Reading Room Illumination

Electrical Engineering

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READING ROOM ILLUMINATION

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READING ROOM ILLUMINATION.

Until the advent of the electric light, a little more than a quarter of a century ago, there had been no essential change in the means of producing light, or rather, illumination. Flames were the only sources of artificial light. The electric light marked a new epoch, and brought about the beginning of a evolution in lighting which is really still only in the first stages of its progress.

So many, and so varied in effect, are the various light sources at the present time, that illumination, which probably formed one of the earliest arts of man, has now become a science, as well as an art. Formerly, the lighting of an enclosure was simply a question of how many candles to be used. Now it is a question, not so much of the number of light sources required, as it is of their kind, their location, the accessories to be used with them.

To secure the illumination that is efficient, that is agreeable to the eyes, that is harmonious in its effect, with apparatus that is artistically designed, and at a reasonable cost, involves a knowledge of all scientific principles underlying the production and use of light, as well as the canons of art, as applied to decorative design. This knowledge constitutes the comparatively new science called Illuminating Engineering.

One of the problems which has confronted the illuminating engineer is that of library illumination, and in spite
of its importance, has received but little technical consideration. This, however, is only natural. As already stated, the science is new, and its workers have not, as yet, had time to attack the problems considered as minor, especially if they do not come up very often. The problems which so far have held the illuminating engineer's attention are purely commercial in character, such as those textile mills and factories in general, stores, show windows, drafting rooms, and to some extent, auditoriums and school rooms.

There are a number of factors to be considered in every problem of illumination, whether library or textile mill. These factors with their sub-factors may be substantially outlined as follows:

A. Physiological

1. Action of the eye. What can it do?
2. Fatigue
3. Glare
   a. Intrinsic brilliancy
   b. Regular reflection
4. Shadow contrasts

B. Engineering

1. Quality
   a. Diffusion
   b. Color
   c. Striations
2. Quantity
   a. Intensity
b. Distribution

(1) Relative intensities

C. Architectural

An attempt will be made to discuss these briefly, more particularly with reference to library reading room illumination.

The problem in any case is efficiency. Efficiency of illumination may be defined simply and specifically by the purpose of illumination, i. e. — The end sought is a physiological process — sight. It is at once evident that to attain this end the requirement is to secure a proper balance of the factors given above.

The illumination of a library reading room necessitates, perhaps, prime consideration of the first factor, the physiological, due to the nature of the work to be done under it. The conditions are often distressing; the print to be read is often fine or indistinct, and the passing and repassing of persons helps to distract attention. If conditions are such that these cast shadows, that the eye experiences glare, or that the illumination is either deficient, or what is as bad, too intense, fatigue of the delicate organ results.

The eye is a physiological camera. The light flux entering the eye is varied in its physical quantity by the reaction of the eye on the light flux density, in contracting or expanding the pupil. The effect of the light flux which enters the eye is varied by the fatigue which depends on intensity and also on color. Distinction, or vision, is due to differences in the light flux density from the illuminated objects, that is differ-
ences in illumination. These may be differences in quality, that is in color, or differences in quantity, that is intensity or brightness. As such distinction includes the effect of shadows as causing the differences in intensity at the edges of objects. The image so imprinted on the retina is transferred to the brain by the distinction of the "purple matter" by the chemical action of the light.

It is the change in size of opening of the pupil, that in part explains the marvelous adaptability of the eye to the enormous range of intensity of illumination as met in nature. Under favorable conditions small print may be read by the light of a small candle or by the light of the blazing sun, which has an intensity varying from one thousand foot candles one hour after daylight to eight or nine thousand foot candles at noon, according to recent experiments.

Fatigue and the logarithmic law of sensation also help to explain the adaptability of the human eye. Experiment has shown that the sensitiveness of the retina to impressions is enormously increased by protecting the eye from all light. It is a fact that if the eyes are bandaged for twenty minutes they will be able to perceive a glimmer of light that ordinarily is not perceptible. On the other hand, the eye becomes fatigued when the "purple matter", mentioned above, can not be created fast enough for the amount of light flux entering, that is, the nerves become less sensitive when exposed to high intensity of illumination. The consequence is that a much greater change of intensity of illumination is necessary to produce conscious im-
pression under circumstances where the eye is exposed. These, of course, are the only conditions found and it becomes the problem of the illuminating engineer to keep his light sources out of the field of vision. The logarithmic law of sensation refers to the fact that sensation is not proportional to the energy which produces it, but is approximately proportional to its logarithm. The sensation, therefore changes very much less than the intensity of light causing it.

