

THESIS

"A STUDY OF THE LIGHTING SYSTEM
OF THE UNIVERSITY LIBRARY."

Presented to the

ENGINEERING FACULTY OF
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For the degree of

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING.

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The purpose of this survey was to determine the amount of light and the way it is distributed in the reading room of the Carnegie Library, University of Tennessee. From this data it is intended that the amount of light can be carefully studied and suggestions made as to how it may be improved.

Good lighting results from the fulfillment of the following requirements:

1. Light of suitable quality.
2. Light from the proper direction.
3. Light of the correct intensity.

1. Quality involves both color of light and diffusion of light, or absence of glare.

Color - Daylight constitutes the standard which should be approached in artificial lighting.

Glare - This is brightness within the field of vision of such a character as to cause discomfort, interference with vision, and eye fatigue.

2. Direction of light is largely responsible for good or bad lighting. In indirect lighting, the light thus diffused from the ceiling and walls should give as near a minimum shadow as possible.

3. Intensity - It is impossible to fix the definite standards of light intensity for various classes of work because of widely differing conditions. However, the figures given below will be found to be of considerable assistance as a guide in the different types of installations.

Types of Installations	Average Lighting.	Very Good Lighting.
Banks	6	10
Schoolrooms	4	8
Hotels	2	4
Drafting room	10	14
Barber shop	5	8
Church auditorium	2	4
Library reading room	6	8
Offices	6	10

In order to carry out the measurement of the number of foot-candles, a Sharp-Millar photometer was used. A photometer is an instrument for measuring the light from any given source. Nearly all photometers are based on the law of inverse squares, i.e., that the intensity of light varies inversely with the square of the distance from the source of light. Briefly, the photometer consists of a standard source of light, a source of light to be measured, and a screen. These two lights are viewed from both sides at once by two mirrors. When seen by a reflected light the center will appear darker than the outside, because part of the light is transmitted and therefore less reflected. If viewed by transmitted light (light from the opposite side), the center will appear lighter than the outside, as the outside does not allow the light to pass through. In operation the comparison lamp is moved back and forth on the optical axis until a balance is secured (that is, until the center spot is equally bright with the outside

portion) in the cube as seen through a telescope. The lamp moves along the scale that is calibrated to read foot-candles direct. Mechanically, the Sharp-Millar photometer (Fig. 1) is a box 5 inches square by 28 inches long; an elbow opposite the photometer head has a 45 degree mirror and a milk glass cap at the end. The lamp is moved back and forth by a knob from the outside. Mounted on the outside are two variable resistances (one high and one low) in series with the lamp. The range of the foot-candle scale is from .4 of a foot-candle to 20 foot-candles, but by means of a neutral tinted absorbing filter the range may be increased from 4/1000 of a foot-candle to 2000 foot-candles. When the instrument has once been calibrated, the foot-candles may be read at a glance. The photometer should be calibrated frequently if any degree of accuracy is to be expected. The equipment necessary to do this work is a voltmeter to keep the voltage across the standard lamp constant, a calibrated standard lamp and an adjustable resistance and a constant voltage supply. The calibrated standard lamp for the purpose can be secured from any electrical testing laboratory or the Bureau of Standards, Washington. The standard lamp used in calibrating the photometer was standard at 106.6 volts and 16 candle-power. Great care was taken not to let the voltage exceed 106.6 volts, also care was used not to burn the standard lamp longer than absolutely necessary, as continued burning will destroy its accuracy.

With the given voltage marked on the standard lamp (106.6 volts), a certain candle-power (16 c.p.) is given in a specified direction. The lamp was set up and the exact voltage was impressed on it, and maintained constant during the calibration. The comparison lamp of the photometer was set at the given candle-power and the resistance on the photometer was varied until a balance was secured. That is, the two sources of light were brought to a point where they were equally bright. After the comparison was secured in this manner, the voltage on the photometer instrument was recorded and it is the point to hold the comparison lamp in the photometer when making the test. The photometer was first standardized with a two candle-power sign lamp and it was standard at 102.2 volts. After trying to use it at this voltage, it was found that 102.2 volts could not be secured at the library. Effort was made to secure a lamp of equal candle-power and a lower voltage, but a lamp of this kind was not on the market. The next best thing left to do was to use a battery lamp. A 3-volt cell and a battery lamp were secured and this lamp was standardized and found to be standard at 2.2 volts. This made a very handy apparatus to work with as it could be carried almost anywhere.

