Report of the Committee of Oculists and Electricians appointed April 29, 1907, on the artificial lighting and color schemes of school buildings, November, 1907.

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REPORT OF THE COMMITTEE

OF

OCULISTS AND ELECTRICIANS

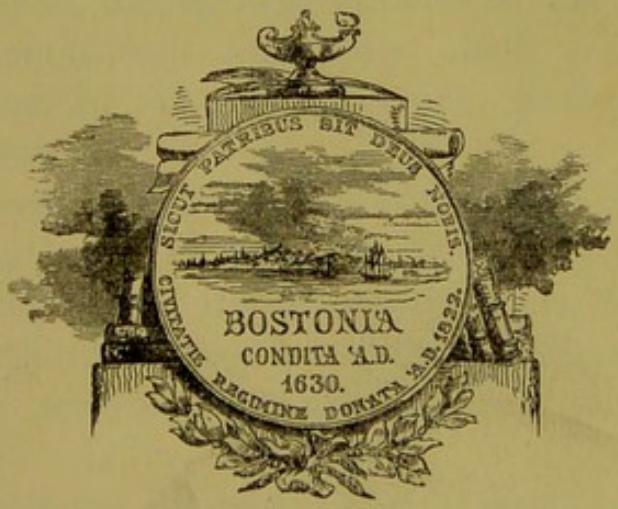
APPOINTED APRIL 29, 1907,

ON THE ARTIFICIAL LIGHTING AND COLOR SCHEMES

OF

SCHOOL BUILDINGS,

NOVEMBER, 1907.



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Attest:

THORNTON D. APOLLONIO,
Secretary.

Boston, November 26, 1907.

The committee appointed in April, 1907, by the Boston School Committee, to consider the artificial lighting of the public schools and their color schemes, respectfully presents its report.

REPORT.

The committee, consisting of three oculists and two electricians, held its first meeting in May, and agreed to take up at the outset a study of the literature on the subject and an inquiry into the various systems of illumination now in use.

The literature on artificial illumination is voluminous, but is lacking in definite information. Although an understanding of this branch of science is of the greatest importance and of daily application, comparatively little research work has as yet been performed, and there is an extraordinary lack of uniformity in the lighting systems of the present day. To the committee's knowledge there is no architectural school in the country which gives a course on this subject.

There are certain general rules which are accepted by all, but when it comes to the actual illumination of a given room the views of those who may be called authorities vary widely, and it becomes evident that the science of illumination is as yet in its infancy.

The artificial illumination of a school-room presents problems which are different from those in a room used for any other purpose. In such a room there

are forty to sixty desks, upon each of which the illumination must be practically the same.

In certain of the subjects taught, such as drawing, sloyd, sewing, and writing, suitable shadows are probably desirable for the comfortable use of the eyes. These shadows should, however, fall in such a manner that the work upon each desk is always in good illumination, and free from the shadow of the head and hand.

Brilliant points of illumination caused by the exposure of the bare filament of an incandescent light, or from facets upon the shade, are highly undesirable, and, if maintained in a constant position in relation to the eye, may be dangerous.

The means of illumination should neither contaminate the air, produce much heat, nor be rich in the injurious rays of the spectrum.

The construction of the fixtures must be such that they can be kept clean with a minimum of labor, and also such that if dust does accumulate upon the shades it shall not materially diminish the amount of light.

The color of the walls, window shades, and woodwork must be very light. This is necessary, first, to enable the walls to reflect the light instead of absorbing it; and second, which is of great importance, to avoid sharp contrasts between the surrounding colors and the white sheet of paper upon which the pupil is looking much of the time. If the contrast is at all marked there is fatigue and discomfort of the eyes, which cannot be avoided, and the greater the illumination of the white page, beyond a certain point, the greater the fatigue and distress.

As school-rooms are used by day as well as in the evening, this fact must be considered in determining the color of the walls.

For the sake of clearness, it may be as well to add a few words of explanation here as to direct and indirect lighting. In pure indirect lighting all the light is reflected upwards to the ceiling and walls and thence to the lower portions of the room, while with direct lighting opaque shades placed immediately above the lamps reflect all the light downward.

Direct lighting is the simplest and cheapest method of illumination at our disposal, but is open to the following grave objections: It is difficult to shade the lamps in such a way as to avoid bright points of light. The shadows are intense. It is hard to distribute the light evenly at each place unless separate lamps be installed upon each desk.