No paper on illumination would, today, be considered complete without a more or less exhaustive discussion of "glare". Glare, however, is one of the features of our new science, which has not had a recognized existence long enough to have a settled definition. There are given to it as many meanings as there are definers. Nevertheless, the illuminating engineer of today must recognize the existence of glare, as an extremely uncomfortable sensation produced by light getting into the eye which should not do so, and he should lay out his work in such a manner that it is avoided as much as possible. Glare, as we consider it here, may be caused by two things, excessive intrinsic brilliancy and regular reflection. The first of these is more or less complex, and its effect is felt only from those light sources which lie exposed in the field of vision. The intrinsic brilliancy of a radiator is the light flux density at its surface, that is, it is the total light flux divided by the luminous area, the result being expressed in lumens per square millimeter.

The illuminants in general use today are of excessive
brilliancy. Due to optical inconveniences these must be kept out of the field of vision; the method usually employed being the use of an indirect system of illumination, or the use of dif-
fusing or diffracting globes or shades.

Regular reflection refers to the direct reflection of light rays from polished surfaces into the eye. This becomes a problem of some importance in library illumination, on account of the use of polished tables and the fact that the paper of books and magazines is always more or less perfectly glazed.

Glare, as here outlined is undesirable not only on account of its painful physiological effects, but also because its pre-
sence always makes necessary a greater intensity of illumination on the work. Steinmetz says:" If points or areas of high bril-
liancy are in the field of vision especially if near to the ob-
ject at which the eye looks, the pupil contracts and thereby re-
duces the amount of the light flux which enters the eye. The same result is produced as if the objective illumination has been correspondingly reduced. The existance of points of high bril-
liancy results in a great waste of lightflux". It has been shown that the presence of a sixteen candle power lamp in the field of vision decreases one's ability to read by approximately thirty per cent. The effect would be more marked if the intensity of the lamp were greater.

The same holds true with regard to excessive light on sur-
faces within the field of vision, as the walls of the room. The efficiency of the eye is decreased and a higher intensity of il-
illumination on the work is made necessary. Then, too, the eye is
offered no place of rest when it seeks relief from work. It is at once seen that light in useless directions is largely wasted, due to low coefficients of diffuse reflection. The absorption of walls and ceilings average about seventy per cent. The use of proper shades and reflectors should put this wasted light flux where it is needed and can be utilized.

This idea, however, should not be carried to the other extreme, as in that case, more harm than good will be done. Instead of finding relief on looking up from the work, the pupil of the eye must adapt itself to such a low value of illumination that a distinct effort is necessary. This results directly in fatigue of the optical muscles.

To illustrate this idea a set of interesting experiments has very recently been performed. The voltage on the lamps of a room was periodically, lowered and raised, lowered and raised, in this way decreasing and increasing the illumination very slightly. It was found to be very restful to the eyes, reducing the fatigue very noticeably and necessitating much less looking up from the work for relief.

Shadow contrasts from a very important factor in general illumination. The main distinction of objects in vision is due to differences in intensity or brightness, and, for producing these, shadows are of foremost assistance. In fact, the differences of intensity are, to a large extent, due to shadows. This, however, refers only to circumstances where the orientation of the object in space is desired, and does not concern our problem in that light. The problem of reading room illumination
does require, tho, that enough contrast be provided between the work proper and the general surroundings to afford rest to the eye when it leaves the printed page. The general principle then is the use of a combination of a local or concentrated illumination of fairly high intensity with a general illumination of a lower intensity. If the eye can rest even momentarily, by a change to a lower intensity of illumination, fatigue is decreased and the concentrated illumination of the work table appears brighter than it would without the possibility of rest.

The "Engineering factor" has two subdivisions,—quality and quantity. Quality considerations naturally split into two parts, those of diffusion and of color. Diffusion may be defined as the proper redistribution of the light rays as they come from the filament to give the result desired, in other words, diffusion is the process of putting the light where it is wanted. Since it is impracticable to secure proper diffusion by means of altering the shape or position of the incandescent filament, recourse must be had to shades and reflectors. The manufacturers of these accessories have taken it upon themselves to solve this problem, and it is now possible to procure reflectors which will give any distribution desired.

Diffusion should perhaps be broken up, into "light directed", and "light diffused", where the latter, so called, means light coming from all directions, so that shadows are eliminated. In library table work, as in all other, a proper proportion of directed and diffused light is necessary. Enough directed light is required to throw shadows of a pen away—to the rear from
the point when writing, in order to give an absolute, clear view of the work which has just been done. On the other hand, since all the objects requiring distinction are in one plane, and distinction is exclusively by differences of color or intensity, a perfectly diffused illumination is required.

Steinmetz says: "Objects are seen and distinguished by differences in quality, that is color, and in intensity, that is brightness, of the light reflected from them". This seems to give some importance to color values in the field of vision. In good illumination, then, differences in color should be sufficiently great to allow clear distinction of objects, but still limited so as not to appear of enough importance to distract attention from smaller differences. Differences in color are only to a limited extent under the control of the illuminating engineer, but he often can control or advise regarding the colors of walls and ceilings. This is an important point, as the amount of light reflected from various colored walls varies greatly. According to National X-Ray Reflector Company data, the coefficient of reflection varies from five hundredths for deep red, crepe ceiling, to sixty-four hundredths for very faint, gray cream with a plain ceiling. An average of fifty-one colors with combinations gives a coefficient value of twenty-six hundredths. Another authority gives the average absorption of walls as seventy per cent of the total incident light.

