U. S. DEPARTMENT OF LABOR
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BUREAU OF LABOR STATISTICS
ETHELBERT STEWART, Commissioner

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SAFETY CODE SERIES

CODE OF LIGHTING SCHOOL BUILDINGS

ILLUMINATING ENGINEERING SOCIETY
AMERICAN INSTITUTE OF ARCHITECTS
JOINT SPONSORS

AMERICAN STANDARD
Approved June 16, 1924
American Engineering Standards Committee

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NOTE ON REVISION OF THE CODE

The present code was revised under the rules of procedure of, and has been officially approved as an "American standard" by, the American Engineering Standards Committee.

For this purpose, a sectional committee made up of representatives officially designated by the societies and organizations listed below was formed by the Illuminating Engineering Society and the American Institute of Architects, joint sponsors of the code:

American Gas Association.
American Institute of Architects.
American Institute of Electrical Engineers.
American Medical Association (Section on Ophthalmology).
American Public Health Association.
American School Hygiene Association.
American Society of Safety Engineers.
Eye Sight Conservation Council of America.
Illuminating Engineering Society.
National Association of Public School Business Officials.
National Bureau of Casualty and Surety Underwriters.
National Committee for the Prevention of Blindness.
National Council on Schoolhouse Construction.
National Education Association.
National Electric Light Association.
National Safety Council.
United States Bureau of Education.
United States Bureau of Standards.
United States Public Health Service.
Women's Bureau of the United States Department of Labor.

ILLUMINATING ENGINEERING SOCIETY

The Illuminating Engineering Society was organized in 1906 for "* * * the advancement of the theory and practice of illuminating engineering and the dissemination of knowledge relating thereto." The society now has about 1,400 members who are interested in the subject of lighting from various standpoints: Engineering, economic, hygienic, aesthetic.

The society has no affiliations with any commercial organization. Anyone interested in its objects may become a member.

AMERICAN INSTITUTE OF ARCHITECTS

The American Institute of Architects is the national organization of the architectural profession. Its objects are to organize and unite in fellowship the architects of the United States, to combine their efforts so as to promote the aesthetic, scientific, and practical efficiency of the profession, and to make the profession of ever increasing service to society.

Every architect who is qualified to practice the profession of architecture and who deals honestly with his brother architect and with those whom he serves is eligible to membership.

The office of the secretary, the headquarters of the institute, is in the Octagon House, Washington, D. C. The office of the Scientific Research Department of the Institute is at 19 West Forty-fourth Street, New York City.

CONTENTS

BULLETIN OF THE
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INTRODUCTION

In 1918 the Illuminating Engineering Society prepared and issued a code of lighting school buildings. Shortly after the publication of the code, the New York State Department of Education adopted it as a guide in planning the artificial lighting of school buildings in that State. The Industrial Commission of Wisconsin used the code as a basis for the preparation of the Wisconsin School Lighting Code, effective 1921. A number of provisions of the code have been incorporated in building codes in several States and municipalities.

Improvements in lighting practice during the past five years have made necessary a revision of the code to conform with modern standards; moreover, there has been a demand for more definite and detailed specifications than those contained in the 1918 code.

The accompanying code aims to meet this demand and is intended to serve not only as a guide for legislators, State and municipal departments of instruction, and other regulatory bodies interested in the formulation of enactments, rules, and regulations for the daylighting and artificial lighting of school buildings, but also as a guide to architects in planning the lighting of school buildings and to school superintendents and other school authorities in bettering lighting conditions. A popularized brief of the code, now in course of preparation, is intended to serve as an aid to teachers in instructing children in the proper use of the eyes and in the underlying principles of correct lighting—an important part of the course in school hygiene that has received as yet but scant attention.

The subject matter of the code as here presented is divided into three parts: (1) Rules; (2) Why the fulfillment of the rules is important; (3) How to comply with the rules.

The code was prepared by a sectional committee consisting of representatives of organizations, societies, and individuals identified with the school-lighting problem in one or another of its various phases. This sectional committee was organized by the Illuminating Engineering Society and the American Institute of Architects, joint sponsors for the code, under the rules of procedure of the American Engineering Standards Committee. The code has been approved by the sectional committee, the Illuminating Engineering Society, and the American Institute of Architects.

Although the rules and recommendations of the code are based upon what is considered the best practice of the present time, it is probable that in the future modifications may become desirable as the art develops and as experience is gained in the application of the code.

The subject of fire hazard in school buildings, though outside the scope of this code, should receive most careful attention. Building codes and local, State, and National regulations should be consulted. In this connection reference should be made to the following pamphlets issued by the National Fire Protection Association, Boston, and promulgated as the regulations of the National Board of Fire Underwriters: "National Electrical Code," "Installation, Maintenance and Use of Piping and Fittings for City Gas," "Installation and Operation of Acetylene Equipment," "Gasoline Vapor Gas Lighting Machines, Lamps and Systems." The subject of safety from fire has received special attention in the school-exits section of the American Engineering Standards Committee's Building Exits Code, which should also be consulted.

Constructive criticism, suggestions, and inquiries in relation to the Code of Lighting School Buildings will be welcome and should be addressed to the Sectional Committee on School Lighting Code, American Engineering Standards Committee, 29 West Thirty-ninth Street, New York City.

EXPLANATION OF TECHNICAL TERMS

In the rules and discussion of the code it is necessary to use some technical terms referring to the measurement of light.[1] All such measurements are now based on standard lamps kept in the national standardizing laboratories of the various countries. The candlepower of these standards is fixed by international agreement, and other lamps are measured by comparison with them. The unit of candlepower is substantially the average intensity of the old standard sperm candle.

Every practical source of light has different candlepowers or intensities in different directions, and consequently "candlepower" is not a direct indication of the total light given out. In order to avoid ambiguity it has become customary in this country to rate lamps in terms of their total light output. The unit used is the *lumen*, The lumen is the light falling upon an area of one square foot all points of which are one foot distant from a source having an intensity of one candle. Such a surface receives an *illumination* of one *foot-candle;* in other words, one lumen of light flux is enough to furnish one foot-candle of illumination on 1 square foot. The lumens needed on a working surface are the product of the number of square feet of area to be lighted by the number of foot-candles required on the surface. The light output of an illuminant, as well as the light received on a given area may be measured in lumens.

[1] Formal and precise definitions of such terms are given in the reports of the Committee on Nomenclature and Standards of the Illuminating Engineering Society, which can be obtained from the office of the society, 29 West Thirty-ninth Street, New York City.

No lighting installation can throw upon the working surface all the light produced. The *coefficient of utilization* of an installation with reference to a given plane is the ratio of the light flux (lumens) received on that plane to the total flux from the lamps illuminating it.

The *reflection-factor* of a surface is the ratio of the light flux reflected from the surface to the flux falling on it. Reflection may be regular, diffuse, or a mixture of the two.

Brightness as used technically means exactly what it does in common speech; that is, the intensity per unit of projected, or apparent, area of the source. The brightness of a surface may be due either to the light emitted by it or to the light reflected by it and may be measured in various units; but in this code brightness values are stated in candles per square inch.

A *luminaire* is a complete lighting unit consisting of a light-source, together with its direct appurtenances, such as globe, reflector, refractor, housing, and support. The term is used to designate completely equipped lighting fixtures, wall brackets, portable lamps, or so-called removable units.

PART I.—RULES

General requirements.

When in use during daylight hours, rooms in school buildings in which pupils are required to study or do any work shall be provided with *natural* light in accordance with the following rules.

When in use during periods when natural lighting fails, rooms in school buildings in which pupils are required to study or do any work shall be provided with *artificial* light in accordance with the following rules.

When in use, other rooms in school buildings, also school grounds, shall be provided with *natural or artificial* light in accordance with the following rules.

Rule 1. Illumination required.

The illumination—natural or artificial—maintained shall be not less than the minimum values in Table I. Values recommended for ordinary conditions of artificial lighting are presented in the last column. Higher values are often desirable.

TABLE I.—*Minimum values of illumination required and values recommended for artificial lighting*

	Minimum required foot-candles	Recommended foot-candles
ON THE SPACE [1]		
Walks, drives, and other outdoor areas, if used at night	0. 1	0. 5
Playgrounds, outdoor, if used at night	. 5	2
Playgrounds, outdoor, if used at night for baseball, basketball, etc	5	10
Storage spaces, passages, not used by pupils	. 25	2
Boiler rooms, power plants, and similar auxiliary spaces	1	3
Stairways, landings, corridors, aisles, exits, elevator cars, washrooms, toilets, locker spaces, dressing-rooms	1	3
Recreation rooms, gymnasiums, swimming-pools	3	7
ON THE WORK [1]		
Auditoriums, assembly rooms	2	3
Auditoriums, assembly rooms, etc., if used for class or study purposes	5	10
Classrooms, study rooms (desk tops)	5	10
Classrooms, study rooms (charts, blackboards)	3	6
Libraries (reading tables, catalogues)	5	10
Libraries (bookshelves, vertical plane)	3	6
Laboratories (tables, apparatus)	5	10
Manual training rooms, workshops, etc	5	10
Drafting rooms, sewing	8	15

[1] Where the space or work is not clearly evident, as for instance in an auditorium, the illumination may be measured on a horizontal plane 30 inches above the floor. However, where the space or work is clearly evident, such as stair steps and desk tops, the illumination shall be measured on the plane of the steps and desk tops, respectively.

Rule 2. Avoidance of glare.

Lighting whether natural or artificial shall be such as to avoid harmful glare, objectionable shadows, and extreme contrasts.

Bare light sources, such as exposed lamp filaments, gas mantles, or bright sky areas located within the ordinary field of vision are presumptive evidence of harmful glare. Seating shall be so arranged that pupils are not compelled to face windows. For specifications of definite requirements under this rule refer to Part III.