Indirect illumination has met with a certain amount of favor in this country and in Germany. It avoids bright points of light coming into the field of vision and the annoying shadows which are so often present when the greatest care is not used in the location of fixtures and the choice of shades. Most of the modern illuminating systems combine the direct and indirect forms; for instance, the standard system in use in the Boston schools may be regarded as indirect plus a certain portion of direct light, while in the system to be described later the larger proportion of the light is direct.

The committee is of the opinion that for school-room lighting there are certain serious disadvantages inseparable from systems in which indirect light preponderates.

(1.) Indirect light produces the unfortunate psychological effect of insufficient illumination.

(2.) Recently published experiments in the "Illuminating Engineer" of October, 1907, point to the fact that with indirect illumination the amount of light for comfort in reading must be 65 per cent. greater than with direct.

(3.) Indirect light is an abnormal form of lighting, seldom or never to be found in nature, to which the eye is unaccustomed.

(4.) With it we lose the shadows by which we judge distance and relief.

(5.) The illumination of surrounding objects and that of the work on the desk are the same, while experience has shown that, whereas it is unwise to light the work greatly in excess of surrounding objects, a small amount of superior illumination makes for comfort.

(6.) It is conceivable that light reflected from the ceiling and colored surfaces may undergo some change interfering with its efficiency.

Discussion of the relative cost follows later.

It will be seen that the problems presented are many and difficult, but the general requirements for schoolroom illumination may be summed up as follows:

(1.) The light should be produced with as little contamination of the air as possible.

(2.) The heat production should be low.

(3.) The light should not be rich in the rays of the spectrum which are irritating to the eye.

(4.) A steady light is indispensable, and the lamps should not be subject to rapid deterioration.

(5.) The light should be well diffused so as to secure uniform illumination throughout the room.

(6.) It should be properly shaded so as to prevent points of great brilliancy from coming within the field of vision, and to avoid annoying and disturbing shadows from falling on the work. For this latter purpose the proper location of the fixtures is of the greatest importance.

(7.) The amount of light necessary varies according to the purpose for which it is required. More is necessary for fine work than for the ordinary class exercises.

(8.) The cost of installation and maintenance should be moderate.

(9.) The fixtures should be of durable construction and easy to clean and repair.

(10.) In considering the color of the walls, the daylight illumination must be taken into account. For the bright, sunny rooms a very light green is probably the best shade. For the darker rooms a light buff.

(11.) The ceiling should be white or slightly tinted.

(12.) The windows should be provided with shades for excluding the direct rays of the sun and diffusing the light throughout the room.

(13.) The woodwork should be of a light color such as that of natural wood. Under no circum stances are dark walls and woodwork permissible.

METHODS OF INVESTIGATION OF THE LIGHTING OF THE BOSTON PUBLIC SCHOOLS.

The committee visited a number of the schools and made a careful examination of them. In addition, meetings were held and various persons were interrogated on this subject.

Among these were illuminating engineers connected with the present system of lighting, a representative of the Schoolhouse Commission, and several masters from the evening schools. All these gentlemen gave freely the information in their possession as to the merits and disadvantages of the present system, and suggested improvements when, in their opinion, they were necessary.

The present lighting system in the more modern of the public schools may be briefly described as follows:

The standard school-room, about 26 feet × 30 feet × 13 feet high, contains desks for some fifty scholars, and a teacher's desk on a raised platform at the end or side of the room. The woodwork generally is of a light yellowish color, the walls of a light green or buff, the ceiling white. Suitable shades are provided for the windows. The lighting arrangements in this room consist of six fixtures suspended from the ceiling, each composed of two eight and two sixteen candle-power incandescent lamps, contained in a shallow bowl of opal glass and covered with a sheet of plate glass. The larger part of the light is reflected to the ceiling and thence downward to the desk, while a smaller amount is transmitted directly through the opal glass shade. Over the teacher's desk is a single light reflected downwards by an opaque shade.

In the opinion of those by whom this fixture has been designed and installed the amount of light given is sufficient in quantity and of a quality pleasant to the eye. On the other hand, however, the fixture soon admits dust, and considerable time and care must be expended in cleaning it and replacing the lamps.