Perhaps striations ought not to be considered as one of the sub-factors under "Engineering". The frequency with which they are found, however, merits some discussion. Striations, or
streaks, are shadows, caused by the lamp bulb and intensified by the reflector. This, of course, is due to defects in design. Their effect is similar to the passing of an object between lamp and working plane. The constant vibration keeps these streaks in motion, and causes shadows constantly flickering over the work. To overcome this flicker the iris of the eye opens and closes, with the immediate consequence of fatigue. The shadow may be so slight as not to be noticeable, but its effect is inevitable.

Quantity should be subdivided into Intensity and Distribution. Intensity, tho not among the first points to be considered is, perhaps, of greatest importance. The main distinction of objects is due to differences in intensity or brightness. The differences in intensity should be high, but at the same time they are limited by the fatigue and contraction of the pupil of the eye. The minimum intensity should be sufficiently high to see clearly. The maximum should not be high enough to cause eye fatigue, due to excessive contrast.

Under some circumstances too great an intensity actually reduces contrast. This is found to be the case when considering the illumination of a printed page. Too bright a light obscures the contrast between the letters and page. No ink is so black that no light is reflected from it. By strongly increasing the intensity of the incident light the increase in the reflection of light from the ink becomes greater in proportion than the increase in reflection from the paper, and hence the contrast which is so essential to clear vision is diminished.
Many of the reflected rays impinge upon the retina in the immediate neighborhood of the retinal image, so that the contrast is still further diminished there. This reflection of light from the printed page is one form of glare.

Distribution refers to relative intensities of illumination on various parts of the enclosure to be lighted. The question of how much light is to be thrown on walls and ceiling again comes up, but this has been discussed in the consideration of the physiological factor. The key to efficient reading room illumination seems to be a proper combination of low general illumination with a local higher intensity at the places of work.

Discussion of the Architectural factor paves the way to the usual exhortation to illuminating engineers and architects to work in harmony. It is perfectly possible and now, even easy, to secure an illumination system that is efficient and harmonious, from the standpoint of both.

The instrument used in these tests was a portable photometer capable of measuring the illumination in foot candles directly. It is made by the Sharp Millar Co. of Philadelphia.

If the distance from the diffusing screen to the source of light is known the candle power of the source can easily be determined. The instrument is so designed and constructed that it can be used equally well for almost any photometric work. It is at the same time simple, portable and meets all the theoretical requirements with a great degree of precision and accuracy within the range of .004 to 2000 foot candles. As a photometer it has all the essential features to make it an ideal instrument.
It has a very sensitive photometric device, a reliable and easily adjusted comparison light source and above all the operation is simple. The sensitive photometric device is a modified form of the Lumner Brodhun arrangement. A thoroly tested and calibrated incandescent lamp is the comparison light source, and its intensity upon the screen is varied by moving the lamp. The movement of the lamp is effected by the milled button or disk mounted on the outside around which runs an inelastic cord attached to the movable carriage that carries the comparison lamp. The comparison lamp is mounted within a circular metal housing and is carried on a small platform that is arranged to slide on a track lengthwise of the box. The movements being effected by the inelastic chords that pass around the pulleys, one of which is turned by the external milled hub or disk.

Besides regulating the intensity of illumination by moving the light there are absorption glasses that are used to regulate the intensity upon the screen when the difference between the two light sources is too great. The method of varying the distance indicates its dependence upon the applicability of the law of inverse squares for the readings of illumination given in foot candles. The light from the comparison lamp falls on the center of a milk glass plate in the end compartment of the box. The scale from which the indications of the photometer are read is set in a lengthwise opening in the side of the box just above the track upon which the comparison lamp moves. The scale consists of an opaque glass having a scale printed upon it. A movable shutter is provided to keep the exterior light from entering the comparison lamp end of the illuminometer, the shutter
being raised so that the scale is illuminated when the readings are being taken. The reading to be taken on the scale is indicated by a thin narrow shadow that falls in the center of a beam of light from the comparison lamp.

The scale is so divided that it can be read in foot candles or in candle power. The range in foot candles being from four tenths to twenty, which is adjustable by two screens so that a range of four thousandths to two thousand foot candles may be obtained. The screens are so designed that one allows ten per cent of the light to pass through and the other one per cent. Either screen may be interposed between the comparison lamp and the prism or between the prism and the elbow when a greater range than that ordinarily used is desired.

