

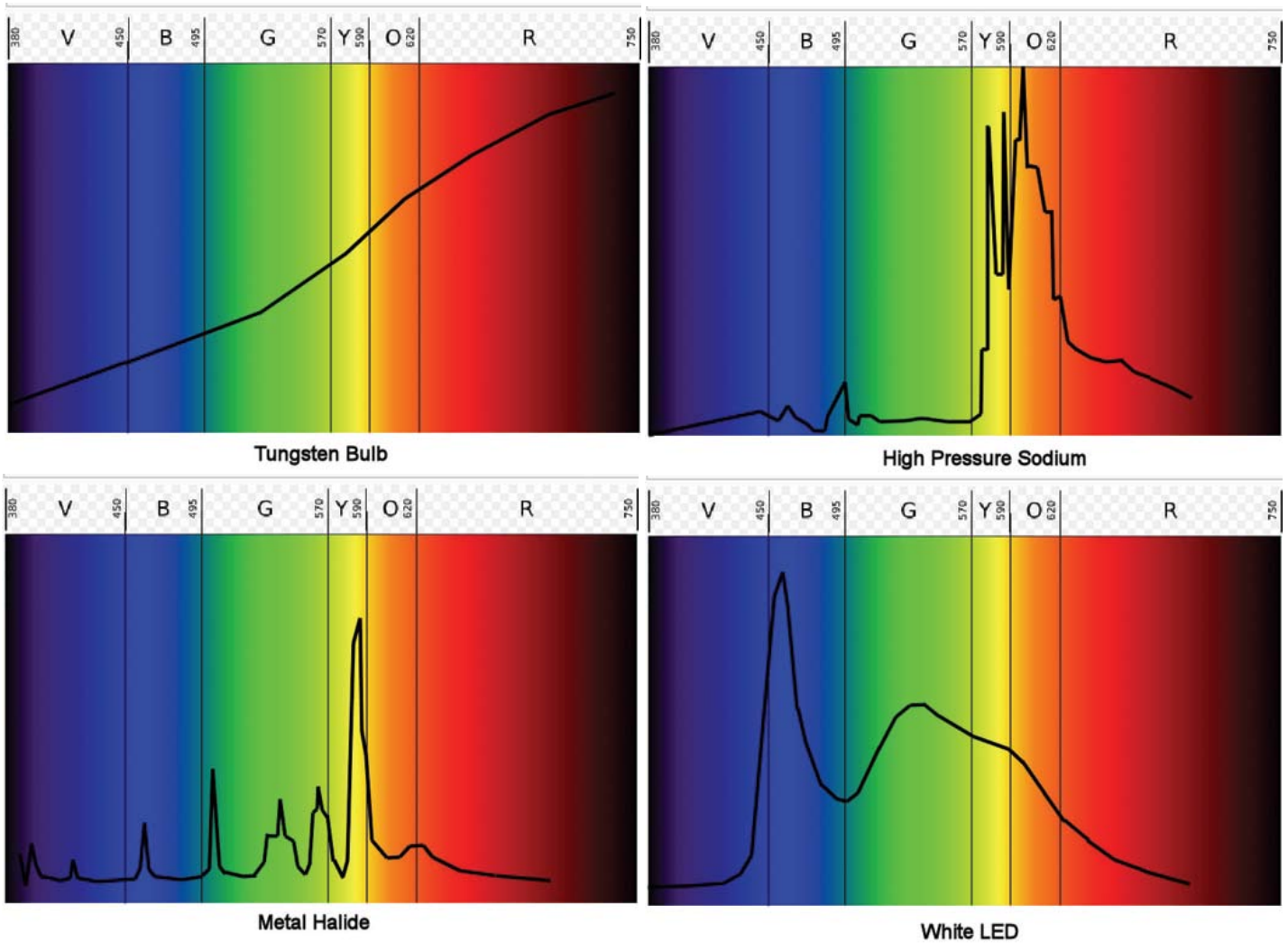
The Performance of LEDs in Low-Visibility Weather Conditions

By Don Lincoln, Product Manager, Lumecon

Regarding the superiority of LED lighting in low visibility conditions such as fog, there is a very limited amount of research data available on the subject and some practical field experience from which to draw an explanation. I'm not a physics expert, but I will make my best attempt at summarizing what I have found related to why LEDs are better for use in low-visibility conditions, and fog in particular. This is by no means meant to be an expert technical treatise on the subject, but it is a compilation of some formal and informal research on the subject from numerous sources.

From what I can gather from the available literature, the advantage of LEDs in fog can be attributed to the inherent directionality of the beam of light emitted and the inherent bichromatic wavelength characteristics of white LED light and the frequency of that wavelength in comparison to other light sources.