The masters make the same criticism, and in addition state that the fixture is not properly kept up, and that the amount of light soon becomes insufficient; also that this form of light is not suitable for fine work such as sewing and for the sloyd classes.

The janitors affirm that much more time than they are able to give is necessary in order to clean the fixtures properly, and that the glass coverings are easily broken.

The committee visited numerous rooms in which these fixtures are installed. The light was found to be steady, moderately well diffused, and free from points of great brilliancy. Shadows, though present, were neither numerous nor disturbing. In those rooms in which these fixtures were clean, the walls of a proper color, and the lamps new and of sufficient candle-power, enough light was given for the ordinary school work. This was the case in those rooms only where this lighting had been recently installed.

In all other rooms visited the amount of light supplied was insufficient for the needs of the scholar, owing to the dust which had fouled the fixtures (in one instance photometric observations showed an increase of 20 per cent. in the amount of light given after the plate glass top on which there was a very light layer of dust had been cleaned) and to lamps which either were of insufficient power or were giving an amount of light below their rated efficiency.

The difficulty of doing fine work under these circumstances was well illustrated in one building where, in a sloyd class-room, the lower shade of opal glass had been removed in order to obtain more light.

Most of the fixtures were dirty, much dust had accumulated on the glass cover and inside the opal shade, covering the bottom and reducing the amount of light transmitted and reflected. Many of the lamps were giving a light below their rated candle-power, and some were found which had burned out entirely. It is apparent that these fixtures require much time and care to keep clean and in repair.

Several of the schools visited were lighted by clusters of incandescent bulbs, the light being reflected downwards by opaque shades. The filaments were in plain view, and caused considerable discomfort by their brightness. The light was unevenly distributed, and gave intense and disturbing shadows. These fixtures were found in the older schools.

In some of the schools the color of the woodwork was satisfactory, while in others not only the desks but also the woodwork was very dark.

The walls of these schools were, in certain instances, of the proper shade of light green or buff, but in most of the rooms the color was too dark for the efficient reflection of light. There appears to be no absolute standard of color adopted.

As regards the color scheme of the room, the worst conditions were found at the Central Evening High School, where the walls several years ago received a dark olive green tint and the woodwork was colored to represent flemish oak. The lighting in these rooms is carried on by means of incandescent bulbs in clusters, direct light being furnished. Photometric observations here gave over 1.5 candle feet at the desks, which illustrates well the effect of contrast on the eyes. All the masters

interviewed in regard to the lighting of this building were outspoken in their condemnation of it, and the committee was informed that at the last session of the evening school a large number of pupils withdrew, giving as a reason that they were unable to use their eyes there without distress. The committee consider this building as a whole very badly lighted. The direct lighting is objectionable for reasons stated previously. The dark walls and woodwork absorb much light that should be reflected, and produce a marked contrast to the book or paper, which is trying and injurious to the eyes.

Window shades were furnished in all rooms which the committee inspected, but nowhere did they appear to be in use. When the masters were interrogated as to the reason for this, they replied that so much dust was thrown into the room by drawing the shades that their use had to be discontinued. Those examined by the committee were indeed covered with dust and showed evidence of neglect on the part of the janitor. This, however, does not furnish a sufficiently good reason for doing away with window shades. Since the area of the windows in a modern Boston school-room must be one-fifth that of the floor area, it is evident that the corresponding area of reflecting surface is lost by leaving the windows uncovered by shades designed to reflect light. The committee believe that the masters should make use of the shades whenever artificial light is necessary. The janitors should be compelled to keep them free from dust and in good working order.

Before leaving the subject of walls, the committee would like to call attention to blackboards. These

structures occupy a very considerable portion of the wall space of each room, and are at a level with the pupils' eyes. Their dark surface absorbs a very considerable amount of light, although this is not so great as would appear at first sight, since the boards soon become covered with a grayish layer of chalk dust and are thereby lightened considerably. They afford a marked and uncomfortable contrast of color to the other surfaces of the room, and the amount of dust arising from the use of chalk is also undesirable. The committee regards the present blackboard as an anachronism in the modern school-room. Although no substitute has been found for it, but little thought has been given to this question, and the committee feels that an investigation along this line might yield gratifying results.

ILLUMINATION EXPERIMENTS.

After a full discussion of the present methods of lighting the school-rooms and a careful examination of the literature, it was decided that no solution of the problem could be made without actual experimental studies.

