STANDARD LIGHTING

CUSHING

(SECOND EDITION)

STANDARD LIGHTING

WITH INCANDESCENT ELECTRIC LAMPS

COMPILED BY

A STAFF OF EXPERTS

Endorsed by the Lighting Department of the Joint Committee for Business Development in the movement to "Electrify" and by the Society for Electrical Development.

The movement for Business Development is being promoted by the following national organizations: National Electric Light Association; Electrical Supply Jobbers' Association; National Association of Electrical Contractors and Dealers; National Council of Lighting Fixture Manufacturers; Lighting Fixture Dealers' Society of America; Illuminating Glassware Guild; Illuminating Engineering Society; Electrical Manufacturers' Council; The American Institute of Electrical Engineers.

In the preparation of this text, the aim has been to present information of real, practical value both to the purchaser and to the installer of lighting equipment.

Analysis of available information revealed that in the transactions of the Illuminating Engineering Society and in the publications of the manufacturers of lighting equipment was to be found the most exhaustive, clearest, and most up-to-date discussion of many of the more important lighting problems.

These publications have, therefore, been freely used in the compilation of this handbook. Acknowledgement is gratefully made to S. E. Doane, G. H. Stickney, D. W. Atwater, A. B. Oday, Ward Harrison, A. L. Powell, S. G. Hibben, H. A. Smith, R. E. Harrington, A. S. Turner, C. A. Atherton, M. Luckiesh, Earl A. Anderson, J. H. Kurlander, G. A. Clewell, H. H. Magdsick and J. R. Colville for permission to use material prepared by them and for constructive suggestions in the presentation of the subjects.

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PART I

ILLUMINATION FUNDAMENTALS

In the last year of the war and in the year immediately following, more progress was made in the application of artificial lighting than in any ten-year period preceding. Continual improvements in lamps and reflecting equipments, the constantly increasing availability of electric service, and the growing knowledge of illumination fundamentals, had, over a period of years, been paving the way for a sudden, sharp advance in lighting practice.

In no field of lighting was the progress so remarkable as in industry, for here the value of good illumination could be most easily measured in terms of dollars and cents. Tests conducted under actual working conditions demonstrated that startling increases in production were possible when antiquated lighting systems were replaced with new ones which produced lighting comparable with the daylight lighting of well designed modern factories. Most executives believed in good lighting, they acknowledged its importance, but what they did not know, and what had not been satisfactorily demonstrated, was that what were then considered good lighting installations were not supplying enough light; in other words, were not good lighting. Once the traditional illumination levels were broken through and levels 3, 4, and 5 times as high tried out in service, the handicap imposed by previous standards became apparent. Artificial lighting in every field moved forward.

Amount of Light

We do not know today how much light is right for the many applications. We do know that 3 or 4 foot-candles will enable one to see more detail than will 1 foot-candle; that 10 foot-candles will reveal more than 3 or 4; that 50 foot-candles will increase perception over 10; that 100, or even more, will sometimes produce still further improvements when the eyes are taxed to the utmost. We know that vision is quickened when the illumination is increased from 2 or 3 foot-candles to 10, 50, or to 100 or more. We know that persons with defective vision, and this means a surprisingly large proportion of the people, are even more greatly handicapped by poor lighting than are those with good vision, and that they respond more markedly to improvement in the lighting. Again we know that bright and cheerful surroundings are stimulating, that they inspire cleanliness, that they make for order and neatness. In these simple fundamental facts we find the reasons why, in industry, higher levels of illumination increase production without imposing strain upon the employees, why they automatically reduce accident hazard, decrease spoilage, and improve morale; why, in the office, they enable more work to be performed with fewer headaches, less mistakes, and better tempers; why, in the store, they attract customers, facilitate the examination of material, and make for quicker sales; and why, in the home, they facilitate reading, working or studying at night.

Diffusion of Light

With the 10 to 1 increase in efficiency of the incandescent lamp, since its invention scarcely two-score years ago, has come the generation of large volumes of light in a small space. This means, of course, light sources of great brilliancy. A bright source does not in itself insure adequate lighting, in fact, unless skillfully handled, it presents a positive menace to vision. Objects are seen by the light which comes from them to the eye; light which comes directly from the light source to the eye or is reflected from the source to the eye by some polished surface is not only useless in illuminating the object viewed but if of high intensity or of large volume, it produces a blinding effect which seriously interferes with seeing and may result in permanent injury to the eyes. "Glare" is the term applied to light which obstructs vision in this way.

Glare blinds the driver of an automobile when approaching another with improperly adjusted headlights at night; it handicaps the workman who is trying to see fine details with a brilliant light source near his line of vision; it produces acute discomfort in the conference room where men sit facing inadequately shaded windows for a long period of time; it is annoying in the home where wall brackets containing unshielded lamps are seen against dark backgrounds; it blinds the ball player, who tries to follow the ball against the sun. In hundreds of ways it is constantly interfering with vision and handicapping us in work and play.

Specular reflection, that is, the reflections of light sources in polished surfaces, while sometimes an aid to vision, is often, because of its insidious nature, more harmful than direct glare. Under proper control, it facilitates the reading of the micrometer scale or the inspection of a polished surface; in excess, it becomes reflected glare, dulls perception, and paves the way for accident. As moderate specular reflection, it brings out the texture of materials and assists the housewife in her sewing; as reflected glare, it blurs the printed page and causes eyestrain in reading. In small amounts, coming from the pavement to the eye it discloses the inequalities of the road to the motorist at night or reveals the pedestrian in silhouette; in large amounts, as from snow in sunlight, it produces painful and serious injury to the eyes.

Fortunately, once the danger in direct glare and the advan-

Had only one row of units been employed in lighting this store, as is quite commonly the case with small stores, the center aisle would have been brightly lighted, but much less light would fall on the counters where most needed and a customer would inevitably cast a shadow on the merchandise. Note the soft even illumination shown in this illustration where correct principles have been followed

tages and disadvantages in specular reflection are understood, the means for eliminating the bad and retaining the good is readily available. The answer lies in proper diffusion of the light. The reflecting equipments now regularly manufactured provide any degree of diffusion considered desirable. The totally indirect type which directs all of the light to the ceiling, whence it is diffused throughout the room, represents the utmost in diffusion; the semi-indirect type, which directs a large proportion of the light to the ceiling, but transmits some through the bowl, provides a degree of diffusion which is preferred by many; so-called light-directing semi-enclosing, or totally enclosing, units are available in designs which provide good control of the light and satisfactory diffusion; enclosing globes of the proper size and density provide diffusion of the light but afford little control of its distribution. Open reflectors of proper design eliminate glare from the lamp filament but afford no protection against reflected glare in polished surfaces. Such reflectors, however, when designed for, and used with, bowl-enameled lamps constitute an equipment which is almost ideal for the large majority of industrial applications. They are inexpensive, easy to maintain, allow considerable control of the light distribution, provide good diffusion, and eliminate objectionable specular reflection while at the same time producing sufficient glint for the reading of a scale or the examination of textiles.

Color Quality of Illumination

Since an object is seen by the light which comes to it from the source and thence by reflection to the eye, it follows that color in the object is seen only when the light contains rays of that color. For example, a red object will appear black under light in which red rays are lacking or a blue object will appear black when blue rays are absent in the source. Daylight is composed of all the colors in proportions seen in the rainbow The light from Mazda lamps contains all the colors composing daylight but if the spectra, or rainbows, of the two were to be compared it would be seen that the Mazda lamp was richer than daylight in the orange-red region and weaker in the blue. For ordinary purposes, the light from clear Mazda lamps is sufficiently like daylight to answer all requirements, but where color discrimination is a factor, as in sorting or grading processes for example, and in the laundry where scorch marks must be readily distinguishable, or where the artificial light is used to supplement daylight, as in an office, daylight lamps, which screen out the majority of the excess orange-red rays, find wide application.

For purposes of color matching, dyeing, process printing, and the like, where extreme accuracy is necessary in the observation of colors, a still further correction of the light is necessary. For this service so-called color-matching units, which provide a light of true and unvarying north-sky quality, are available.

The high efficiency of present incandescent lamps which makes practicable the approximation, or the duplication, of daylight on a large scale also permits the modification of light to any desired extent for obtaining striking and unusual effects in display windows, in decorative lighting, and in the home.

Equipments designed especially for the control of color are readily available.

Shadow

Contrary, perhaps, to popular opinion, a certain amount of

Correct lighting for every service conforms to certain fundamental principles. Note the evenness of illumination, the absence of sharp shadows, and the bright and cheerful appearance of the interior

shadow is desirable in artificial lighting. Objects illuminated by perfectly diffused light appear flat and uninteresting, contours are lost, and it is difficult for the eye to form a correct judgment of the shape of an object. On the other hand, deep, black shadows are troublesome and are a source of constant danger because of what they may conceal. Shadows having a sharp edge or a series of sharp edges, which result from several small light sources near one another, are particularly annoying in office work, where they dance about the pencil point most disconcertingly. In general, in interior lighting, only soft illuminated shadows with gradually fading outlines should be tolerated.

The number of shadows cast by an object and their length depends upon the number and the position of sources directing light toward the object; the softness of the shadow depends upon the area of the surfaces from which the light comes and upon the number of directions from which light is received. Indirect and dense semi-indirect units which make the ceiling serve as the principal light source, and large units of the direct-lighting type, therefore, make for soft shadows, small units of the direct type make for sharp shadows. As a general rule, lighting units which are satisfactory for the application from the standpoints of light diffusion and low brightness will also prove satisfactory from the standpoint of shadow when a sufficient number are used to provide a satisfactory degree of uniformity in the lighting of the work.

Uniformity of Illumination

Where the prime purpose of lighting is the production of artistic effects, uniformity of illumination may be undesirable. On the other hand, it is not an uncommon experience to find in industrial plants that, because of too great a spacing between units, some workmen are supplied with only one half or one third as much light for their work as are others. Many office employees are forced to work under the same handicap. There are cases on record where the suspected incompetency of an employee with respect to his co-workers has been traced to the unsuspected cause of poor lighting.

Definite relations exist between the height at which units are mounted above the work and the distance by which they may be separated to provide reasonable uniformity in lighting, and light from a sufficient number of directions so that shadows will not prove troublesome. These relations have been reduced to simple tabular form for the convenience of the designer of lighting systems. In general, the permissible distance between units should not be more than one and one-half times the height of the light sources above the work; closer spacings can do no harm and are often desirable but when this spacing distance is exceeded, the illumination between units falls off very rapidly. The user of light should consider carefully before allowing his desire to keep initial costs low, lead him to install a system in which the proper spacing distance is materially exceeded.

Illumination of Vertical Surfaces

For many locations, such as offices and drafting rooms, light is required principally on horizontal planes, such as desk tops or table tops, and it has been the custom to calculate illumination on the basis of that delivered to horizontal surfaces with the assumption that the oblique surfaces of objects would be sufficiently lighted. This practice may result in inadequate illumination. In a machine shop, for example, the lighting of the vertical surfaces of the work or of machine parts is fully as important as

There is no necessity for imposing a handicap on any worker because of poor light. Though illumination requirements for drafting rooms are comparatively severe on account of close visual application, these requirements are met by the uniform, thoroughly diffused, shadowless illumination of high intensity shown here

the lighting of the horizontal surfaces. As a matter of fact, most shops are lighted during the day by light from windows, which give a greater light on the vertical surfaces than on the horizontal. In all such cases where direct lighting is used, only those lighting units should be installed which show a reasonably good candlepower in the 50-70 degree zone as well as below these angles. A shop lighted by closely spaced automobile headlights directing the light downward from the ceiling would furnish ample light on a horizontal plane but such lighting would be far from satisfactory.

Desirable Wall Brightness

The effectiveness of a lighting system depends not only on the effectiveness of the lighting unit, but also on the reflecting properties of the walls, ceiling, and surroundings, and upon the size and proportions of the room. It is, in fact, entirely possible to find an installation of reflectors of poor design and inferior from the standpoint of glare, which is nevertheless, from the single standpoint of the percentage of light reaching the illumination plane, better than an installation where reflectors of good design are used, if the former are installed under favorable conditions such as light walls, ceiling, etc., and the latter under unfavorable conditions. On the other hand, it must be borne in mind that a large expanse of wall surface finished so light as to reflect a large volume of light into the eyes is objectionable for offices, residences, and all rooms where the occupants are likely to sit more or less directly facing the walls for considerable periods of time. Such data as are available indicate that where the brightness of the walls is equal to, or greater than, the brightness of white paper lying on a table or desk, annoying glare will result. In fact, a wall brightness one-half that of the paper has been found unsatisfactory—a brightness of one-fifth is, apparently, comfortable. With the usual types of lighting units, walls are not illuminated to intensities as high as those obtaining on desk or table tops, and walls which reflect less than 50 per cent. of the light which strikes them should not produce discomfort, providing, of course, that they are of a mat or semi-mat finish. Walls finished in buff, light green, or gray reflect about the proper proportion of light and their use is meeting with general favor. Walls finished in a high gloss are not satisfactory from a glare standpoint.

Maintenance

The experiences of those who have installed high levels of illumination prove conclusively that every foot-candle delivered at the work has a definite tangible value.

The man who provides a system capable of delivering 10 foot-candles at the work and then allows the system to depreciate until it delivers only 3 or 4 is losing not only 60 or 70 per cent. of the light he is paying for but, what is far more important, he is losing the profit on the difference between the output of his employees at this low level of illumination and their output at the higher level. If the depreciation of a lighting system were of the order of 2 or 3 per cent. or even 10 per cent. the matter would not be so serious a one, but surveys of installations in service show depreciations of 50 per cent., 60 per cent., and more. Many users are not getting one third of the light their systems are capable of delivering.