The elbow at the end of the box may be turned about a horizontal axis and set at any desired angle thus measuring the intensity of illumination in any direction. In the bottom of the elbow tube there is a fixed mirror plate while at its outer end, entirely free from any obstruction to light is a translucent glass or diffusing screen ground on its upper surface so that it has the power of reflection well destroyed. Its diffusing properties are such that its illumination varies nearly as the angle of incidence of the light.

If it is desired to measure candle power a diffusely reflecting surface is turned toward the inside of the tube at the elbow and the end of the elbow tube is left open thus screening off stray light from the plate. The distance from the plate and the light source must be known. To calibrate the instrument for the measurement of candle power or illum-
ination the method is to use a known candle power or illumination produced by a standard lamp. The voltage of the comparison lamp is adjusted by means of sliding rheostat until the comparison lamp has the proper voltage to give the required illumination on the screen for calibration. A few careful trials as described elsewhere served to calibrate the comparison lamp and its voltage was found to be ninety six and eight tenths. Since the c.p. varies as an exponential function of the voltage there should not be more than a volts variation either way from the normal for good results.

Calibration of Illuminometer.

Nothing was known regarding the candle power or proper voltage of the test lamp beyond that it had been properly seasoned and was supposed to give sixteen candle power at somewhere near one hundred ten volts, since in field work the standard was intended to be connected directly to the lighting circuit of the room under investigation. The following method was used to calibrate the illuminometer. The object of this calibration was to obtain the exact voltage on the standard at which the illuminometer would read correctly, that is be balanced and show one foot-candle when the illumination on the screen was equal to that value. Direct current was used and the connections were as shown in the sketch.

The mirror in the elbow of the illuminometer below the diffusing screen was placed a measured distance, D, from the standard lamp filament, so that the illumination to be measured was known from the candle power varying inversely
Connections - Calibration of Illuminometer

D - Distance, Standard to Mirror in Elbow
T - Test Lamp - Standard in Illuminometer
L - Standard 16 C.P. at 109.2 Volts
I - Illuminometer
M - Mirror
S - Screen
Stove Pipe Rheostats
## Calibration of Lamp and Illuminometer

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<th>Voltage Standard</th>
<th>Test Foot Candles</th>
<th>Illuminometer Calculated</th>
<th>Test</th>
<th>Amperes</th>
<th>Distance Illuminometer to Standard in Feet</th>
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Average Voltage on Test Lamp 96.8

Standard Lamp Number 3300 Q,16 Horizontal C.P.

at 109.2 Volts.

Test Lamp Number 5111.
with square of the distance law. The illuminometer lamp moved so that the scale reading indicated, in foot candles, the calculated illumination. Then the voltage on the test lamp was carefully varied till the Lummer Brodhun photometer attachment was balanced. Sets of data were taken with three values of illumination on the illuminometer screen, with results as given in the data for the test.

An average of the voltages on the lamp was taken and used when taking "field data". When taking "field data" the rheostat was adjusted to give ninety-six volts on the illuminometer lamp when the voltage of the illuminating circuit was normal, at its particular value. The lamp voltage was then allowed to vary with that of the circuit while readings were taken.

The purpose of the thesis was to investigate the illumination of the University of Illinois Library reading rooms, and if possible, to suggest improvements. The investigation proper consisted of taking sets of measurements of illumination on the reading room tables in foot candles, and the analysis of the data obtained. This was done as follows.

The intention was to take enough measurements so that curves might be plotted and from them the illumination at any point on the surface of the table be determined. The table was never moved into an advantageous position or the lights changed, the idea being to work under existing conditions. The usual procedure was to lay out the outlines of the table surface on the floor. Then the illuminometer stations were located and indicated by chalk marks. In the University of
Illinois Library tables were chosen as shown in the diagram.

It was assumed that the maximum amount of work would be done at a distance of five inches from the edge of the table. For the larger books and magazines the working zone would be between five and twelve inches in. Working along these lines sufficient data was secured to plot lines of equal illumination, isolux curves, on the table. The distance $X$ was taken small enough to give points necessary to plot accurately foot candle illumination along any line, lengthwise, over the table. Generally $X$ was taken as eighteen inches. When a table lamp was provided this was set on a stand placed so that it occupied the same position relative to stations as it did on the table. The stand was just the height of the table. The screen of the illuminometer was placed in the table surface plane, so that actual values could be measured. Readings in foot candles di-
rect were taken at each station. At the same time the positions of the lamps with respect to the table were determined, also, their size, and the size and name of the shade. Other points of interest were noted, as shadows cast by passing persons, the presence of glare, and dark spots on the table.

