

an object and its contrast with the background are to visual acuity. Visual acuity is proportional to the reciprocal of threshold size.

Time is important where speed of seeing is essential to good visual performance, as for industrial inspection, high-speed machine work, and accident prevention. The contrast between an object and its background has great influence on the time required for certainty of recognition. Likewise the illumination intensity in foot-candles has a direct effect on the time factor by its effect on surface brightness of the object. An increase from 1 to 100 ft.-c. approximately doubles or triples the speed of seeing.

In accordance with the fundamental law of physiological response that states that a sensation (vision) is proportional to the logarithm of the stimulus (brightness) it has been suggested that significant change or improvement in the effectiveness of seeing depends on geometric rather than arithmetic increments of illumination. Thus, the recommended foot-candles in Table 1 are arranged as a progressing scale in the order of 5, 10, 20, 50, and 100, representing rounded numbers with ratios of approximately 2.

TABLE 1
Recommended Illumination Levels^a

Number of foot-candles	To be used for
100 or more	Very severe and prolonged tasks, such as fine needlework, fine engraving, fine penwork, fine assembly, sewing on dark goods, and discrimination of fine details of low contrast, as in inspections.
50 to 100	Severe and prolonged tasks, such as proofreading, drafting, difficult reading, watch repairing, fine machine work, average sewing, and other needlework.
20 to 50	Moderately critical and prolonged tasks, such as clerical work, ordinary reading, common benchwork, and average sewing and other needlework on light goods.
10 to 20	Moderate and prolonged tasks of office and factory, and when not prolonged, ordinary reading and sewing on light goods.
5 to 10	Visually controlled work in which seeing is important, but more or less interrupted or casual, and not involving discrimination of fine details or low contrast.
1 to 5	Inadequate for most critical seeing; satisfactory for perceiving larger objects and for casual or conversational seeing.

^a Recent studies have indicated that eye fatigue may be experienced in some installations above 50 ft.-c.¹⁷

A more comprehensive treatment of lighting requirements for industrial operations is given in the American Standards Association code on industrial lighting.¹⁸ The following excerpt from this code summarizes the requirements of three grades of visual tasks:

"Group A. These seeing tasks involve (a) the discrimination of extremely fine detail un-
 "M. Luckiesh and F. K. Moss, *Trans. Illum. Eng. Soc. (N. Y.)* 29, 661 (1934).
 "M. A. Tinker, *Am. J. Pub. Health*, 36, 963 (1946).
 " (Recommended industrial lighting). ASA Code A-17-1942. Sponsored by Illum. Eng. Soc. (N. Y.) (1942).

conditions of (b) extremely poor contrast, (c) for long periods of time. To meet these requirements, illumination levels above 100 footcandles are recommended. To provide illumination of this order, a combination of at least 20 footcandles of general lighting plus specialized supplementary lighting is necessary. The design and installation of the combination systems must not only provide a sufficient amount of light but also must provide the proper direction of light diffusion, eye protection, and insofar as possible must eliminate direct and reflected light as well as objectionable shadows.

Group B. This group of visual tasks involves (a) the discrimination of fine detail under conditions of (b) a fair degree of contrast (c) for long periods of time. Illumination levels of 50 to 100 footcandles are required. To provide illumination of this order a combination of at least 20 footcandles of general lighting plus specialized supplementary lighting is necessary.

Group C. The seeing tasks of this group require the discrimination of fine detail by utilizing (a) the reflected image of a luminous area or (b) the transmitted light from a luminous area.

The essential requirements are (1) that the luminous area shall be large enough to cover the surface which is being inspected and (2) that the brightness be within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low brightness in which the source brightness is the principal factor rather than the footcandles produced at a given point."

In 1942 a committee of the Illuminating Engineering Society canvassed a substantial cross section of American war industry to obtain field opinions on the practical values of improved lighting.¹⁹ The reported benefits were summarized as follows: (1) accuracy of workmanship; (2) less spoilage; (3) faster seeing; (4) greater ease of seeing; (5) less eyestrain and fatigue; (6) better utilization of floor space; (7) greater ease of keeping plant clean; (8) improved labor conditions; (9) greater safety.

"The increases in production, decreases in spoilage and the reduction in the number of accidents, accompanying the introduction of higher levels of illumination in industrial plants, are accredited to better visual conditions. Under higher levels of illumination the eye has been shown to respond accordingly, by: (1) increased ability of perception; (2) increased speed of discrimination or rapidity with which the eye is able to identify a difference or differences in objects; (3) increased accommodation, or the ability of the eye to focus upon objects at different distances; (4) improvement in sustained vision, or the ability of the eye to keep a clear view of all details of an object under continuous observation; and (5) increased speed of vision or speed of reading . . ."

An extensive literature is already available for further study of the psychology and physiology of seeing,²⁰⁻²¹ and a great deal of additional industrial data will undoubtedly emerge from the experience of World War II.

- ¹⁷ *Illum. Eng.*, 36, 13 (1943).
- ¹⁸ W. Harrison and K. A. Staley, *Fundamentals of Illumination*. General Electric Company, Cleveland, 1931.
- ¹⁹ M. Luckiesh, *Light and Work*. Van Nostrand, New York, 1924.
- ²⁰ M. Luckiesh and F. K. Moss, *The Science of Seeing*. 2nd ed., Van Nostrand, New York, 1938.
- ²¹ M. Luckiesh and F. K. Moss, *Trans. Illum. Eng. Soc. (N. Y.)*, 31, 855 (1938).
- ²² W. Harrison and M. Luckiesh, *Illum. Eng.*, 36, 1109 (1941).
- ²³ L. Remick, *Eye Hazards in Industry*. Columbia Univ. Press, New York, 1941.
- ²⁴ L. R. White, R. H. Britten, J. E. Ives, and L. R. Thompson, *U.S. Pub. Health Bull. No. 181* (1929).