Rule 3. Distribution of artificial light.

Lamps, reflectors, or other suitable accessories shall be of such light-distributing character and shall be so installed in regard to mounting height, location, and spacing as to avoid excessive variation in illumination upon workplaces. In a classroom at the desk tops the ratio of the maximum intensity of artificial illumination to the minimum intensity of artificial illumination, measured in foot-candles, shall be less than 4.

Rule 4. Color and finish of interior.

In rooms in which close visual application is necessary, walls shall have a reflection factor within the range from 30 to 50 per cent. Ceilings and friezes (the latter in the case of high ceilings) shall have a reflection factor of at least 65 per cent. Desk tops and other woodwork shall have a reflection factor not exceeding 25 per cent.

In corridors and halls, ceilings and walls shall have a reflection factor of at least 50 per cent. Dadoes and blackboards are obvious exceptions. Glossy finishes shall be avoided wherever they are likely to cause glare. The preferred colors for walls are light warm gray, light buff, dark cream, and grayish green; for ceilings and friezes, white and light cream.

The nosing of treads on all stairs used as exits should be such as to show the edge of each step by contrast when viewed as in descending.

Rule 5. Switching and controlling apparatus.

Switching and controlling apparatus shall be installed at each point of entrance to school buildings, also in classrooms, basements, hallways, and stairways, also wherever required in other parts of buildings. Rooms having several entrances require such equipment only at the principal entrances.

Rule 6. Exit and emergency lighting.

Artificial lighting to be provided under rule 1 in all stairways and exits and in the passageways appurtenant thereto shall be supplied preferably from an independent source or from a connection extending back to the main service entrance for the building so that failure of room lighting from internal causes will not affect the exit and emergency lighting. In case of unusual danger which may exist on account of type of building, nature of the work, crowded conditions, or lack of suitable exit space, an independent service shall be insured by connecting to a separate source of supply without or within the building.

Classrooms and auditoriums during stereopticon and motion-picture exhibitions may be dimmed. After dark, if more than 50 persons are gathered in rooms having an illumination less than 0.1 foot-candle, the exits from rooms and all passages to the exits of the building shall be indicated by adequately illuminated exit signs, so as to clearly indicate the paths of safe exit from the building in case of emergency.

Rule 7. Inspection and maintenance.

All parts of the natural and artificial lighting systems, including windows, skylights, lamps, luminaires, walls and ceilings, shall be systematically inspected and properly maintained and cleaned so as to assure illumination levels indicated in rule 1.

Rule 8. Blackboards.

Blackboards shall be illuminated and located with respect to light sources so as to avoid glare. The surface of blackboards shall be made and kept as dull as possible. Blackboards shall not be located in the same wall with windows.

PART II.—WHY THE FULFILLMENT OF THE RULES IS IMPORTANT

General requirements.

Examinations of thousands of school children, extending over many years, have shown that a considerable proportion suffer from defects of vision—the result largely of continued use of the eyes in close work under unhygienic conditions. It is well established that defective vision is often progressive and is therefore found to a greater extent among older children.

It is found that, in general, children with defective vision are retarded in their progress in school work. They also enter upon their life work seriously handicapped.

The severe requirements imposed upon children's eyes by modern educational methods create need for the best of working conditions. Among these conditions lighting is of primary importance. Improper and inadequate lighting causes eyestrain, resulting in functional disorders, nearsightedness, and other defects of the eyes to which the immature eyes of children are especially susceptible.

Schools require a high standard of illumination, because immature eyes are more susceptible to injury than those of adults, and learners must necessarily apply their eyes more continuously than older persons who have acquired skill through repetition.

It is, therefore, essential that the lighting of school buildings, both natural and artificial, should conform to the requirements specified in the code.

Rule 1. Illumination required.

Definite minimum intensities of illumination on the work places are specified for the conservation of vision. In halls, stairways, passages to exits, etc., adequate intensities are imperative for safety. In addition to the benefits derived from lighting of the levels specified, the desirable effects of cheerful interior surroundings are obtained. These minimum intensities are the least permissible considering all the factors involved. From the standpoint of best vision much higher intensities are advantageous.

Rule 2. Avoidance of glare.

Glare is objectionable because it tends to injure vision and to disturb the nervous system; it causes discomfort and fatigue and thus reduces the efficiency of the student; it interferes with clear vision and increases the risk of accident. From both the humanitarian and economic viewpoints glare should be avoided.

Glazed paper reflects light somewhat like a mirror and introduces glare due to images of light sources reflected from it. The use of unglazed paper and suitable type promotes the conservation of vision.

Rule 3. Distribution of artificial light.

A substantially uniform intensity of illumination at work places provides equal advantages for all students. Light reaching any particular point at a work place from a number of sources, such as is implied in rule 3, reduces the harshness of shadows. General lighting eliminates the probability of improper direction resulting from the use of a very predominant light source.

Rule 4. Color and finish of interior.

Walls are within the field of vision a considerable part of the time. A moderate reflection factor with dull surfaces assures comfortable brightness contrast. Inasmuch as walls are juxtaposed to blackboards a moderate reflection factor of the walls assist in reducing the brightness contrast between these surfaces.

Luminaires are more comfortable to view when seen against light backgrounds. Ceilings and friezes having a high reflection factor provide for this and increase the efficiency of the lighting system.

Glossy finishes and glass surfaces reflect bright images of windows and artificial light sources, thereby contributing to visual discomfort.

Rule 5. Switching and controlling apparatus.

Switching and controlling apparatus properly located is necessary in order that artificial lighting may be properly controlled and used, and that persons may proceed in safety from point to point in a building.

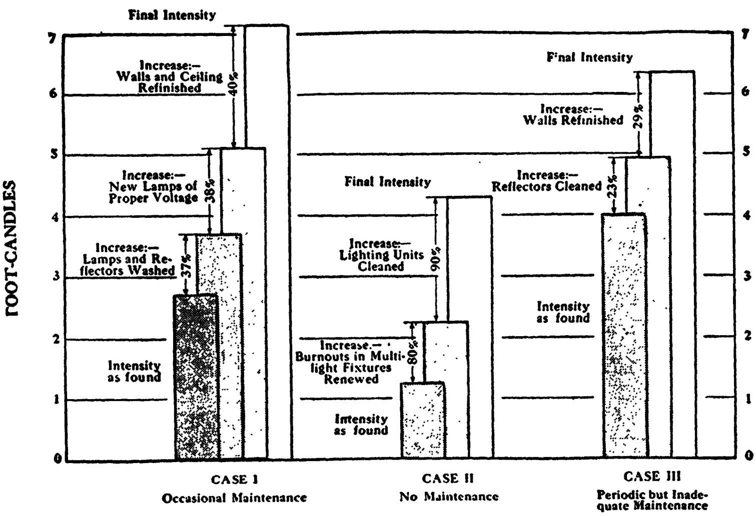

FIG. 1.—Chart showing the importance of prompt renewal of burned-out lamps and systematic cleaning of lighting equipment. Tests on semi-indirect and indirect lighting systems

Rule 6. Exit and emergency lighting.

Emergency lighting makes for the reduction of accidents and hazard. Building codes should be consulted for local requirements covering exit lights. (See reference to fire hazard in the introduction.)

Rule 7. Inspection and maintenance.

Walls and ceilings darkened by smoke and dust, dirty windows and skylights, grimy reflectors, blackened lamps, or broken mantles, or lamps of incorrect size or voltage, will render even a well-designed lighting system ineffectual. The value of regular inspection and maintenance is diagrammatically illustrated in Fig. 1. In each of these cases the failure to observe simple maintenance requirements resulted in an unnecessary economic loss.

The decrease in illumination due to these causes is often so gradual that it is not noticed. Inasmuch as the levels of artificial illumination now in use are so low any considerable decrease in illumination is almost certain to interfere more or less with vision. The illumination intensities in Table I are values to be maintained.

Rule 8. Blackboards.

Unless properly illuminated and located with respect to light sources, blackboards in combination with the other conditions are a source of eyestrain. Pupils are often required to look at blackboards for long periods of time; hence it is important that the best conditions be provided. Blackboards with dull surfaces reduce the annoyance of reflected images and facilitate reading the markings thereon.

In order to avoid excessive brightness contrast, which is trying to the eyes, blackboards should not be placed on a white or highly reflecting wall.

The location of blackboards between windows introduces a bad visual condition due to contrast with adjacent bright areas.

PART III.—HOW TO COMPLY WITH THE RULES

The following sections discuss in detail the ways and means of providing adequate and proper lighting as required by the rules of this code.

Rules 1, 2, 3, and 4. Natural light.

One of the established rules for proper lighting of desks from windows in walls is to have the dominant light come from the left side. Most authorities on daylighting advocate *unilateral* lighting; that is lighting by windows located on one side of the room only, especially for classrooms (see Fig. 3). This method of lighting is recommended where the width of the room does not exceed twice the height of the top of the window from the floor.

Rooms of unusual width, such as auditoriums, may have windows on the right and left sides. However, where cross shadows are objectionable, windows at the left and rear are preferable.

An eastern exposure is generally considered to be the most desirable for classrooms and a northern exposure the least desirable.

Lighting by overhead sources of natural illumination, although sometimes used for assembly rooms, auditoriums, and libraries with relatively high ceilings, has but little application in classrooms. When overhead sources of natural illumination are used the light should come from a north skylight or saw-tooth construction oriented to exclude direct sunlight.

To secure the highest lighting values in a side-lighted room it is recommended that the room be so designed that no work space is more distant from the window than twice the height of the top of the window from the floor.