It was especially fortunate that these experiments could be carried on in conjunction with those which were being made by Mr. B. B. Hatch, Electrical Engineer for the Schoolhouse Commission (at the Old Dearborn School), who co-operated with the committee in every possible way, and to whose experience, intelligence and progressive ideas the success of the experiments is chiefly due.

The windows in one of the rooms of this school were boarded up so as to shut out all daylight. The

size of the room was 28 feet × 28 feet, height 14 feet, or slightly larger and higher studded than the standard school-room recently adopted. The color of the side walls was light yellow, the ceiling white. The wiring in this room was so arranged, with duplicate circuits, that one experiment could be tried immediately after another by merely throwing a switch. The committee found this of great assistance in obtaining comparative results from the various forms of lighting that were tried.

Three methods of lighting were considered.

(1.) Indirect method, depending wholly upon light reflected from walls and ceiling.

(2.) Direct method, with light obtained from open clusters or single lamps.

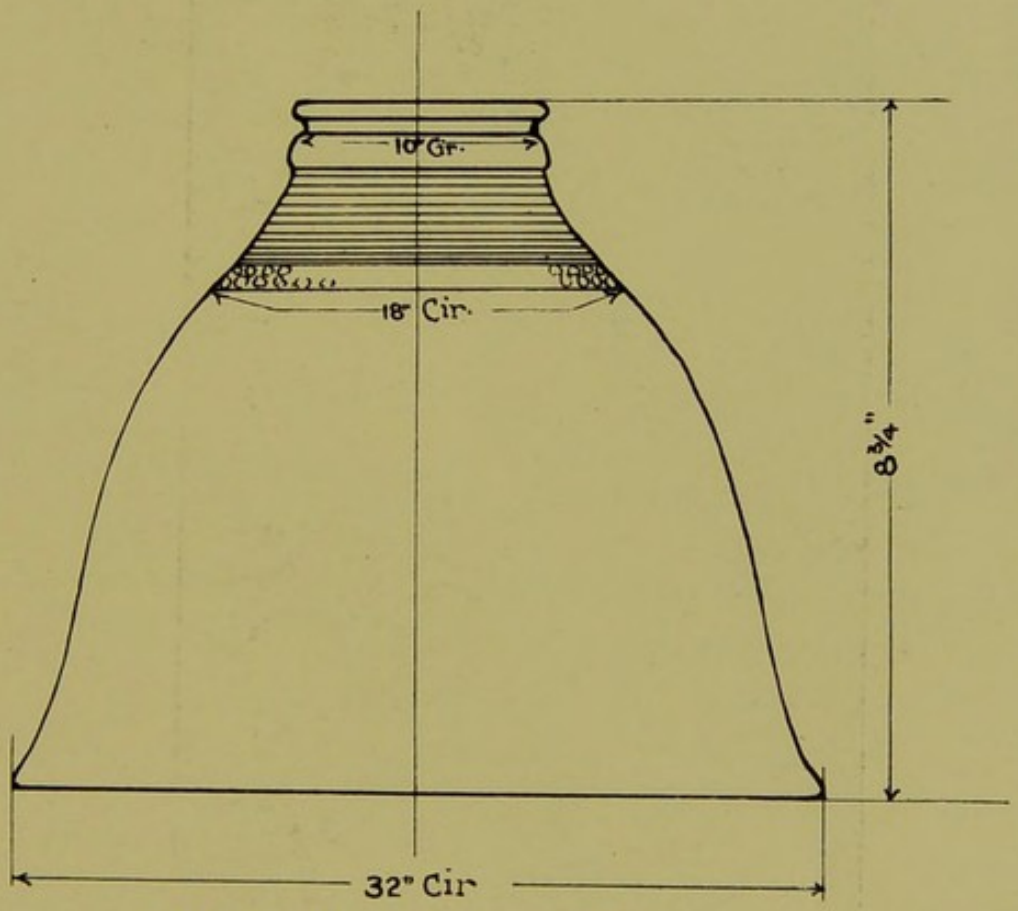
(3.) Combination method, depending partially on direct and partially on diffused light.

