What color are your markers?

Color of escapeway markers does make a difference

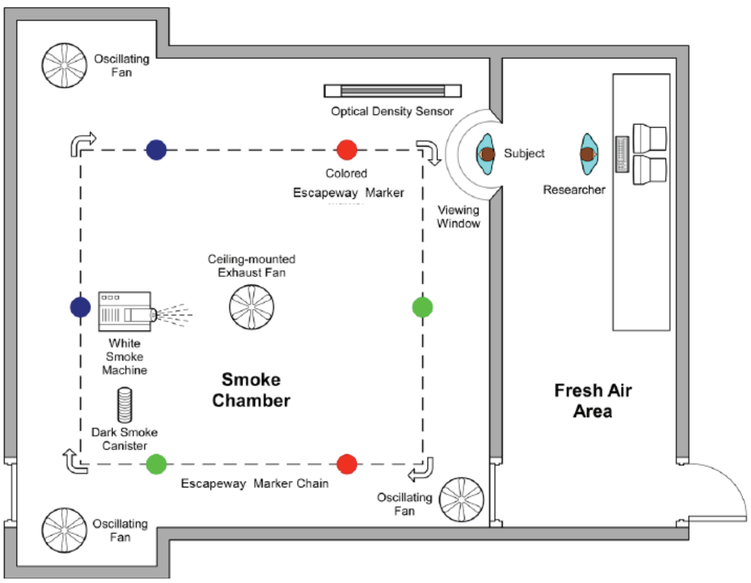
by John J. Sammarco

The mining industry has made great strides in making mining safer and reducing the occurrence of mine disasters. Nevertheless, sometimes miners encounter smoke while trying to escape from a mine. Underground miners use different visual cues to help them escape from a smoke-filled environment. Foremost, miners look for primary and secondary escapeways that are typically indicated with reflective markers of various colors, with at least 11 colors available from manufacturers. Federal regulations require that escapeways be marked, but they do not specify the colors to be used. Thus, no standard color code exists and some colors can be more difficult to see in a smoke-filled mine.

Researchers at the National Institute for Occupational Safety and Health (NIOSH) Office of Mine Safety and Health Research (OMSHR) tackled this problem by taking a human-centered approach to provide miners with better visual information that would improve their ability to see escapeway markers in smoke, thus enhancing their ability to self-escape.

Figure 1

Floor plan of the Mine Illumination Laboratory smoke chamber (not to scale).



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What marker colors does your mine use?

Does your mine use blue retro-reflective markers to indicate primary or secondary escapeways? Is your mine ready to purchase new or replacement retro-reflective markers? Color is important and blue had the poorest visibility as determined by OMSHR's recent research investigating the visibility of markers in smoke. OMSHR researchers are not alone in their interest to improve a miner's ability to escape — specifically when their efforts are hampered by smoke. For instance, there is a LinkedIn Mining Safety subgroup called "Standardized Color Code for Escape Ways and Returns in Underground Mines," and a recent National Academy of Sciences report recommended the development of human-centered technologies to enhance self-escape from underground mines. The mining industry has a common goal of helping improve miner safety, especially when it can be done by way of a simple and relatively low-cost solution of using escapeway colors that are more visible.

The vision science behind the research

All colors are not created equal for the human visual system. The eye is more sensitive to certain colors depending on the level of ambient lighting. For instance, we know from vision science research that green is most visible when the ambient light is daylight (photopic), while violet is most visible when the ambient light approaches moonlight (scotopic). In underground mines, the ambient lighting falls in a range between photopic and scotopic — that range is called mesopic — where the peak sensitivity moves from green toward colors with shorter wavelengths such as cyan. Knowing this information allows researchers to

Figure 2

OMSHR researcher Tim Lutz adjusts the escapeway marker test apparatus chain.

design visibility testing experiments like the one described here, with the goal of determining what colors are most visible in specific and challenging lighting conditions.

How visibility testing was done

Controlled tests in a simulated mine were conducted to determine which colors of markers were most visible when illuminated by a miner's cap lamp. Visibility was determined by measuring the distance over which red, green and blue markers could be detected in white smoke. Thirty-one test subjects were used to conduct the testing.

