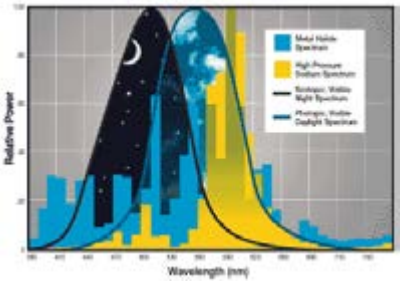
Lighting Design for Low Light Levels



Studies on nighttime visibility demonstrate experimentally that the sensitivity of the human eye to different colors of light at various light levels determines the true, or effective, lumen output of a lamp. Recent research shows that the color output of the light source has a significant effect on nighttime visibility, which is important because road accidents occur mostly at night. Also, it is well known that the eye responds to color depending upon the amount of light available.

Photopic, Scotopic And Mesopic Conditions

Lumens are the standard measure of light output, but light is actually defined as energy evaluated by the eye. Standard lumen measurements define the light output response of a person only during high light levels (called photopic light), typical of daylight and interior lighting. The light meter measures photopic light as seen by the central region of the eye.

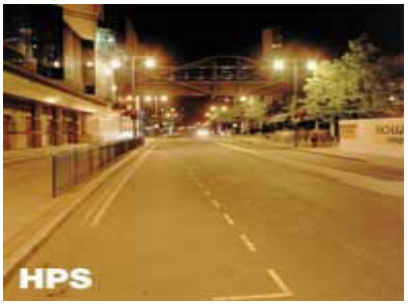
When light levels are very low, like starlight, the viewing conditions are referred to as “scotopic.” Under these conditions, the eye’s visual response changes dramatically. Sensitivity to yellow and red light is greatly reduced, while response to blue light is vastly increased. If lamp lumens under scotopic viewing conditions have been determined using photopic measurements, the lumen value does not accurately measure the true amount of light production as perceived by the human eye.

The eye response does not shift suddenly from high light levels to low light levels. A gradual change occurs as light levels are reduced in twilight and typical street lighting conditions. This is the “mesopic” condition in which the eye’s response lies somewhere between photopic and scotopic.

Rods And Cones

The change in the eye’s spectral response is due to the presence of two types of light receivers in the retina, called rods and cones. Rods are responsible for human vision at low light levels and are located in the peripheral field of view. Conversely, only objects viewed directly by the eye are seen by the cones. Rods are sensitive to scotopic light; cones react to photopic light. Therefore, as the light level is reduced, cones become less active and rods become more active.

Eye Color Sensitivity And Lumens



The value of a lamp’s lumen output is different when considering the shifting color sensitivity of the eye at low light levels. The effective lumens will be different from the measured photopic lumens. As light diminishes from photopic to scotopic conditions, the effective lumens of yellow HPS light sources are reduced and the effective lumens of white light with blue/green content increases.

This effect is dramatic for low pressure sodium (LPS) lamps. Almost all energy output from this lighting system is yellow, resulting in high photopic lumen output. At low light levels, the effectiveness of LPS lamps is drastically reduced.

Metal Halide Lamps For Low Light Levels

A typical metal halide lamp has strong light output in the blue, green and yellow areas, resulting in high lumen output at all light levels. The blue light output of metal halide is in the high sensitivity region of the eye for low light levels. This means that the effective lumens actually increase for a metal halide lamp as the light level reduces and the eye shifts to a blue/green peak sensitivity.

The ability to detect fine contrast is also significantly better under metal halide sources than sodium. Reaction time under LPS and HPS lighting is roughly 50% longer than for metal halide. Therefore, the color output of a light source has an important influence on safety. Studies have shown that metal halide lighting, in some circumstances, can be up to six times as effective as HPS. This can make a difference in peripheral viewing and dark areas where hidden hazards may be present.