No actual experiments were made with indirect lighting, as objections to its use seemed so obvious as to render them unnecessary. To light a school-room with incandescent lamps by the indirect method would require a maximum of current with a minimum of efficiency. The cost of current to secure a proper illumination by this method would in the opinion of the committee be prohibitive. A school-room could be lighted by the indirect method with arc-lamps, and the New York Trade School, visited by one of the members of this committee, is lighted in this way, and was said by teachers in the school to be satisfactory, although when the lights were exhibited to the visitor a considerable amount of flickering was observed. Some lecture halls in Germany, which were also visited during the summer

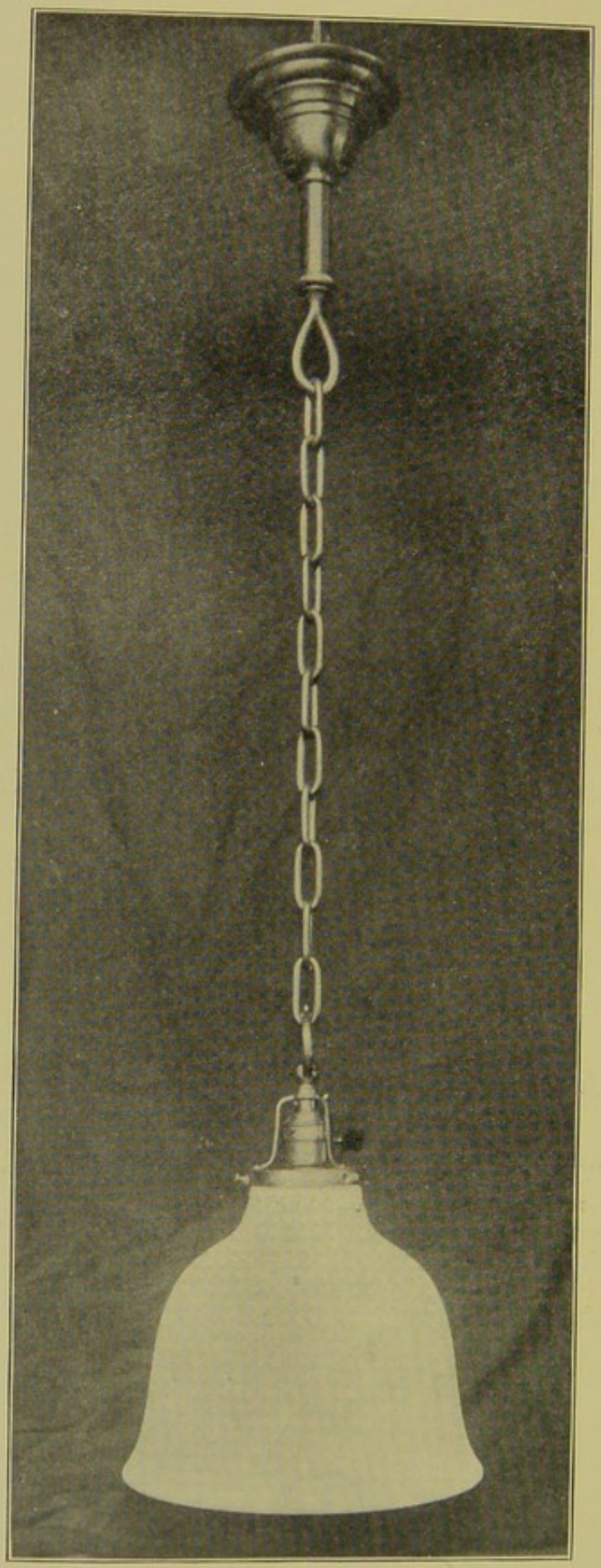
by one of the members of this committee, appeared to be satisfactorily lighted by indirect arcs. This method of illumination, however, is better adapted to large rooms or halls where the evenness of the light is not so imperative as in a school-room. To distribute light properly in a standard class-room, it would, we believe, be necessary to install at least four arcs, which would necessitate changes in the present wiring of the class-rooms. These arcs would consume more electric current than is at present used. The care of an arc-lamp requires more or less expert knowledge and if not properly trimmed it is apt to flicker and burn unevenly. As before mentioned, the committee made no actual experiments in indirect lighting with either incandescent or arc lamps, believing this method not to be readily adapted for school-house work.

Several experiments were made with direct lighting which were unsatisfactory, as it was impossible to locate the lights so as to bring them out of the vision of both pupils and teacher.