The following instructions were carried out for standardization measurements of the Sharp-Millar photometer:

For illumination measurements.

At end of rotating tube	milk glass	milk glass
At elbow of rotating tube	mirror	mirror
Absorbing screens	none	none
Prism and lamp	knob out	knob in
Volts	110	battery

For candle-power measurements.

At end of rotating tube	diaphragm	diaphragm
At elbow of rotating tube	milk glass	milk glass
Absorbing screen	none	none
Prism and lamp	knob out	knob in
Volts	110	battery

Transmission coefficient of absorbing screens:

Light screen	0.0428
Dark screen	0.00675

Screw the comparison lamp into the socket tightly, and then unscrew it until the seal is at right angles to the length of the box. (The seal is a line through the base of both filaments.)

When an absorbing screen is between the prism, and the elbow tube, the scale values are to be divided by the transmission coefficient; when between the prism and the standard lamp, the scale reading is to be multiplied by the transmission coefficient of the screen.

If the light source to be measured is placed at 6' $1\frac{1}{2}$ " (186.7 cm.) from the center of the milk glass at the elbow of the rotating tube, the scale multiplied by 10 gives the candle-power directly. For illumination measurements, the scale is direct reading.

(The distance from the end of the tube to the middle of the milk glass at the elbow = 8.85 cm.)

The following measurements were made with the Sharp-Millar photometer in the reading room of the library.

1. Illumination at the edge of the table where a person would hold a book when reading, with overhead lights on, was found to be 1.45 foot-candles. This point is marked on plate 2 by X_1 .

2. Illumination at the edge of the table in between the two table lamps, with overhead lights on, was found to be .75 foot-candle. This point is marked on plate 2 by X_2 .

3. General illumination between two tables with the table lights on was found to be $6.6 \times .0428 = 9.282$ foot-candle. This point is marked on plate 2 by X_3 .

4. General illumination at same place with the table lights and after the overhead lights and reflectors had been cleaned, $7.9 \times .0428 = .338$ foot-candle.

5. General illumination at same place as 3 and 4 but

without table lights, $6.9 \times .0428 = .257$ foot-candle.

6. General illumination at same place as 3, 4, and 5, without the table lights and after the overhead lights and reflectors had been cleaned, $6.7 \times .0428 = .286$ foot-candle.

7. General illumination in center of aisle and between two rows of tables, without table lights, as shown in plate 2 by X_4 , $5.1 \times .0428 = .218$ foot-candle.

8. General illumination at same place as 7 without table lights but with the overhead lights and reflectors cleaned, $6.3 \times .0428 = .269$ foot-candle.

9. General illumination at same place as 7 and 8 with the table lights, $6.5 \times .0428 = .278$ foot-candle.

10. General illumination at same place as 7, 8, and 9, with table lights but after the overhead lights and reflectors had been cleaned, $7.4 \times .0428 = .317$ foot-candle.

11. General illumination in aisle and between two tables as shown in plate 2 by X_5 , with table lights, $7.1 \times .0428 = .304$ foot-candle.

12. General illumination at same place as 11 with table lights but after the overhead lights and reflectors had been cleaned, $8.3 \times .0428 = .355$ foot-candle.

13. General illumination at same place as 11 and 12

but without table lights, $6.4 \times .0428 = .274$ foot-candle.

14. General illumination at same place as 11, 12, and 13 without table lights and after the overhead lamps and reflectors had been cleaned, $7.2 \times .0428 = .308$ foot-candle.

The reason for the readings being multiplied by the constant .0428 was because the absorbing screen had to be used in making the comparison readings. The coefficient given with the photometer is .354 but this was proven to be wrong by this method. The photometer was arranged so as to secure a reading at one end of the scale (by setting the runner at a certain point and turning the rotating tube until the two lights were balanced. Then, by turning the knob in the head of the photometer to the position for the light screen, another comparison was read with the screen and the coefficient was obtained in the following manner.

Reading without screen.	Reading with light screen.	Coefficient.
.8	18.5	.0432
.575	13.5	.426
.69	16.5	.0419
.5	11.5	.0435

Transmission coefficient of the screen = $.1712/4 =$
.0428.

