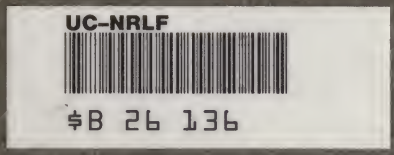

# DATA ON ARTIFICIAL LIGHTING

*Supplementary to Section II of "Scientific Office Management" by W. H. Leffingwell*



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# DATA ON ARTIFICIAL LIGHTING

Where gas light is used incandescent inverted mantles wil usually give the best results. In electric lighting rapid progress within recent years has made possible a wide range of choice in the kind of lighting, and there is naturally more or less dispute as to which light is really the most efficient.

In considering the efficacy of lighting methods it is important to know in just what respect one method is more efficient than another. It is possible that while one method may consume less current it will give light of much poorer quality or with a harmful effect upon the eyes of the workers. It is therefore necessary for us to know which is more important, economy in the consumption of current or economy in labor.

There are perhaps three methods of lighting in common use. In the direct lighting method the source of light is visible and the light rays shine directly upon the work. In the semidirect or semiindirect lighting systems the source of light is visible, but only a small portion of the light rays shines directly upon the work, and these rays are still further modified by translucent globes. In the indirect lighting systems the source of light is invisible, all the rays being thrown against the ceiling or some other light colored surface and reflected down upon the work.

Direct lighting is the oldest and most common method, and so far as mere consumption of current is concerned, much the cheapest of the three. Nowadays, however, the actual economy of this method is being sharply questioned. One of the most frequent objections to direct lighting is the glare which is caused by the exposed light. One authority states:

> What constitutes scientific and practical illumination? There are so many varieties of industries and the conditions of production are so diverse that it is at once apparent that

no one specification can fit them all. Illumination entirely satisfactory under one set of conditions might be wholly inadequate, not to say impossible, in another. There are, however, some general principles involved which apply to practically all situations.

There is a physiology as well as a psychology of industrial lighting. The psychological states—the mental alertness and the attitude toward the work—are mostly reflexes of the physiological. It is worth while to consider how these come about, and how those that tend towards inefficiency may be eliminated.

The eye is a most delicate mechanism, just as delicate in the roughest laborer as in the trained artist. It is a living photographic camera. It has every essential feature of the camera and some besides. The iris, for example, which is a diaphragm regulating the amount of light admitted to the eye, is wholly automatic, adjusts itself to meet varying conditions of illumination; the lens which focuses the light upon the retina (the sensitized plate in the camera) is also automatic, and adjusts itself for distance. The retina, under stimulus of light rays, becomes fatigued; the lens and iris are controlled by minute muscles which also tire under constant use. Abuse of these delicate mechanisms leads to impotency, just as overuse of any other organ does—a set of muscles, say, which, when tired, cannot be made to work so strongly, as continuously, or as accurately as when normal.

Everybody is aware of the effect of gazing, even for a short time, at any bright light. The eye becomes dazzled, irritated; if continued there is even pain. The retina becomes fatigued by overstimulation. Also the muscles of the iris, and lens, in their effort to adjust themselves, are tired. The effect of this does not wear off immediately. The blinding effect persists to some degree for a long time, often a half hour or more, according to the length of exposure and the intrinsic brightness of the light.

The tense feeling, the strain, and often the tingling and itching of the eye following continued close application, as in reading fine print, or closely observing fine work, is also well known. It is in part, at least, the direct and indirect result of a fatigue of the ciliary muscles controlling the shape of the crystalline lens. When looking at objects near at hand the muscles tighten and make the lens more convex. For distances of fifteen feet and

beyond, in normal eyes the image focuses on the retina when the ciliaries are relaxed. If the eye is allowed to relax occasionally by a look at relatively distant objects, fatigue is to a considerable extent avoided. Likewise the iris, the disklike curtain which controls the size of the pupil and therefore the amount of light admitted, if kept tense by an exposure to high light, or if subjected to fluctuating intensities, also tires and the sense of discomfort is increased. Moreover it is a peculiarity of the sense of light that movement or change of any sort taking place outside the limited field of direct vision, but still within the range of perception, is percieved more quickly even than when in direct range; and the effort of the eye to adjust itself to these environmental conditions when the light is unsteady or the surroundings dark in comparison with the field upon which attention is concentrated, is not only annoying and fatiguing, but becomes intensely distracting to anyone compelled to face it.