The lighting of the home should be flexible to permit lighting effects suitable to various occasions to be obtained, but in all cases, the fundamentals of lighting hold. All bright lights should be adequately shielded from view, though enough light should be available for reading or sewing comfortably.

PART II
ILLUMINATION DESIGN DATA

To take the several essential factors entering into illumination design properly into account has appeared so complicated a task that many designers have adhered to rule-of-thumb methods which, while adequate in some cases, are likely to lead to unsatisfactory results when applied generally.

The method of design here presented will be found fully as simple as any of the common short-cuts. It has the decided advantage that the technical considerations which are important as influencing the result and which require the experienced judgment of the engineer have been taken into account in the preparation of the charts and tables and therefore automatically receive due allowance in the lighting design. The data apply in interiors where standard types of reflecting equipment are used to obtain general lighting of substantially uniform intensity.

The four steps to be carried out in the design of a general lighting system for a room are:

1. Decide the foot-candle illumination required.
2. Select the type of lighting unit best adapted to the location.
3. Determine the location of outlets, the mounting height and number of lighting units required.
4. Ascertain the size of MAZDA lamp which will provide the foot-candles desired.

1. Foot-Candle Illumination

Tables 3 and 4, pages 25 to 31, list the foot-candle values, corresponding to present standards, for different classes of industrial operations, offices, stores, etc. The desirable illumination

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DEFINITIONS

Lumen: The lumen is the unit of light flux quantity. The number of lumens required to light a given surface is proportional to the illumination in foot-candles and to the area of the surface in square feet. The light output of MAZDA lamps is given in lumens.

Foot-Candle: The degree to which a surface is illuminated is measured in foot-candles. One lumen will light a surface of 1 square foot to an average intensity of 1 foot-candle.

Coefficient of Utilization (Percentage of Lumens Effective): The proportion of the lumens generated by the lamps which reaches the plane of work is known as the Coefficient of Utilization. It is dependent upon the type of diffusing and reflecting equipment, color of walls and ceiling and also the proportions of the room, that is, the size and shape of the room and the height of the light source above the plane of work. These room proportions are classified in this section by **Room Index** tables. The plane of work, unless otherwise specified is ordinarily considered to be horizontal and 2½ feet above the floor.

Depreciation Factor: This represents a safety factor which provides added initial illumination sufficient to compensate for aging of the lamps and the falling off in reflecting efficiency of the reflectors, walls, and ceilings due to deterioration and the collection of dust and dirt. A depreciation factor should always be applied to the recommendations for foot-candles of illumination since these are always stated in terms of average service, or sustained illumination.

varies rather widely depending on the conditions in any particular installation, such as the accuracy of the operation and fineness of detail to be observed, the color of goods worked on or handled and, in the case of stores, the advertising value resulting from the attractiveness of a well lighted interior. The foot-candle values recommended in the table are the minimum to be adhered to if fully satisfactory lighting is to be assured. Under particular conditions considerably higher illumination is often desirable.

2. Type of Lighting Unit

The selection of the type of lighting unit depends not only upon the requirements of the work but in some cases upon the construction of the room and the color of ceiling and walls. For example, semi and totally indirect lighting is unsuited to rooms with very dark ceilings. It is important to specify the type of lamp to be used since, for example, as shown in Table 1, bowl-enameled lamps used in open reflectors, such as RLM standard domes, form a much superior lighting unit from the standpoint of glare, reflected glare, and shadows than clear lamp units of the same type. In general, clear MAZDA C lamps should not be used in open reflectors where the mounting height is less than 20 feet.

Factors other than those listed in Table 1 may enter into the choice of the lighting unit in certain instances. For example, in stores, offices and other public installations, decorative effect is often an important item. The charts on pages 21 and 22 rate the various types of units comparatively to serve as a basis for judgment of the adaptability of a unit for a particular class of installation.

3. Location of Outlets, Mounting Height, and Number of Lighting Units

Make a diagram to scale of the floor area of the room. If the units are of semi or totally indirect type, measure the ceiling height of room and refer to Table 2-b, page 24, for the permissible spacing of units and preferred suspension distance of lighting units corresponding to this ceiling height.

If the units are of direct lighting type, determine the mounting height and refer to Table 2-a for the permissible spacing corresponding to this mounting height. If the units are mounted as close to the ceiling as possible (a minimum allowance of one foot is usually necessary to provide for the drop of the reflector from the ceiling), a wider spacing is permissible and fewer units are therefore necessary for an even distribution of light. Considerations of shadows, appearance and arrangement of work may make a lesser mounting height desirable even though a closer spacing of outlets would be needed to keep the same uniformity of illumination. Ordinarily lamps should not be mounted less than 10 feet above the floor unless a low ceiling makes it necessary.

Having determined the permissible spacing proceed to locate the outlets on the diagram of the floor area. Locate the units as nearly symmetrically as possible without appreciably exceeding the permissible spacing for uniform illumination. At a greater height, a spacing closer than that in Table 2 results in greater freedom from shadows but increases the number of units required and makes the installation cost more. If a spacing somewhat closer than the permissible value is adopted, as is often the case, it is allowable, though not necessary, to refer back to Table 2 and select a lower mounting height corresponding to the new spacing. The distance between the outside row of outlets and the wall should not exceed one-half the spacing distance. For office spaces, or where work is carried on at benches or machines near the wall, this distance should be approximately one-third the spacing distance.

4. Lamp Size

After the outlets have been located on the plan, the lamp size to be used may be determined by the following calculation:

$$\text{A} \quad \text{Area in Square Feet Per Outlet} = \frac{\text{Total Floor Area in Square Feet}}{\text{Number of Outlets}}$$

$$\text{B} \quad \text{Lamp Lumens Required per Square Foot} = \frac{\text{Foot-Candles x Depreciation Factor}}{\text{Coefficient of Utilization}}$$

$$\text{C} \quad \text{Lamp Lumens Required per Outlet} = \text{Area in Square Feet per Outlet (From A)} \times \text{Lamp Lumens Required per Square Foot (From B)}$$

Foot-Candles—Illumination decided upon.

Depreciation Factor—Safety factor or allowance for depreciation due to aging of lamps, dirt, dust, and deterioration of reflecting value of walls. Use 1.3 for fairly clean locations. Use 1.5 for dirty locations or where cleaning is infrequent.

Coefficient of Utilization—Proportion of the generated light from the lamps which reaches the plane of work. The Coefficient of Utilization for the installation is determined as follows:

Table 5, pages 32 to 35, shows that the Coefficient of Utilization varies according to the type of fixture, the proportions of the room expressed by "Room Index," and the color of the walls and ceiling. From the "Room Index" Table 6, pages 36 to 42, find the Room Index corresponding most nearly to the dimensions of the installation. Then the Coefficient of Utilization for the installation of the type of lighting unit selected will be found from Table 4, in the proper column of wall and ceiling color opposite the correct Room Index.

Having determined the lamp lumens required per outlet by the above calculations, the wattage of Mazda lamps to be used may be found by reference to Table 7, page 43, which lists the lumen output rating for each size of Mazda and Mazda Daylight lamps. Locate in this table the size of lamp of the desired type which most nearly meets the requirement of lumen output. When the lamp lumens required fall nearly midway between two sizes, choose the larger rather than the smaller, unless it is certain that the less illumination from the smaller will suffice.

* * * * * *

Computed Illumination Values

The foot-candles of illumination in service, allowing a depreciation factor of 1.3, obtained for systems having different Coefficients of Utilization and areas per lamp are worked out in Table 8, pages 44 and 45. Table 8 can be referred to as an approximate check on design computations made as outlined above.

ILLUMINATION DESIGN FOR A FACTORY ROOM

The floor plan of the factory space to be lighted is 60′ x 120′ as shown. The work carried on in the room is assembly of sewing machine heads.

Height of floor to roof trusses is 12 feet.

The roof is of sawtooth construction and the walls and upper structure are painted a medium color. A considerable amount of dark material is kept stacked along the walls of the room.

Following the steps outlined on Pages 14 to 17 the lighting design is determined as follows:

1. Foot-Candle Illumination

From Table 4, Page 27, 8 foot-candles are recommended for assembly, medium grade.

2. Type of Lighting Unit

Consulting the Guide to the Selection of Reflecting Equipment of Table 1, Page 21, Unit No. 2, the RLM dome with bowl-enameled lamp is selected based on efficiency and favorable showing from the standpoints of glare, reflected glare, shadows, and maintenance.

3. Location of Outlets, Mounting Height, and Number of Units

The height of the benches and therefore the plane of work is 3½′ above the floor. The maximum mounting height of the lamps above the floor is 11′ (12′ height from floor to truss less 1′ allowed for reflector drop). Hence, maximum mounting height of units above plane of work is 11′—3½′ or 7½′.

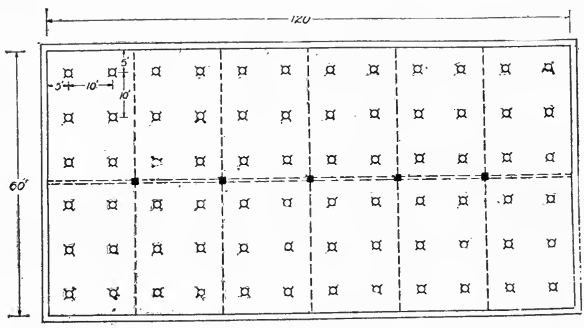
From Table 2-a of Spacing-Mounting Height, Page 23, a $7\frac{1}{2}'$ mounting height above plane for direct lighting units is found to indicate a permissible spacing of approximately 11′ and since the section of the room near the walls consists of aisles and storage, $5\frac{1}{2}'$ may be allowed for the distance between the last row of outlets and the side walls.

Reference to floor plan of the room shows that a 10′ spacing each way (outside units 5′ from walls) would make a symmetrical layout in the 20′ x 30′ bays and this spacing is therefore adopted. Outlet locations for the entire space are marked on the plan as shown and 72 are found to be required.

4. Lamp Size

(*A*)

$$\text{Area in Square Feet per Outlet} = \frac{\text{Total Floor Area in Sq. Ft.}}{\text{Number of Outlets in Room}} = \frac{7200}{72} = 100$$



Outlet for 1-150 watt bowl enameled MAZDA C lamp, equipped with an RLM Standard Dome Reflector, with suitable holder. Reflector located 11 feet above the floor

(B)

$$\text{Lamp Lumens Required per Square Foot} = \frac{\text{Foot-Candles x Depreciation Factor}}{\text{Coefficient of Utilization}} = \frac{8 \times 1.30}{.57} = 18.2$$

Area in square feet per outlet—100.

Foot-Candles—8.

Depreciation Factor—1.30.

To find Coefficient of Utilization.

From Room Index, Table 6, page 37, in a room 60′ x 120′, where the mounting height of direct lighting units above plane of work is 7′, the Room Index is 5.0 or from Page 38 in the same room where the mounting height is 8′ the Room Index is 4.0. Either value might be used for the Room Index with equal accuracy as to the result but 4.0 is more conservative.

Referring to Table 5, Coefficients of Utilization, Page 32, for RLM dome bowl-enameled lamps in a location with a Room Index of 4.0 and where the ceiling and walls are fairly dark the Coefficient of Utilization is found to be .57.

(*C*) Combining (*A*) and (*B*)

$$\text{Lamp Lumens Required per Outlet} = \text{Area in Square Feet per Outlet} \times \text{Lamp Lumens Required per Square Foot} = 100 \times 18.2 = 1820$$

From Table 7, Lumen Output of Mazda Lamps, Page 43, a 150 watt Mazda C lamp giving 2100 lumens is found to most nearly meet the requirement. The actual service illumination using this lamp will, of course, be slightly greater than originally designed for, or

$$\frac{2100}{1820} \times 8 = 9.2 \text{ foot-candles}$$

As an approximate check on the computation reference may be made to Table 8 where with a Coefficient of Utilization of 0.55 (the table value nearest to 0.57) and an area per lamp of 100 square feet the illumination, using 150-watt MAZDA C lamps, is found to be 8.9 foot-candles.

CHOICE OF REFLECTING EQUIPMENT

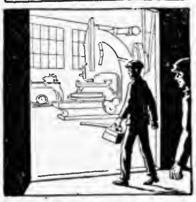
Various lighting units are rated in accordance with seven fundamentals, illustrated on the following page. The importance of these criteria is different for different classes of work. It must be emphasized that the relative importance of the various criteria should be carefully weighed with respect to the particular problem at hand. For instance, in an office the criteria would rank in importance: (1) Direct glare; (2) Reflected glare; (3) Shadows; (4) Efficiency based upon illumination on horizontal; (5) Maintenance; (6) Vertical illumination. On the other hand, where lamps are to be hung above a crane in a foundry, the order of importance would be: (1) Efficiency based upon illumination on horizontal; (2) Vertical illumination; (3) Maintenance; (4) Shadows; (5) Direct glare; (6) Reflected glare.

In the chart the best rating given is A +, which denotes the highest degree of excellence, while D, the lowest, indicates that an installation of units so rated in any particular, will very likely prove unsatisfactory in an installation where this factor is important. The ratings B and C while indicating a result not equal to A, are decidedly superior to rating D. In other words a rating B, C + or C in certain respects does not disqualify a unit provided that in the essential requirements of a given location, the unit is rated A or B +.

A +		B +		C +		
A	Excellent	B	Good	C	Fair	D Very Bad
A —		B —		C —		

ILLUMINATION ON HORIZONTAL SURFACES is a prime requisite in offices, drafting rooms and those shops where the problem is to provide the best illumination for sustained vision of flat surfaces on the horizontal or slightly oblique planes in which papers, books and other flat objects are usually examined.

ILLUMINATION ON VERTICAL SURFACES of work or machine parts is fully as important as the lighting of the surface in the horizontal plane. In a consideration of the amount of light necessary for factory illumination, the criterion must be the intensity on all working surfaces whether vertical, horizontal or oblique.