The sky as seen through a window or skylight is a source of glare. For this reason the seating arrangements should always be such that pupils do not face windows or skylights.

Windows.—Tests of daylight in well-lighted school buildings indicate that in general the window-glass area should not be less than 20 per cent of the floor area. As the upper part of the window is more effective in lighting the interior than the lower part, it is

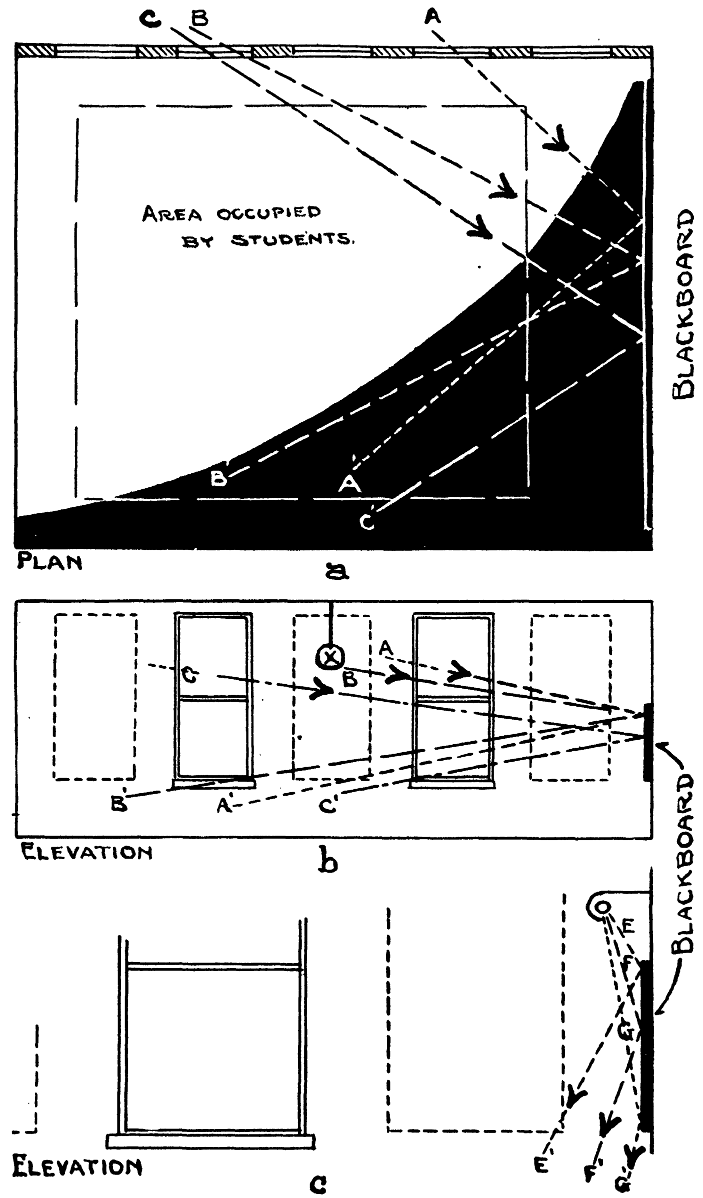

FIG. 2.—Diagrammatic illustration of glare from blackboards: (a) Showing that occupants of seats in shaded area are subjected to daylight glare from blackboards. (b) Showing angles at which glare is experienced from daylight and from artificial light. (c) Arrangement of local artificial lighting to minimize glare

recommended that the top of the glass be at no greater distance than six inches below the ceiling. The sills of side windows should be not less than 3 feet or more than 4 feet above the floor. No direct light should reach the eyes of seated pupils from below the horizontal.

Lighting value of a window.—The lighting value of a window at any given location in the room, will depend primarily upon the brightness of the sky, the amount of sky visible through the window at the given location in the room, and secondarily upon the reflection factor of the surroundings and the dimensions of the room.

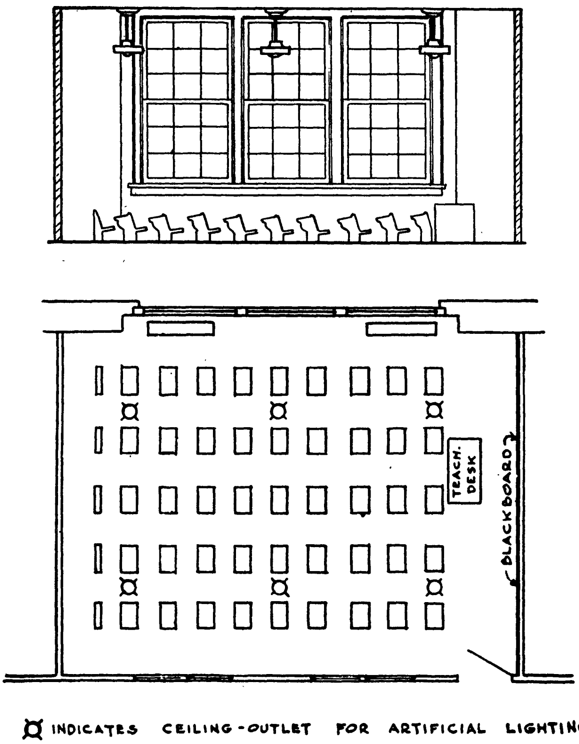

FIG. 3.—Elevation and plan of a classroom illustrating the position of outlets and luminaires of a direct lighting system; also showing a good arrangement of windows for natural lighting. In recent practice the width of room varies from 22 feet to 25 feet, the length from 28 feet to 32 feet, and the height from 12 feet to 14 feet. If the architectural design permits, it is preferable to increase the glass area by extending the windows as near to the rear wall of the room as possible

Observations in well-lighted schoolrooms having a comparatively unobstructed horizon show that under normal conditions of daylight satisfactory illumination is usually obtained when the visible sky subtends a minimum vertical angle of 5° at any workplace of the room. It is recommended that a sky exposure for any pupil's desk in the room be at least 50 square degrees, preferably about 5 degrees vertically and 10 degrees horizontally. This should be borne in mind when selecting sites for new buildings inasmuch as the proximity of adjacent buildings may seriously interfere with the natural lighting.

Window shades.—Although direct sunlight is desirable in interiors from a hygienic standpoint, it is often necessary to exclude or diffuse it by means of window shades. Shades should perform several functions such as the diffusion of direct sunlight; the control of illumination to secure reasonable uniformity; the elimination of glare from the visible sky or from bright areas outdoors, such as light courts, or adjoining buildings; and the elimination of glare from blackboards.

These requirements can be met by a number of arrangements, several of which have been found satisfactory and easy to maintain. For instance, windows can be equipped with two shades operated on two rollers. These can be arranged with both rollers at the middle of the window, one operating upwards and the other downwards, or with one roller at the middle and one at the bottom, both operating upwards. Shades so placed may be operated independently, thereby facilitating the shading and diffusion of the light.

Instead of two shades a single shade can be used with a device that permits the roller to be placed at any position on the window. Such a shade can be so placed that the light will come in from the top of the window and will be shut out from the lower portion, or will come in from the top and the bottom and will be shut out from the middle portion. Another way of controlling the light is to use a translucent shade, which unrolls from the top down, and an opaque shade which unrolls from the bottom upward. Since it is the top portions of the windows which supply the illumination to the spaces in the room farthest from them, it is bad practice to cut out light by pulling down the shade from the top more than is absolutely necessary. Pulling down a shade from the top also interferes with ventilation when windows are lowered from the top.

The material of the shades should be sufficiently translucent to transmit a considerable percentage of the light and at the same time diffuse it. Their color should be such as to harmonize with the interior decorations of the room. A translucent shade transmits a considerable amount of light, hence care should be taken that this transmitted light not only harmonizes with the color of the room but meets visual requirements. A light tan or a light buff material will, in general, be satisfactory. With such shades it is possible to exclude all direct sunlight and at the same time to permit a considerable amount of light to reach the ceiling, which light in turn is diffused throughout the room.

Shades should be wide enough to cover the window and to extend over each side of the window frame so as to prevent direct light from passing its edges.

Light courts.—Reflection of light from the walls of courts or other exterior walls is often very helpful in increasing interior illumination. Hence the nearby walls which are visible through the windows should, as a rule, have high reflection factors. Care, however, should be taken to avoid glare.

Rules 1, 2, 3, and 4. Artificial light.

In the consideration of how rules 1, 2, 3, and 4 can be complied with in artificial lighting, the subjects of illumination intensities, avoidance of glare, distribution of light on the work, and color and finish of the interior are so closely related and interdependent that it is thought advisable to discuss the four subjects together. This will be done first by describing the different forms of lighting systems and the characteristics of each; second, by giving the details of the design of a typical schoolroom lighting installation, choosing for sake of brevity one popular and recognized method of lighting; and third, by indicating the salient points which should be stressed in the selection of the luminaire. The capacity of the wiring installed should be ample to provide for the illumination recommended in the last column of Table I, even though cost considerations may make it seem desirable to employ a lower level. The additional

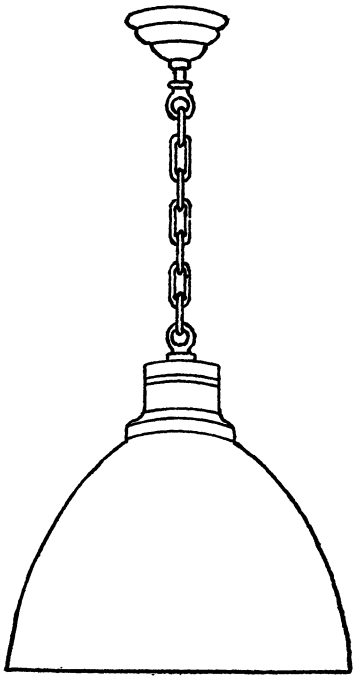

FIG. 4—Open-bottom direct-lighting luminaire.