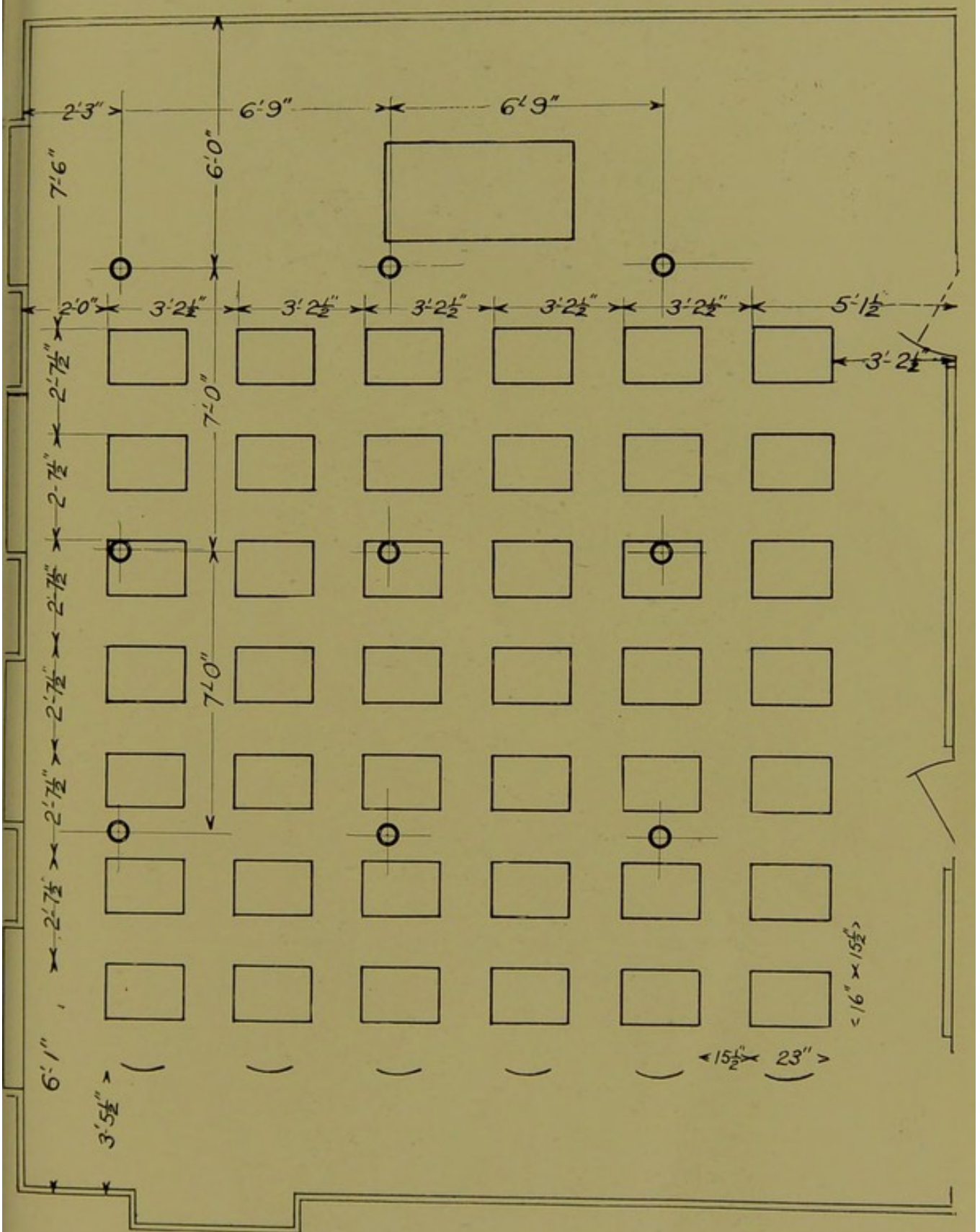
The experiments were chiefly confined to schemes of illumination depending partially upon direct and partially on diffused light. The lamps used were what is known as high efficiency or low watt incandescent lamps which have recently come on the market. The most satisfactory results were obtained from nine thirty-six candle-power forty-watt Tungsten lamps, each equipped with the diffusing prismatic reflector shown in the accompanying cut. These shades are constructed of prismatic glass coated on the outer or inner surface with a white enamel. The lights were arranged in three rows of three lamps, each running



PLAN OF REFLECTOR FOR TUNGSTEN LAMP.