To work up the data a sketch of the table top was made to scale, and the positions of the effective lamps noted on the drawing. The illuminometer stations were spotted and the value of the particular readings written in. Then curves were plotted representing foot candle illumination lengthwise along the lines 1, 2, 3, 4. Similar curves were plotted for lines running across the table. All curves run from the lower left hand corner of the table. This arrangement has been consistently used throughout the paper. Finally a sketch of the table top was made and isolux curves were drawn in. These show lines of equal illumination similar to lines of equal elevation in a contour map in Civil Engineering. With such a set of curves it is possible to analyze the illumination of a surface at a glance, as regards intensity, and distribution. At the same time it becomes easy to suggest improvements.

Champaign Public Library.

Data was taken in three rooms of the Champaign library. In the west room, two narrow tables run along the north and south walls, and are illuminated by lamps on wall brackets. Other tables are placed crosswise in the room and are provided with table fixtures carrying the usual green porcelain shades,
conical in shape.

Measurements were taken only on one of the tables running along the walls, the north one being chosen. A sketch of the table with values found and the affecting lamps are given on Page 23. The lamp fixture shown in the lower left hand corner is fastened to a column. All lamps were the common sixteen candle power carbon and the shades were of clear glass with some ornamental etching, five inches deep, and six inch mouth. The illumination on this table was very poor, the highest foot candle value being one and seventy-five hundredths. The left lamp in the fixture above the table was almost burned out, and undoubtedly caused the sag in the curve as shown on Page 24. On the whole, the lighting of this room is very unsatisfactory, altho the center tables are fairly good.

The north room is probably the best. It contains two tables, and is lighted by a chandelier carrying sixteen candle power lights, projecting at an angle of thirty degrees to the horizontal. The shades are of clear glass as described above. The table most nearly under the chandelier was investigated, as the illumination on the other was very poor. The table is diagram shown on Page 25 and the curves on Pages 26 and 27. In this case actual values show a high enough intensity, but the general effect is spoiled by the fact that glare is excessive and that persons sitting between the tables have the chandelier on their back and, consequently are in their own light. Book shelves are placed along three of the walls and the illumination on the books is very good indeed.

The northeast reference room contains two tables, a
Curves showing distribution of light lengthwise of table.

Curve 1. 5 inches from edge.

Distance - inches

Candle Feet
Curves showing distribution of light lengthwise of table.

Curves 1+4, 5 inches from edge.

2+3 12  

80 Distance inches.
Curves showing distribution of light lengthwise of table.

Curves 1 + 4 5 inches from edge

2 + 3 12 " " " "

Distance - inches.
Curves showing distribution of light crosswise of table. Curves as lettered refer to points as shown on table diagram.
large one running lengthwise and a smaller one at one end. Light is furnished from two chandeliers, one carrying three, the other two sixteen candle power lamps, the shades being the same as in the other rooms. Here, again, the illumination is very low in intensity but is very evenly distributed. Glare is serious. Book shelves on the walls are well lighted, as in the north room. The table diagram and curves are given on Pages 29, 30, and 31.

No remedy for improvement of the illumination of the Champaign library suggests itself, unless the power consumption be increased. Intensities would be increased if tungstens, say sixty watt, were used. Glare would be eliminated by the use of opalescent globes, perhaps sand blasted on the inside, and completely covering the light sources.

The Mendota Library.

The Mendota Carnegie library has two main reading rooms, one provided with two reading tables and the other with one. The tables are ten feet long and three feet six inches wide. Over each table is a four lamp fixture built as shown on Page 32. The dimensions and location of the fixture with respect to the table are given there. Lamps are hung at the ends of three of the arms. These lamps are entirely enclosed in globes of opalescent glass, sand blasted on the inside surface. From the fourth arm a lamp is suspended by a cord, and is shaded with a common green conical reflector, eight inches in diameter at the mouth. In all cases ordinary six-
Fixture Arrangement—Mendota Library
Fixture over Center of Table
Table Diagram of Data. Mendota Library-Reading Room.
Curves Showing Distribution of Light Lengthwise of Table, Menasha Library, Reading Room.
teen candle power carbon lamps are used. The walls and ceiling are finished with a rough gray surface mortar, which has a very high coefficient of absorption. The idea seems to be to provide fair illumination over the whole table, and an area of higher intensity for any close work. This result is accomplished, altho the intensity is quite low. Considering the fact, however, that no extended work is done, and since these tables are used but a short while at any one time it would seem that the illumination were sufficient. The use of the sand blasted opal globes gives a soft, thoroly diffused general illumination, most agreeable to the eyes. There is absolutely no glare and the passing of persons between the tables casts no shadows whatever. The curves and data for one of the tables are on Pages 33 and 34.

The illumination of these tables might be improved in two ways. In the first place a greater amount of light would be secured at lower cost by the substitution of forty watt tungstens for the carbon lamps. Secondly, the use of a Holophane extensive reflector on the drop would give a better distribution and increase the area of intense illumination.

John Crerar Medical Library.

