

Understanding Light Intensity Specifications for Flashing Signal Lights

GENERAL

The purpose of this reference section is to promote understanding of light intensity specifications for flashing signal lights.

The term "Effective Intensity" or "Candela Effective" is used by signal engineers to describe a flashing signal light which has the same signaling effectiveness as an equivalent steady burning light.

The method of calculating the Effective Intensity of flashing signal lights discussed herein has been taken from the IES Guide for "Calculating The Effective Intensity of Flashing Signal Lights, Section 4.3 Condenser-Discharge Lights" and is used by agencies of the Federal Government to specify strobe beacon Light requirements.

XENON STROBE FORMULAS

Electrical Relationships

- P = Power in watts
- J = Joules (Also known as wattseconds)
- F = Flashes per second
(flash frequency)
- C = Capacitance in microfarads
- V = Voltage in kilovolts

Basic Electrical Formulas

$$J = \frac{CV^2}{2}$$

$$P = J \times F$$

PHOTOMETRIC RELATIONSHIPS

- I_{eff} = Effective intensity (Also known as candela effective)
- HCPS = Horizontal Candlepower seconds
- BCPS = Beam Candlepower seconds
- M = Lens or reflector amplification factor
- ϕ = Efficiency of flashtube in lumen seconds/watt seconds
- Q = Light output of flashtube in lumen seconds (empirically derived for helix flashtubes)
- Lb = Foot-Lamberts background illuminance
- d = Distance in feet that a light intensity can be seen

BASIC PHOTOMETRIC FORMULAS

$$Q = J \times \phi \text{Lumen Seconds}$$

$$HCPS = \frac{Q}{10}$$

$$BCPS = M \times HCPS(\text{candela})$$

$$I_{eff} = 5 \times BCPS(\text{candela})$$

$$I_{eff} = (6.37Lb + 18.60)d^2 \times 10^{-7}(\text{candela})$$

$$d = \sqrt{\frac{I_{eff}}{\sqrt{(6.37Lb + 18.60) 10^{-7}}}}$$

PEAK CANDELAPOWER, CANDELA SECONDS AND CANDELA EFFECTIVE

When comparing two different warning lights, the first question usually asked is how bright are these lights and how do they compare to one another? This can be a complicated question when one is comparing very different light sources such as rotating incandescent lights and xenon strobe lights. Let's briefly discuss three different commonly specified "intensity" ratings:

- 1) **PEAK CANDELA or PEAK CANDLEPOWER** – This quantity is the maximum light intensity generated by a flashing light during its light pulse. It indicates NOTHING ABOUT HOW BRIGHT THE LIGHT APPEARS TO THE HUMAN EYE. Peak candela alone **cannot** be used to directly compare two warning lights. In addition there is **no** set multiplication factor for converting peak candela, a unit of luminous intensity, to either candela seconds or effective candela, both units of luminous energy. Tomar Electronics Inc. strongly discourages the use of peak candela ratings when comparing warning lights.
- 2) **CANDELA SECONDS or CANDLEPOWER SECONDS** – This quantity is the actual light energy contained in a pulse of light. Candela seconds is used by the Society of Automotive Engineers and the California Highway Patrol to specify the minimum requirements for light output from a flashing light because flash energy has been shown to be a relatively accurate and fair way of comparing radically different types of lights such as incandescent rotators and xenon strobe lights. Candela seconds is merely a relative measure of how bright a flash of light will appear to a human eye. A light with a higher candela second rating will appear brighter than a light with a lower candela second rating even if the lower rated light has a much higher peak candela rating.
- 3) **CANDELA EFFECTIVE or EFFECTIVE CANDLEPOWER** – Candela effective is based on candela seconds and attempts to equate the brightness of a flashing light source to the brightness of a steady burning source. If a flashing light has a candela effective rating of 100 then it will be visible at the same distance as a 100 candela steady burning source. The National Bureau of Standards, the FAA, and the Illuminating Engineering Society use candela effective in specifying intensities of flashing light source because this rating is the most meaningful when it becomes necessary to predict the visible range of flashing warning lights versus steady burning light sources.

Tomar Electronics uses only candela effective as measured using the technique outlined in the **IES GUIDE FOR CALCULATING THE EFFECTIVE INTENSITY OF FLASHING SIGNAL LIGHTS** using visible light only. We recommend only the use of candela effective or candela seconds when comparing any two flashing warning lights.

LENS PLASTIC TYPE AND COLOR

TOMAR uses only the finest optical grade plastics available. All lenses are molded from GE LEXAN® which is listed in the AAMVA publication entitled "Listing of Acceptable Plastics for Optical Lenses and Reflectors Used on Motor Vehicles" and meet SAE Color Specification J578d.

