TECHNICAL NOTE

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An Extinction-Type Photometering Technique for Low-Light-Level Luminance Measurements in Accident Investigations

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ABSTRACT: An extinction-type luminance measurement method using an inexpensive illuminance meter for low-light-level measurements is described. The method has application in nighttime crime and accident scene investigations where poor and inadequate visibility may be a contributing factor. The meter is useful for measuring luminances under field conditions.

KEYWORDS: criminalistics, luminescence, accidents

Several aspects of human vision are impaired at low light levels. These include (1) acuity, (2) color discrimination, (3) depth perception, and (4) contrast sensitivity. Photometric analyses are almost always required in investigations at crime and accident scenes where low-light-level conditions may have been contributing factors in the accident or crime. These normally involve both illuminance (incident illumination) and luminance (brightness) measurements in critical areas of the scene. Illuminance measurements are the easiest to make but are the least important of the two in determining a person's abilities to detect, recognize, or identify visually objects (or targets) under low-light-level conditions. Illuminance meters with sufficient sensitivity for low-light-level investigations are relatively inexpensive. This is not the case for luminance spot meters capable of measuring luminance levels in the range of 0.001 to 0.05 footlamberts (0.003 to 0.17 cd/m^2), which are typical values in nighttime accident investigations. Luminance meters sensitive to these low light levels are relatively expensive and difficult to use under field conditions.

Contrast Determination

One of the most common causes of nighttime accidents is failure to see an object (hereafter referred to as the *target*) against its background because the contrast sensitivity of the eye is insufficient to differentiate between the luminance levels of the target and its background. Contrast is defined as follows:

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$$C = \left| \frac{L_b - L_t}{L_b} \right| \tag{1}$$

where

C = contrast,
L_t = target luminance, and
L_b = background luminance.

One investigative procedure in nighttime accident work is to measure the background luminance and compare it to the luminance level of the target existing at the time of the accident. Target luminance values can be calculated from target illuminance measurements under certain conditions when the reflectance (R_t) of the target being illuminated is known. The relationship is:

$$L_t = I_t \times R_t \tag{2}$$

where

L_t = target luminance,
I_t = target illuminance, and
R_t = target reflectance.

L_t and I_t are commonly expressed in English units of footlamberts and footcandles or in metric units of $1/\pi$ candela per square metre and lux, respectively. An exemplary application of Eq 2 involves the determination of the luminance of a pedestrian involved in a nighttime accident. If the clothing worn by the pedestrian has a reflectance of, say, 0.2 and the vertical illuminance of the position occupied by the pedestrian is 0.04 footcandles (0.43 lux), the luminance (L_t) is the product of 0.04 and 0.2, or 0.008 footlamberts. L_t is used in combination with background luminance (L_b) to determine the contrast (C) between the pedestrian and the background. A vertical illuminance reading taken at the time of the accident provides an indirect means of determining the value of L_t. A more direct and credible method is to measure the luminance of a similarly dressed person at the same location using a luminance meter. It is usually not practical to measure background luminance (L_b) in outdoor settings by means of Eq 2. This determination usually requires direct measurement with a luminance meter in combination with the target luminance measurement above.

There are specific contrast threshold levels at which observers are just able to distinguish targets against their backgrounds. These vary inversely with background luminances (L_b) as shown in Fig. 1. In addition to background luminances, visual contrast threshold values vary with the age of the observer, the angle subtended by the target, and the viewing time. There are multiplication factors that can be applied under each of these conditions to determine the probable value of contrast threshold for a particular observer under specified viewing conditions.

Extinction Photometry

The illuminance meter to be described here measures luminance within a small angular field. The basic meter is a conventional illuminance meter (Fig. 2). The author uses a Minolta Illuminance Meter T-1 capable of measuring down to 0.001 footcandles or 0.01 lux. A small plaque of known reflectance (R_p) is mounted on top of the meter as shown in *a* in Fig. 2. The plaque in this case is a circular disk 1 cm in diameter cut from a Kodak gray card having a known reflectance of 0.18.[2] When the meter is held normally at arm's length, the

[2]Manufactured by Eastman Kodak Co. and available at most camera stores.

