Indulux Technologies Inc.

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S/P Ratio Considerations

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Abstract:

As people pay more attention to the visual effects of lighting technologies, Scotopic/Photopic (S/P) ratios of the light sources play an increasingly important role. The S/P ratios quoted for almost all induction lighting products are currently an approximation, based on valid data. There are many variations in S/P ratios caused by a number of factors. The only true way to determine the actual S/P ratio of a particular light source is to measure it in the appropriate manner.

Why is S/P Ratio Important?

It is gratifying to see that some of the major manufacturers are now publishing S/P ratios for their products - for example, see http://genet.gelighting.com/LightProducts/Dispatcher?REQUEST=COMMERCIALSPECPAGE&PRODUCTCODE=46724&BreadCrumbValues=CATG,_Lamps_Linear%20Fluorescent_Straight%20Linear_T5&SearchFieldCode=null It is to be hoped that this trend will continue and that other lighting manufacturers will start offering this data.

The Scotopic/Photopic ratio of a light source is important to calculating the Visually Effective Lumens (VEL - also called Pupil Lumens) produced by a lamp. Since we are lighting for human vision, and since the 1951 CIE curve used by typical light meters only takes primarily Photopic vision into account (see graphs on next page), it is important to use the S/P ratio to determine the actual amount of light useful to human vision which is delivered, rather then just the "meter lumens". Those who slavishly follow the readings shown on light meters calibrated to a half-century old standard, will be over-lighting areas to satisfy the meters and thus wasting energy and resources, plus contributing to Co2 emissions.

The S/P ratio is used as a multiplier to determine the amount of light the lamp is emitting that is useful to human vision. If a 150W High Pressure Sodium (HPS) lamp has a rated output of 84.2 lumens per watt and an S/P ratio of 1.14, and a 100W, 5000K, induction lamp has a rated output of 78.5 lumens per watt and an S/P of 1.96, we can apply the respective S/P ratios as follows:

- 150 W HPS lamp X 84.2 L/W = 12,630 Lumens X 1.14 = 14,398.2 VEL.
- 100 W Induction lamp X 78.5 L/W = 7,850 Lumens X 1.96 = 15,386 VEL - more useful light for 33% less energy! (ignoring for the moment the ballast overhead).

Using the S/P ratio, we can see why Induction Lamp based Highbay fixtures can reduce energy consumption by replacing a conventional lamp of a much higher wattage:

- 400W Metal Halide lamp X 54.6 L/W = 21,840 Lumens X S/P of 1.49 = 32,541 VEL
- 200W Induction lamp X 82 L/W = 16,400 Lumens X S/P of 1.96 = 32,144 VEL

Note: The calculations above do not take into account actual electrical energy consumption which would include losses in the ballasts and would show the Induction Lamp to be even more efficient.

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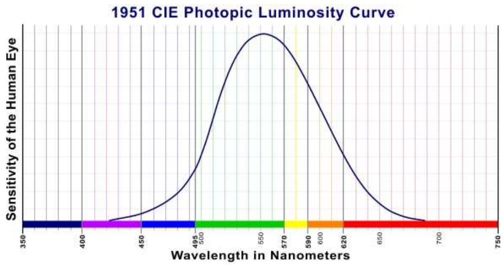
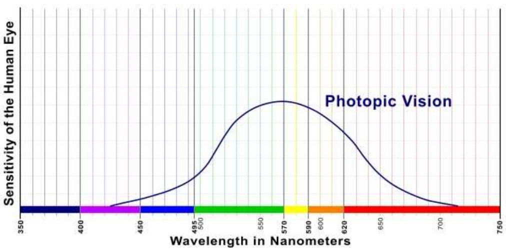
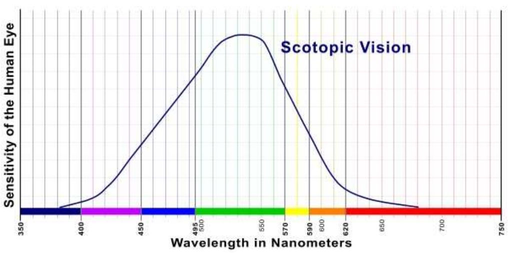