The visible spectrum of light ranges from about 400 to 700 nm in wavelength, and each of the different types of light sources has its own characteristic pattern of peaks that equate to where on the spectrum the majority of their energy is emitted as visible light. Sodium light sources emit energy primarily in the yellow and orange bands of the visible spectrum, and this is why the light appears yellow to our eye. White LEDs, which are the kind that we use in our high output fixtures, are actually blue LEDs with a small amount of a yellow phosphor mixed in to yield what appears to be white light. So the white LED light exhibits a bichromatic pattern primarily in the blue and green bands. I have included the spectral signatures of a few different types of light sources for comparison:



The difference between LED lighting and all other light sources is the predominant wavelength at which it emits energy, and how water droplets interact or affect a beam of light at that wavelength, especially as the size of those water droplets changes. Light in the violet region of the spectral range has a shorter wavelength than light in the red region. Water vapor particles in the atmosphere will generally pass light that is in the yellow-orange-red range, but it will tend to scatter blue light. This appears to be due to the fact that water particles are generally of similar size to the blue wavelength, which is

Continued on page 36

The Performance of LEDs in Low-Visibility Weather Conditions . . .

Continued from page 34

around 400nm¹. This phenomenon is called Rayleigh scattering, and is the reason why the sky is blue (now I know!), and is the reason why the sun appears yellow, as this is the visible light that makes it to the ground.

However, in foggy conditions, the size of the water vapor particles is increased to the point where they are no longer of similar size to the blue light wavelengths, and are now of similar size to the yellow-orange-red wavelengths, and will tend to scatter and extinguish light in these bands, but will pass blue light.² This is why sunlight will sometimes appear bluish or greenish through a fog. Given this, light sources that primarily already emit light energy within the blue wavelength of the visible spectrum will perform much better in foggy conditions than other light sources. It should also be noted that as with any relatively new technology, there is also some conflicting research that shows that it is the yellow and red LED lights that are more visible, and not blue or green ones.³

Peter Hochstein (founder of Relume) also believes that forward light scatter also contributes to the superior performance of LEDs:

“From a purely physical optics standpoint, distributed sources [LEDs] generally do a better job in reducing interfering backscatter compared to single higher intensity sources. But the real question is more likely the forward scatter - which is basically uncontrolled light that interferes with vision. In that regard, the LEDs are better, as the extreme cut-off that we can achieve [directionality] virtually eliminates ALL light above the horizon. Achieving such cut-offs with either MH or HPS lamps is difficult, especially if the lamp is to cover much more than one mounting height. The merits of effective cut-off or dark sky compliance are easily seen with existing HPS lamps in Troy, MI. The new lamps along Big Beaver by the Somerset Mall are a mixture of cut-off and non cut-off [drop lens] fixtures. In relatively dense fog, the advantages that the cut-off fixtures provide are immediately apparent as the driver isn't trying to look past the bright veil of scattered light from the drop lens luminaires.”

In practical terms, what Peter is saying is that the advantage that LEDs have in these conditions is the same advantage that they have in any circumstance, in that it is a directional emission source as opposed to a spherical one. Imagine trying to light your way down a foggy pathway using a bare tungsten bulb. The difficulty is that you cannot see your way through the mass of scattered light being thrown out in all directions from the bulb, and the result is that what little light that is making it to the pathway and reflected back to the observer would be obscured by the much brighter “glob” of scattered light from the bulb itself. Now imagine lighting the same pathway using a directional light source, such as the narrow conical beam of light from an LED light source. You do not get the same scattered glob of light surrounding the “bulb” because the bulb is only emitting light from a relatively small percentage of the dome surface area of the LED. To use a weak analogy, it is the difference between slicing a watermelon with a knife rather than a bowling ball.

Beyond all of this, there have been some real-world studies done on the effectiveness of LED light versus other light sources in low-visibility conditions. The FAA has some ongoing and as-yet unpublished research being conducted on this, and that one of the primary reasons why many airfields are converting much of their signal and runway directional lighting to LED is because of its visibility in foggy and rainy conditions as reported by pilot observation surveys.

Finally, there was an informal study of the use of LED highway warning lights in low visibility conditions by the North Carolina DOT, which showed that the LED lights were the only source capable of being visible at distances in excess of 1,500 feet in fog.

FOOTNOTES:

¹ <http://www.worsleyschool.net/science/files/bluelight/scattering.html>

² “Apparent Anomalous Extinction in Fog,” M. Gazzì, et al, *Atmospheric Environment*, Vol. 35, Sept. 2000, pp. 5151-5156.

³ <http://resources.metapress.com/pdf-preview.axd?code=vw520545578k6341&size=larger>