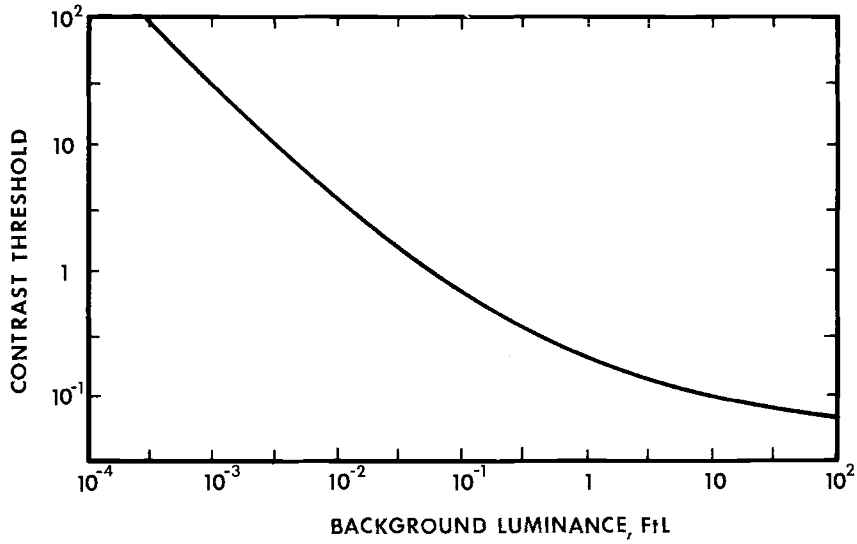

FIG. 1—*Visibility reference function for threshold visibility of a 1/15° luminous disk exposed for 1/5 s to 20- to 30-year-old observers.*

FIG. 2—*Minolta illuminance meter outfitted with a circular reference plaque* (a), *flashlight* (b), *and supplemental reference plaque* (c) *as described in article.*

disk subtends an angle of approximately 1° at the observer's eye. Luminance measurements are made by illuminating the meter and the disk with a light source while viewing the disk against the background to be measured. A convenient light source is a Mini-Maglite,[3] shown at *b* in Fig. 2, fitted with one or more layers of white paper over the lens to reduce the light output to a satisfactory level. Some trial-and-error experimentation is usually required in selecting the number of paper disks to attenuate the light output to the required range. A useful accessory is a rubber ring that fits over the lens and facilitates holding the paper disks in place.

With the meter in one hand and the flashlight in the other, the disk illuminance is varied by moving the source toward and away from the meter causing the disk to fade in and out of sight. Two meter readings are made, one at each end of the extinction range. Consider, for example, the case in which the disk appears darker than the background. As the illuminating source is slowly moved toward the meter, the disk will first fade from sight and then reappear again brighter than the background. The opposite occurs when the light is moved away from the meter. Illuminance measurements are made under the two conditions where the disk just emerges from extinction. If these two readings are indicated by I_1 and I_2, the background luminance (L_b) of the area surrounding the plaque is given by:

$$L_b = \frac{(I_1 + I_2) \times R_p}{2} \tag{3}$$

Plaques of different sizes, shapes, and reflectances may be used for particular applications. A plaque simulating the shape and subtending the same angle as a pedestrian is shown at *c* in Fig. 2. Lower luminance levels can be measured within the limits of the meter's range by using plaques of lower known reflectance values.

Some practical situations do not require the use of a portable flashlight to illuminate the plaque and the meter. Permanent sources such as streetlights located behind the observer often suffice for this purpose. In these cases, the observations are made by walking back and forth between the source and the background being measured. The angle subtended by the plaque remains the same, but the illuminance falls off with distance from the fixed source.

Luminance measurements by these techniques are not practical under good lighting conditions where the higher contrast thresholds of the eye make it virtually impossible to obtain complete extinction of the plaque against its background. Extinction is easily obtained at the low light levels typically encountered in nighttime accident and crime scene investigations so that background luminances can be determined under actual field conditions. The extinction values I_1 and I_2 obtained in this way apply specifically to the eyes of the observers performing the luminance matches.

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[3]Manufactured by MAG Instrument Co., Ontario, California, and available at most sporting goods stores.