

substantiate these results. Investigations have shown that these brightness relationships between a task and its surroundings are of greatest importance within about a 60-degree zone around the line of vision.

Another cause of visual impairment and discomfort is the brightness of more remote areas such as lighting equipments. Extensive investigations⁸³⁻⁸⁵ have shown that large areas of even apparently moderate brightnesses are disturbing and produce discomfort even when located at considerable angular distances from the normal line of vision. Factors such as size, position, and brightness of source and the adaptation or field brightness, all are important. In Figure 8 are illustrated

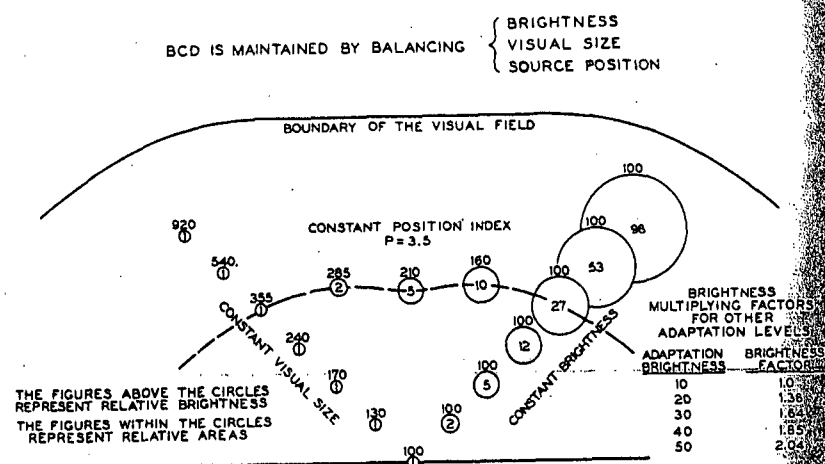


Figure 8. The relative effects of size, brightness and location of a source of brightness upon visual comfort (BCD = borderline between comfort and discomfort).

the relative effects of these factors and how they must be balanced so that the work area will be visually comfortable. When sources of brightness are located near the line of vision (indicated by the horizontal line), they must be small in size or low in brightness. As they are moved farther from the task area, size and brightness may be increased, as shown by the values in and above the circles. The combined effects are shown by the circles on the broken line, which is for a constant position index.⁸⁶ In order to maintain a constant visual sensation as area is

⁸³ M. Luckiesh and S. K. Guth, Brightnesses in visual field at borderline between comfort and discomfort (BCD), *Illum. Eng.*, **44**, 650 (1949).

⁸⁴ S. K. Guth, BCD brightness ratings in lighting practice, *Illum. Eng.*, **47**, 184 (1952).

⁸⁵ P. Petherbridge and R. G. Hopkinson, Discomfort glare and the lighting of buildings, *Trans. Illum. Eng. Soc. (London)*, **15**, 39 (1950).

⁸⁶ Position index is an indicator of how much the brightness of a source may be increased as it is moved from the line of vision in order to maintain a constant visual sensation.

increased from relative values of 1 to 27, relative brightness must be reduced progressively from 355 to 100. For larger areas, the brightness must be decreased at an even greater rate. The table in the lower right corner of Figure 8 illustrates how the source brightness may be increased for higher adaptation brightnesses. Thus, if adaptation brightness is doubled (corresponding to a doubling of the footcandle level) the source brightness may be increased by only one third. Methods have been proposed for evaluating the comfort of lighting systems and are being used for design purposes.⁸⁷

Seeing is a dynamic activity of human beings. Since a worker may look at any part of a visual environment, it is important to eliminate extremes of brightness or darkness. If they are not eliminated, the worker's eyes must continually be adapting to a greatly changing brightness pattern. Fatigue and ease of seeing studies have shown that pupil diameter,⁸⁸ precision and rate of working,⁸⁹ and blink rate⁹⁰ are adversely affected by improper brightness relationships.

V. Color

The subject of light and color⁴⁰ is large and complex. However, it is not as mysterious as some people try to make it. While spectral quality of light is important in some visual situations, it is generally of secondary importance in visibility and seeing. So-called white light ranges from a yellowish white with tungsten-filament lamps to a bluish white with daylight fluorescent lamps. All of them are suitable for general lighting use. No real practical advantage has been demonstrated for any one over another. Footcandle level and brightness are of paramount importance.

For specialized tasks involving color discrimination, lamps emitting all colors must be used. A wide range of fluorescent lamps now is available. Those designated as *de luxe* provide balanced spectrums and have been found completely satisfactory for color-critical work. For other tasks, relatively saturated color of light can be used to enhance the contrast within the task. In such cases the color of the light should be complementary to the surface color.

Color of light also is useful for creating a warm or cool atmosphere. This has been found to be particularly desirable to help counteract the effects of hot or cold industrial operations and to create a more livable environment.

VI. The Human Element

All researches in seeing must of necessity involve the human element. However, in most cases differences among individuals are submerged in averages.

O. P. Meaker and R. L. Osting, Visual comfort index and tables—their meaning and use in lighting design, *Bulletin LS-108*, Lamp Division, General Electric Co., October, 1953.

⁸⁷ M. Luckiesh and F. K. Moss, Size of pupil as a possible index of ocular fatigue, *Am. J. Ophthalmol.*, **16**, 393 (1933).

⁸⁸ M. Luckiesh and F. K. Moss, The rate of working on alternating fields of different brightnesses, *J. Franklin Inst.*, **200**, 731 (1925).

⁸⁹ A. H. Taylor, The nature and causes of small color differences in industry, *J. Opt. Soc. Amer.*, **32**, 651 (1942).