use very low current to energize a special diode designed to release a photon in the visible portion of the electro-magnetic spectrum. A white LED light produces a crisp white light that "appears" brighter to the human eye.This is noticeable on cars when comparing cars with LED lights with those with halogen lights. Ofimportance here, however, is that LED lights retain their color saturation as the intensity is reduced, unlike incandescent lights. This is due to the technological design of solid-state systems. The current through an LED remains unchanged. The reduction of intensity is accomplished by modulation (increase) of the width of the digital pulse, reducing the frequency ofthe signal sent to the diode but not slow enough for the eye to notice any flickering. The result is an appearance to the human eye of a "reduced" brightness of the light while maintaining its color.

8.3 The most noticeable difference is in the lowest settings, where the incandescent light in a very low brightness setting has turned to a warm yellowish white while the LED has maintained its cool white, given a much higher "perceived" brightness to the human eye. Yet, the measured luminous intensity of both types of lights at the same brightness step is the same in terms of candela output, which means that the acquisition distance of both lights will remain the same; the LED simply "appears" brighter, only because the eye sees a pure white instead of a yellowish white.

9.0 Conclusion

Aerodrome operators need to be aware of the difference in “perceived” brightness between incandescent and solid-state systems and adjust their default settings for given visibilities to suit their operational needs or in responding to pilot requests. For example, setting step 3 for a five- step incandescent system may work in a given visibility but on a LED system, that same step 3 in that same visibility may prove to give a brightness level to annoy the pilot enough that a further reduction to step 2 may be more suitable.