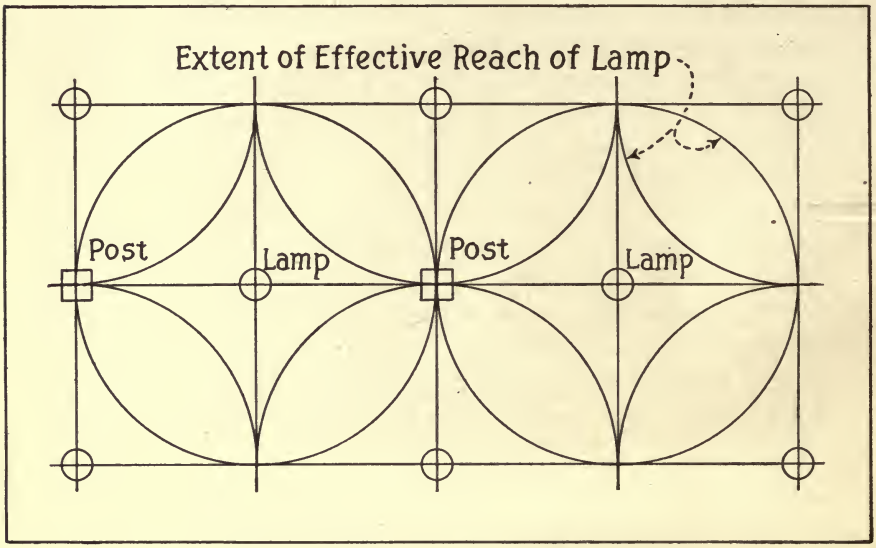
Here then we have a combination of paraial visual paralysis, optic fatigue, general discomfort and distraction from the work in hand, with all the physical and mental ills and the inefficiencies following in their train. Evidently the physiological effects of lighting are very practical factors in illumination, quite as practical as the immediate dollars-and-cents considerations which are more easily sensed.

It must be apparent that scientific and therefore economic lighting not only provides a sufficiency of light flux, steady and so distributed as to avoid obscurity and deep shadows anywhere within the ordinary range of the workers' eyes, but takes care that the source of illumination, if considerably concentrated as in the case in most lighting units now in use, shall be concealed, enclosed in a diffusing envelope, or placed outside the range of vision unless at such a distance that the brilliancy is greatly reduced before the rays reach the eye. Otherwise the main purpose of lighting is defeated, and the workers themselves are physically harmed and are rendered less efficient for their work.

Common practice is to have individual desk lamps. These throw a very strong light upon the work and nowhere else. In spite of the fact that most clerks working with a lamp of this sort wear dark green eye shades, the strain upon the eyes is very great. In still other places there are individual lamps

as well as overhead illumination. This arrangement gives better light than the individual lamps but it is not economical.

If direct lighting be used it is much better to have uniform illumination at least eight or ten feet above the floor, using as many lamps as will give each desk enough light for comfortable work. The light coming from so many directions reduces the glare more or less and heavy shadows are not so noticeable. It is helpful if the light units be placed so that the upright posts do not shut off she light. The diagram on this page shows Mr. Becker's plan for the proper arrangement of direct lights.




HOW TO SPACE LAMPS

The diagram shown here gives a good idea of one of the ways that light may be evenly distributed. Many offices have an uneven distribution of the light and in such cases desk lamps are an expensive necessity. With the spacing indicated in the diagram, satisfactory results are usually obtained

If you use the 60 or 100 watt tungsten lights you will probably get the best results simply because the light source is not brilliant enough to cause excessive glare. Ordinarily the unprotected nitrogen or gas-filled lamp of high intensity, although the economy in current consumption is more apparent, should never be used for the direct lighting of offices, since the glare from this light is often injurious to the eyes.

