Equivalent Visual Efficiency Factor

As LED lighting becomes more widely adopted there has been quite a bit of discussion on Scotopic vision vs Photopic vision. In a nutshell Scotopic refers to how the eye sees in low light conditions. Photopic refers to how the eye sees in high light conditions and where colors can be seen. Our high school anatomy class taught us about rods and cones. Rods are the cells in the eye that allow us to see in low light conditions or scotopic vision. In terms of wavelength rod cells or scotopic vision are most sensitive to light wavelengths around 498 nm or green-blue light and are largely insensitive to light wavelengths longer than 640 nm or red light. Cones are cells in the eye that activate in well-lit conditions and allow us to see different colors. They are roughly the complement to the rods in terms of light wavelength sensitivity. This difference in types of vision as it relates to luminous efficiency compared to the wavelength of the light can be seen in figure 1.

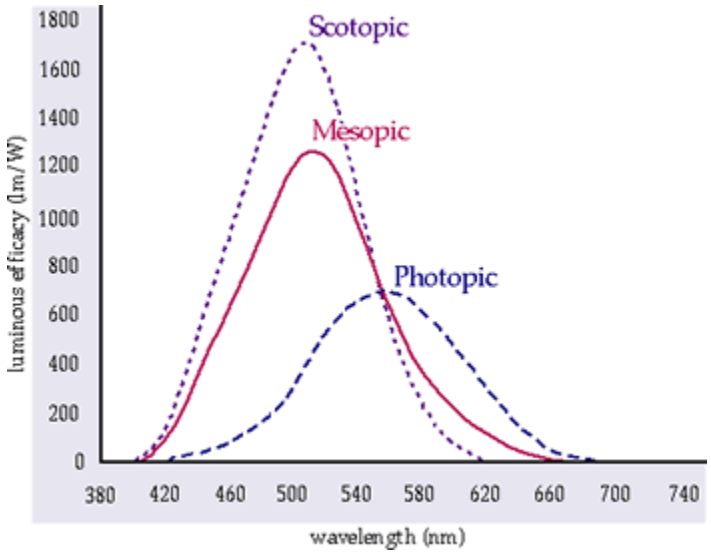

Figure 1. Lighting Research Center

The graph shows that as the wavelengths get longer as in photopic vision our eyes have a harder time processing the light which reduces the luminous efficiency. This is because there is 120 million rods (scotopic range) and only 6 to 7 million cones (photopic range) in the human eye.

So what does all this have to do with LED lighting? In the lighting industry the historical way to measure light has been to use a light meter and measure foot candle or candela light output. This is not always best however when applying LED lighting due to how the eye actually uses light and it's scotopic versus photopic vision characteristics.

Earlier we stated that scotopic vision or our rods were most active in the green-blue color spectrums. Well what are white LED's? They are actually blue LED's coated with some phosphorous to create a white appearing light. Thus, LED's perform significantly better in Scotopic or dark conditions. Even though traditional light meters measure lower light levels with LED than traditional HID lighting the human eye perceives light conditions to actually be better. Ask for our previous paper published 8/28/2012 and titled "LED lighting for Car Dealers". Notice the candela numbers and look at the pictures to understand this difference. The light meter said there was less light but the eye said there was more and the colors of the cars look better as well.

1000 Watt Metal Halide producing 22.9 measurable foot candles

270 Watt LED fixtures producing 4 measurable foot candles

Several experiments have confirmed the difference between light meters and the human eye. The most cited of these is an experiment at the Intel campus in Hillsboro, Oregon. Dr. Sam Berman's article "The Coming Revolution in Lighting Practice," details how Intel facilities staff observed during the study that one could see better under the scotopically rich lights. In the past it was not believed feasible to replace 1000 Watt HID lights with LED lights. Our company Electro-Matic Products Inc. is now replacing 1000 Watt HID lights with 270 Watt LED lights and getting very good results.

This new data has created a new set of standards and equations for calculating equivalent light levels for LED's compared to the HID style lighting. The first value that must be considered is the ratio of scotopic to photopic levels that the light produces. This value is expressed as a ratio of scotopic over photopic (S/P). A higher S/P ratio allows for less foot candles to be needed to achieve the same amount of perceived luminance. Table 1 shows a list of typical S/P values for a variety of different types of luminaires.

Lamp Type	**Typical S/P Ratio**
Low-pressure sodium	0.2
High-pressure sodium	0.4 to 0.6
Halogen headlamp	1.4
Linear fluorescent	1.3 to 2.3
Metal halide	1.2 to 2.1

Table 1: IES TM-12-12

The CREE chip that is currently being used in all of our fixtures has an S/P ratio of 1.49. This information is published in CREE's photometric testing and evaluation of the XP-G2 chip, report number CESTL-2013-0068 and was conducted on March 21, 2013.

The IES TM-24-13 standard uses figure 2 to calculate the reduction allowed by finding the equivalent visual efficiency (EVE) factor. This factor is produced as a percentage allowing it be applied to any value regardless of what units the light is being measured in.

$$P_2 = P_1 \cdot \left[\frac{(S/P)_1}{(S/P)_2}\right]^{0.8}$$

Figure 2

Sample Problem High Pressure Sodium:

Recommended light level using HID: 1.5f.c.
Assumed S/P value for existing High Pressure Sodium: 0.6
Recorded value for LED replacement fixture: 1.49

Variables
P1 = 1.5
S/P1 = 0.6
S/P2 = 1.49
0.8 = is the approximation of the decreased pupil size

$$P2 = 1.5 * \left[\frac{0.6}{1.49}\right]^{0.8}$$

This creates a reduction of 48% which applied to the 1.5f.c. allows .72f.c. to be used without a noticeable difference in brightness.

Sample Problem Metal Halide:

Recommended light level using HID: 1.5f.c.
Assumed S/P value for existing High Pressure Sodium: 0.6
Recorded value for LED replacement fixture: 1.49

Variables
P1 = 75
S/P1 = 1.2 (typical for older metal halide fixtures)
S/P2 = 1.49
0.8 = is the approximation of the decreased pupil size

$$P2 = 75 * \left[\frac{1.2}{1.49}\right]^{0.8}$$

This creates a reduction of 16% which applied to the 75f.c. allows 63f.c. to be used without a noticeable difference in brightness. The S/P1 value of 1.2 for metal halide is assuming that the fixtures are still producing white light and have not discolored due to age. Any discoloration in the light will reduce the S/P ratio for the existing fixture.

This new way of designing based on perceived brightness allows lighting designed to be even more efficient and cost effective. It is important when trying to apply LED lighting as an energy-saving substitute for traditional HID lighting, it is not as simple as taking light meter readings and matching up similar candela or foot-candle outputs. As it turns out due to the better performance of LED lighting in the Scotopic vision of the human eye, we can use less LED light and get much better performance as viewed by the human eye. The human eye is far superior to measuring light than a simple light meter.