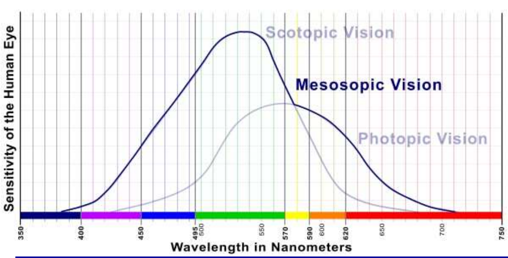
The 1951 CIE Photopic Luminosity Curve - The calibration curve used in typical light meters (on left), peaks around 550 nanometres which is in the green region. Thus light sources which emit a large amount of green are seen by light meters as "brighter" than other light sources which, while they may have less green, have other spectral components that are equally important for good vision. This is because the meter calibration is largely ignoring additional blue components in the lamp output which are seen by the scotopic vision of the human eye (See chats blow).



Photopic vision - This is the scientific name for human vision under well lit conditions such as daylight or bright artificial light. The cone cells are responsible for sensing light in three different bands of colour, Red (around 575 nanometres), Green (around 535 nanometres), and Blue (around 445 nanometres). We use Photopic vision in daylight and the CIE response curve used in light meters is close to the spectral sensitivity of Photopic vision.



Scotopic vision - This is the scientific name for the generally monochromatic vision of the eye in low lighting conditions, so-called "night vision". The rod cells are responsible for Scotopic vision and they are more sensitive to blue light than other colours. The CIE response curve for light meters does not take Scotopic vision into account.

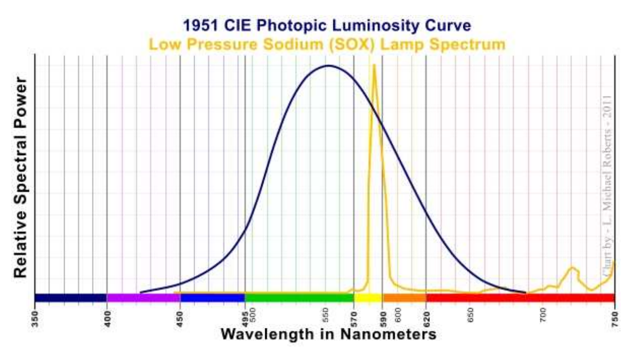


Mesopic Vision - This is the scientific name for a relatively new way of looking at human vision which takes both the Photopic and Scotopic visual response curves into account. This is somewhat complicated as it takes the extra element of wavelength sensitivity into account.

Why The Light Meters are Wrong - A Practical Example

For years, and even today, Low Pressure Sodium lamps (LPS/SOX) have been touted at the most "energy efficient" light source as they appear to provide the highest lumens per watt when measured with conventional light meters calibrated to the 1951 CIE curve.

Looking at the diagram on the right, we can see why this claim is made, despite the fact that the light is almost monochromatic. The yellow/orange light of LPS lamps does not allow for quality vision. You will note from the graph that the LPS lamps (orange line) have a very large and well defined output spike around 589 nm. This spike occurs near the peak of sensitivity of the CIE Luminosity curve (blue line) of around 550 nm. As a result, the LPS lamps score high in the Lumens/Watts readings, while actually producing nearly monochromatic light where people have difficulty distinguishing colours and which is not pleasant to work under.



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Current Induction Lighting S/P Ratios:

The S/P ratios currently used by almost all of the induction lighting manufacturers today can be traced back to charts first published in “The Science Behind Magnetic Induction Lighting” paper. Those S/P ratios were derived in consultation with Francis Rubenstein but were based on using the colour temperature of the induction lamps for placement on the S/P ratio chart.

While this approached is reasonably accurate - within +/- 7.5% - there are a number of factors that can influence the actual S/P ratio of the Induction Lamps.