FAVORABLE APPEARANCE OF LIGHTED ROOM refers only to the general or casual effect produced by the complete system, and is not intended to rate the unit as to satisfaction from the standpoint of good vision or freedom from eye fatigue.

DIRECT GLARE is the most frequent and serious cause of bad lighting. It results among other things from unshaded or inadequately shaded light sources located within the field of vision, or from too great contrast between the bright light source and a dark background or adjacent surfaces. Glare should be avoided by the use of proper reflecting and diffusing equipment.

REFLECTED GLARE from polished working surfaces is particularly annoying because of the necessity of directing the eyes toward those surfaces, and further because the eyes are by nature especially sensitive to light rays from below. The harmful effects of this specular reflection can be minimized by properly shielding from below or diffusing the source.

SHADOWS, that is, differences in brightness of surfaces, are essential in observing objects in their three dimensions, but are of little or no value in the observation of flat surfaces. Where shadows are desirable, they should be soft and luminous, not so sharp and dense as to confuse the object with its shadow.

MAINTENANCE depends upon contour of reflector, construction of fixture, and condition of ceiling. The rating is based upon the likelihood of breakage, the labor involved in maintaining the units at comparable degrees of efficiency, and indication given of need of cleaning.

TABLE 1

A GUIDE TO THE SELECTION OF REFLECTING EQUIPMENT									
	LIGHTING UNIT		EFFICIENCY BASED UPON		FAVORABLE APPEARANCE OF LIGHTED ROOM	DIRECT GLARE	REFLECTED GLARE	SHADOWS	MAINTENANCE
			ILLUMINATION ON HORIZONTAL	ILLUMINATION ON VERTICAL					
			DIRECT LIGHTING PORCELAIN ENAMEL REFLECTORS						
1	R L M DOME Clear Lamp	90° to 180°—0% 0° to 90°—76%	A+	B+	C+	C	D	C+	A+
2	R L M DOME Bowl-Enameled Lamp	90° to 180°—0% 0° to 90°—66%	A−	B	B	B+	B	B+	A−
3	GLASS TOP DOME Bowl-Enameled Lamp	90° to 180°—8% 0° to 90°—55%	B	C+	A−	A−	B	B+	B
4	DEEP BOWL Clear Lamp	90° to 180°—0% 0° to 90°—65%	B+	B−	C	C+	D	C	A
5	DEEP BOWL Bowl-Enameled Lamp	90° to 180°—0% 0° to 90°—58%	B	C+	C	B	C+	C+	B+
6	FLAT CONE Shielding Band Clear Lamp	90° to 180°—1% 0° to 90°—54%	B	C+	C+	C+	D	C	B+
7	FLAT CONE Clear Lamp	90° to 180°—10% 0° to 90°—74%	B	B	C	D	D	C	A+
			DIRECT LIGHTING OPEN GLASS REFLECTORS						
8	LIGHT DENSITY OPAL Clear Lamp	90° to 180°—33% 0° to 90°—54%	B+	B	B+	C+	D	B−	B
9	LIGHT DENSITY OPAL Bowl-Enameled Lamp	90° to 180°—36% 0° to 90°—45%	B	B−	A−	B−	B−	B+	B−
10	DENSE OPAL Clear Lamp	90° to 180°—15% 0° to 90°—67%	A+	B+	B+	B	D	C+	A−
11	DENSE OPAL Bowl-Enameled Lamp	90° to 180°—16% 0° to 90°—60%	B+	B−	A−	B+	B−	B	B
12	MIRRORED GLASS Clear Lamp	90° to 180°—0% 0° to 90°—68%	A	B	C	C+	D	C	A−
13	MIRRORED GLASS Bowl-Enameled Lamp	90° to 180°—0% 0° to 90°—55%	B	C+	C	B−	C	C+	B−
14	PRISMATIC INDUSTRIAL Clear Lamp	90° to 180°—18% 0° to 90°—73%	A+	A−	B+	C+	D	C+	B−

TABLE 1

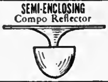
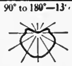
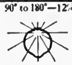
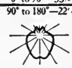
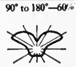
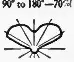
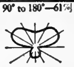
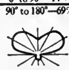
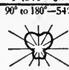
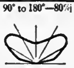
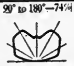
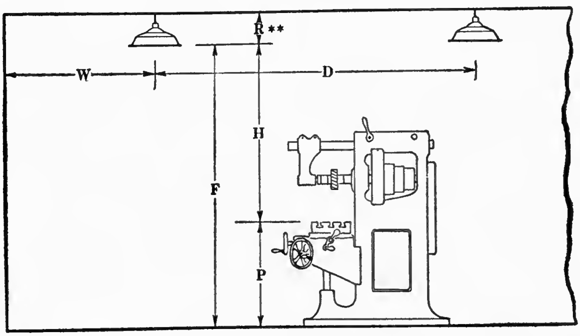
A GUIDE TO THE SELECTION OF REFLECTING EQUIPMENT									
LIGHTING UNIT			EFFICIENCY BASED UPON		FAVORABLE APPEARANCE OF LIGHTED ROOM	DIRECT GLARE	REFLECTED GLARE	SHADOWS	MAINTENANCE
			ILLUMINATION ON HORIZONTAL	ILLUMINATION ON VERTICAL					
DIRECT LIGHTING ENCLOSING AND SEMI-ENCLOSING UNITS									
15	DIFFUSING GLOBE Light Opal 	90° to 180°—35%  0° to 90°—40%	B−	B−	A	B−	B	B+	B+
16	ONE-PIECE OPAL Flattened Reflecting Top 	90° to 180°—35%  0° to 90°—45%	B	B	A	B	B	B+	A−
17	DIFFUSING GLOBE Large Metal Reflector 	90° to 180°—6%  0° to 90°—58%	B	B	B+	B	B	B+	B+
18	SEMI-ENCLOSING Metal Reflector 	90° to 180°—20%  0° to 90°—56%	B	B	A	B	B	B+	B−
19	SEMI-ENCLOSING Compo Reflector 	90° to 180°—13%  0° to 90°—60%	B	B	A	A	A−	A−	C+
20	TWO-PIECE GLASS Opal Refl and Enam Bowl 	90° to 180°—12%  0° to 90°—53%	B	B	A	B+	B+	A−	B
21	ONE-PIECE GLASS Enameled Refl and Bowl 	90° to 180°—22%  0° to 90°—50%	B	B	A	B+	B+	A−	A−
SEMI-INDIRECT AND INDIRECT LIGHTING UNITS									
22	LIGHT OPAL 	90° to 180°—60%  0° to 90°—25%	B−	C+	A	B+	B+	A−	C
23	DENSE OPAL (or Light Opal and Bowl-Enameled Lamp)	90° to 180°—70%  0° to 90°—10%	C+	C	A	A+	A	A+	C
24	ENAMELED METAL REFLECTOR Opal Glass Bottom 	90° to 180°—61%  0° to 90°—14%	B−	C	A	A	B+	B+	C
25	ENAMELED METAL REFLECTOR Opal Glass Bottom Bowl-Enameled Lamp	90° to 180°—69%  0° to 90°—6%	C+	C	A	A+	A	A	C
26	CLEAR TOP ENCLOSED Enameled Glass 	90° to 180°—54%  0° to 90°—21%	C+	C	A	A+	A	A	B
27	MIRRORED INDIRECT 	90° to 180°—80%  0° to 90°—0%	C+	C	B+*	A+	A	A+	C
28	ENAMELED METAL INDIRECT 	90° to 180°—74%  0° to 90°—0%	C	C	B+	A+	A	A+	C

TABLE 2-a SPACING—MOUNTING HEIGHT

Direct Lighting Units, Including Semi-enclosing and Totally Enclosing Units, No. 1 to No. 21

Mounting Height of Unit		Permissible Distance Between Outlets	Permissible Distance Between Outlets and Sidewalls	
Above Plane of Work (H)	Above Floor* (F)	(D)	In Usual Locations Where Aisles & Storage Are Next to Wall (W)	In Offices or Where Work Benches are Next to Wall (W)
4	6½	6	3	2
5	7½	7½	3½	2½
6	8½	9	4½	3
7	9½	10½	5	3½
8	10½	12	6	4
9	11½	13½	6½	4½
10	12½	15	7½	5
11	13½	16½	8	5½
12	14½	18	9	6
13	15½	19½	9½	6½
14	16½	21	10½	7
15	17½	22½	11	7½
16	18½	24	12	8
18	20½	27	13½	9
20	22½	30	15	10
22	24½	33	16½	11
24	26½	36	18	12
27	29½	40½	20	13½
30	32½	45	22½	15
35	37½	52½	26	17½
40	42½	60	30	20



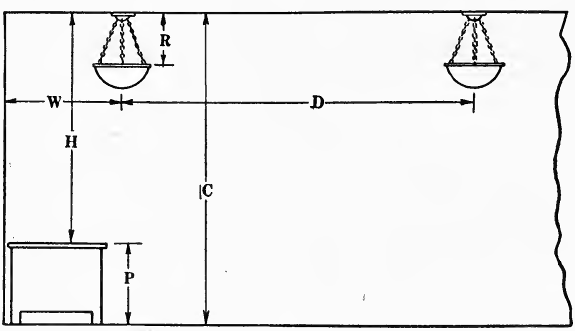
*Plane of work (P) assumed to be 2½ feet above floor. When the plane of work is higher or lower than 2½ feet above floor, neglect column (F) and work from column (H).

**Minimum allowance for (R) usually 1 foot.

TABLE 2-b SPACING—MOUNTING HEIGHT

Semi and Totally Indirect Lighting Units, No. 22 to No. 28

Ceiling Height		Permissible Spacing Distance Between Outlets	Permissible Distance Between Outlet and Sidewalls		Suspension Distance Ceiling to Top of Reflector**
Above Plane of Work (H)	Above Floor* (C)	(D)	In Usual Locations Where Aisles and Storage Are Next to Wall (W)	In Offices or Where Work Benches Are Next to Wall (W)	(R)
5	7½	7½	3½	2½	1¼
6	8½	9	4½	3	1½
7	9½	10½	5	3½	1¾
8	10½	12	6	4	2
9	11½	13½	6½	4½	2¼
10	12½	15	7½	5	2½
11	13½	16½	8	5½	2¾
12	14½	18	9	6	3
13	15½	19½	9½	6½	3¼
14	16½	21	10½	7	3½
15	17½	22½	11	7½	3¾
16	18½	24	12	8	4
18	20½	27	13½	9	4½
21	23½	31½	15½	10½	5¼
24	26½	36	18	12	6
27	29½	40½	20	13½	6¾
30	32½	45	22½	15	7½
35	37½	52½	26	17½	8¾
40	42½	60	30	20	10



*Plane of work (P) assumed to be 2½ feet above floor. When the plane of work is higher or lower than 2½ feet above floor, neglect column (C) and work from column (H).

**Suspension distances (R) in Table are based on best distribution of light and efficiency of utilization for standard units. In some installations other considerations may require a different suspension distance.

TABLE NO. 3

Present Standards of Foot-Candles Illumination for Stores, Commercial and Public Interiors

	Foot-Candles Recommended	Range
Department Stores and Large Specialty Stores		
Main Floors	10	6- 12
Basement Store	10	6- 12
Other Floors	8	5- 10
Show Windows	..	10-100
Stores of Medium Size		
Clothing, Dry Goods, Furniture, Etc.	8	5- 10
Exclusive Small Stores		
Light Goods	8	5- 10
Dark Goods	12	8- 16
Small Stores		
Art	8	5- 10
Automobile Supply	6	4- 8
Bake Shop	6	4- 8
Book	6	4- 8
China	6	4- 8
Cigar	8	5- 10
Clothing	8	5- 10
Confectionery	8	5- 10
Dairy Products	6	4- 8
Decorator	8	5- 10
Drug	8	5- 10
Dry Goods	8	5- 10
Electrical Supply	8	5- 10
Florist	6	4- 8
Furrier	8	5- 10
Grocery	6	4- 8
Haberdashery	8	5- 10
Hardware	6	4- 8
Hat	8	5- 10
Jewelry	8	5- 10
Leather, Handbags and Trunks	6	4- 8
Meat	6	4- 8
Millinery	8	5- 10
Music	6	4- 8
Notions	6	4- 8
Piano	6	4- 8
Shoe	8	5- 10
Sporting Goods	6	4- 8
Tailor	8	5- 10
Tobacco	8	5- 10
Variety Store	10	6- 12
Armories, Public Halls	5	3- 6
Auditoriums	3	2- 4
Automobile Show Room	8	5- 10
Bank		
Lobby	6	4- 8
Cages and Offices	10	6- 12
Barber Shop	8	5- 10
Cars		
Baggage	4	3- 6
Daycoach, Subway	6	4- 6
Dining	6	4- 8
Mail	10	6- 12
Pullman	6	4- 8
Street Ry.	6	4- 8

TABLE NO. 3 (Continued)

Present Standards of Foot-Candles Illumination for Stores, Commercial and Public Interiors