In the John Crerar library the indirect system is in use. The National X Ray apparatus is employed in the lighting scheme. The old desk lamps were fitted with the X Ray reflectors and hung inverted about thirty inches from the ceiling. The fixtures in the main room had six arms each and
were supplied with one hundred watt tungstens. A table in each of the main and Senn rooms was examined. The Senn room had three light chandeliers also fitted with one hundred watt tungstens. The walls were a light green in color and were thereby designed to absorb but little light in the process of reflection.

The first thing noticeable was the absolute uniformity of the illumination, no shadows being in evidence. The illuminometer showed an illumination of one and four tenths to two and four tenths foot candles. This is hardly sufficient to read by, and was partly due to the high ceiling which caused the light to be reflected so far that it was none too bright on the table surfaces. The lighting of the Senn room did not show the uniformity that the main room did, due perhaps to the method of placing the fixtures. The illumination of the main room while not so good as that of the Senn room showed a more even distribution.

In taking the data for these curves it was necessary to place the illuminometer on the table as the tables were permanently fixed. A set of readings was taken with the instrument on the table, and another with the instrument on the stand, the screen flush with the table surface and as near to the edge as the elbow would permit. A similar set was taken at a distance of one foot from the table edge. Curves for the various sets of readings were plotted as shown and explained on curve sheets.

Attendants at the library were consulted as to the suitability of the system and while opinions varied it seemed
Table Diagram of Data. Creer Library. Senn Room.
Curves Showing Distribution of Light Lengthwise of Table.
3 x 4 Illuminometer Set on Table.
2 x 5 Illuminometer Near Edge of Table and Screen Even with Surface.
John Crerar Library, Senn Room.
Table Diagram of Data. Crerar Library Main Room.
Curves Showing Distribution of Light Lengthwise of Table.
2 + 3 - Illuminometer Set on Table.
1 + 4 - Illuminometer Near Edge of Table and Screen Even with Surface.
John Crerar Library, Main Room.
to be fairly satisfactory. Lately a factor has been discovered which calls for a change in indirect lighting systems. That is the eye stress due to the evenness of the light. There are no places of contrast for the eye to observe and thus change the eye opening by contracting or expanding. What has been advised and advocated for the indirect system is some means of varying the intensity, say at regular intervals. This can be done by the use of dimmers. Indirect systems so operated have proven entirely successful.

The purpose of examining the rooms in this library was to test out the different systems of lighting as to efficiency, cost, and comfort.

The indirect possesses two of these features relative efficiency and cost but comfort only in a small degree for the reasons above named. Architectural features of buildings sometimes prohibit indirect systems. Cost figures seem to favor the indirect with the tungsten and its low power consumption, while the factor of eye comfort is unfavorable to either system. The indirect system supplemented by a certain amount of visible light is a very good one. Even in this case means should be taken to vary the intensity of illumination.

The Holophane Reflector Company in designing the lighting system of the Boston schools have a daylight effect produced by maximum illumination coming from the side. This is accomplished almost entirely by the use of reflectors so designed and constructed as to throw the light in the desired direction. The Holophane reflectors and frosted or
sand blasted tungstens eliminate all brilliant light sources by their diffusion.

In conclusion it may be said that for even distribution of light, absence of shadows and general illumination the indirect system is the better. The table diagrams and curves for this library are on Pages 38, to 41.

University of Illinois Library.

The conditions existing in the University of Illinois library are not such as to warrant a careful or correct design without radical changes, as to ceiling outlets and fixtures. What was desired in this study was to better the present conditions by changing reflectors, positions of lamps and tables so that the general effects might be improved.

In view of this fact, tables were chosen in each room one on either side of the aisle. It was that that a representative set of readings could be obtained in this manner. The east room has two rows of tables and three rows of lights, while the west room which is somewhat larger has four rows of lights. The pendant lights are hung quite uniformly eight feet six inches from the floor and are equipped with Prismatic, Pagoda Holophane reflectors, number 6061. The lamps were, in nearly all cases, forty watt tungstens. The equipment of the table lamps was again, in most cases, twenty-five watt tungsten with seven inch enamelled reflectors. Either due to carelessness or oversight nearly one third of the pendant lights in the east room were not burning on several occasions. Some
desk lamps were also equipped with burned out tungstens or a blackened carbon lamp.

Curve sheets on Pages 45 to 50 show the curves plotted for a representative table in the East Reading room on the north side. The data on the table diagram sheet represents the conditions. That in black was taken with the desk lamp in its normal position and that in red with the desk lamp raised four inches. It was found that four inches was the maximum height which the lights could be raised without letting the direct rays pass into the eyes. This comparison shows that the high local intensity under the desk lamps was cut down and the illumination of the dark spots was increased by raising the desk lamps. Even with this change the illumination is insufficient for reading rooms.