The curve on plate 3 shows the correction to be made on the voltmeter used with the photometer. The voltmeter was calibrated by the use of the potentiometer as shown on plate 4.

The position of the lights is shown on plate 2 (table lights by ϕ and overhead lights by ) and the positions of the photometer are shown by the marks X_1 , X_2 , X_3 , X_4 , and X_5 . As the lights are placed symmetrically, and all four walls are of approximately the same characteristics, an exploration of one quarter of the room was thought to be sufficient for the purpose indicated.

In making the measurements the following features were borne in mind:

1. Care was taken to make sure that the observer did not cast any shadows that would interfere.
2. Be sure, at all times, that the current and voltage flowing through or applied to the comparison lamp in the portable photometer corresponds to the calibration values.
3. Great care was taken to see that the readings made were correct as it is very hard to get the two lights to match at the same point twice.

The picture on Figure 2 is a good illustration of the use of the Sharp-Millar photometer for making readings on the horizontal plane.

The floor plan showing test stations and lighting outlets is shown on plate 2.

The use of a library reflects to a greater or lesser degree the intellectual and artistic standing of the school, and there is, perhaps, no better way to invite patronage than by making the interior attractive and comfortable. Even though the building is beautifully designed and well provided with books, unless its lighting is suitable and adequate, it is not a thoroughly effective institution. The primary function of the lighting installation is to enable printed matter to be read with ease, but in addition it offers an opportunity for making the beauty of the library more prominent.

It is quite a common practice to install decorative fixtures in the high ceiling reading room of the first class libraries. These supply a moderate intensity of general illumination, necessary for supervision and to prevent severe contrast of brightness, but are seldom designed to supply enough light for continued reading. The contrast should not be so that when one looks from one direction which is bright to some other direction that it will cause the pupil of the eye to change rapidly.

The lighting in the library shown in Figure 3 is an excellent example of the principle of co-operation between

architect, fixture specialist, and illuminating engineer. Indirect illumination, as used in this room, offers certain advantages in eliminating reflections from polished table tops and providing good illumination on vertical surfaces, such as shelves and files, without the use of special lamps. In the University of Tennessee Library reflectors have to be placed on the table lights in order to throw light horizontally on the book shelves. With the absence of the hanging ceiling fixtures the installation is made especially effective and gives the room an appearance of spaciousness.

The overhead general illumination should be of from two to four foot-candles, and, in addition to this, local lighting should be supplied on the tables. These lamps should be very carefully chosen, so placed, and of such a character that direct or reflected glare is minimized. An even distribution of light on the table top, of an intensity of from 6 to 8 foot-candles, is suitable, although higher intensities are sometimes necessary where faded manuscripts or books with very fine type are likely to be used.

The length of the line from the generator to the library is 1500 feet. One half of this distance the line is 00 wire and the other half 000. The resistance of 00 is .0811 and the 000 .0642 per 1000 feet. The resistance of the line equals $.0811 \times 15 + .0642 \times 15 = .199$. When the library is carrying full load, it draws 44 amperes. The voltage at full load is 102. The I R drop is equal to $.199 \times 44 = 8.75$ volts. According to the figures, the

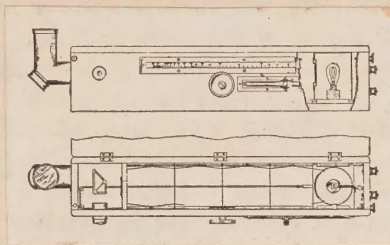
drop measured and the drop calculated are within .75 of a volt of each other.

The percent. normal voltage is 92.6 then from curve showing variation of foot-candles of tungsten filament with variation of voltage above or below normal. The percent. normal c.p. at 92.6 is 77 and at 100 it is 100. Therefore a variation of 23% below normal candle-power.

If the illumination in the library amounts to a maximum of 1.45 foot-candles at 102 volts, then if the voltage be increased to 110 volts, the foot-candles would be $\frac{1.45}{77} \times 100 = 1.818$ foot-candles.