Factors that influence S/P ratios:

There are a number of factors which influence the S/P ratio of an Induction lamp (or of fluorescent lamps for that matter as induction lamps produce light by the same principal);

- Most of the manufacturers use a standard, pre-mixed, tri-phosphor coating from domestic suppliers. China limits the export of ‘rate earth’ materials thus imported phosphors tend to be much more expensive.
- Even within the 5,000K coatings (as an example) provided by the domestic suppliers, there are variations in the amount of red, green and blue phosphors in the mixture. While the overall colour temperature is 5,000K, these minor variations in the ratio of the Red, green and Blue phosphors can affect the S/P ratio.
- Further, even small batch-to-batch variations in the phosphors can lead to colour temperature drift of as much as +/- 500K.
- Within the domestically produced tri-phosphor coatings, there are also variations in the types of the red, green and blue phosphors used. Each particular phosphor has its peak of spectral emission at a different wavelength, so while the overall colour temperature may be as specified, the differences in emission peaks can cause variations in the S/P ratio. Thus a 5000K formulation from supplier A may have a slightly different S/P ratio than a 5000K formulation from supplier B.
- The gas fill within the induction lamp can also play a role in the S/P ratio depending on it’s composition. Some gas fills will produce slightly more blue, red or green light which can affect the overall spectral balance of the lamp. This is more likely to be a manufacturer-to-manufacturer variation as each manufacturer tends to use their own gas-fill formula.

Since the overall objective of the manufacturers is to produce lamps with as low an input cost as possible, little attention has been devoted to the effort of formulating a phosphor coating that offers a high S/P ratio and consistent colour temperatures (less than +/- 250K drift). The manufacturers tend to use the standard domestic coatings as used in the production of CFL lamps as these phosphors are plentiful and relatively cheap.

Measuring the S/P ratio:

Since the industry currently relies on approximations published some years ago, and customers seem to be happy to accept these approximations, no real effort has gone into providing

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more accurate numbers.

To accurately determine the S/P ratio of a lamp, the ideal approach would be for the manufacturer to conduct tests in an integrating sphere. The test would require the mounting of the lamp and then running it for 30 minutes so that the emissions have had time to stabilize and the lamp is at the maximum working temperature.

A standard spectral sweep would then be taken for reference purposes. This will give you the total light output data and the spectral break down of the light output. A second sweep would now be run but this one would be based on the Photopic sensitivity curve only. This would provide the total light output in the Photopic region. Similarly, a third sweep based on the Scotopic sensitivity curve is also required to determine the light output in the Scotopic region.

The best method of doing this would be to place a dielectric Photopic curve pass-band filer over the detector for the second sweep, and then a Scotopic pass-band filter for the third sweep. This is somewhat time consuming, impractical and expensive. A more practical method would be to use filtering software, adjusted to the Photopic and Scotopic curves, so that all the data could be derived in a single pass. Once you have the data-sets for the Photopic and Scotopic regions, it is fairly east to crunch the numbers and derive the S/P ratio.

As an alternative, and something of interest to induction lighting professionals, one can use a portable S/P ratio meter such as the SL-3101 Dual Scotopic/Photopic Meter. The advantage of this approach is that you can measure the light levels and S/P ratio of the HID lighting to be replace for a set of 'before' measurements. These measurements can be initialed by the client and a copy provided to them. After the induction lighting is installed, measurements can again be taken, initialed, and a set provided to the client so that they can see for themselves that the light levels match, or have been exceeded based on the S/P and VEL of the lighting.

Obviously, the two sets of light measurements have to be taken according to the same protocol. For example, you should take 4 or more measurements distributed throughout the space so you can average them. Measurement locations should be marked on the floor with tape, marker or paint so that they can be taken on the same places for each of the before and after measurements. Finally, care must be taken to exclude external light sources such as lamps in adjoining areas that spill over into the are you are working on, or skylights which will necessitate measuring after dark.

Along with before and after real-time wattmeter measurements, the light level measurements show that the induction lighting has successfully replaced the previous lighting [or even improved the light levels] while demonstrably showing the energy savings on the wattmeter.

Summary:

Until such time as induction lamps manufacturers devote the time and effort to formulating their own high S/P phosphor coatings and perform actual measurements on the resulting products, we will have to be content with the reasonable approximations of S/P ratios we are using now.