The position of the tables in relation to the pendant lights is rather poor or unsymmetrical. The three rows of lights for the illumination of the two rows of tables necessitate a rather unsymmetrical arrangement. In the case of the table on the south side of the room the intensity was rather low as the desk lamps in some cases were carbon. There was a noticeable darkness at the ends of the table and a rather annoying shadow was cast when some one walked behind the reader's chair. All together the illumination on this table was about as poor as any one examined. Table diagram and curves are on Pages 51, 52, and 53.

West reading room.

In this room the two rows of lights over each set of
Table Diagram of Data - East Reading Room.
Curves showing distribution of light lengthwise of table.

Curves 1 & 4 5 inches from table edge

2 & 3 12 "  "  "  "

Foot Candles

Distance - inches
Curves showing distribution of light crosswise of table. Curves as lettered refer to points as shown on table diagram.
Curves showing distribution of light lengthwise of table

Curves 1 and 4, 5 inches from edge

2, 3, 12

Curves from data in red, taken with table lamps raised 4 inches.
Curves showing distribution of light crosswise of table.
Curves as lettered refer to points as shown on table diagram in red.
Table Diagram of Data - East Reading Room.
Curves showing distribution of light lengthwise of table.

Curves 1 + 4 5 inches from edge

2 + 3 12

Distance - inches.
tables give a more symmetrical arrangement. The curves on
Pages 55 to 58 show the conditions in the west reading room
and on the south table.

The row of lamps near the edge of the wall hangs di-
rectly over the end of the table, while the lamps near the mid-
dle aisle are hung three feet and six inches from the end of
the table. The curves as plotted for the conditions, show the
illumination along the lines where data was taken. A dark
spot is in evidence between the desk lamp and the lamp next to
the wall. This illumination was found to be less than one
foot candle over a considerable area.

Curve sheets Pages 59 to 61, show a table examined in
the north side of the reading room. Here the experiment was
tried of raising the table lamps four inches. The curves again
show that the high local intensity near the desk lamps was cut
down and the illumination over the rest of the table quite
uniformly increased. A further discussion of this same table
with lamps equipped with different types of reflectors follows
on another page.

Magazine room University of Illinois.

The magazine room of the University of Illinois lib-
rary is brilliantly illuminated in some spots and insufficient-
ly in others. On Page 62 is given a rough plan of the room and
location of the lamp fixtures. Each chandelier carries four
forty watt, frosted tip, tungsten lamps. These are covered by
opal shades, of a pattern designed to be artistic rather than
useful. The shades were in very poor condition,—dirty.
Table Diagram of Data.
West Reading Room.
Curves showing distribution of light lengthwise of table.

Curves: 1 - 4 - 8 - 16 inches from edge.

Distance: Inches

Candle Flare
Curves showing distribution of light crosswise of table. Curves as lettered refer to points as shown on table diagram.
Isolux Curves - Table West Reading Room
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</table>

Table Lamps. 16" above table.

Data in red. Table Lamps raised 4".

Table Diagram of Data - West Reading Room.
Curves showing distribution of light lengthwise of Table
Curves 1+4, 5 inches from edge. 2+3, 12 inches as above. Table lamps raised 4 inches 2+3 as above.

Distance
180 Inches
Curves showing distribution of light crosswise of table.
Curves in red show distribution as above with table lamps raised 4 inches.
Glare was present but not very noticeable, due to the frosted tips.

The magazine shelves along the walls were well lighted. The room contains one large table and four smaller ones. It is impossible, with only two light sources, to arrange these tables in such a manner that a person reading will not be in his own light in many of the places. The edges of the tables where this is true are so marked in the diagram. Measurements were taken on the long table and the small one in the south east corner. Table diagrams and distribution curves are given on Pages, 64, to, 69. An effective, tho hopelessly inartistic method of improving the illumination at a low cost would be to tear out the chandeliers and hang lamps from drop cords over the tables, three over the large table and one over each of the small ones. This would save one forty watt lamp. Each drop would, of course, have to be supplied with such a shade and hung at such a height that it would properly illuminate its assigned area.

Design.

In accordance with conclusions previously reached, the object of the design, was to secure a proper combination of general and concentrated illumination. In this case the question of general illumination is of greater importance than usual, because the proposition of eye relief, alone, is not to be considered. There is a book stack of four shelves running along all four walls of the room and it becomes necessary to
Data - S.E. table of Magazine Room. Univ. of Illinois.
Curves showing distribution of light lengthwise of table.

Curves 1+4, 5 inches from edge.

2+3 12 • • •
illuminate these properly. It was found, however, that when a mediocre illumination was obtained on the reading tables, the book stacks were very well lighted. It is at once seen that this, then, takes care of itself and that it need not be considered.

Likewise, the question of securing a proper general illumination on the walls and ceilings is easy of solution. There is no reflector on the market, outside of metal ones, that does not allow enough light to pass thru to give a high enough intensity on walls and ceilings. The only wall ornaments above the book stacks are a few pictures, and these are large portraits, so that special attention need not be paid to them. The illumination of walls and ceiling is not solely dependent on light flux passing thru the reflectors, but it is very much helped out by reflection from the lower parts of the room.