Conclusion. We can see that the data secured show the lighting of the library to be somewhat inefficient. It has previously been recommended that the library should have at least 4 foot-candles to have average lighting and 8 foot-candles to be very good. The maximum intensity is not over 1.5 foot-candles and the average illumination is less than .5 foot-candle. The lighting could be improved if the reflectors were kept cleaned and if the voltage were increased to normal, the illumination would be increased to a much higher efficiency. This voltage can be increased by installing a line that will not cause any voltage drop between the generator and library.

FIGURE 1.



THE FRONT AND TOP VIEW
OF THE SHARP-MILLAR
PORTABLE PHOTOMETER.

FIGURE 2.



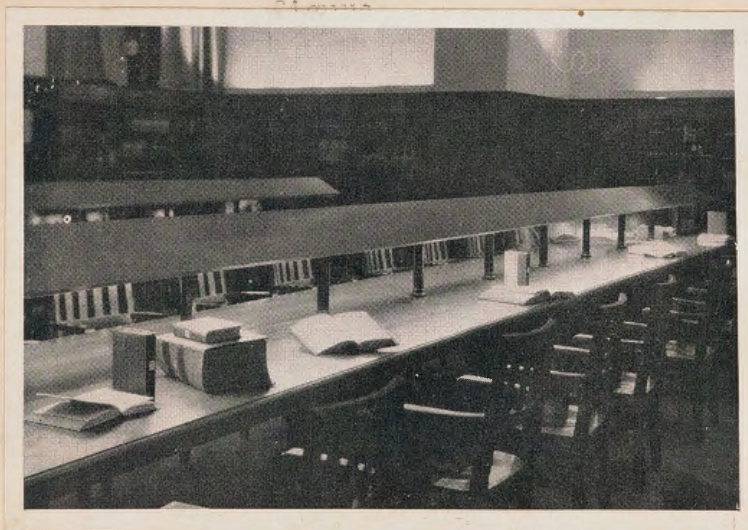
READING ILLUMINATION ON
THE HORIZONTAL PLANE WITH
THE SHARP-MILLAR PHOTOMETER.

FIGURE 3.