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SAMPLE CALCULATION OF STROBE LIGHT INTENSITY

Calculate the Effective Intensity of a typical Strobe Warning light as follows:

Suppose we consider a TOMAR Model 804 Single Flash Strobe Light which operates at a lamp voltage of 400 Volts with a 150 MFD capacitor. Let's also assume a flash rate of 85 flashes per minute.

The input energy of the flashlamp is...

$$J = \frac{CV^2}{2} = \frac{150 \times .4^2}{2} = 12 \text{ Joules per flash}$$

and the average power is...

$$P = J \times F = 12 \times 1.4 = 16.8 \text{ Watts input to lamp}$$

Next, the total spherical light output "Q" of the flash tube can be estimated (by assuming a conversion efficiency of 35 Lumen seconds/watt seconds) to be...

$$Q = J \times \phi$$

$$Q = 12 \times 35 \text{ lumen seconds/watt second}$$

$$Q = 420 \text{ lumen seconds}$$

Next, convert total spherical light output to "HCPS" Horizontal Candle Power Seconds to depict the intensity seen by a distant observer

$$\text{HCPS} = \frac{Q}{10} = \frac{420}{10} = 42 \text{ HCPS}$$

This is the intensity of the lamp without the outer lens. Next add the effect of the lens by computing the Beam Candle Power Seconds

$$\text{BCPS} = m \times \text{HCPS} = 2.0 \times 42$$

$$\text{BCPS} = 84$$

Last compute the Effective Intensity...

$$I_{\text{eff}} = 5 \times \text{BCPS} = 5 \times 84 = 420 \text{ Candela Effective}$$

Please note that the actual light output of a typical commercial strobe warning light depends on a number of factors which can vary the light output by a factor of 10 or more for a given amount of Joules per flash, some of these factors are:

- Color of lens
- Size and efficiency of lens
- Physical shape of strobe lamp and arrangement within lens (optical coupling)
- Efficiency of strobelamp itself

Therefore, Tomar Electronics recommends that only certified light output in candelas effective, or candela seconds including visible radiation only, be used when comparing the intensity of various lights, and Joules per flash times flash frequency be used to determine the capability of the power supply only.

SIGNAL LIGHT LUMINOUS RANGE CALCULATION

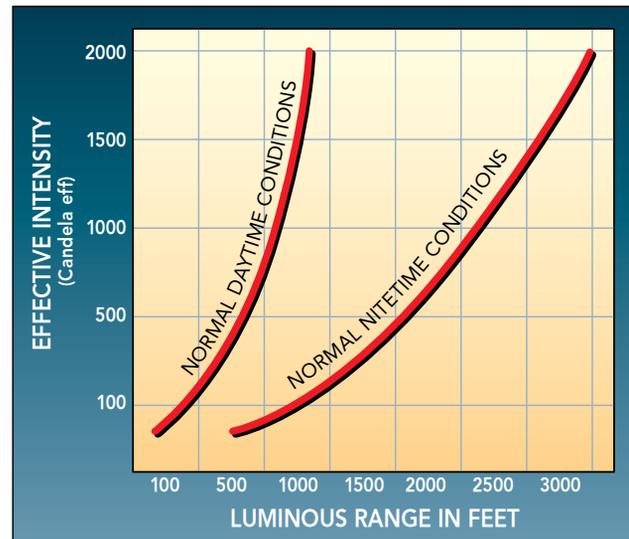
The fundamental quantitative specifications needed for warning lights is intensity. This is not a simple matter. The brightness required for "adequate" warning depends upon the individual's physical and emotional characteristics, the ambient light level, and the entire visual context. This problem has been studied by others, and the results of studies by Cole and Brown for traffic signals in general are shown here to provide a useful guide to determine the viewing distance of a light with known intensity.

Their basic finding is that the source intensity I_{eff} (candela) appropriate to a viewing distance d (ft), with ambient illuminance L_b (ft-Lamberts), is given by the expression

$$I_{\text{eff}} = (6.37 L_b + 18.60)d^2 \times 10^{-7} \text{ (Candela)}$$

As an example, "Normal daytime conditions"

($L_b = 2919 \text{ ft-L} = L$) imply $I_{\text{eff}} \approx 200$ candela to be necessary for a viewing distance of 330 feet. Background illuminance can, at times, reach three to four times this value. Further, the intensity required if one seeks to alert as well as inform can increase this value. However, this equation provides a useful starting point, and is readily modified if necessary.



NOTE: THESE CURVES ARE BASED ON NORMAL VISIBILITY