In the choice of a reflector the following points should receive consideration:

1. It should provide perfect diffusion, should "soften" the light thoroly.

2. At the same time it should have powerful reflecting qualities.

3. It should be free from streaks or striations.

4. It should have uniformity, should give exact results, and all of its type should be exactly alike.

5. It should possess high quality.

6. It should have a soft appearance, so that it can be used close to the eyes.
7. There should be no chance of its clogging with dust and consequent deterioration while in use.

8. It should be easy to keep clean.

9. It should have a refined, graceful style, to make it adaptable to high grade work.

10. It should fit the quality and size of the light source used.

11. It should be light in weight.

12. It must match well with the style and finish of the fixture.

13. It must be of correct scientific design.


15. It must be easy to use, must be so built as to be easily put on and taken off.

Of these the first, second, third, sixth, seventh, eighth, and thirteenth, are of the utmost importance in reading room work.

No attempt was made to calculate foot-candles of illumination in fixing on the design on account of the number, kinds, and positions of the light sources. Instead of this, trial installations were made and illuminometer readings taken as outlined previously. This method was applicable because it was impracticable to increase the amount of power consumed or to change the positions of the fixtures. The Holophane people recommend an allowance of thirty per cent in watts per lumen for dirt and depreciation of lamps and shades. This point may be of interest here.

The following outlines the method of determining on the
design. A table in the west room was chosen for the work because there are five rows of lamps and five tables, so that it is possible to place each table symmetrical with a row of lamps over its center. First a set of readings was taken under existing conditions, with green conical shades on the table lamps and Holophane Prismatic Pagoda Reflectors number six thousand sixty one above, on the pendants. The data obtained is given in column number one of the design data, Pages 75 and 76.

Column number two was taken with Holophane shades type E-7, extensive, on the table lamps and a Holophane type E-ll, intensive, on the pendants.

Column number three is result with Holophane type E-7, extensive, on the table lamps and Holophane type Prismatic Pagoda above.

Column number four was taken with Opalux type number S three on the table lamps and Opalux type number F two above.

Column number five was taken with Opalux type number S three on the table lamps and Holophane type E-ll, intensive, on the pendants.

In all cases twenty-five watt tungstens formed the light sources, in table fixtures and forty watt lamps in pendants.

Curves were plotted for the existing conditions and for the case of the lamps equipped with Holophane reflectors. The black curves show the conditions as existing while the red curves show the effect of Holophane reflectors. These curves are found on Pages 77, 78, and 59, and 60. In the places of lower intensity the Holophane reflectors nearly double the in-
Design Data.

Explanation of Tables.

On Page 74 is a sketch of the table top showing the illuminometer stations. These are numbered and the corresponding values of illumination are placed opposite the numbers on Pages 75 and 76, which carry the tabulated data.

The conditions were as follows.

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<td>O. S-3</td>
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H.--Holophane
O.--Opalux
75

Design Data.

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Curves Showing Distribution
Of Light Length Wise of Table
West Reading Room
Univ. of Ill. Library
Black Curves Existing Conditions
Red Curves: Holophane
Reflectors

Distance in inches.
Distribution Curve about Holophane Prismatic Pagoda Reflector. No. 6061

40 watt tungsten lamp.
Opalux Shades

Type 3-3

Type F-2
Fig. 15

Intensive High Efficiency Reflector, No. 106150, with 60 watt frosted tip Tungsten lamp.
Light distribution curves of 40 (large bulb), 60 and 100 watt units.

Fig. 16
Extensive High Efficiency Reflector, No. 106250, with 60 watt frosted tip Tungsten lamp.
Light distribution curves of 40 (large bulb), 60 and 100 watt units.
tensity. The high local intensity near the desk lamps was not cut down much owing to the proximity of the two lamps to one another and the fact that maximum illumination with type E-7 reflectors is forty-five degrees to the vertical.

The data tabulation as given and described shows for itself which is the best system for light distribution. The Holophane reflectors from their design do not cause any eye distress as the light is evenly diffused. The Opalux shades do not diffuse the light but rather leave the lamp filament in view.

Conclusion.

The conclusion that the physiological factor is most important in the design of reading room illumination, has already been reached. If the possible personal equations of the users of the illumination are considered as dependent on their physiological peculiarities, that is, the sensitiveness of their respective optical organs to color or intensity, it is seen that the success of a design depends largely on the judgement of the engineer. As the science of Illuminating Engineering is still so young, this judgment must be, necessarily, uncertain, since it is not guided by any exact experience. The great variation in the personal equation of people, with regard to the eye, leads, at once, to the conclusion that the design of a system of illumination can never approach the exactness possible in the design, for instance, of a long distance transmission line or other engineering work.