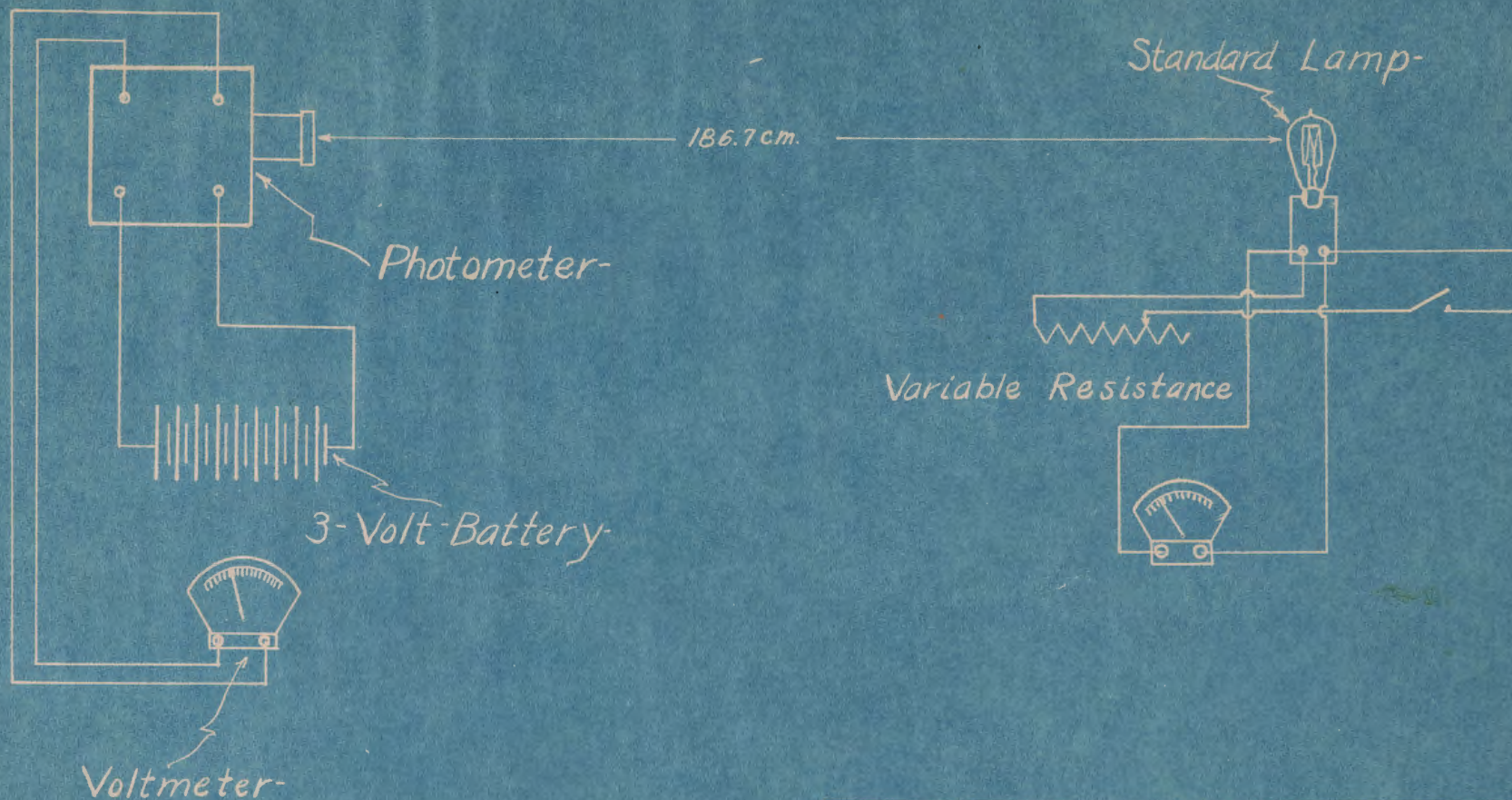


NIGHT VIEW OF THE LIBRARY AT THE UNIVERSITY OF MICHIGAN.

FIGURE 4.



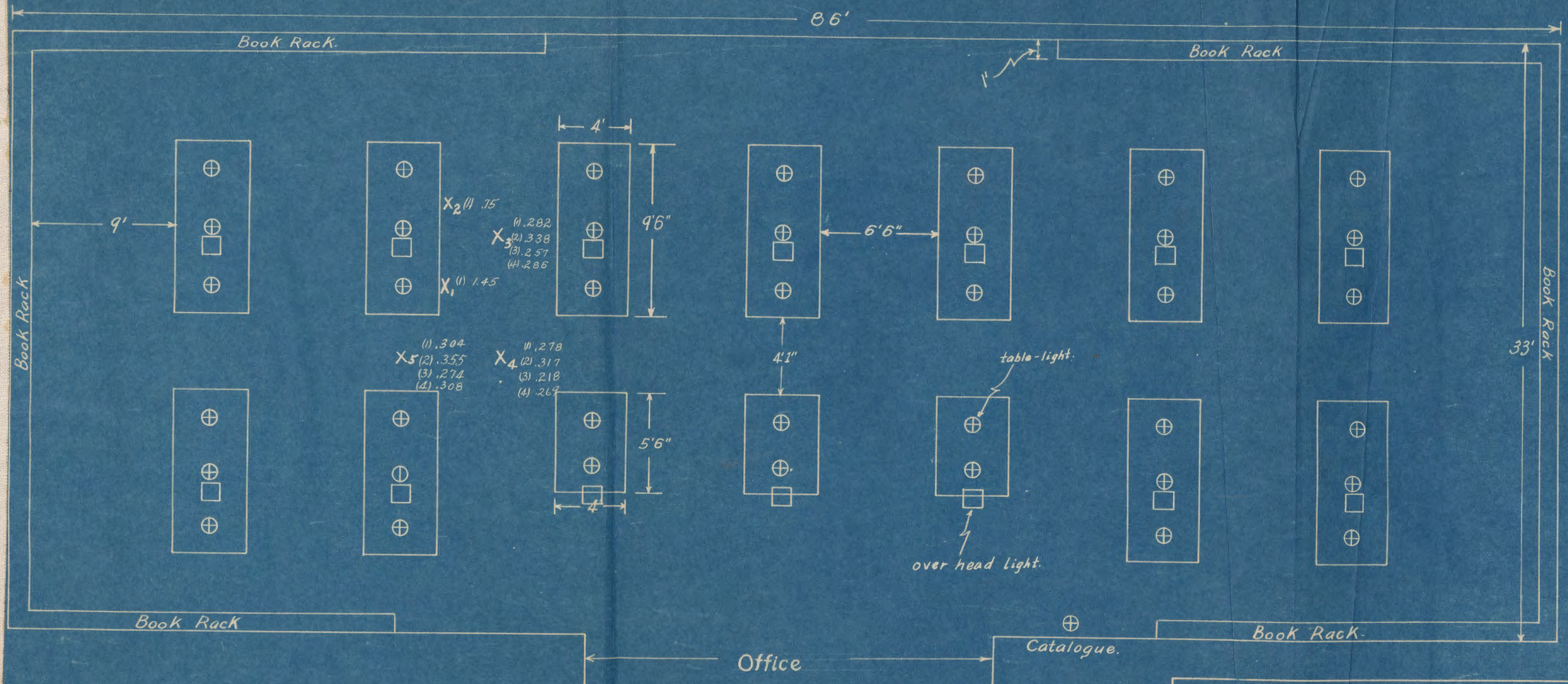
NIGHT VIEW OF A READING TABLE. THE CONTINUOUS TROUGH DISTRIBUTES THE LIGHT UNIFORMLY AND PRESENTS A PLEASING APPEARANCE.