The term semidirect, or semiindirect lighting, is applied to the method of casting light on the walls or ceiling by means of translucent reflectors, which is the only difference between

indirect and semiindirect system of lighting. The current consumption for an equal amount of semiindirect light is said to be from forty to fifty per cent more than for a direct lighting system properly designed, while the current consumption for a purely indirect system is stated to be from fifty to seventy-five per cent more than the direct. This difference probably explains the frequent compromises resulting in the semiindirect systems. Undoubtedly the semiindirect system of lighting is less tiresome to the eyes than the direct system, but some office managers question whether there is any real saving over the indirect systems.

With indirect lighting the eyes are protected from the brilliancy of the lamps, since the light reflected from the ceiling is largely diffused before reaching the working plane. Indirect lighting is perhaps the only practical means of hiding the lamp without cutting down its light giving qualities. Where this system is used the ceiling or reflecting surface must of course be white. When offices are located in factories or buildings of mill construction this is often impossible, but usually even there it is possible to get a fairly good reflecting surface by painting the ceiling properly.

From the standpoint of eye efficiency, indirect lighting is about the nearest approach to sunlight that can be devised. It is true that the consumption of current by this method is from forty to seventy per cent greater, but some managers who are using this system believe that the increased efficiency of the workers pays for the difference in cost many times over.

Dr. C. E. Ferree has arrived at some very interesting conclusions. Some of them have been disputed by electrical illuminating engineers, but his experiments were very thorough and the results should cause a widespread investigation.

Dr. Ferree started out to find whether or not the eye shows a loss of efficiency after three or four hours' work under a given lighting system. He prepared a series of test cards from which the factor of memory was eliminated, containing a number of conventional letters and lines at which the subject was required to look intently and record on a rotating drum the time during which he saw them clearly and the time he saw them blurred. This test was continued during periods of three and

four hours and a ratio established showing the proportion of clear vision time to blurred vision time. Those who wish to go further into the detail of Dr. Ferree's experiments will find his paper unusually clear and interesting.* Dr. Ferree states:

> The intensity recommended by the Illuminating Engineering Society in its primer issued in 1912 ranges from two or three to seven or ten foot candles, depending upon the kind of work. Five foot candles are taken as a medium value. This medium value is approximately three times the amount we have found to give the least loss of efficiency for the type and installation of semidirect lighting we have used. The intensity we have found to give the least loss of efficiency for this type of lighting does not give maximum acuity of vision as determined by the momentary judgment. At an intensity that does give maximum acuity of vision as determined by the momentary judgment the eye runs down rapidly in efficiency. That is, in this type of lighting one or the other of these features must be sacrificed. High acuity and little loss of efficiency cannot be had at the same intensity. This can be had only under daylight or under the indirect systems of artificial lighting. However, the amount of light we find to give the least loss of efficiency seems to be sufficient for much of the work ordinarily done in the office or home.
>
> The semiindirect systems of lighting are intended to represent a compromise between the direct and indirect systems. A part of the light is transmitted directly to the eye through the translucent reflectors placed beneath, and a part is reflected to the ceiling. By giving better distribution, this system is also supposed to be a concession to the welfare of the eye, but our tests show that the concession is not so great as it was supposed to be. In fact, installed at the intensity ordinarily used, or at an intensity great enough for all kinds of work, it is little better for the eye than the direct system. At these intensities the bright sources of light, which seem to be the fundamental cause of damage, have not been eliminated, nor even reduced, so as to give much relief to the suffering eye. Until this is done in home, office and public lighting we cannot hope to get rid of eye strain with its complex train of physical and mental disturbances.

* "The Efficiency of the Eye under Different Systems of Illumination," by C. E. Ferree, a paper read at the seventh annual convention of the Illuminating Engineering Society, Pittsburgh, Pa., Sept. 22-26, 1913.