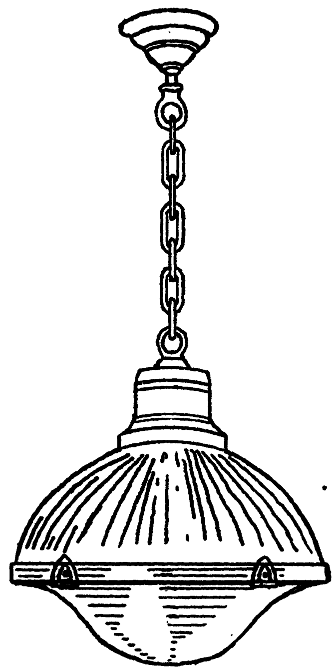

FIG. 5—Inclosed prismatic direct-lighting luminaire.

cost of such wiring is slight compared with the cost of reconstruction.

Lighting systems.—In general there are three distinct systems of artificial lighting, namely; *direct*, *semi-indirect*, and *indirect*. These names are descriptive and designate broad classes of lighting, the boundary lines of which are indefinite.

The *direct-lighting systems* deliver at least half of the light below the horizontal so that the dominant light on the work places is received directly from the luminaires. Such systems may be divided into two groups; the direct-lighting system employing open-bottom luminaires and the direct-lighting system using inclosed and semi-inclosed luminaires.

An open-bottom luminaire *direct-lighting system* is one in which the dominant light reaches the work places directly from the luminaires which are open at the bottom and in which the light source may be seen from below. Such a lighting system may be further classified as local or general. In the former the luminaires are placed close to the work and illuminate a very limited area; in the latter they are installed overhead in such a way as to illuminate the whole room area as well as the limited area upon which the work is done. An inclosed luminaire is one in which the light source is completely surrounded by the globe and holder. Some luminaires (sometimes termed semi-inclosing) having open or clear glass spaces in conjunction with diffusing glass, opaque reflecting surfaces, etc., may be considered from the standpoint of lighting to belong to the direct-lighting class.

A *semi-indirect system* is one in which an appreciable portion of the light reaches the work place directly from the luminaire, but in which more than half of the light is directed to the ceiling and upper

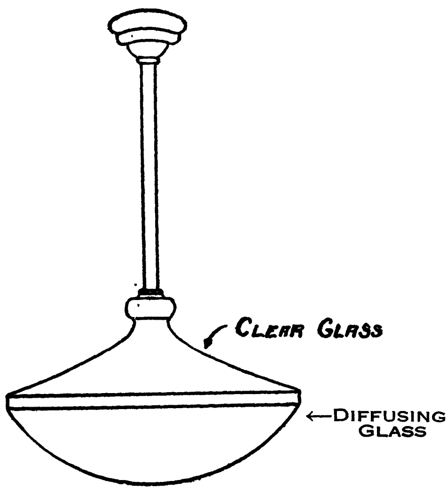

FIG. 6.—Semi-indirect luminaire (inclosed)

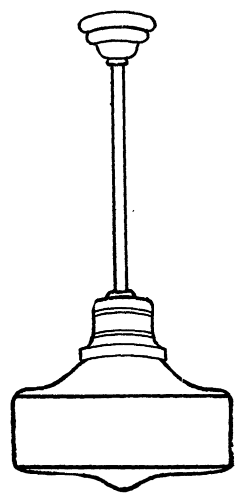

FIG. 7.—Inclosed diffusing-glass direct-lighting luminaire whose shape is a composite of several commercial shapes

walls and thence reflected to illuminate the work places. A *semi-indirect* luminaire usually consists of a lamp equipped with a diffusing bowl or inverted glass reflector, as illustrated in Figs. 6 and 8. The relation between the relative amounts of light above and below the horizontal through the light center of such a unit depends largely upon the character of the transmission of the bowl. When the glass bowl or inverted reflector of the *semi-indirect* luminaire has a high transmission, the illumination approaches that of *direct lighting*, and when of low transmission the effect approaches that of *indirect lighting.*

A *totally indirect-lighting system* is one in which all of the light reaches the work indirectly after reflection from the ceilings and walls. The luminaire usually consists of a light source equipped with an opaque bowl or inverted reflector, as illustrated in Fig. 9.

Direct-lighting systems. The open-bottom luminaire is subject to criticism even though the light sources are shielded from the normal angle of vision because of the harshness of shadows and the glare due to reflected images of light sources from shiny paper, textbooks and polished desk tops. Diffusing-bulb or bowl-enamelled lamps or frosted inner cylinders for gas effect a considerable improvement when used in this type of luminaire. One of the chief advantages of this type of equipment is its relatively high efficiency.

The inclosed luminaire, when made of a good diffusing glass and of sufficient size to insure low brightness of both the luminaire and reflected images, produces satisfactory lighting results from the standpoint of shadows and glare. Furthermore the coefficient of utilization is high. The depreciation due to the collection of dust and the resultant loss of light are less than in most systems. Partly because of economy, the inclosed unit is one of the practicable solutions of school-lighting problems. It is generally advantageous

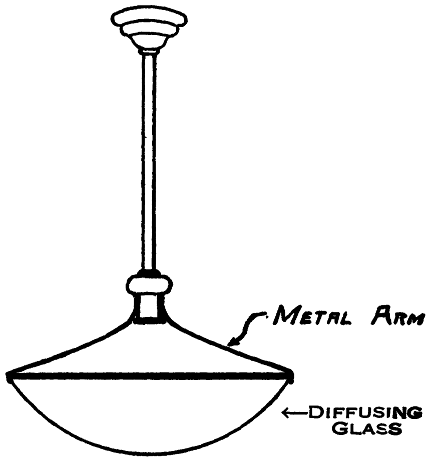

Fig. 8.—Semi-indirect luminaire (open)

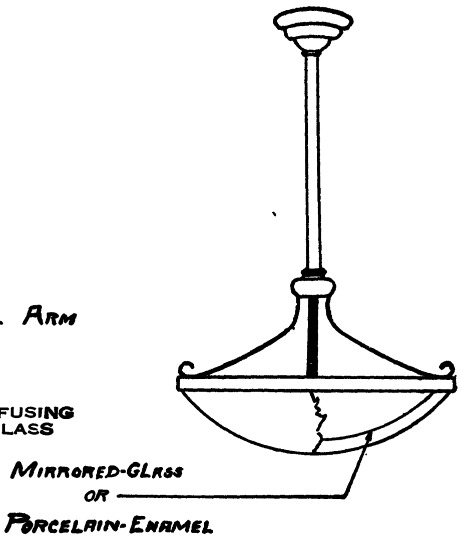

Fig. 9.—Indirect luminaire

to select glassware having the horizontal dimension large as compared with the vertical dimension in order to obtain a satisfactory utilization of light.

The *semi-indirect system* employing good diffusing glass, of sufficiently low transmission to insure low brightness, provides excellent lighting. Inasmuch as this system employs the ceiling and upper walls for redirecting a large part of the light reaching the work place, these surfaces should have fairly high reflection factors. For this reason these surfaces should be properly maintained. When used in smoky or dirty environment very material losses in the illumination result unless frequent cleaning is adhered to.

The *indirect system* provides excellent lighting as characterized by the desirable qualities of good distribution, absence of strong shadows, and low surface brightness. As in the case of the semi-indirect luminaire, ceiling, upper walls, and the luminaire require frequent cleaning in order to maintain the illumination intensity for which the installation was designed. For a comparison of the coefficient of utilization of these three systems see Table III.

Design of a lighting installation.—The subject is too involved to be handled in a short treatise unless limitations are set on the scope of the discussion. These considerations therefore will be confined to the design of a lighting installation for a classroom 32 feet by 24 feet, with a ceiling height of 12 feet, the ceiling having a reflection factor of 70 per cent and the walls having a reflection factor of 50 per cent.

To comply with rule 2 on the "Avoidance of glare" it is necessary to diffuse and redirect the light proceeding from the filament or mantle. To comply with rule 3 on "Distribution of light" it is necessary to specify the number of lamps, their size, spacing, hanging height, etc. Rule 4 on "Color and finish of interior" plays an important part in this discussion.

For the sake of simplicity and brevity a typical lighting installation, employing totally inclosed diffusing luminaires, will be discussed.

The factors which should be considered in determining the size and number of lamps to be used in a given room are: First, the illumination in foot-candles to be supplied; second, the floor area, which in this case is 32 feet by 24 feet or 768 square feet; third, the amount of light in lumens emitted from each lamp obtained from Table II; fourth, the coefficient of utilization of the lamps and their accessories as installed in the room. The last quantity involves many factors, such as the relative dimensions of the room, the reflection factor of the surroundings, the number and character of luminaires, their locations and hanging height. In Table III coefficients of utilization for modern lighting equipment are given for a typical standard classroom. These values refer to the initial installation without any allowance for depreciation due to aging of lamps and dust collection. The plane of the work in this case is the desk tops, generally 24 inches above the floor.

TABLE II.—*Luminous flux emitted: By gas-filled incandescent tungsten lamps*[1]

[Standard lighting service 110-115-120 volt]

Lamp size (watts)	Clear lamp (initial lumens)
75	885
100	1,290
150	2,145
200	3,060
300	4,950
500	9,050
750	14,325
1,000	20,000

[1] These data, while correct at the time of writing, are subject to change.

NOTE.—"Daylight" lamps of a given wattage emit approximately two-thirds the amount of light emitted by the clear lamp. The "daylight" lamp is a gas-filled tungsten lamp with a blue-glass bulb producing light more closely approximating daylight.

