objects (a lamp filament, for example), localized brilliant lighting by means of a special fixture can be used to "magnify" the work. Listed in Table 4 are some representative visual tasks and current recommendations believed to provide

TABLE 4

Recommended Illumination for Various Types of Tasks[40,41]

Tasks comparable to	Recommended illumination (footcandles)
Reading legible print (10 point)	10–15
Sorting, rough inspecting, bookkeeping, reading newsprint	15–20
Setting 6-point type, stitching, gross assembly work	30–40
Severe industrial tasks, such as fine inspection, engraving, grading and sorting, proofreading	40–50

adequate levels of illumination (Cf. Chapter XX). For persons who have some slight eye disabilities or those with corrections, the lower levels in the table can be increased by 5 to 10 footcandles.[42] An increase in the illumination may be beneficial to persons in the older age groups.

A number of devices are available for measuring illumination of the working area and its surrounding environment. Some of these depend on visual matching (for example, the Macbeth illuminometer), whereas others operate entirely on physical principles (for example, photocells of various types). When any type of photometer is used, it is important to remember that the illumination measurement should be made at the place at which the eyes look and not at the lighting fixtures that produce the illumination.

e. Time of Exposure. Many industrial jobs may not be affected by this variable, since the employee ordinarily can control the rate of his operations. In some jobs, however, such as high-speed assembly-line work or vehicle driving, the operator must obtain visual information very quickly. In these cases, there may not be time to detect the necessary information.[43] Fortunately, however, a drop in exposure time may be in part compensated for by increasing the illumination. Some of the other factors already listed also can be used instead of, or in conjunction with, illumination to overcome the loss of visual perception due to short exposure. Thus, one can increase the size of the visual detail, raise the illumination, increase the contrast, or decrease the glare when a fast operation depends on the use of the eyes. Whenever feasible, each variable should be used to its fullest extent. When this is impossible (as when time is short or the size of the visual detail is dictated by the operation itself), it should be recognized that other factors are available and can be utilized to create a more satisfactory visual display.[2]

[41] M. A. Tinker, Trends in illumination standards, *Illum. Eng.*, **43**, 886–891 (1948).

[42] J. E. Kuntz and R. B. Sleight, Effect of target brightness on normal and subnormal visual acuity, *J. Applied Psychol.*, **33**, No. 1, 83–91 (1949).

[43] P. M. Fitts and R. E. Jones, Psychological aspects of instrument display: I. Analysis of 270 "pilot error" experiences in reading and interpreting aircraft instruments, AMC MR *TSEAA-694-12A*, October 1, 1947.

f. Color of Illumination. The use of color should be considered with reference to both normal and color-defective vision. Although the figures usually cited show that as many as 5 per cent of the male population are color-blind, recent estimates indicate that as high as 15 per cent of males may be "color-weak." The incidence of color blindness in females is much less. Many accessory visual aids, such as maps, charts, signs, and posters which have color designs, are unintelligible to color-blind individuals and sometimes may be confusing even to the color-normal.

In recent years, color has been used as an illuminant in incandescent or fluorescent fixtures and colored paints have been used for bench surfaces, walls, working materials, tools, and machines. It is necessary to distinguish among the purposes for which color is used in these various circumstances. In some instances, the primary interest is only that objects may be seen easily and comfortably. In other instances, color is used as a code or symbol to signify a particular bit of information (red for danger areas, green for electrical connections, black for tool handles, and so forth). In cases where colored lights are used as warnings, it is obviously important that the most easily discriminable colors be used. For viewing colored points of light, it has been shown that red, green, and blue are the most easily recognized, followed by white and yellow.[44]

One way of evaluating the effects of color is to compare the effectiveness of achromatic contrasts (such as black objects on a grey surface) with chromatic contrasts (such as green objects on a yellow background). Most studies have shown that achromatic contrast is a more powerful factor than chromatic contrast in producing discriminable effects.[45] In fact, the increased visibility that one obtains with the use of colors often can be attributed to the difference in brightness (achromatic contrast) between the colors rather than to the difference in hue. Thus, for maximal visibility, black on white or vice versa seems to be the best arrangement, although black and yellow have also been shown to produce good contrast.

3. Types of Visual Displays

Analysis of the different ways in which workers use visual displays indicates that three basic, but different, types of instruments should be used, according to the type of information required. The simplest type of information is concerned with whether the equipment is working normally or not. The indicator in this case need only be a warning signal (such as a green light to show things are normal, a red light to show danger or faulty operation). This is called a *check display*. A second type of required information is whether, and in which direction, a phase of an operation has departed from normal. Many dials showing revolutions, temperature, and pressure are used in this way. Since under normal working conditions all these functions should be within a certain range, it is possible to cover up

[44] N. E. C. Hill, The recognition of coloured light signals which are near the limit of visibility, *Proc. Phys. Soc. (London)*, **59**, 560–574 (1947).

[45] D. Ballamy and S. M. Nurhall, Attributive limens in selected regions of the Munsell color solid, *J. Opt. Soc. Amer.*, **32**, 465–473 (1942).