CAP LAMP LIGHTING

NIOSH conducted LED cap lamp research in two phases, where the first phased focused on enhancing the color of light to improve visual performance, especially for older workers. The second research phase focused on the lighting distribution such that floor and moving machinery hazards received more light to improve visibility.

Phase I: Light color

In general, as a person's age increases less light reaches the retina. One method to address this is to increase illumination; however, this has the negative effects of increasing glare and decreasing the availability of battery power for battery-powered lighting such as cap lamps. Our approach to address age-related issues was to manipulate the visible light color spectrum of a cap lamp so that the light is perceived brighter although the luminous flux is the same as measured by mesopic photometry. At low-light (mesopic) ambient conditions found in underground mining, an increased short-wavelength spectral content can improve visual performance because the eye is more sensitive to short wavelengths of visible light. Prior research findings indicated that visible light having more short-wavelength energy enables improved detection of off-axis objects when the visual environment is mesopic (He et al., 1997; Van Derlofske et al., 2005; Bullough and Rea, 2000). NIOSH developed an LED cap lamp that used cool-white LEDs that emit more of the short wavelengths of light as compared to warm-white LEDs or INC lights. Cool-white LEDs have more short-wavelength energy thus giving the appearance of bluish-white light versus traditional warm-white INC bulbs that emit a yellowish light and have more longer-wavelength energy. There are categories of white available for LEDs such as warm-white, neutral-white, daylight, and cool-white.

The results of a comparative study using an INC cap lamp, a commercially-available LED cap lamp, and a NIOSH prototype LED cap lamp indicated significant improvements for older subjects when using the NIOSH prototype LED cap lamp. Moving hazard detection improved 15.0%, trip hazard detection improved 23.7%, and discomfort glare was reduced 45.0% (Sammarco et al., 2009c, 2010b).

Phase II: Light distribution

The lighting distribution from cap lamps has traditionally been provided by a single, primary light source along with a circular optical reflector to direct light to a circular spot ranging from about 6° to 10° as depicted by Figure 4 (left photo). This is very similar to a flashlight—a design approach unchanged since the 1914 Edison cap lamp. This spot beam provides a tunnel vision visual environment that limits peripheral vision given that it provides very little illumination of the floor or mine ribs. To address this issue, NIOSH developed a prototype LED cap lamp having a radically different beam distribution as depicted in Figure 4 (right photo). This cap lamp has multiple, phosphor-white LEDs as the primary light source along with secondary total internal reflection optics to direct and distribute the light to specific hazardous areas in the mine. The intent is to provide more illumination for miners in order to facilitate detection of STF hazards located on the mine floor, as well as the detection of moving machinery hazards associated with pinning/striking accidents. The NIOSH prototype LED cap lamp meets the required photometric requirements (CFR, 2005). The cap lamp beam distribution and intensity are software controlled. This enables the flexibility of matching the cap lamp lighting to the task at hand which varies considerably. For instance, the visual needs vary between a roof bolt operator and a mechanic. Currently, cap lamps have a "one size fits all approach" where an intense, tight spot beam is provided regardless of the visual task.

NIOSH researchers conducted the investigation by comparing two commercially-available LED cap lamps and a NIOSH prototype LED cap lamp at varying power settings. The cap lamps had similar spectral power distributions; thus, the visible light color was not a factor for the visual performance of hazard detection. Visual performance was quantified by measuring times of detection for finding rotating targets in the peripheral field of view, which is important for detecting moving machinery hazards and trip and fall hazard objects on the floor.

Results show that the NIOSH prototype LED cap lamp improved the ability to perceive objects in the visual field by improving peripheral motion detection times by as much as 79.5% and up to 94% faster trip hazard detection, no increase in discomfort glare, and using up to 50% less power compared to commercially available LED cap lamps (Reyes et al., 2011) (Sammarco et al., 2011).

LIGHTING AND THE PHYSICAL BODY

Balance

Lighting can influence the performance of people in the industrial workplace by way of ten mechanisms that include visual performance, visual comfort, visual ambience, interpersonal relationships, job satisfaction, and problem solving (Juslén and Tenner, 2005). Poor lighting and reduced visual feedback decreases detection of STF hazards and has also been shown to decrease postural stability, increasing one's risks for falls (Brooke-Wavell et al., 2002). Therefore, an initial investigation involving human subjects was conducted to determine if cap lamp lighting significantly influences measures of static postural stability (displacement and velocity of center of pressure).

Fig. 4. Illumination from a traditional LED cap lap (left) and from the NIOSH LED cap lamp (right).

Subjects were tested for balance in addition to visual screening tests. Only subjects who passed balance and visual screening tests were accepted for the study. The balance screening tests consisted of horizontal gaze nystagmus, walk and turn, one-leg stand, and Romberg tests (Khasnis and Gokula, 2003; Tharp et al., 1981). First, baseline balance measurements were collected given the lighting conditions found in a laboratory environment. The data were collected as a subject stood on a force plate (ACCUGAIT, Advanced Mechanical Technology, Inc., Watertown, MA). Next, testing was conducted in the NIOSH Safety Research Coal Mine (SRCM). A force plate was embedded into the mine floor flush with the walking surface of the mine. From the force plate, an un-obstructed view of 287.7 m (944 ft) could be seen down an entry that had a nominal width of 3.2 m (10.5 ft). All mine light sources were turned off during testing with the only light source coming from the cap lamp being tested. Three cap lamps were used. Two of them were commercially available and used a single phosphor-white LED as the primary light source, along with an optical reflector to direct the light to a circular spot beam ranging from about 6° to 8°. The NIOSH LED cap lamp was the third cap lamp.

Results of this investigation showed no statistically significant differences in the balance measures of interest among three LED cap lamps tested. However, balance was shown to significantly decline ($p < 0.05$) when tested in the SRCM compared to the laboratory baseline testing condition. A significant limitation of this initial investigation concerned the nominal entry width of