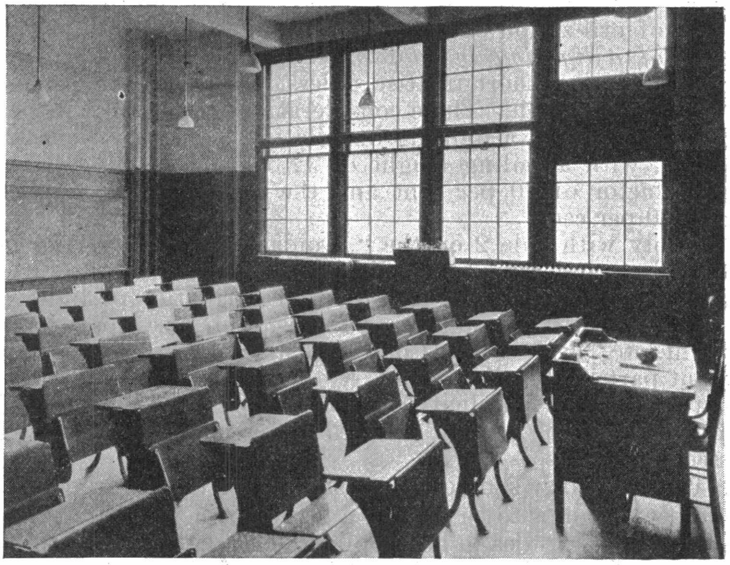

FIG. 10.—Interior view of a classroom showing an excellent arrangement of windows. Note the double shade rollers placed at middle of windows which permit either the upper or lower part of the window to be shaded independently

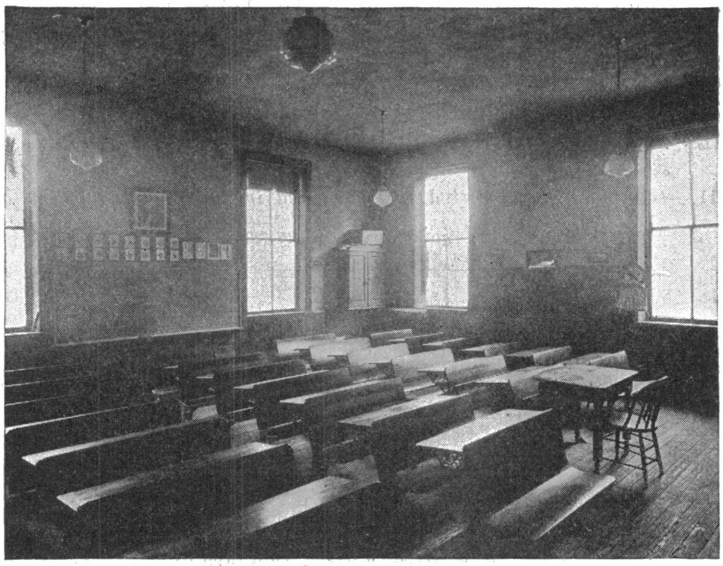

FIG. 11.—Poor daylighting: Badly placed window openings; blackboards located between windows

NOTE.—A better arrangement would be to have the four windows on one side and none in the rear.

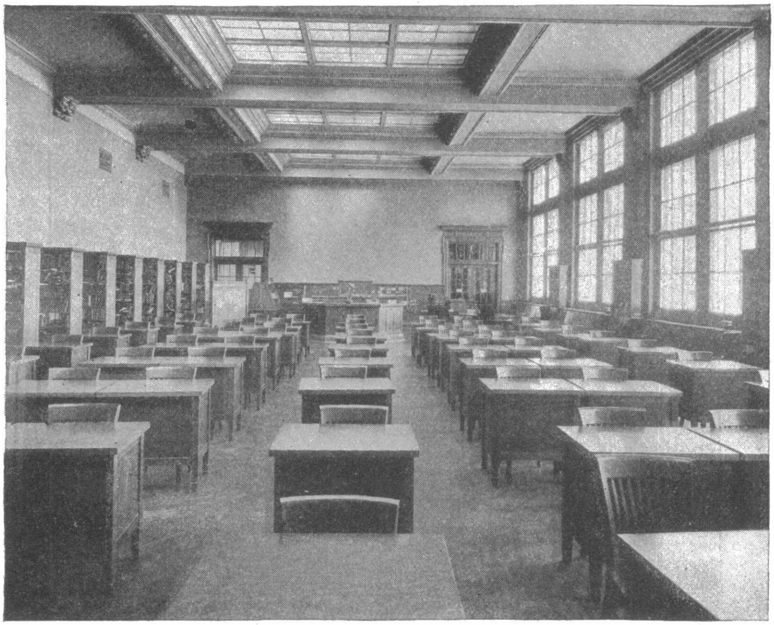

Fig. 12.—Good daylighting of a school library

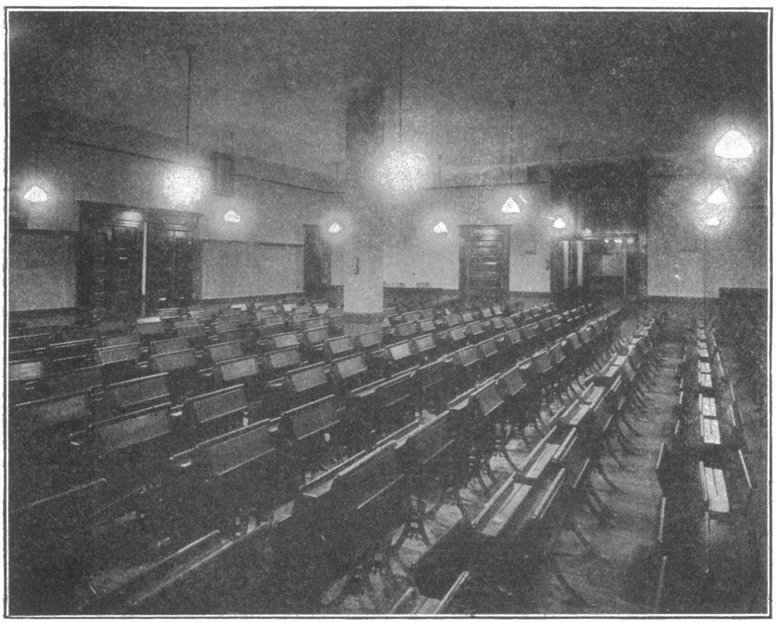

Fig. 13.—Bad lighting. The luminaires are hung too low and the light sources are not adequately shaded. Note that the glossy varnished surfaces add to the glare

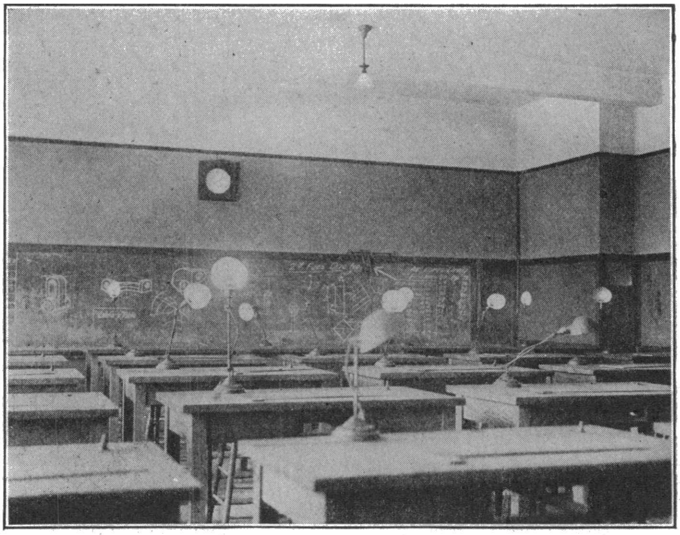

Fig. 14.—Bad lighting. The use of local lighting by adjustable table lamps usually results in glare from lamps on neighboring tables; also in annoying shadows

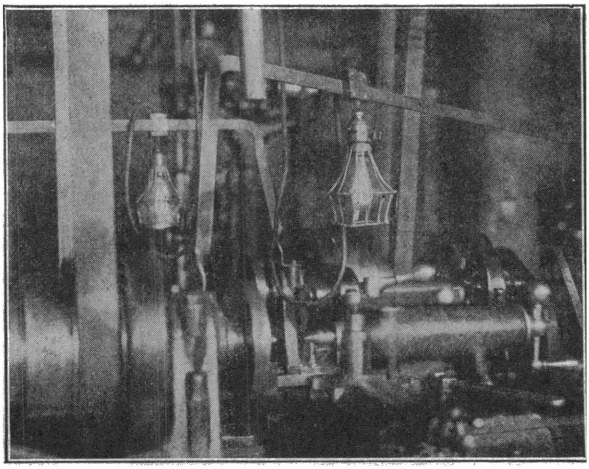

Fig. 15.—Bad lighting. The local lamps if used at all, should be provided with reflecting shades to protect the eyes from glare and at the same time to direct the light to the work