	Foot-Candles Recommended	Range
Churches		
Auditorium	3	2- 4
Sunday School Room	5	3- 6
Club Rooms	4	3- 6
Dance Halls	4	3- 6
Dental Office		
Waiting Room	4	3- 6
Office	15	10- 20
Depot—Waiting	4	3- 6
Drafting Room	15	10- 20
Elevators—Freight and Passenger	4	3- 6
Gymnasiums		
Main Exercising Floor	8	5- 10
Swimming Pool	4	3- 6
Shower Rooms	4	3- 6
Locker Rooms	4	3- 6
Fencing, Boxing, Wrestling	8	5- 10
Halls, Passageways in Interiors	2	1- 4
Hospitals		
Lobby and Reception Room	4	3- 6
Corridors	3	2- 4
Wards and Private Rooms — with local illumination	3	2- 4
Wards and Private Rooms — with no local illumination	6	4- 8
Wards and Private Rooms — night illumination	0.1	0.1-0.2
Operating Table	75	50-100
Operating Room	10	6- 12
Laboratories	10	6- 12
Hotels		
Lobby	4	3- 6
Dining Room	5	4- 8
Kitchen	6	4- 8
Bedrooms	6	4- 8
Corridors	1	1- 2
Writing Room	8	5- 10
Indoor Recreations		
Basketball and Indoor Baseball	10	6- 12
Bowling (On Alley, Runway and Seats)	5	3- 6
(On Pins)	15	10- 20
Billiards (General)	4	3- 6
(On Table)	15	10- 20
Racquet, Handball, Squash and Indoor Tennis	15	10- 20
Skating Rinks	5	4- 8
Library		
Reading Rooms	8	5- 10
Stack Room	4	3- 6
Lodge Rooms	4	3- 6
Lunch Room	8	5- 10
Market	8	5- 10
Moving Picture Theatre		
During Intermission	3	2- 4
During Pictures	0.1	0.1-0.2
Museum (General)	5	4- 8
(On Walls)	8	5- 10

TABLE NO. 3 (Continued)

Present Standards of Foot-Candles Illumination for Stores, Commercial and Public Interiors

	Foot-Candles Recommended	Range
Office Buildings		
General Office	10	6- 12
Private Offices	10	6- 12
File Room	4	3- 6
Stenographer and Bookkeeping Rooms	10	6- 12
Vault	4	3- 6
Restaurants	5	4- 8
Schools		
Auditorium	5	4- 8
Class Rooms, Library, and Office	8	5- 10
Corridors and Stairways	3	2- 4
Drawing	15	10- 20
Laboratories	10	6- 12
Manual Training	10	6- 12
Sewing Rooms	15	10- 20
Study Room		
Desks	8	5- 10
Blackboards	6	4- 8
Studio		
Art and Photographic	10	6- 12
Moving Picture—General	5	3- 6
—Sets (Photographic Daylight)	..	500-2000
Telephone		
Manual Exchanges	5	3- 6
Automatic Exchanges	10	6- 12
Theatres		
Auditorium	4	3- 6
Foyer	5	3- 6
Lobby	8	5- 10
Toilet and Washrooms	5	3- 6

TABLE NO. 4

Present Standards of Foot-Candles Illumination for Industrial Interiors

	Foot-Candles Recommended	Range
Offices		
Private, General	10	6-12
Drafting Room	15	10-20
Industrial		
Aisles, Stairways, Passageways and Corridors	2	1- 2
Assembling		
Rough	5	3- 6
Medium	8	5-10
Fine	10	8-16
Extra Fine	10–50	....
Automobile Storage	3	2- 4
Bakeries	8	5-10
Boilers, Engine Rooms and Power Houses		
Boilers, Coal and Ash Handling, Storage Battery Rooms	3	2- 4
Auxiliary Equipment, Oil Switches and Transformers	5	3- 6
Switch Boards, Engines, Generators, Blowers, Compressors	6	4- 8

TABLE NO. 4 (Continued)

Present Standards of Foot-Candles Illumination for Industrial Interiors

	Foot-Candles Recommended	Range
Book Binding		
Folding, Assembling, Pasting, etc.	5	3- 6
Cutting, Punching, and Stitching	8	5-10
Embossing	10	8-12
Candy Making	8	5-10
Canning and Preserving	8	5-10
Chemical Works		
Hand Furnaces, Boiling Tanks, Stationary Driers, Stationary or Gravity Crystallizing	3	2- 4
Mechanical Furnaces, Generator and Stills, Mechanical Driers, Evaporators, Filtration, Mechanical Crystallizing, Bleaching	4	3- 6
Tanks for Cooking, Extractors, Percolators, Nitrators, Electrolytic Cells	6	4- 8
Clay Products and Cements		
Grinding, Filter Pressing, Kiln Rooms	3	2- 4
Molding, Pressing, Cleaning and Trimming	5	3- 6
Enamelling	6	4- 8
Coloring and Glazing	10	6-12
Cloth Products		
Cutting, Inspecting, Sewing		
Light Goods	10	6-12
Dark Goods	20	10-50
Pressing, Cloth Treating (Oil Cloth, etc.)		
Light Goods	8	5-10
Dark Goods	12	8-16
Coal Breaking & Washing, Screening	3	2- 4
Construction—Indoor General	3	2- 4
Dairy Products	6	5-10
Electric Manufacturing		
Storage Battery, Molding of Grids, Charging Room,	6	4- 8
Coil and Armature Winding, Mica Working, Insulating Processes	10	8-16
Elevator, Freight and Passenger	5	3- 6
Engraving	20	10-50
Forge Shops and Welding		
Rough Forging	6	4- 8
Fine Forging and Welding	10	6-12
Foundries		
Charging Floor, Tumbling, Cleaning, Pouring* and Shaking Out*	5	3- 6

* Since Pouring and Shaking Out are carried on in the same location as either Rough or Fine Molding, different illumination levels may be secured for these operations by cutting out some of the lighting circuits when space is used for the former.

Rough Molding and Core Making	6	4- 8
Fine Molding and Core Making	10	6-12
Glass Works		
Mix and Furnace Rooms, Pressing and Lehr, Glass Blowing Machines	8	5-10
Grinding, Cutting Glass to Size, Silvering	8	5-10
Fine Grinding, Polishing, Beveling, Inspection, Etching and Decorating	10	6-12
Glass Cutting (Cut Glass), Inspecting Fine	10-50	

TABLE NO. 4 (Continued)

Present Standards of Foot-Candles Illumination for Industrial Interiors

	Foot-Candles Recommended	Range
Glove Manufacturing		
Light Goods		
Cutting, Pressing, Knitting	8	5-10
Sorting, Stitching, Trimming and Inspecting	10	8-16
Dark Goods		
Cutting, Pressing, Knitting	10	6-12
Sorting, Stitching, Trimming and Inspecting	20	10-50
Hat Manufacturing		
Dyeing, Stiffening, Braiding, Cleaning and Refining		
Light	6	4- 8
Dark	10	6-12
Forming, Sizing, Pouncing, Flanging, Finishing, Ironing		
Light	8	5-10
Dark	10	6-12
Sewing		
Light	10	8-16
Dark	10-50	
Ice Making		
Engine and Compressor Room	6	4- 8
Inspecting		
Rough	6	4- 8
Medium	10	6-12
Fine	15	10-20
Extra Fine	10-50	
Jewelry and Watch Manufacturing	10-50	
Laundries and Dry Cleaning	8	5-10
Leather Manufacturing		
Vats	3	2- 4
Cleaning, Tanning and Stretching	4	3-6
Cutting, Fleshing and Stuffing	6	4- 8
Finishing and Scarfing	10	6-12
Leathing Working		
Pressing and Winding		
Light	8	5-10
Dark	10	6-12
Grading, Matching, Cutting, Scarfing, Sewing		
Light	10	8-16
Dark	10-50	
Locker Rooms	4	2- 4
Machine Shops		
Rough Bench and Machine Work	6	4- 8
Medium Bench and Machine Work, Ordinary Automatic Machines, Rough Grinding, Medium Buffing and Polishing	10	6-12
Fine Bench and Machine Work, Fine Automatic Machines, Medium Grinding, Fine Buffing and Polishing	12	8-16
Extra Fine Bench and Machine Work, Grinding (fine work)	10-50	
Meat Packing		
Slaughtering	5	3- 6
Cleaning, Cutting, Cooking, Grinding, Canning, Packing	8	5-10

TABLE NO. 4 (Continued)

Present Standards of Foot-Candles Illumination for Industrial Interiors

	Foot-Candles Recommended	Range
Milling and Grain Foods		
Cleaning, Grinding or Rolling	5	3- 6
Baking or Roasting	8	5-10
Flour Grading	16	10-20
Packing		
Crating	4	3- 6
Boxing	6	4- 8
Paint Manufacturing	6	4- 8
Paint Shops		
Dipping, Spraying, Firing	5	3- 6
Rubbing, Ordinary Hand Painting and Finishing	8	5-10
Fine Hand Painting and Finishing	10	8-16
Extra Fine Hand Painting and Finishing (Automobile Bodies, Piano Cases, etc.)	15	10-50
Paper Box Manufacturing		
Light	6	4 8
Dark	8	5 10
Storage of Stock	3	2- 4
Paper Manufacturing		
Beaters, Machine, Grinding	4	3- 6
Calendaring	6	4- 8
Finishing, Cutting and Trimming	8	6-12
Plating	5	3- 6
Polishing and Burnishing	8	5-10
Printing Industries		
Matrixing and Casting, Miscellaneous Machines, Presses	8	5-10
Proof Reading, Lithographing, Electrotyping	10	6-12
Linotype, Monotype, Typesetting, Imposing Stone, Engraving	10-50	
Receiving and Shipping	4	3- 6
Rubber Manufacturing and Products		
Calendars, Compounding Mills, Fabric Preparation, Stock Cutting, Tubing Machines, Solid Tire Operations, Mechanical Goods Building, Vulcanizing	8	5 10
Bead Building, Pneumatic Tire Building and Finishing, Inner Tube Operation, Mechanical Goods Trimming, Treading	10	6-12
Sheet Metal Works		
Miscellaneous Machines, Ordinary Bench Work	8	5-10
Punches, Presses, Shears, Stamps, Welders, Spinning, Fine Bench Work	10	8-16
Tin Plate Inspection	10	6-12
Shoe Manufacturing		
Hand Turning, Miscellaneous Bench and Machine Work	8	5-10
Inspecting and Sorting Raw Material, Cutting, Lasting and Welding (light)	10	6-12
Inspecting and Sorting Raw Material, Cutting, Stitching (dark)	10-50	
Soap Manufacturing		
Kettle Houses, Cutting, Soap Chip and Powder	5	3- 6
Stamping, Wrapping and Packing, Filling and Packing Soap Powder	6	4- 8

TABLE NO. 4 (Continued)

Present Standards of Foot-Candles Illumination for Industrial Interiors

	Foot-Candles Recommended	Range
Steel and Iron Mills, Bar, Sheet and Wire Products		
Soaking Pits and Reheating Furnaces	3	2- 4
Charging and Casting Floors	5	3- 6
Muck and Heavy Rolling, Shearing, rough by gauge, Pickling and Cleaning	6	4- 8
Plate Inspection	10	6-12
Automatic Machines, Rod, Light and Cold Rolling, Wire Drawing, Shearing, fine by line	8	5-10
Stone Crushing and Screening		
Belt Conveyor Tubes, Maine Line Shafting Spaces, Chute Rooms, Inside of Bins	2	1- 2
Primary Breaker Room, Auxiliary Breakers under Bins	3	2- 4
Screen Roms	5	3- 6
Store and Stock Rooms		
Rough	3	2- 4
Medium	6	4- 8
Structural Steel Fabrication	6	4- 8
Sugar Grading	16	10-20
Telephone		
Manual Exchanges	5	3- 6
Automatic Exchanges	10	6-12
Testing		
Rough	5	3- 6
Fine	10	6-12
Extra Fine Instruments, Scales, etc.	20	10-50
Textile Mills		
(Cotton)		
Opening and Lapping, Carding, Drawing, Frame Roving, Dyeing	5	3- 6
Spooling, Spinning, Drawing in, Warping. Weaving, Quilling, Inspecting, Knitting, Slashing (over beam end)	8	5-10
(Silk)		
Winding, Throwing, Dyeing	12	8-16
Quilling, Warping, Weaving and Finishing		
Light Goods	8	5-10
Dark Goods	10	8-16
(Woolen)		
Carding, Picking, Washing and Combing	4	3- 6
Twisting and Dyeing	6	4- 8
Drawing in, Warping		
Light Goods	6	4- 8
Dark Goods	10	8-16
Weaving		
Light Goods	8	5-10
Dark Goods	12	10-20
Knitting Machine	10	6-12
Tobacco Products	8	5-10
Toilet and Wash Rooms	4	3- 6
Warehouse	2	1- 2
Wood Working		
Rough Sawing and Bench Work	5	3- 6
Sizing, Planing. Rough Sanding, Medium Machine and Bench Work, Gluing. Veneering. Cooperage	8	5-10
Fine Bench and Machine Working, Fine Sanding and Finishing	8	6-12

TABLE 5. COEFFICIENTS OF UTILIZATION

Find *Room Index* from Table 6.