The NIOSH Mine Illumination Laboratory in Pittsburgh, PA, which contains a smoke chamber (Fig. 1) and the associated test apparatuses, was used to conduct mine illumination research in a simulated smoke-filled mine. The smoke chamber was sealed to contain the simulated smoke. It was also constructed to isolate the test subjects and the researchers from the smoke during the testing, allowing the subjects to remain in a fresh-air environment. A viewing window located at one end of the chamber (top right side of Fig. 1) and partially encircling the subjects enabled them to see into the smoke-filled chamber and gave the perception that they were immersed in the smoke. White theatrical smoke, emitted from a smoke machine, was used to simulate the smoke resulting from a mine fire. This white smoke is commonly used for mine search and rescue training. The smoke optical density, which is a measure of light transmission through smoke, was maintained at 0.028 m (0.09 ft). This enabled a maximum viewing distance into the smoke of about 2 m (6 ft).

A test apparatus located inside of the smoke chamber included colored escapeway markers on a continuous chain loop (Figs. 1 and 2) mounted to the ceiling. The colored markers were spaced at unequal distances to help reduce predictability, and the markers traveled at walking speed (about 1 m/s or 3 ft/sec) toward the stationary subject. Subjects were given 15 minutes for their eyes to adjust to the darkened environment of the smoke chamber. After the dark adjustment, subjects were instructed to stand near the clear window (Fig. 1) with their chins on a chin rest to enable a consistent field of view among the subjects. Subjects pressed and held a mouse button to start the tests, which caused the markers to move toward them. They released the mouse button when they saw the marker. The distance to detection was measured electronically by counting the chain links and was recorded by a data acquisition unit connected to a computer for data analysis.

And the winning color is ...

The results (Figs. 3 and 4) indicate that the green marker was the most visible (detected on average from 195 cm or 76.7 inches away) followed by red (detected on average from 182 cm or 71.7 inches away) and blue (detected on average from 152.9 cm or 60.2 inches away). The detection distances indicate marker visibility — the greater the distance away when the marker was detected, the better the visibility.

The results show that marker color does affect visibility in white smoke. Green and red colors are the best of the three colors tested, and should be considered by mine operators when replacing existing or purchasing new escapeway markers. Blue marker visibility is poor. ■

Figure 3

The detection distances for green, red and blue markers.

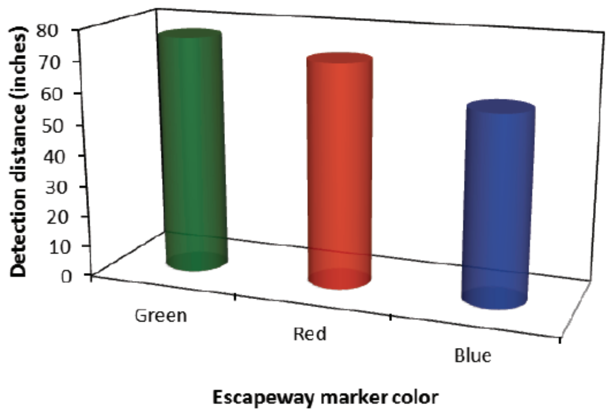
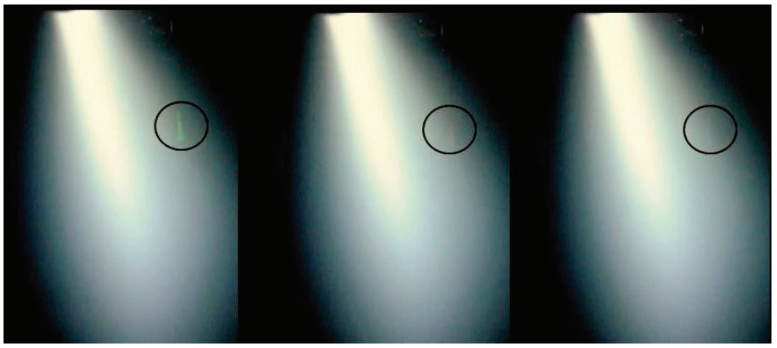


Figure 4

Green (left), red (center) and blue (right) escapeway markers in white smoke. The black circles were added to this photo to identify the markers.



Reference:

A Comparison of Cap Lamp and Laser Illumination for Detecting Visual Escape Cues in Smoke," Lutz TJ; Sammarco JJ. Gallagher, S.; Srednicki, J (2013). 2013 Transactions of the Society for Mining, Metallurgy, and Exploration. Vol. 334. pp. 401-409.

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