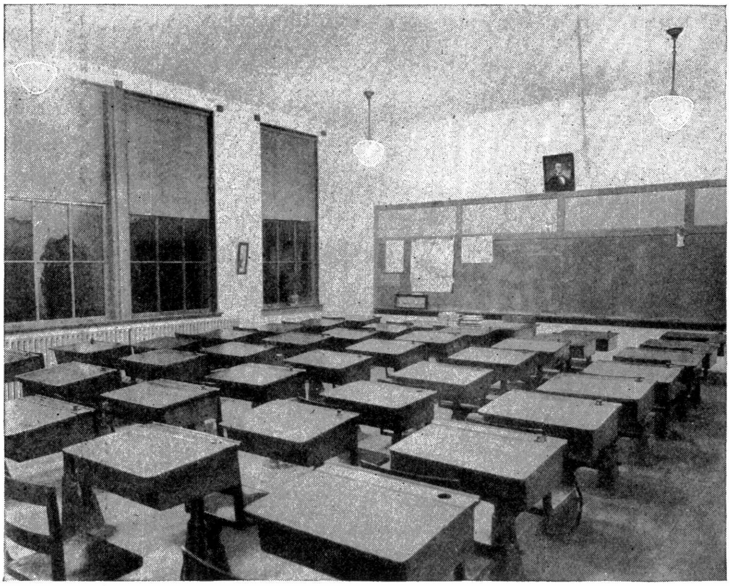

FIG. 16.—Good general lighting with inclosed luminaires

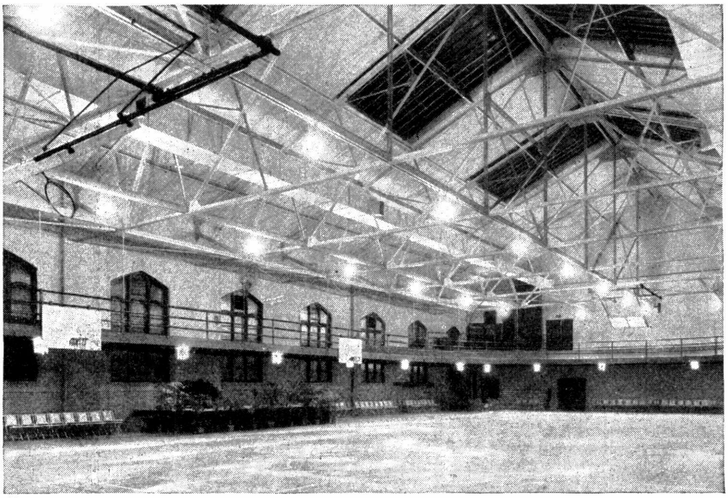

FIG. 17.—Good general lighting with open bottom reflectors suspended 20 feet above the floor

Fig. 18.—A school corridor showing natural lighting through transom sash in the classroom partitions and ceiling-type luminaires for artificial lighting

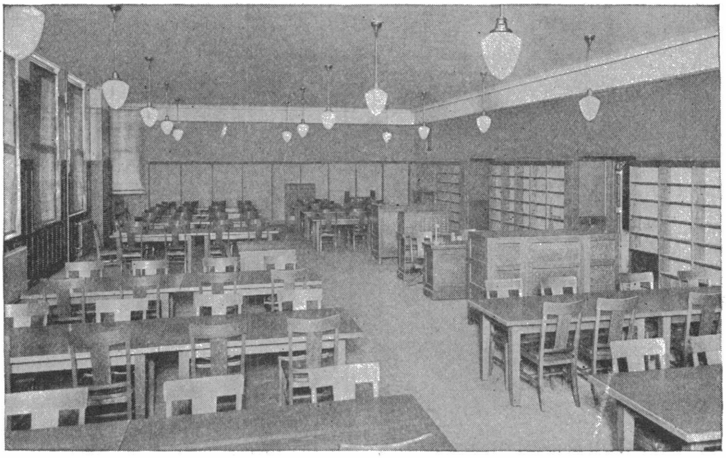

Fig. 19.—Study room equipped with inclosed luminaires

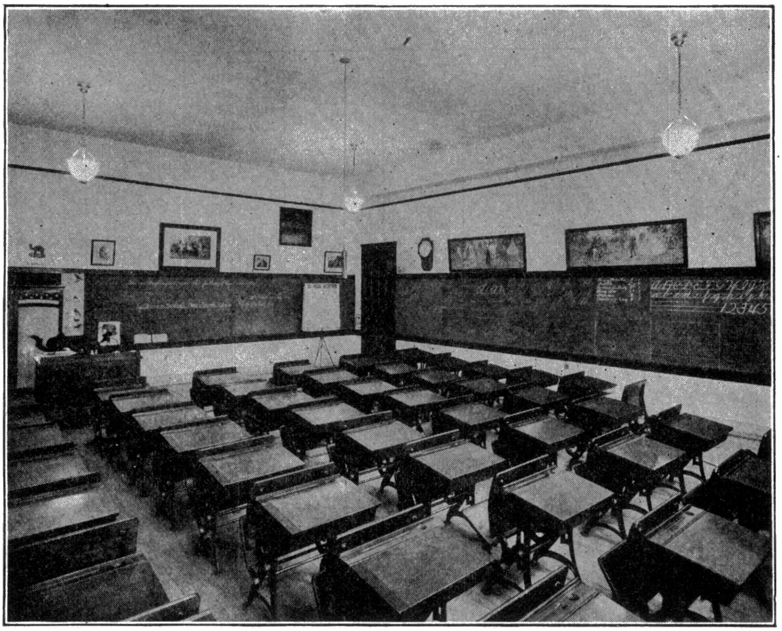

FIG. 20.—Good semi-indirect lighting

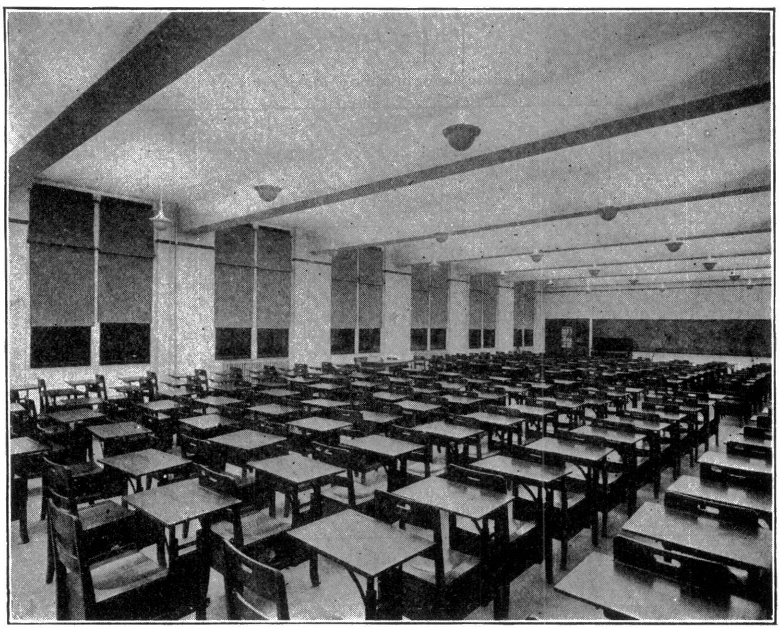

FIG. 21.—Good indirect lighting

TABLE II.—*Luminous flux emitted*—(Concluded):

By gas mantle burners[2] *at gas pressure of 2.5-inch water column*

Number of mantles to each burner	Size of mantles (inches)	Gas consumption (cubic feet per hour)	Base mantle (lumens)
1	1⅛	3.66	994
2	1⅛	4.37	1,326
3	1⅛	6.71	1,978
4	1⅛	9.14	2,445
5	1⅛	10.60	3,654
6	1⅛	12.10	4,125

By gas mantle burners which are self-contained[3] *at gas pressure of 2.5-inch water column*

Number of mantles in each burner	Size of mantles (inches)	Gas consumption (cubic feet per hour)	Mantles inclosed in clear glass cylinders (lumens)
1	1⅛	2.21	686
1	1⅝	4.00	866
1	2⅛	8.15	2,486

[2] These burners are known as horizontal inverted burners and are made for use in semi-indirect luminaires. By combining two or more of these burners in a single luminaire the total lumens available can be increased as desired. If 1⅝-inch mantles are used, 10 per cent increase in total lumens is available.

[3] These burners are furnished complete with clear inner cylinders and shade or globe holders to take outside globes and shades as selected. These are inverted burners and are used generally as complete luminaires. Semi-inclosed shades or totally inclosed globes can be used as desired.

TABLE III.—*Coefficients of utilization for a classroom 32 feet by 24 feet, ceiling 12 feet high.*[1]

[Reflection factor of ceiling, 70 per cent]

Lighting system	Reflection factor of walls	
	50 per cent	30 per cent
DIRECT LIGHTING		
1. High reflection factor open-bottom glass reflectors (see fig. 4) with bowl-enameled lamp	0.47	0.43
2. Prismatic inclosing unit; clear lamp (see fig 5)	.47	.42
3. Inclosed unit of white glass (highly diffusing, one in which the lamp position can not be seen) clear lamp (see fig. 7)	.39	.34
SEMI-INDIRECT LIGHTING		
4. Low transmission, high reflection factor glass bowl with clear lamp (see figs. 6 and 8)	.33	.29
5. Medium transmission, glass bowl with clear lamp	.37	.33
INDIRECT LIGHTING		
6. Metal, compo or glass bowl containing mirror reflector; clear lamp (see fig. 9)	.30	.27

[1] Transactions Illuminating Engineering Society, Vol. XV, No. 2, Mar. 20, 1920.

Computations to determine the proper size of incandescent electric or gas lamps may be made by the use of the following equation:

$$L=\frac{AI}{EN}$$

In this equation:

L=the lumens emitted by the lamp (Table II)
A=the area of the floor or horizontal work plane in square feet.
I=the illumination in foot-candles (Rule 1)
E=the coefficient of utilization (Table III)
N=the number of lamps required.