DIRECT LIGHTING PORCELAIN ENAMEL REFLECTORS

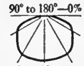
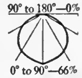
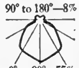
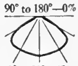
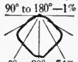
	COLOR REFLECTION FACTOR	CEILING	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
		WALLS	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
	REFLECTOR TYPE	ROOM INDEX	COEFFICIENTS OF UTILIZATION							
1	R L M DOME  Clear Lamp	0.6	.34	.29	.24	.34	.29	.24	.28	.24
		0.8	.42	.38	.34	.42	.37	.33	.37	.33
		1.0	.46	.43	.39	.45	.42	.39	.42	.39
		1.25	.50	.47	.43	.49	.46	.43	.45	.42
		1.5	.53	.50	.46	.52	.49	.46	.48	.45
	90° to 180°—0%  0° to 90°—76%	2.0	.58	.55	.51	.57	.54	.51	.53	.51
		2.5	.62	.59	.56	.61	.58	.56	.58	.56
		3.0	.64	.61	.58	.63	.60	.58	.60	.58
		4.0	.67	.65	.63	.66	.64	.62	.63	.61
		5.0	.69	.67	.65	.67	.66	.64	.65	.63
2	R L M DOME  Bowl-Enameled Lamp	0.6	.32	.28	.25	.32	.28	.25	.27	.25
		0.8	.40	.36	.34	.39	.35	.33	.35	.33
		1.0	.43	.39	.37	.42	.39	.37	.39	.37
		1.25	.46	.43	.41	.45	.43	.41	.43	.41
		1.5	.48	.45	.43	.47	.45	.43	.45	.43
	90° to 180°—0%  0° to 90°—66%	2.0	.52	.50	.48	.51	.49	.47	.49	.47
		2.5	.56	.54	.52	.55	.53	.51	.53	.51
		3.0	.57	.55	.53	.56	.54	.52	.54	.52
		4.0	.60	.58	.56	.59	.57	.55	.57	.55
		5.0	.61	.59	.57	.60	.58	.57	.58	.56
3	GLASS TOP DOME  Bowl-Enameled Lamp	0.6	.28	.25	.22	.27	.24	.22	.23	.21
		0.8	.34	.31	.29	.33	.30	.28	.30	.28
		1.0	.38	.35	.33	.36	.34	.32	.33	.32
		1.25	.41	.38	.36	.39	.37	.35	.36	.35
		1.5	.43	.40	.38	.41	.39	.37	.38	.37
	90° to 180°—8%  0° to 90°—55%	2.0	.47	.44	.42	.45	.43	.41	.41	.40
		2.5	.50	.47	.45	.48	.46	.44	.44	.43
		3.0	.51	.49	.47	.49	.47	.46	.46	.45
		4.0	.53	.51	.50	.51	.49	.48	.48	.47
		5.0	.55	.53	.51	.52	.50	.49	.49	.48
4	DEEP BOWL  Clear Lamp	0.6	.31	.26	.23	.30	.26	.23	.25	.23
		0.8	.38	.34	.31	.37	.34	.31	.33	.31
		1.0	.41	.38	.35	.41	.38	.35	.37	.35
		1.25	.44	.41	.38	.44	.41	.38	.40	.38
		1.5	.47	.44	.41	.46	.43	.41	.43	.41
	90° to 180°—0%  0° to 90°—65%	2.0	.51	.48	.45	.50	.47	.45	.47	.45
		2.5	.54	.51	.49	.53	.51	.49	.51	.49
		3.0	.56	.54	.51	.55	.53	.51	.53	.51
		4.0	.58	.56	.54	.57	.55	.54	.55	.53
		5.0	.60	.58	.56	.58	.57	.55	.56	.55
5	DEEP BOWL  Bowl-Enameled Lamp	0.6	.29	.26	.23	.29	.26	.23	.25	.23
		0.8	.35	.33	.31	.35	.32	.30	.32	.30
		1.0	.38	.36	.34	.38	.36	.34	.35	.34
		1.25	.41	.39	.37	.41	.39	.37	.38	.37
		1.5	.44	.41	.39	.43	.41	.39	.40	.39
	90° to 180°—0%  0° to 90°—58%	2.0	.47	.45	.43	.46	.44	.43	.43	.43
		2.5	.50	.48	.46	.49	.47	.46	.46	.46
		3.0	.51	.49	.47	.50	.48	.47	.47	.47
		4.0	.53	.51	.50	.52	.50	.49	.49	.49
		5.0	.54	.52	.51	.53	.51	.50	.50	.49
6	FLAT CONE Shielding Band  Clear Lamp	0.6	.27	.23	.21	.26	.23	.21	.23	.21
		0.8	.32	.30	.28	.32	.29	.27	.29	.27
		1.0	.35	.33	.31	.35	.33	.31	.32	.31
		1.25	.38	.36	.34	.37	.36	.34	.35	.34
		1.5	.40	.38	.36	.39	.37	.36	.37	.36
	90° to 180°—1%  0° to 90°—54%	2.0	.43	.41	.39	.42	.41	.39	.40	.39
		2.5	.46	.44	.42	.45	.43	.42	.43	.42
		3.0	.47	.45	.43	.46	.44	.43	.44	.43
		4.0	.49	.47	.46	.48	.46	.45	.46	.45
		5.0	.50	.48	.47	.49	.47	.46	.47	.46
7	FLAT CONE  Clear Lamp	0.6	.26	.20	.16	.26	.19	.16	.19	.16
		0.8	.32	.26	.22	.32	.26	.22	.26	.22
		1.0	.36	.30	.26	.36	.30	.26	.30	.26
		1.25	.41	.35	.30	.39	.34	.30	.33	.30
		1.5	.44	.38	.33	.42	.37	.33	.36	.33
	90° to 180°—10%  0° to 90°—74%	2.0	.50	.44	.38	.48	.43	.38	.42	.38
		2.5	.54	.48	.42	.52	.47	.42	.46	.42
		3.0	.57	.51	.46	.55	.50	.45	.49	.45
		4.0	.62	.56	.51	.60	.54	.50	.53	.50
		5.0	.65	.60	.54	.62	.56	.53	.55	.53

TABLE 5. COEFFICIENTS OF UTILIZATION

Find *Room Index* from Table 6.

DIRECT LIGHTING OPEN GLASS REFLECTORS

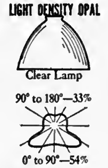
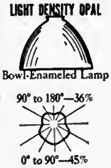
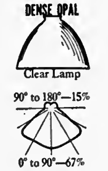
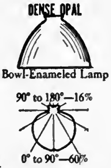
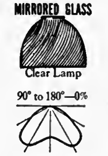
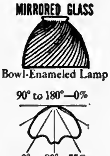
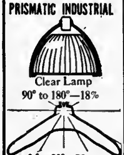
	COLOR REFLECTION FACTOR / REFLECTOR TYPE	CEILING / WALLS / ROOM INDEX	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
			FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
			COEFFICIENTS OF UTILIZATION							
8	LIGHT DENSITY OPAL  Clear Lamp; 90° to 180°—33%; 0° to 90°—54%	0.6	.26	.21	.17	.24	.19	.16	.18	.15
		0.8	.32	.27	.23	.30	.25	.22	.24	.21
		1.0	.36	.31	.27	.34	.29	.26	.27	.24
		1.25	.40	.35	.31	.37	.32	.29	.30	.27
		1.5	.44	.38	.34	.40	.35	.32	.32	.30
		2.0	.49	.44	.39	.45	.40	.37	.37	.34
		2.5	.53	.48	.44	.49	.44	.41	.40	.38
		3.0	.56	.51	.47	.51	.46	.43	.42	.40
		4.0	.60	.55	.51	.55	.50	.47	.46	.44
		5.0	.62	.58	.54	.57	.53	.50	.48	.46
9	LIGHT DENSITY OPAL  Bowl-Enameled Lamp; 90° to 180°—36%; 0° to 90°—45%	0.6	.22	.17	.14	.20	.16	.13	.14	.12
		0.8	.27	.22	.19	.25	.21	.18	.19	.16
		1.0	.31	.26	.23	.28	.24	.21	.22	.19
		1.25	.35	.30	.26	.31	.27	.24	.24	.22
		1.5	.38	.33	.29	.34	.30	.26	.27	.24
		2.0	.43	.38	.34	.38	.34	.31	.30	.28
		2.5	.47	.42	.38	.42	.38	.34	.34	.31
		3.0	.49	.44	.40	.44	.40	.37	.36	.33
		4.0	.53	.49	.45	.48	.44	.41	.39	.37
		5.0	.56	.52	.48	.50	.46	.43	.40	.39
10	DENSE OPAL  Clear Lamp; 90° to 180°—15%; 0° to 90°—67%	0.6	.32	.27	.23	.31	.26	.22	.25	.22
		0.8	.40	.35	.31	.38	.34	.31	.33	.30
		1.0	.44	.39	.36	.42	.38	.35	.37	.35
		1.25	.47	.43	.40	.46	.42	.39	.40	.38
		1.5	.51	.47	.43	.49	.45	.42	.43	.41
		2.0	.56	.52	.48	.54	.50	.47	.48	.46
		2.5	.60	.56	.53	.57	.54	.52	.52	.50
		3.0	.63	.59	.55	.60	.56	.54	.54	.52
		4.0	.66	.63	.60	.63	.60	.58	.57	.55
		5.0	.67	.65	.62	.65	.61	.59	.59	.57
11	DENSE OPAL  Bowl-Enameled Lamp; 90° to 180°—16%; 0° to 90°—60%	0.6	.29	.24	.20	.28	.23	.20	.22	.20
		0.8	.35	.31	.28	.34	.30	.27	.29	.27
		1.0	.39	.35	.32	.38	.34	.32	.33	.31
		1.25	.43	.39	.36	.41	.38	.35	.36	.34
		1.5	.46	.42	.38	.44	.40	.37	.38	.36
		2.0	.51	.47	.44	.48	.45	.42	.43	.41
		2.5	.55	.51	.48	.52	.49	.46	.47	.45
		3.0	.57	.54	.50	.54	.51	.48	.48	.46
		4.0	.60	.57	.54	.57	.54	.52	.51	.50
		5.0	.62	.59	.56	.58	.56	.54	.53	.52
12	MIRRORED GLASS  Clear Lamp; 90° to 180°—0%; 0° to 90°—68%	0.6	.32	.27	.24	.31	.27	.24	.27	.24
		0.8	.39	.35	.32	.39	.35	.32	.35	.32
		1.0	.43	.39	.37	.42	.39	.37	.39	.37
		1.25	.46	.43	.40	.46	.43	.40	.42	.40
		1.5	.49	.46	.43	.48	.45	.43	.45	.43
		2.0	.53	.50	.48	.52	.50	.48	.49	.48
		2.5	.57	.54	.52	.56	.54	.52	.53	.52
		3.0	.58	.56	.54	.57	.55	.54	.54	.53
		4.0	.61	.59	.57	.60	.58	.56	.57	.56
		5.0	.63	.61	.58	.61	.59	.58	.58	.57
13	MIRRORED GLASS  Bowl-Enameled Lamp; 90° to 180°—0%; 0° to 90°—55%	0.6	.26	.22	.19	.25	.22	.19	.21	.19
		0.8	.32	.29	.26	.31	.28	.26	.28	.26
		1.0	.35	.32	.30	.34	.32	.30	.31	.30
		1.25	.38	.35	.33	.37	.35	.33	.34	.33
		1.5	.40	.37	.35	.39	.37	.35	.36	.35
		2.0	.43	.41	.39	.42	.40	.39	.40	.39
		2.5	.46	.44	.42	.45	.43	.42	.43	.42
		3.0	.47	.46	.44	.46	.45	.44	.44	.43
		4.0	.49	.48	.46	.48	.47	.46	.46	.45
		5.0	.50	.49	.47	.49	.48	.47	.47	.46
14	PRISMATIC INDUSTRIAL  Clear Lamp; 90° to 180°—18%; 0° to 90°—73%	0.6	.33	.26	.21	.31	.25	.21	.24	.20
		0.8	.41	.35	.30	.39	.33	.29	.32	.29
		1.0	.45	.40	.35	.43	.39	.34	.37	.33
		1.25	.50	.44	.39	.47	.42	.38	.40	.37
		1.5	.52	.48	.43	.50	.45	.42	.43	.40
		2.0	.58	.54	.49	.56	.51	.47	.49	.46
		2.5	.63	.59	.54	.60	.56	.53	.54	.51
		3.0	.66	.62	.58	.63	.59	.56	.56	.54
		4.0	.71	.67	.63	.67	.63	.61	.60	.58
		5.0	.73	.69	.66	.69	.65	.63	.62	.60

TABLE 5. COEFFICIENTS OF UTILIZATION

Find *Room Index* from Table 6.