TUNGSTEN LAMP, SHADE, AND SUPPORTING FIXTURE.



PLAN OF STANDARD SCHOOL-ROOM, SHOWING LOCATION OF LIGHTS.

Suggested Colors for School-room Walls.

1.

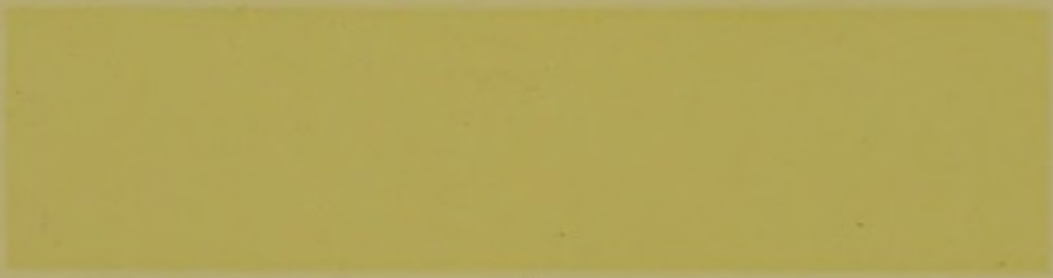
WHITE, CHROME GREEN.

White reflects 74 per cent. This tint reflects 45 per cent.

2.

CHROME YELLOW, CHROME GREEN, WHITE.

White reflects 74 per cent. This tint reflects 46 per cent.



3.

WHITE, LEMON, CHROME YELLOW.

White reflects 74 per cent. This tint reflects 51.4 per cent.

4.

WHITE, STONE YELLOW.

White reflects 74 per cent. This tint reflects 51 per cent.

parallel to the rows of desks. The accompanying plan of a standard school-room shows the exact location of lights. It will be seen that the centre of light distribution is slightly to the left of the middle of the room when facing the teacher's desk. This was arranged in order, as far as possible, to throw the dominant shadow from left to right on the pupil's desk. It was found that the location of these fixtures was a matter of great importance in getting the best results. The candle foot illumination on top of desks with lamp 10 feet 6 inches above the floor was approximately 2.5 candle feet at every desk, a remarkably even distribution.

About the same results were obtained from 100 watt G. E. M. lamps with the same style of shades.

The diffusing quality of these shades is so great that the candle foot illumination on the desk directly below one of the lamps was appreciably no greater than the illumination on the desk in any one corner.

The direct light is greater than that obtained from the standard fixture, as is evidenced by the more pronounced shadows. The dominant shadow is so thrown as not to be disturbing, and, in the opinion of the committee, is, for certain work, a distinct advantage.

The illustrations give a good idea of the shade, Tungsten lamp, and supporting fixture. It will be seen that the fixture is extremely simple, consisting merely of a rod or chain, from which is suspended a shade holder, shade, and lamp socket. The shade is open at the base, is made of clear glass, with the inner or outer surface enamelled in a manner to give an appearance of frosting, and the outer surface fluted in a manner similar to the ordinary prismatic shade. The extreme simplicity of

the fixture reduces the cost of keeping it clean. In this respect it is vastly superior to the present standard fixture. The Tungsten lamp is similar in appearance to a slightly elongated standard incandescent lamp with the lower portion frosted. The amount of light furnished by these lamps and shades was considerably greater than that derived from the standard clusters.

The room at the Old Dearborn School was equipped with the standard lighting and the new lights as just described. By the duplicate wiring in this room, previously described, light could be obtained first from the Tungsten lamps and then from standard clusters.

In the mind of the committee there was no question but that the light furnished from the Tungsten lamps, with the shades described above, was superior to that furnished by the standard clusters.