The first step in using this equation is the determination of the number of lamps required. From experience it is ascertained that in order to obtain the desired distribution of illumination. the light sources in direct lighting should not be spaced farther apart than a distance of 1.5 times their elevation above the desk tops. For instance, if the light sources are hung 8 feet above the desk tops, the maximum spacing between should not exceed 12 feet, in order that the requirements of rule 3, "Distribution of light," may be fulfilled. Now, considering the problem of a classroom (32 by 24 feet) having the minimum ceiling height of 12 feet, we must first determine the number of luminaires required. The plane of the work will be that of the desk tops which is a horizontal plane approximately 24 inches above the floor. Then if the luminaires are installed in ceiling-type fixtures and an allowance of 18 inches for depth of fixture and globe is made, the elevation of the light source above the plane of work will be approximately 8½ feet. Hence the maximum spacing between luminaires must not exceed 12 feet 9 inches. With a room of these dimensions, six luminaires therefore would be required, spaced approximately 12 feet apart as illustrated in Fig. 3. In this example we will assume that an illumination of 10 foot-candles is desired. We will also assume that a luminaire of the type listed under item 3, Table III, is chosen and that the ceiling and walls have reflection factors of 70 and 50 per cent, respectively. Under these conditions the coefficient of utilization will be 0.39 (see Table III). Now applying the formula we have—

$$L=\frac{32\times 24\times 10}{0.39\times 6}=3{,}282 \text{ lumens.}$$

To offset the decrease in illumination due to lamp depreciation and dust collection on the luminaires the number of lumens required per lamp will have to be somewhat increased. For this a safety factor should be used which will insure adequate illumination when the lighting installation shows a maximum depreciation under the system of cleaning adopted. How much to allow for depreciation, with a given type of luminaire, depends to a considerable extent on the locality and nature of work carried on. Experience has shown that a factor of 1.3 provides for average conditions if a schedule of regular and frequent cleaning is adhered to. Applying this factor to the problem at hand it will be necessary that each lamp supply (3,282 by 1.3) 4,267 lumens.

Referring to Table II, lamps for standard 110–120 volt service, it will be noted that the 300-watt lamp is the nearest size of clear-bulb gas-filled tungsten lamp which will supply the required lumens, whereas the nearest size of "daylight" gas-filled tungsten lamp which will supply the required lumens is the 500-watt lamp. The nearest size of gas burner that will supply the required lumens is two 2-mantle burners consuming a total of 12 cubic feet of gas per hour.

The above example is intended solely to illustrate the method of computation. Estimates of the illumination obtained from an actual installation may also be made by a similar computation.

Only four outlets are necessary if indirect-lighting luminaires or semi-indirect luminaires with dense glass bowls are used in a room of this size. In Table III it is seen that the utilization factor for semi-indirect lighting with dense glass luminaires is 0.33 for the same room and conditions used in the previous computation. Applying the formula we have—

$$L = \frac{32 \times 24 \times 10}{0.33 \times 4} = 5{,}818 \text{ lumens.}$$

Allowing for depreciation, we have 5,818 multiplied by 1.3 or 7,563 lumens necessary from each of the four light-sources. The nearest size of clear-bulb electric filament lamp is seen in Table II to be 500 watts. Here a total of 2,000 watts would be used as compared with 1,800 watts in the direct-lighting case, but the illumination intensity would be slightly greater in the former case. Of course the illumination intensity would be identical in the two cases if it were possible to obtain lamps of the exact size computed in the two cases.

Selecting a luminaire.—It is not possible with bare incandescent electric or gas lamps to meet the requirements of the school-lighting code in respect to rule 2, "Avoidance of glare" or economically in respect to rule 3, "Distribution of light." It therefore becomes necessary to equip the lamp with reflecting and diffusing accessories. Far from being a hardship however, this is actually an economy since the light flux from the unshielded lamp is not distributed in an economical manner. Efficient reflecting and diffusing accessories redirect the light, thereby increasing the efficiency of utilization considerably over the value obtainable with the bare lamps, irrespective of the fact that the diffusive and redirecting media in themselves absorb a portion of the light flux. Aside from this, the ability to utilize the light produced, because of "eye ease" and lack of brilliant sources within the field of vision, is noteworthy, and justifies the use of proper reflecting and diffusing accessories.

Any of the types of luminaires from 1 to 6, inclusive, in Table III will meet the requirements for overhead lighting provided lamps of the proper size and type for the particular accessory are employed. It is particularly necessary to guard against the use of lamps too large for the reflector or globe in the direct or semi-indirect systems if rule 2, "avoidance of glare," is to be fulfilled.

The following table shows the sizes of inclosing globes of high efficiency (80 per cent output) good diffusing glassware (through which the position of the lamp filament can not be seen) to be used with various sizes of clear lamps.

In this table the brightness of the brightest square inch is given rather than average brightness or some other specification. An average brightness specification allows wide variations of brightness between maximum and minimum. In effect two samples of diffusing glass, one practically uniform in brightness and the other having a small area exceedingly bright but with the rest of the globe sufficiently low in brightness to average the same as the first, could be rated alike although their acceptability from the standpoint of glare could be widely different. For other factors contributing to glare see rule 2, " Avoidance of glare," Part III.

TABLE IV.—*Recommended globe sizes of high efficiency good diffusing glass*

1	2	3	4	
Size of lamps (watts) to be used with (3)	Lamps, lumens (maximum)	Minimum globe diameter (measured at maximum width) to be used with (1)	Brightness of brightest square inch (candles per square inch)	
			Zone 35°	Zone 70°
		Inches		
75–100	1, 300	12	4. 0	3. 5
100–150	2, 100	14	4. 5	4. 0
150–200	3, 000	16	4. 5	4. 0
300	4, 900	18	5. 6	5. 0

From the utilization factors in Table III, it will be noted that some luminaires have the advantage of being more efficient than others. This characteristic should be given considerable weight in the selection of a lighting accessory. However, other items should be considered, such as the appearance of the lighted room, quality of light and freedom from glare, reflected glare from images of the luminaire in polished surfaces, character of shadows, and ease and cost of maintenance.

The characteristics of the luminaires related to these desirable or undesirable features of a lighting installation are, diffusive ability, relation between the size of the lamp and diameter of the diffusive unit, shape of the unit, correct centering of light center to secure the correct surface brightness, and relation between the holder and the reflecting surface, and the over-all efficiency.

The first point is that of efficiency. Since inclosing glassware is being extensively used in school-lighting systems, some of the pitfalls which might be encountered in considering this phase of the question may be pointed out. Variations in the distribution curves obtained from individual units of lighting equipment are sufficient to make it undesirable to place too much dependence upon tests secured by measurements of a single luminaire. Purchasers of the equipment can protect themselves by specifying that illumination measurements made upon a completed installation shall show values corresponding to the representative luminaire offered by the manufacturers or installers of such equipment.

To be representative of the efficiency, 10 or more globes, selected at random, should be tested.

The factors of direct and reflected glare should be made the paramount ones for schoolrooms. Brightness and diffusive ability are closely allied. Globes of the best diffusive ability only should be considered. A test for diffusive ability is the inability of the observer to locate the position of the light source within the luminaire when the lamp is correctly centered. Under these conditions all parts of the projected area appear equally bright.

A consideration of shadows on the work is closely allied with brightness and diffusion of the luminaire. There should be no shadows so dense as to make vision difficult or so sharply defined as to cause confusion between the edge of the shadow and a drawn line, as in drafting. Shadows should be soft and luminous, and where we are concerned with work on a horizontal plane only, as in study rooms, they should be reduced as much as practicable.

Excessive and objectionable brightness can occur even when the table of recommended globe diameters for various sized lamps is adhered to. The light source should be so centered within a diffusive enclosing globe that no area of the globe is made unduly bright because of its proximity to the incandescent lamp filament or mantle. If this precaution of correctly centering the filament is overlooked, one of the essential characteristics of a good diffusing glass is sacrificed.

It should be realized that 2 to 10 per cent in the over-all efficiency of a luminaire may be gained by using a holder which is white enameled on the inside. When stress is laid upon high efficiency of units such a point can not be disregarded.

Electric luminaires ventilated by means of holes in the globe, reflector, bowl, or accessory parts are subject in most cases to greater depreciation, due to dust, dirt, and insects, than is found with luminaires in which there are no ventilating holes. In addition to the normal collection of dust on exposed surfaces, holes in the luminaire permit dust accumulation due either to air currents through the luminaire or to "breathing" of the luminaire when it is turned on and off. That satisfactory cooling of luminaires can be effected by radiation has been proved by many nonventilated luminaires now in service. Whether or not ventilation holes are used, care must be exercised in the design to insure against excessive temperatures of sockets, fixtures, etc.

Rule 2. Avoidance of glare.[1]

There are five principal causes of glare:

Brightness of source.—The light source may be too bright; that is, the candles per square inch of area may be too great. A glance at the sun proves that an extremely bright light source within the field of vision is capable of producing acute discomfort. Light sources of far lower brightness than the sun, such as the filament of an incandescent electric lamp or the incandescent mantle of a gas lamp, may also cause discomfort, although the annoying effect is usually not quite so marked.

Total volume of light.—Experience has shown that a 500-watt lamp in a 10-inch opal globe, hung 7 or 8 feet above the floor and a similar distance ahead of the observer, will prove quite as glaring as the exposed filament of a 50-watt incandescent lamp in the same location. The brightness of the "opal" globe luminaire is only a few times that of a candle flame, but the quantity of light which reaches the eye is so great that its effect is worse than that of the

[1] Adapted from the Code of Lighting Factories, Mills, and Other Work Places, Illuminating Engineering Society.

bare filament of lower candlepower, although the latter may have a brightness as high as 3,000 candles per square inch. An unshaded window often causes glare, due, of course, to the large volume of light rather than to the high brightness of the sky.