DIRECT LIGHTING ENCLOSING AND SEMI-ENCLOSING UNITS

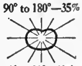
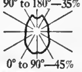
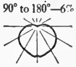
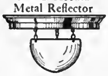
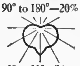
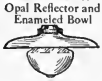
	COLOR REFLECTION FACTOR	CEILING	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
		WALLS	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
	REFLECTOR TYPE	ROOM INDEX	COEFFICIENTS OF UTILIZATION							
15	DIFFUSING GLOBE Light Opal 	0.6	.18	.13	.10	.16	.12	.10	.10	.09
		0.8	.22	.17	.14	.20	.16	.13	.14	.12
		1.0	.26	.21	.18	.23	.19	.16	.17	.14
		1.25	.29	.24	.21	.26	.22	.19	.19	.16
		1.5	.32	.27	.23	.29	.24	.21	.22	.19
	90° to 180°—35% 	2.0	.37	.32	.28	.32	.28	.25	.25	.22
		2.5	.40	.35	.31	.35	.31	.28	.28	.25
		3.0	.43	.38	.34	.38	.33	.30	.30	.27
		4.0	.47	.42	.38	.41	.37	.34	.33	.31
	0° to 90°—40%	5.0	.49	.45	.41	.43	.39	.36	.34	.33
16	ONE-PIECE OPAL Flattened Reflecting Top 	0.6	.22	.17	.14	.20	.16	.13	.14	.12
		0.8	.27	.22	.19	.25	.21	.18	.19	.17
		1.0	.31	.26	.23	.28	.24	.21	.22	.19
		1.25	.35	.30	.26	.31	.27	.24	.25	.22
		1.5	.38	.33	.29	.34	.30	.27	.27	.24
	90° to 180°—35% 	2.0	.42	.38	.33	.38	.34	.31	.31	.28
		2.5	.46	.41	.37	.41	.37	.34	.34	.31
		3.0	.49	.45	.40	.43	.39	.36	.36	.33
		4.0	.53	.48	.44	.47	.43	.40	.38	.36
	0° to 90°—45%	5.0	.55	.51	.47	.49	.45	.42	.40	.38
17	DIFFUSING GLOBE Large Metal Reflector 	0.6	.22	.17	.14	.22	.17	.14	.17	.14
		0.8	.28	.23	.20	.27	.23	.19	.23	.19
		1.0	.31	.26	.23	.31	.26	.23	.26	.23
		1.25	.34	.30	.26	.33	.29	.26	.29	.26
		1.5	.36	.32	.29	.36	.32	.28	.31	.28
	90° to 180°—6% 	2.0	.41	.37	.33	.40	.36	.33	.35	.32
		2.5	.44	.41	.37	.43	.40	.37	.39	.36
		3.0	.47	.43	.39	.45	.42	.39	.41	.39
		4.0	.50	.47	.43	.48	.45	.43	.44	.42
	0° to 90°—58%	5.0	.52	.49	.45	.50	.47	.44	.46	.44
18	SEMI-ENCLOSING Metal Reflector 	0.6	.22	.17	.13	.21	.16	.13	.15	.13
		0.8	.28	.22	.19	.26	.21	.18	.21	.18
		1.0	.31	.26	.23	.30	.25	.22	.24	.21
		1.25	.35	.30	.26	.32	.28	.25	.27	.24
		1.5	.38	.33	.28	.36	.31	.27	.30	.26
	90° to 180°—20% 	2.0	.43	.38	.33	.40	.36	.32	.34	.30
		2.5	.46	.41	.37	.44	.39	.36	.37	.34
		3.0	.49	.44	.40	.46	.42	.38	.40	.37
		4.0	.54	.49	.44	.50	.45	.42	.43	.40
	0° to 90°—56%	5.0	.56	.51	.47	.52	.47	.45	.44	.43
19	SEMI-ENCLOSING Compo Reflector 	0.6	.24	.18	.14	.23	.18	.14	.17	.14
		0.8	.30	.24	.21	.29	.24	.20	.23	.20
		1.0	.33	.28	.25	.32	.28	.24	.27	.24
		1.25	.37	.32	.28	.35	.31	.27	.30	.27
		1.5	.39	.35	.31	.38	.34	.30	.32	.29
	90° to 180°—13% 	2.0	.44	.40	.35	.42	.38	.34	.37	.34
		2.5	.48	.44	.39	.46	.42	.38	.41	.38
		3.0	.50	.46	.42	.48	.44	.41	.43	.40
		4.0	.55	.51	.47	.53	.49	.45	.46	.44
	0° to 90°—60%	5.0	.57	.53	.49	.54	.50	.47	.48	.46
20	TWO-PIECE GLASS Opal Reflector and Enameled Bowl 	0.6	.22	.17	.14	.21	.17	.14	.16	.14
		0.8	.27	.23	.20	.26	.22	.19	.22	.19
		1.0	.30	.26	.23	.29	.26	.23	.25	.22
		1.25	.33	.29	.26	.32	.28	.26	.29	.25
		1.5	.36	.32	.29	.35	.31	.28	.31	.27
	90° to 180°—12% 	2.0	.41	.37	.33	.39	.35	.32	.34	.31
		2.5	.44	.40	.36	.42	.38	.35	.37	.35
		3.0	.46	.42	.38	.43	.40	.37	.39	.37
		4.0	.49	.45	.42	.47	.43	.41	.42	.40
	0° to 90°—53%	5.0	.51	.48	.44	.48	.45	.43	.43	.41
21	ONE-PIECE GLASS Enameled Reflector and Bowl 	0.6	.22	.17	.14	.21	.16	.14	.15	.14
		0.8	.27	.23	.20	.26	.22	.19	.20	.18
		1.0	.30	.26	.23	.29	.25	.22	.23	.21
		1.25	.34	.30	.26	.32	.28	.25	.26	.24
		1.5	.37	.33	.29	.34	.30	.27	.28	.26
	90° to 180°—22% 	2.0	.41	.37	.33	.38	.34	.31	.32	.30
		2.5	.44	.40	.36	.41	.38	.35	.35	.33
		3.0	.47	.43	.39	.43	.40	.37	.37	.35
		4.0	.51	.47	.43	.47	.44	.41	.41	.39
	0° to 90°—50%	5.0	.53	.49	.45	.48	.45	.42	.42	.40

TABLE 5. COEFFICIENTS OF UTILIZATION

Find *Room Index* from Table 6.

SEMI-INDIRECT AND INDIRECT LIGHTING UNITS

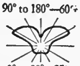
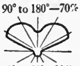
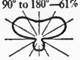
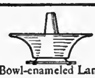
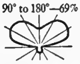
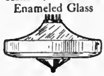
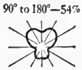
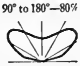
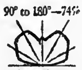
	COLOR REFLECTION FACTOR	CEILING	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
		WALLS	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
	REFLECTOR TYPE	ROOM INDEX	COEFFICIENTS OF UTILIZATION							
22	LIGHT OPAL 	0.6	.18	.14	.11	.15	.12	.09	.09	.07
		0.8	.22	.18	.15	.19	.15	.12	.12	.10
		1.0	.26	.22	.18	.22	.18	.15	.14	.12
		1.25	.30	.25	.22	.25	.21	.18	.16	.14
		1.5	.33	.28	.24	.27	.23	.20	.18	.16
	90° to 180°—60%	2.0	.38	.33	.29	.31	.27	.24	.21	.19
		2.5	.41	.36	.32	.34	.30	.27	.24	.22
		3.0	.44	.39	.35	.36	.32	.29	.25	.23
		4.0	.49	.44	.40	.40	.36	.33	.28	.26
	0° to 90°—25%	5.0	.51	.46	.42	.42	.38	.35	.29	.28
23	DENSE OPAL (or Light Opal and Bowl-enameled Lamp)	0.6	.16	.13	.11	.12	.10	.08	.07	.06
		0.8	.20	.17	.15	.16	.13	.11	.09	.08
		1.0	.23	.20	.17	.18	.15	.13	.10	.09
		1.25	.27	.23	.20	.21	.18	.16	.12	.11
		1.5	.29	.26	.22	.23	.19	.17	.13	.12
	90° to 180°—70%	2.0	.33	.29	.26	.26	.22	.20	.15	.14
		2.5	.36	.32	.29	.28	.25	.23	.17	.16
		3.0	.39	.35	.32	.29	.27	.25	.18	.17
		4.0	.43	.39	.36	.32	.30	.28	.20	.19
	0° to 90°—10%	5.0	.45	.41	.38	.34	.32	.30	.22	.20
24	ENAMELED METAL REFLECTOR Opal Glass Bottom	0.6	.18	.15	.13	.14	.12	.11	.09	.08
		0.8	.22	.19	.17	.18	.16	.14	.12	.11
		1.0	.25	.22	.20	.20	.18	.16	.14	.13
		1.25	.29	.25	.22	.23	.21	.19	.15	.15
		1.5	.31	.28	.25	.25	.22	.20	.17	.16
	90° to 180°—61%	2.0	.34	.31	.29	.28	.25	.23	.19	.18
		2.5	.37	.34	.32	.30	.28	.26	.21	.20
		3.0	.39	.36	.34	.31	.29	.27	.21	.20
		4.0	.43	.40	.38	.34	.32	.30	.23	.22
	0° to 90°—14%	5.0	.45	.42	.40	.36	.34	.32	.25	.23
25		0.6	.16	.13	.11	.12	.10	.08	.07	.06
		0.8	.19	.16	.14	.15	.13	.11	.08	.08
		1.0	.22	.19	.17	.17	.15	.13	.10	.09
	Bowl-enameled Lamp	1.25	.25	.22	.19	.20	.17	.15	.11	.10
		1.5	.27	.24	.21	.21	.18	.16	.12	.11
	90° to 180°—69%	2.0	.31	.28	.25	.24	.21	.19	.14	.13
		2.5	.34	.31	.28	.25	.23	.22	.15	.15
		3.0	.36	.33	.31	.27	.25	.23	.16	.15
		4.0	.40	.37	.34	.29	.28	.26	.18	.17
	0° to 90°—6%	5.0	.41	.38	.37	.31	.29	.28	.19	.18
26	CLEAR TOP ENCLOSED Enameled Glass	0.6	.16	.12	.10	.13	.10	.08	.07	.06
		0.8	.20	.16	.13	.17	.13	.11	.10	.09
		1.0	.23	.19	.16	.19	.15	.13	.12	.10
		1.25	.26	.22	.19	.21	.18	.15	.14	.12
		1.5	.29	.25	.21	.24	.20	.17	.15	.13
	90° to 180°—54%	2.0	.32	.28	.25	.26	.23	.20	.18	.16
		2.5	.36	.31	.28	.29	.26	.23	.20	.18
		3.0	.38	.34	.31	.31	.28	.25	.22	.20
		4.0	.42	.38	.35	.34	.31	.29	.24	.22
	0° to 90°—21%	5.0	.44	.40	.37	.36	.33	.31	.25	.24
27	MIRRORED INDIRECT	0.6	.15	.12	.10	.11	.09	.07	.05	.04
		0.8	.18	.15	.13	.13	.11	.09	.07	.06
		1.0	.22	.19	.16	.15	.13	.11	.08	.07
		1.25	.25	.22	.19	.18	.15	.13	.09	.08
		1.5	.27	.24	.21	.20	.17	.15	.10	.09
	90° to 180°—80%	2.0	.30	.27	.25	.22	.19	.17	.11	.10
		2.5	.34	.31	.28	.24	.22	.20	.13	.12
		3.0	.36	.33	.30	.26	.24	.22	.14	.13
		4.0	.40	.37	.34	.28	.26	.24	.15	.14
	0° to 90°—0%	5.0	.42	.39	.37	.30	.28	.26	.17	.15
28	ENAMELED METAL INDIRECT	0.6	.14	.11	.10	.10	.08	.07	.04	.04
		0.8	.17	.14	.13	.13	.10	.09	.06	.05
		1.0	.20	.17	.15	.14	.12	.10	.07	.06
		1.25	.23	.20	.17	.17	.14	.13	.08	.07
		1.5	.25	.22	.19	.18	.15	.14	.09	.08
	90° to 180°—74%	2.0	.28	.25	.23	.21	.18	.16	.10	.10
		2.5	.31	.28	.26	.22	.20	.18	.12	.11
		3.0	.33	.30	.28	.24	.22	.20	.13	.12
		4.0	.37	.34	.32	.26	.24	.22	.14	.13
	0° to 90°—0%	5.0	.39	.36	.34	.28	.26	.24	.15	.14

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 5

Direct Lighting-SOURCES 4 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
10	1.25	1.25	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
12	1.25	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
14	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
16	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
18	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
24	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
35	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
40	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
50	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
60	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
70	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
80	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
100	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
120	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 6 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 5 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
10	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
12	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
14	1.0	1.25	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
16	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
18	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
20	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
24	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
40	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
50	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
60	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
70	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
80	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
100	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
120	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 7½ FEET ABOVE WORK PLANE

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 4

Direct Lighting-SOURCES 6 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
10	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
12	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
14	1.0	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
16	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
18	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
20	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
24	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
30	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
50	1.5	1.5	2.0	2.0	2.0	2.0	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
60	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
70	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
80	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
100	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
120	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 9 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 7 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.0
12	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.25
14	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
16	0.8	0.8	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5
18	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
20	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
24	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
30	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35	1.0	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
50	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
60	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
70	1.25	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
80	1.25	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
100	1.25	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
120	1.25	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 10½ FEET ABOVE WORK PLANE

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 5

Direct Lighting-SOURCES 8 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET 10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25	1.25
12	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5
14	0.6	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
16	0.6	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
18	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
20	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
24	0.8	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
30	0.8	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
35	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
50	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
60	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
70	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0
80	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
100	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
120	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 12 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 9 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET 10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
12	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
14	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5
16	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
18	0.6	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
20	0.6	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
24	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
30	0.8	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5
35	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
40	1.0	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0
50	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
60	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0
70	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
80	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0
100	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0
120	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 13½ FEET ABOVE WORK PLANE

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 5

Direct Lighting-SOURCES 10 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET 10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0
10	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0
12	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25
14	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5
16	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5
18	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5
20	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
24	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
30	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
35	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5
40	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
50	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
60	0.8	1.0	1.25	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
70	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0
80	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
100	1.0	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0
120	1.0	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 15 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 12 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET 10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8					0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8
10			0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0
12		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0
14	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25
16	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25	1.25
18	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5
20	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5
24	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
30	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0
35	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
40	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5
50	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
60	0.8	0.8	1.0	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0
70	0.8	0.8	1.0	1.25	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
80	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0
100	0.8	1.0	1.25	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0
120	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 18 FEET ABOVE WORK PLANE

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 5

Direct Lighting-SOURCES 14 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8							0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8
10						0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8
12					0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
14			0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0
16			0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0
18	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.25
20	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.25	1.25
24	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5
30	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0
35	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0
40	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
50	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5
60	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0
70	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0
80	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0
100	0.8	0.8	0.8	1.0	1.0	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0
120	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	5.0

Semi and Indirect Lighting-CEILING 21 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 16 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8									0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
10								0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8
12						0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0
14					0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0
16				0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0
18			0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25
20		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25
24		0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.5	1.5
30	0.6	0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5
35	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	2.0	2.0
40	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0
50	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
60	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5
70	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0
80	0.6	0.8	0.8	0.8	0.8	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.0
100	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0	3.0
120	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	4.0	4.0	4.0	4.0

Semi and Indirect Lighting-CEILING 24 FEET ABOVE WORK PLANE

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 5

Direct Lighting-SOURCES 20 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8																			
10										0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8
12									0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8
14									0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0
16								0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0
18							0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0
20						0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0
24					0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25
30				0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.25	1.25	1.25	1.5
35		0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5
40	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5
50	0.6	0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0
60	0.6	0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0
70	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5
80	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5
100	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0
120	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.25	1.25	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0

Semi and Indirect Lighting-CEILING 30 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 24 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8																			
10																			
12											0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8
14										0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8
16									0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8
18									0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0
20								0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0
24							0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0
30						0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25
35				0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25
40			0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25	1.5
50		0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5
60		0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	1.5	2.0
70		0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0
80		0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.25	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0
100		0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	2.5
120		0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.5	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0