Standard Connections Used
in standardizing Sharp-
Millar Photometer- with
standard light-

Plate 1

May-22-'22.
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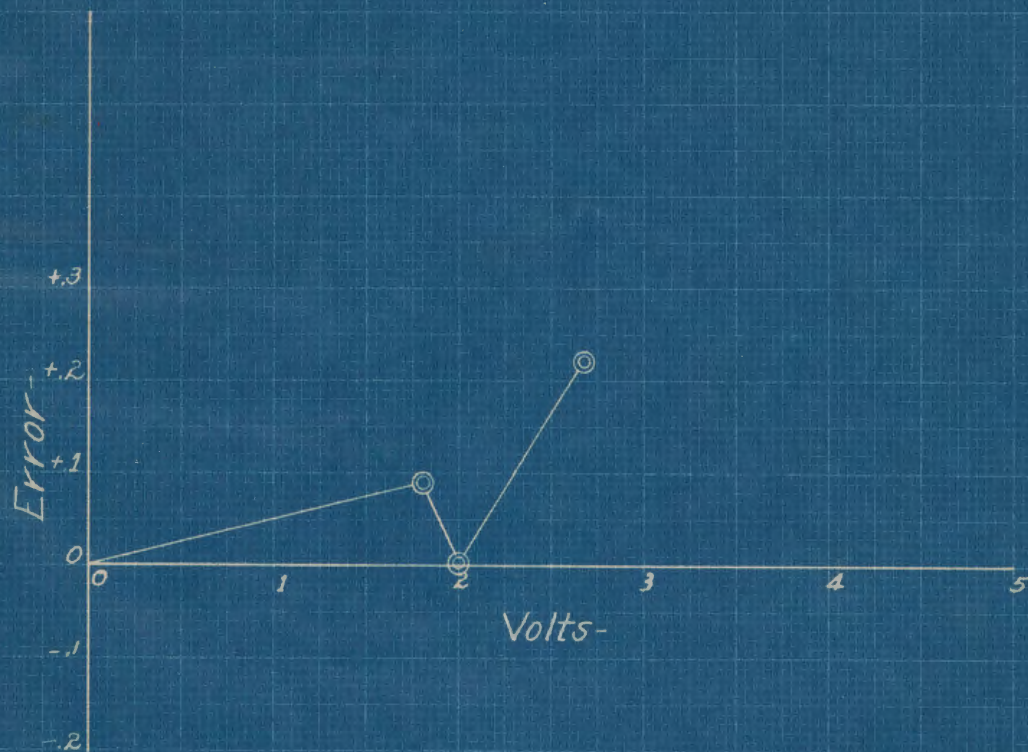


(1) With table and over head lights on before cleaning reflectors.
 (2) " " " " " " " " after "
 (3) With overhead lights only before cleaning reflectors.
 (4) " " " " " " " " after "

Diagram Showing Position
 of the lights in the read-
 ing room of the Library
 University of Tennessee.
 May 22-1922. Plate-II
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PLATE-III

D.C. Voltmeter No. 16901
(0-5).



4-13-'22.

E. H. Shelton-