Location in the field of view.—A given light source may be located at too short a distance from the eye, or it may lie too near the center of the field of vision for comfort; that is, within too small an angle from the ordinary line of sight. For example, the 500-watt "opal" globe unit discussed in the previous illustration would seldom cause discomfort if placed, say, 80 feet away from the observer, for at this distance the total quantity of light entering the eye would be only one one-hundredth of that received at 8 feet. Again, the same light source would probably be found quite unobjectionable at a distance of 8 feet from the eye, provided this distance was obtained by locating the lamp 4 feet ahead of the observer and 7 feet above the eye level; in this case the lamp would scarcely be within the ordinary field of view.

The natural position of the eye during intervals of rest from any kind of work is generally in the horizontal direction, and it is desirable that during such periods the pupil should be freed from the annoyance caused by glare. Glare becomes more objectionable the more nearly the light source approaches the direct line of sight. While at work the eye is usually directed either horizontally or as an angle below the horizontal. Glaring objects at or below the horizontal should especially be prohibited. The best way to remove light sources out of the direct line is to locate them well up toward the ceiling. Local lamps—that is, lamps placed close to the work—if used at all, must be particularly well screened.

Contrast with background.—The contrast may be too great between the light source and its darker surroundings. It is a common experience that a lamp viewed against a dark wall is far more trying to the eyes than when its surroundings appear relatively light. A light background requires, first, that the surface should be painted in a color which will reflect a considerable portion of the light which strikes it, and, second, that the system of illumination employed should be such as to direct light upon the background. In many cases the ceiling appears almost black under artificial light simply because no light reaches it. With daylight, on the other hand, the walls of a room are often so well illuminated that they appear brighter than the work itself, and this also is a condition which is not conducive to good vision. In general, a light tone for ceilings and upper portions of walls and a paint of medium reflecting power for the lower portion of walls will ordinarily be found most satisfactory under both artificial and natural lighting.

Where strictly local lighting systems are employed—that is, where individual lamps are supplied for all benches and machines and no overhead lighting is added—the resulting contrasts in illumination will usually be found so harsh as to be objectionable even though the lamps themselves are well shielded. The eyes of the pupil looking up from his brightly lighted machine or bench are not adapted for vision at low illuminations; hence, if adjacent objects and aisles are only dimly lighted, he will be compelled either to grope about, losing time and risking accident, or to wait until his eyes have become accommodated to the low illumination. Glancing back at his work, he again loses time while his eyes adjust themselves to the increased amount of light which reaches them. If long continued, this condition leads to fatigue, as well as to interference with vision, and to accidents. In other words, where local lamps are employed there should also be a system of overhead lighting which will provide a sufficient illumination of all surrounding areas to avoid such undesirable contrasts.

Time of exposure.—The time of exposure may be too great; that is, the eye may be subjected to the strain caused by a light source of given strength within the field of vision for too long a time.

When a pupil is seated and his field is fixed for several hours at a time, light sources of lower brightness and lower candlepower are required than where the pupil stands at his work and shifts his position and direction of view from time to time. In the first case the image of the light source is focused on one part of the retina for considerable periods of time and is obviously more likely to cause discomfort and eyestrain than when present for short periods only. Those who are forced to work all day at desks facing the windows are particularly likely to suffer from this form of glare. Such conditions should not be tolerated.

Rating light sources from the glare standpoint.—It is evident that the first two factors mentioned as causes of glare, namely, excessive brightness and excessive candlepower, concern the light source itself, the third factor concerns its location in the field of view, and the fourth and fifth depend upon the conditions of its use.

Measurements of brightness and candlepower have been made on a number of light sources found in everyday practice, both natural and artificial, and Grades from I to X have been assigned to them. (See Tables V and VI.)

Light sources in Grades I and II may be termed soft or well diffused; those in Grades VIII, IX, and X are harsh and almost certain to cause glare.

Grade III is the limiting grade permissible for the lighting of schoolrooms. Softer grades are recommended. Light sources other than those included in Table VI will be found in use; however, from those which are given in the table it is possible to estimate in what grades others should be placed.

TABLE V.—*Classification of light sources from the standpoint of glare*

[Grade I indicates sources of maximum softness. Grade X indicates sources of maximum harshness.]

Maximum visible brightness (candles per square inch)	Candlepower in direction of eye				
	Less than 20	20 to 50	50 to 150	150 to 500	500 to 2,000
	Grade	*Grade*	*Grade*	*Grade*	*Grade*
Less than 2	I	I	II	II	III
2 to 5	II	II	III	IV	V
5 to 20	II	III	IV	VI	VII
20 to 100	IV	V	VI	VII	VIII
100 to 1,000	V	VI	VII	VIII	IX
1,000 and up	VI	VII	VIII	IX	X

TABLE VI.—*Specific classification of light sources from the standpoint of glare as derived from Table V*

NATURAL LIGHT SOURCES AS SEEN THROUGH WINDOWS OR SKYLIGHTS

	Grade
Sun	X
Very bright sky	V
Dull sky	III
Sun showing on prism glass	IX

INCANDESCENT MANTLE GAS LAMPS [1]

Lamp	Mantles consuming—		Large single mantle or cluster		Cluster or high-pressure lamp consuming above 20 cubic feet per hour
	2–5 cubic feet per hour	5–8 cubic feet per hour	8–12 cubic feet per hour	12–20 cubic feet per hour	
	Grade	*Grade*	*Grade*	*Grade*	*Grade*
Clear glassware	V	VI	VII	VIII	IX
Diffusing glassware:					
6-inch globes	II	III			
8-inch globes	I	II	IV–VI		
10-inch globes			III–V	V–VII	
12-inch globes					VI–VIII
Indirect units			I–II	II	III
Semi-indirect units			II–III	II–IV	III–VI

LUMINAIRES EQUIPPED WITH TUNGSTEN FILAMENT LAMPS

Luminaires	Watt lamps	Grade
Diffusing glass inclosing units: [1]		
12-inch maximum diameter	75–100	II–III
	150–200	III–V
	300	IV–VI
16-inch maximum diameter	150–200	II–V
	300	IV–VI
18-inch maximum diameter	300	III–V
Semi-inclosing units [1]	75–100	III–IV
	150–200	IV–VI
	300	IV–VII
Semi-indirect units [2]	75–100	I–III
	150–200	II–III
	300	II–IV
Indirect-lighting units	75–100	I–II
	150–200	I–II
	300	II

[1] Where a range is given, the best grade, that is the lowest, applies to globes that are evenly luminous, and the poorest to globes which have a decidedly bright spot in the center.

[2] Where a range is given, the best grade, the lowest, applies to bowls that are of dense glass; that is, bowls which reflect nearly all of the light to the ceiling.

Rule 5. Switching and controlling apparatus.

Switches should be installed at each point of entrance so that enough lamps of the regular or emergency lighting can be turned on to enable a person to proceed safely to the next point of control.

In locating switches or control apparatus it is desirable to arrange them systematically in all rooms, as this simplifies the finding of such apparatus by those responsible for turning on and off the lights. A satisfactory arrangement of circuits for the outlets indicated on the plan of Fig. 3 consists of two circuits parallel to the windows, controlled by separate switches. As natural light fails, the lighting along the side of the room farthest from the windows becomes inadequate first. This arrangement of circuits permits the addition of artificial light to this area without having to resort to the full system until such time as its use becomes necessary.

Rule 6. Exit and emergency lighting.

Exit lights are often designed to serve only as light signals or markers, whereas they can be designed to serve as a part of the emergency lighting system. For example, a direct-lighting open-bottom luminaire made of opal glass, with green or red screen, serves as a colored signal by transmitted light and provides uncolored light on the space beneath the luminaire.

Rule 7. Inspection and maintenance.

In order to assure satisfactory results from a lighting system it is necessary that systematic periodic examinations of the equipment be made. The reflectors and globes should be washed thoroughly at least once in every two months. In the interim they should be cleaned by wiping with a damp cloth. During the monthly cleaning the condition of the lamps should be noted, and any burned-out or blackened lamps should be replaced. A sufficient supply of gas mantles and of lamps of the proper voltage and wattage should be kept on hand to take care of any contingencies. Any defects in wiring, switches, or other parts of the system should be promptly repaired. Walls and ceilings should be cleaned at given intervals and redecorated when necessary. Some responsible person or persons should be assigned the duty of maintaining the equipment and a definite schedule of inspection should be laid out and adhered to. The foot-candle meter, a device which will indicate illumination intensities at the work place, reveals the combined effect of all possible causes of depreciation. This instrument used systematically in conjunction with written records affords an excellent means of insuring the maintenance of illumination intensities provided by the lighting installation when originally installed. The illumination intensities in Table I are values which should be maintained; therefore, in order to anticipate depreciation a surplus of light should be allowed for in the original design.

Rule 8. Blackboards.

In Fig. 2 are shown some simple graphical considerations of blackboard lighting. In (a) is shown a plan view of a room with windows on one side. Rays of light are indicated by A, B, and C in horizontal projection. These are supposed to come from a bright sky. By the application of the simple optical law of reflection—the angle of reflection is equal to the angle of incidence—it is seen that pupils seated in the shaded area will experience glare from the blackboards on the front wall, if they have a glossy surface. In (b) is shown the vertical projection of the foregoing condition. It will be apparent from this graphical illustration that by tilting the blackboard away from the wall at the top edge, the pupils in the back part of the room will be freed from the present glaring condition. Whether or not this tilting will remedy bad conditions may be readily determined in a given case. In (b) the effect of specular reflection of the image of an artificial light source is shown by B. In (c) is shown a proper method of lighting blackboards by means of local artificial lighting units. This will often remedy bad lighting conditions whether due to an insufficient illumination intensity of daylight or to reflected images of bright natural or artificial light sources.

Experience has shown that black slate is the most satisfactory material of which to make a blackboard.

SUBJECT INDEX

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