Semi and Indirect Lighting-CEILING 36 FEET ABOVE WORK PLANE

TABLE 6 ROOM INDEX

For Finding Coefficient of Utilization from Table 5

Direct Lighting-SOURCES 30 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8																			
10																			
12																			
14																			
16											0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8
18											0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8
20											0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8
24										0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8
30								0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
35								0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0
40							0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.25
50				0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.25
60				0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.0	1.25	1.25	1.25	1.5	1.5
70				0.6	0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.25	1.25	1.25	1.5	1.5	1.5	1.5
80				0.6	0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5	2.0
100				0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0
120				0.6	0.6	0.6	0.6	0.8	0.8	1.0	1.25	1.25	1.5	1.5	1.5	2.0	2.0	2.0	2.5

Semi and Indirect Lighting-CEILING 45 FEET ABOVE WORK PLANE

Direct Lighting-SOURCES 40 FEET ABOVE WORK PLANE

ROOM WIDTH	ROOM LENGTH—FEET																		
	10	12	14	16	18	20	24	30	35	40	50	60	70	80	100	120	140	170	200
8																			
10																			
12																			
14																			
16																			
18																			
20														0.6	0.6	0.6	0.6	0.6	0.6
24													0.6	0.6	0.6	0.6	0.6	0.6	0.6
30												0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8
35											0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8
40										0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8
50									0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0
60								0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0
70							0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.25	1.25
80						0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.25	1.25	1.25	1.5
100						0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.0	1.25	1.25	1.5	1.5	1.5
120						0.6	0.6	0.6	0.6	0.6	0.8	1.0	1.0	1.25	1.25	1.5	1.5	1.5	1.5

Semi and Indirect Lighting-CEILING 60 FEET ABOVE WORK PLANE

TABLE 7 LUMEN OUTPUT OF MULTIPLE MAZDA LAMPS

Subject to Change Without Notice

Size of Lamp in Watts	110-115-120 Volt Standard Lighting Service			220-230-240-250 Volt	
	MAZDA C	MAZDA B	Daylight MAZDA	MAZDA C	MAZDA B
	Approximate Lumen Output, Clear Lamps				
10	....	80	....	....	....
15	....	130	....	....	....
25	....	240†	....	....	200
40	....	400	....	....	....
50	450*	500†	....	....	450
60	....	620	....	....	....
75	880‡	....	600	....	....
100	1300	....	900	1000	1050
150	2100	....	1400	....	....
200	3000	....	2100	2600	....
300	4900	....	3400	4300	....
500	9000	....	5800	7800	....
750	14000	....	....	....	....
1000	20000	....	....	17500	....

* White MAZDA.

†These two sizes in mill type construction give 200 and 420 lumens respectively. 5

‡The 75-watt white Mazda lamp gives approximately 770 lumens.

TABLE 8
COMPUTED ILLUMINATION VALUES
Using Depreciation Factor of 1.3
(See Page 17 for method)

Area in Square Ft. per Lamp	Size of Lamp		COEFFICIENT OF UTILIZATION															
			.14	.16	.18	.20	.22	.25	.28	.32	.36	.40	.45	.50	.55	.60	.65	.70
	Watts	Lumens	FOOT-CANDLES															
60	100	1300	2.3	2.7	3.0	3.3	3.7	4.2	4.7	5.3	6.0	6.7	7.5	8.3	9.2	10.0	10.8	11.7
	150	2100	3.8	4.3	4.8	5.4	5.9	6.7	7.5	8.6	9.7	10.8	12.1	13.5	14.8	16.2	17.5	18.8
	200	3100	5.6	6.4	7.2	7.9	8.7	9.9	11.1	12.7	14.3	15.9	17.9	19.9	21.8	23.8	25.8	27.8
	300	4900	8.8	10.0	11.3	12.6	13.8	15.7	17.6	20.1	22.6	25.1	28.3	31.4	34.6	37.7	40.8	44.0
70	100	1300	2.0	2.3	2.6	2.9	3.1	3.6	4.0	4.6	5.1	5.7	6.4	7.1	7.9	8.6	9.3	10.0
	150	2100	3.2	3.7	4.2	4.6	5.1	5.8	6.5	7.4	8.3	9.2	10.4	11.5	12.7	13.8	15.0	16.2
	200	3100	4.8	5.4	6.1	6.8	7.5	8.5	9.5	10.9	12.3	13.6	15.3	17.0	18.7	20.4	22.1	23.8
	300	4900	7.5	8.6	9.7	10.8	11.8	13.5	15.1	17.2	19.4	21.5	24.2	26.9	29.6	32.3	35.0	37.7
80	100	1300	1.8	2.0	2.2	2.5	2.8	3.1	3.5	4.0	4.5	5.0	5.6	6.2	6.9	7.5	8.1	8.7
	150	2100	2.8	3.2	3.6	4.0	4.4	5.0	5.7	6.5	7.3	8.1	9.1	10.1	11.1	12.1	13.1	14.1
	200	3100	4.2	4.8	5.4	6.0	6.6	7.4	8.3	9.5	10.7	11.9	13.4	14.9	16.4	17.9	19.4	20.9
	300	4900	6.6	7.5	8.5	9.4	10.4	11.9	13.2	15.1	17.0	18.8	21.2	23.6	25.9	28.3	30.6	33.0
90	100	1300	1.6	1.8	2.0	2.2	2.4	2.8	3.1	3.6	4.0	4.5	5.0	5.6	6.1	6.7	7.2	7.8
	150	2100	2.5	2.9	3.2	3.6	3.9	4.5	5.0	5.7	6.5	7.2	8.1	9.0	9.9	10.8	11.7	12.6
	200	3100	3.7	4.2	4.8	5.3	5.8	6.6	7.4	8.5	9.5	10.6	11.9	13.2	14.5	15.9	17.2	18.5
	300	4900	5.9	6.7	7.5	8.4	9.2	10.5	11.7	13.4	15.1	16.8	18.8	20.9	23.0	25.1	27.2	29.2
100	100	1300	1.4	1.6	1.8	2.0	2.2	2.5	2.8	3.2	3.6	4.0	4.5	5.0	5.5	6.0	6.5	7.0
	150	2100	2.3	2.6	2.9	3.2	3.6	4.0	4.5	5.2	5.8	6.5	7.3	8.1	8.9	9.7	10.5	11.3
	200	3100	3.3	3.8	4.3	4.8	5.2	5.9	6.7	7.6	8.6	9.5	10.7	11.9	13.1	14.3	15.5	16.7
	300	4900	5.3	6.0	6.8	7.5	8.3	9.4	10.6	12.1	13.6	15.1	17.0	18.8	20.7	22.6	24.5	26.4
110	100	1300	1.3	1.5	1.6	1.8	2.0	2.3	2.5	2.7	3.3	3.6	4.1	4.5	5.0	5.5	5.9	6.4
	150	2100	2.1	2.4	2.6	2.9	3.2	3.7	4.1	4.7	5.3	5.9	6.6	7.3	8.1	8.8	9.5	10.2
	200	3100	3.0	3.5	3.9	4.3	4.8	5.4	6.1	6.9	7.8	8.7	9.8	10.8	11.9	13.0	14.0	15.2
	300	4900	4.3	5.5	6.2	6.9	7.5	8.6	9.6	11.0	12.3	13.7	15.4	17.1	18.8	20.6	22.3	24.0
120	100	1300	1.2	1.3	1.5	1.7	1.8	2.1	2.3	2.7	3.0	3.3	3.8	4.2	4.6	5.0	5.4	5.8
	150	2100	1.9	2.2	2.4	2.7	3.0	3.4	3.8	4.3	4.8	5.4	6.1	6.7	7.4	8.1	8.8	9.4
	200	3100	2.8	3.2	3.6	4.0	4.4	5.0	5.6	6.3	7.1	7.9	8.9	9.9	11.0	12.0	13.0	14.0
	300	4900	4.4	5.0	5.7	6.3	6.9	7.9	8.8	10.1	11.3	12.6	14.1	15.7	17.3	18.8	20.4	22.0
130	100	1300	1.1	1.2	1.4	1.5	1.7	1.9	2.2	2.5	2.8	3.1	3.5	3.8	4.2	4.6	5.0	5.4
	150	2100	1.7	2.0	2.2	2.5	2.7	3.1	3.5	4.0	4.5	5.0	5.6	6.2	6.8	7.5	8.1	8.7
	200	3100	2.6	2.9	3.3	3.7	4.0	4.5	5.1	5.9	6.6	7.4	8.3	9.2	10.1	11.0	11.9	12.8
	300	4900	4.1	4.6	5.2	5.8	6.4	7.2	8.1	9.3	10.4	11.6	13.1	14.5	16.0	17.4	18.9	20.3
140	100	1300	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.2	3.6	3.9	4.3	4.6	5.0
	150	2100	1.6	1.8	2.1	2.3	2.5	2.9	3.2	3.7	4.2	4.6	5.2	5.8	6.3	6.9	7.5	8.1
	200	3100	2.4	2.7	3.1	3.4	3.8	4.3	4.8	5.5	6.1	6.8	7.7	8.5	9.4	10.2	11.1	11.9
	300	4900	3.8	4.3	4.9	5.4	5.9	6.7	7.5	8.6	9.7	10.8	12.1	13.5	14.8	16.2	17.5	18.8
160	150	2100	1.4	1.6	1.8	2.0	2.2	2.5	2.8	3.2	3.6	4.0	4.5	5.0	5.6	6.1	6.6	7.1
	200	3100	2.1	2.4	2.7	3.0	3.3	3.7	4.2	4.8	5.4	5.9	6.7	7.4	8.2	8.9	9.7	10.5
	300	4900	3.3	3.8	4.2	4.7	5.2	5.9	6.6	7.5	8.5	9.4	10.6	11.8	13.0	14.1	15.3	16.5
	500	8800	5.9	6.8	7.6	8.5	9.3	10.6	11.8	13.5	15.2	16.9	19.0	21.2	23.3	25.4	27.5	29.6
180	150	2100	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.9	3.2	3.6	4.0	4.5	4.9	5.4	5.8	6.3
	200	3100	1.8	2.1	2.4	2.6	2.9	3.3	3.7	4.2	4.8	5.3	5.9	6.6	7.3	7.9	8.6	9.3
	300	4900	2.9	3.4	3.8	4.2	4.6	5.2	5.9	6.7	7.5	8.4	9.4	10.5	11.5	12.6	13.6	14.7
	500	8800	5.3	6.0	6.8	7.5	8.3	9.4	10.5	12.0	13.5	15.0	16.9	18.8	20.7	22.6	24.4	26.3
200	150	2100	1.1	1.3	1.5	1.6	1.8	2.0	2.3	2.6	2.9	3.2	3.6	4.0	4.4	4.8	5.3	5.7
	200	3100	1.7	1.9	2.1	2.4	2.6	3.0	3.3	3.8	4.3	4.8	5.3	6.0	6.5	7.1	7.7	8.3
	300	4900	2.6	3.0	3.4	3.8	4.1	4.7	5.3	6.0	6.8	7.5	8.5	9.4	10.4	11.3	12.3	13.2
	500	8800	4.7	5.4	6.1	6.8	7.4	8.5	9.5	10.8	12.2	13.5	15.2	16.9	18.6	20.3	22.0	23.7
220	150	2100	1.0	1.2	1.3	1.5	1.6	1.8	2.1	2.4	2.6	2.9	3.3	3.7	4.0	4.4	4.8	5.1
	200	3100	1.5	1.7	1.9	2.2	2.4	2.7	3.0	3.5	3.9	4.3	4.9	5.4	5.9	6.5	7.0	7.5
	300	4900	2.4	2.7	3.1	3.4	3.8	4.3	4.8	5.5	6.2	6.9	7.7	8.6	9.4	10.3	11.1	12.0
	500	8800	4.3	4.9	5.5	6.2	6.8	7.7	8.6	9.8	11.1	12.3	13.8	15.4	16.9	18.5	20.0	21.5
250	200	3100	1.3	1.5	1.7	1.9	2.1	2.4	2.7	3.1	3.4	3.8	4.3	4.8	5.2	5.7	6.2	6.7
	300	4900	2.1	2.4	2.7	3.0	3.3	3.8	4.2	4.8	5.4	6.0	6.8	7.5	8.3	9.0	9.8	10.6
	500	8800	3.8	4.3	4.9	5.4	6.0	6.8	7.6	8.7	9.7	10.8	12.2	13.5	14.9	16.2	17.6	18.9
	750	14000	6.0	6.9	7.8	8.6	9.5	10.8	12.1	13.8	15.5	17.2	19.4	21.5	23.7	25.8	28.0	30.2
280	200	3100	1.2	1.4	1.5	1.7	1.9	2.1	2.4	2.7	3.1	3.4	3.8	4.3	4.7	5.1	5.5	6.0
	300	4900	1.9	2.2	2.4	2.7	3.0	3.4	3.8	4.3	4.8	5.4	6.1	6.7	7.4	8.1	8.8	9.4
	500	8000	3.4	3.9	4.4	4.8	5.3	6.0	6.8	7.7	8.7	9.7	10.9	12.1	13.3	14.5	15.7	16.9
	750	14000	5.4	6.2	6.9	7.7	8.5	9.6	10.8	12.3	13.8	15.4	17.3	19.2	21.2	23.1	25.0	26.9

TABLE 8
COMPUTED ILLUMINATION VALUES
Using Depreciation Factor of 1.3
(See Page 17 for method)