The comparative current consumption of a schoolroom lighted with nine 40-watt Tungsten lamps, nine 100-watt G. E. M. lamps, and the present standard lighting with indirect clusters, is as follows:

9 Tungsten 40-watt lamps . . .	360 watts.
9 G. E. M. 100-watt lamps . . .	900 "
6 Indirect clusters (present standard two 8-candle power and two 16-candle power each)	960 "

The saving in current by the substitution of nine G. E. M. lamps for the present standard clusters is not great, but the increase in illumination is considerable, as the average candle foot from the present standard clusters, when clean, is about 1.5, as against 2.5 from the G. E. M. lamps and shades as just

described. The saving by substitution of Tungsten lamps is 62½ per cent. in current consumption, which, applied to the entire school lighting bill, would amount to a considerable sum. From this sum, however, should be deducted the cost of lamp renewals, after which deduction the apparent saving is about 45 per cent. This saving could not be obtained, however, without discarding or remodelling the standard clusters now in use. These clusters necessitate a horizontal position for the lamp, while the Tungsten lamp as at present made can be placed in a vertical position only.

The Tungsten fixture, as above described, including lamp, costs approximately $5. The standard cluster, exclusive of lamps, costs about $6.50.

The life of the Tungsten lamp is about 1,000 hours, considerably longer than the ordinary carbon filament lamp, and gives practically even light throughout its entire life.

The first cost of the wiring installation for a school building lighted with the Tungsten lamps is smaller than for a building lighted with the standard clusters. Tungsten lamps require less current, and, consequently, the current can be carried on smaller wires. The saving on first cost of installation in a building of twenty-eight class-rooms is approximately $850. This saving is effected after allowing for the first cost of the Tungsten lamp.

The committee regards the amount of light furnished in school-rooms equipped with standard fixtures as too low for practical purposes. The maximum amount is rarely over 1.3 candle feet, which is barely sufficient for reading, and is not enough for

carrying on the finer work. Owing to the accumulation of dust and the rapid deterioration of the lamps, the candle-power at the desk soon sinks below one candle foot, and complaints become frequent. This committee feels that it would be wise to furnish a considerably greater amount of light, sufficient for all ordinary school work. Under proper conditions, two candle feet at each desk should be enough, and, as the system recommended furnishes 2.5 candle foot, there is .5 of a candle foot provided for deterioration.

The committee does not regard the system just described as an ideal illumination for school-rooms, but as the nearest approach to it which can be obtained in the present undeveloped stage of the science and art of lighting. It does regard this system as superior to that now in use. A greater amount of light with equally good diffusion is obtained at a greatly reduced cost. The fixtures are simpler in design, more durable and much easier to keep clean.

The committee has also carried out investigations in regard to colors and shades of colors, the amount of light reflected in each case being determined by measurement.

SUMMARY.

The committee, as a result of investigation, is of the opinion that the methods of lighting now in use in the Boston public schools are open to improvement. The direct lighting in the older schools is undesirable, and the standard semi-indirect system is also unsatisfactory. The current consumption and consequent cost of operation with this latter system is almost double that of the system recommended.

There is no standard color for the walls, and in many cases they are too dark for the proper reflection of light and the avoidance of marked contrasts. In certain cases, notably in the Central Evening High School, the color is especially bad.

Window shades are not properly cared for, and do not serve the purpose for which they are intended.

The committee has, as a result of its investigations, selected a system of illumination which it regards as markedly superior to that in use.

As a result of an investigation, certain shades of color have been selected as best fulfilling the requirements for school-room walls, and are included in this report.

The committee therefore recommends:

RECOMMENDATIONS.

(1.) That a standard of illumination be adopted in the Boston Public Schools, to-wit: That the minimum illumination at each desk be two-foot candles.

(2.) That the fixtures, lamps, and shades of the type described in this report be installed in the schools.

(3.) That the number and location of these lights should be as in the accompanying plan.

(4.) That the shades of light green and buff, illustrated by the enclosed samples, be adopted as standard colors for the school-rooms.

(5.) That the woodwork and desks, in all cases, be of a light color.

(6.) That suitable window shades be installed and used in all rooms where artificial light is necessary.

(7.) That janitors be required to pay closer attention to the cleaning of lighting fixtures and dusting of window shades.

The committee wishes to express its warm appreciation to Mr. B. B. Hatch, Electrical Engineer of the Schoolhouse Commission, for his valuable assistance throughout the work; to Dr. Louis Bell, consulting Illuminating Engineer, for determining the amount of light reflected by the various samples of color submitted; to Major E. A. Zalinsky, U. S. A. (retired), for suggestions regarding shades; to Professor Hanus of Harvard University, and Messrs. Fleischner and Bierstadt of the Boston Public Library, for assistance in looking up the literature.

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