Area in Square Ft. per Lamp	Size of Lamp		COEFFICIENT OF UTILIZATION															
			.14	.16	.18	.20	.22	.25	.28	.32	.36	.40	.45	.50	.55	.60	.65	.70
	Watts	Lumens	FOOT-CANDLES															
320	200	3100	1.0	1.2	1.3	1.5	1.6	1.9	2.1	2.4	2.7	3.0	3.4	3.7	4.1	4.5	4.9	5.2
	300	4900	1.6	1.9	2.1	2.4	2.6	2.9	3.3	3.8	4.2	4.7	5.3	5.9	6.5	7.1	7.7	8.2
	500	8800	3.0	3.4	3.8	4.2	4.7	5.3	5.9	6.8	7.6	8.5	9.5	10.6	11.6	12.7	13.8	14.8
	750	14000	4.7	5.4	6.1	6.7	7.4	8.4	9.4	10.8	12.1	13.5	15.1	16.8	18.5	20.2	21.9	23.6
360	200	3100	0.9	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.4	2.7	3.0	3.3	3.6	4.0	4.3	4.6
	300	4900	1.5	1.7	1.9	2.1	2.3	2.6	2.9	3.4	3.8	4.2	4.7	5.2	5.8	6.3	6.8	7.3
	500	8800	2.6	3.0	3.4	3.8	4.1	4.7	5.3	6.0	6.8	7.5	8.5	9.4	10.3	11.3	12.2	13.2
	750	14000	4.2	4.8	5.4	6.0	6.6	7.5	8.4	9.6	10.8	12.0	13.5	15.0	16.4	18.0	19.4	20.9
400	200	3100	0.8	0.9	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2
	300	4900	1.3	1.5	1.7	1.9	2.1	2.4	2.6	3.0	3.4	3.8	4.2	4.7	5.2	5.7	6.1	6.6
	500	8800	2.4	2.7	3.0	3.4	3.7	4.2	4.7	5.4	6.1	6.8	7.6	8.5	9.3	10.2	11.0	11.8
	750	14000	3.8	4.3	4.8	5.4	5.9	6.7	7.5	8.6	9.7	10.8	12.1	13.5	14.8	16.2	17.5	18.8
450	200	3100	0.7	0.8	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.2	3.5	3.7
	300	4900	1.2	1.3	1.5	1.7	1.8	2.1	2.3	2.7	3.0	3.4	3.8	4.2	4.6	5.0	5.4	5.9
	500	8800	2.1	2.4	2.7	3.0	3.3	3.8	4.2	4.8	5.4	6.0	6.8	7.5	8.3	9.0	9.8	10.5
	750	14000	3.4	3.8	4.3	4.8	5.3	6.0	6.7	7.7	8.6	9.6	10.8	12.0	13.2	14.4	15.6	16.8
500	300	4900	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.4	2.7	3.0	3.4	3.8	4.1	4.5	4.9	5.3
	500	8800	1.9	2.2	2.4	2.7	3.0	3.4	3.8	4.3	4.9	5.4	6.1	6.8	7.4	8.1	8.8	9.5
	750	14000	3.0	3.4	3.9	4.3	4.7	5.4	6.0	6.9	7.8	8.6	9.7	10.9	11.9	12.9	14.0	15.1
	1000	20000	4.3	4.9	5.5	6.2	6.8	7.7	8.6	9.8	11.1	12.3	13.8	15.4	16.9	18.4	20.0	21.5
600	300	4900	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.5	2.8	3.1	3.5	3.8	4.1	4.4
	500	8800	1.6	1.8	2.0	2.3	2.5	2.8	3.2	3.6	4.1	4.5	5.1	5.6	6.2	6.8	7.3	7.9
	750	14000	2.5	2.9	3.2	3.6	4.0	4.5	5.0	5.7	6.5	7.2	8.1	9.0	9.9	10.8	11.7	12.6
	1000	20000	3.6	4.1	4.6	5.1	5.6	6.4	7.2	8.2	9.2	10.3	11.5	12.8	14.1	15.4	16.7	18.0
700	300	4900	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.2	2.4	2.7	2.0	3.2	3.5	3.8
	500	8800	1.4	1.5	1.7	1.9	2.1	2.4	2.7	3.1	3.5	3.9	4.4	4.8	5.3	5.8	6.3	6.8
	750	14000	2.2	2.5	2.8	3.1	3.4	3.8	4.3	4.9	5.5	6.2	6.9	7.7	8.5	9.2	10.0	10.8
	1000	20000	3.1	3.5	4.0	4.4	4.8	5.5	6.2	7.0	7.9	8.8	9.9	11.0	12.1	13.2	14.3	15.4
800	300	4900	0.7	0.8	0.8	0.9	1.0	1.2	1.3	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.1	3.3
	500	8800	1.2	1.4	1.5	1.7	1.9	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.7	5.1	5.5	5.9
	750	14000	1.9	2.2	2.4	2.7	3.0	3.4	3.8	4.3	4.8	5.4	6.1	6.7	7.4	8.1	8.8	9.4
	1000	20000	2.7	3.1	3.5	3.8	4.2	4.8	5.4	6.2	6.9	7.7	8.7	9.6	10.6	11.5	12.5	13.5
900	300	4900	0.6	0.7	0.8	0.8	0.9	1.0	1.2	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9
	500	8800	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.4	2.7	3.0	3.4	3.8	4.1	4.5	4.9	5.3
	700	14000	1.7	1.9	2.2	2.4	2.6	3.0	3.4	3.8	4.3	4.8	5.4	6.0	6.6	7.2	7.8	8.4
	1000	20000	2.4	2.7	3.1	3.4	3.8	4.3	4.8	5.5	6.2	6.8	7.7	8.6	9.4	10.3	11.1	12.0
1000	300	4900	0.5	0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.4	2.6
	500	8800	0.9	1.1	1.2	1.4	1.5	1.7	1.9	2.2	2.4	2.7	3.0	3.4	3.7	4.1	4.4	4.7
	700	14000	1.5	1.7	1.9	2.2	2.4	2.7	3.0	3.4	3.9	4.3	4.8	5.4	5.9	6.5	7.0	7.5
	1000	20000	2.2	2.5	2.8	3.1	3.4	3.8	4.3	4.9	5.5	6.2	6.9	7.7	8.5	9.2	10.0	10.8
1200	300	4900	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.0	2.2
	500	8800	0.8	0.9	1.0	1.1	1.2	1.4	1.6	1.8	2.0	2.3	2.5	2.8	3.1	3.4	3.7	3.9
	750	14000	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.9	3.2	3.6	4.0	4.5	4.9	5.4	5.8	6.3
	1000	20000	1.8	2.1	2.3	2.6	2.8	3.2	3.6	4.1	4.6	5.1	5.8	6.4	7.1	7.7	8.3	9.0
1400	300	4900	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.8	1.9
	500	8800	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.7	1.9	2.2	2.4	2.7	2.9	3.1	3.4
	750	14000	1.1	1.2	1.4	1.5	1.7	1.9	2.2	2.5	2.8	3.1	3.5	3.8	4.2	4.6	5.0	5.4
	1000	20000	1.5	1.8	2.0	2.2	2.4	2.7	3.1	3.5	4.0	4.4	4.9	5.5	6.0	6.6	7.1	7.7
1600	300	4900	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.6
	500	8800	0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.8	3.0
	750	14000	0.9	1.1	1.2	1.3	1.5	1.7	1.9	2.2	2.4	2.7	3.0	3.4	3.7	4.0	4.4	4.7
	1000	20000	1.3	1.5	1.7	1.9	2.1	2.4	2.7	3.1	3.5	3.8	4.3	4.8	5.3	5.8	6.2	6.7
2000	300	4900	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.3
	500	8800	0.5	0.5	0.6	0.7	0.7	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4
	750	14000	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.2	2.4	2.7	3.0	3.2	3.5	3.8
	1000	20000	1.1	1.2	1.4	1.5	1.7	1.9	2.2	2.5	2.8	3.1	3.5	3.8	4.2	4.6	5.0	5.4
2500	300	4900	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1
	500	8800	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.8	1.9
	750	14000	0.6	0.7	0.8	0.9	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.2	2.4	2.6	2.8	3.0
	1000	20000	0.9	1.0	1.1	1.2	1.4	1.5	1.7	2.0	2.2	2.5	2.8	3.1	3.4	3.7	4.0	4.3

PART III
STORE AND SHOW WINDOW LIGHTING

To illuminate a store successfully, light must be provided *where it is needed.* Granting first that the light is, therefore, upon the objects or surfaces to be seen, and not in the eyes, there yet remains the requirement that it must be not only sufficient in *amount* for the particular store under consideration but must be of the proper *diffusion, color,* and *direction.* Obviously the illumination adequate for one store might be insufficient for another, and conversely the quality or amount necessary for one type of establishment—for example a Jewelry store—might be extravagant in another, such as a Music or Furniture store. In the latter case a soft, well-diffused illumination is all-important since the best of wood and upholstery suffers under a glary light. The Jewelry store, however, involves entirely different treatment. A direct undiffused component of light assists in giving the jewels and cut glass a sparkling appearance. Shadowless illumination would make the faceted gems appear flat and would detract much from the display, and furthermore the soft, mellow light that would enrich the appearance of a pearl, would give no life whatever to the diamond.

GENERAL CLASSES OF STORE LIGHTING

Each store presents an individual problem, but for convenience of discussion, retail stores may be divided into three classes according to quality and direction of the lighting required:

> *First:* Those whose unchanging floor or counter operations require a particular location of the light sources.
> *Second:* Those for which general illumination with the most convenient symmetrical placing of the outlets is satisfactory.
> *Third:* Those stores in which artistic and decorative appearance is the chief consideration.

The first class includes stores of the following types: Jewelry, Haberdashery, Cigar, Shoe, Drygoods, Hardware, Drug, and Stationery. In these the lighting system must be designed to illuminate the particular sections where merchandise is inspected, usually the counters on which goods are displayed and sold. The majority of stores in this class have two rows of counters, one on each side and extending the length of the store. This would, of course, suggest a double row of lighting units. A common error, however, is to place a single row down the center aisle with the inevitable result that the customer casts a shadow on the exact spot where light is most needed, and that the light is too strong where the customer is walking, and too weak where he is looking.

The Shoe store is a representative type of this first general class. Here light is required primarily on the floor where the shoe is tried on, secondarily upon the side walls where the clerk should instantaneously read box labels. Most Shoe stores have two rows of chairs back to back down the center of the store and it is therefore well to have two rows of units located over the front edge of the chairs so that neither the salesman nor the customer casts a shadow on the shoe.

The second class, those requiring general uniform illumination from the most economical and symmetrical spacing of the outlets, includes Clothing, Fur, Carpet, Furniture, Butcher, Baker, and Grocery stores. A single row of units in the long narrow room is generally satisfactory, although local illumination plays a rather important part in some cases. Carpet stores require special lighting where vertical rug racks are used. In Clothing stores additional lights are often needed in front of wall cases or mirrors.

The third class covers Confectionery, Florist, and Music stores, and exclusive shops which lend themselves to what might be termed "ultra-artistic treatment." Here individual taste, of course, plays an all-important part, but the chief thought should be first to provide a background or a foundation illumination of soft, not too bright, and well-diffused character, using either direct or indirect fixtures selected for their ornamental fitness. Lighting from concealed sources is often most pleasing for stores of this character. Then, to the soft broadcast illumination may be added highlights or colored spots, such as from wall brackets or portable table lamps with tinted shades, avoiding utterly all bare, glittering, or garish light sources.

THE VALUE OR AMOUNT OF ILLUMINATION REQUIRED

With these general principles in mind, the next consideration is the amount of light required for various kinds of stores. The tendency today is toward illumination that, while not lavish, is yet not limited by the old requisites of carbon filament or oil lamp days, but which reaches the higher values needed for sure and easy vision. It is therefore wise to install a system which, in its adequacy and its flexibility, will not be obsolete in a few years. Five foot-candles of illumination should be the minimum value for any good retailing store, while eight is an average of general practice in metropolitan districts. Many stores, however, find twelve and fifteen foot-candles desirable, and do not consider this excessive in comparison to daylight which reaches several hundred.

The following table gives the recommended standards of illumination that experience has found satisfactory in store lighting:

TABLE No. 1

VALUES OF ILLUMINATION RECOMMENDED FOR RETAIL STORES

Type of Store	Foot-Candles Range
Art	5 – 10
Baker	4 – 8
Book	4 – 8
Butcher	4 – 8
Carpet	5 – 10
Rug Rack	10 – 20
China	4 – 8
Cigar	5 – 10
Clothing	5 – 10
Confectionery	5 – 10
Decorator	5 – 10
Department (See each department)	
Drugs	5 – 10
Dry Goods	5 – 10
Florist	4 – 8
Furniture	4 – 8
Furrier	5 – 10
Grocery	4 – 8
Haberdashery	5 – 10
Hardware	4 – 8
Hat	5 – 10
Jewelry	5 – 10
Leather	4 – 8
Millinery	5 – 10
Music	4 – 8
Notions	4 – 8
Piano	4 – 8
Shoes	5 – 10
Stationery	4 – 8

Note:—The foot-candle is the unit of illumination value or "intensity" of light upon a surface. The foot-candles of illumination may be thought of as similar to the feet of thickness of a snowfall. Foot-candles must not be confused with candle power, the unit of light brilliancy or intensity of radiation; nor with lumens, the units of light quantity.

It has been necessary to give a range instead of a specific value for each type of store, as its location and the kind of merchandise sold determine the illumination required. To permit the customer to examine dark-colored merchandise as readily as that of a lighter shade, the higher value must be provided. Another consideration is the character of the neighboring stores. One merchant cannot afford to struggle along on the minimum value suitable for the mere discernment of objects, if his neighbors, in addition thereto, have so brightly lighted or so tastefully decorated their stores that their cheerful and welcome atmosphere makes the former establishment appear dark and uninviting by contrast.

Glare should not be mistaken for *illumination.* Stores equipped with shallow open reflectors, and especially those using bare lamps, generally do not have as much actual useful illumination as those in which well-diffused or shielded light sources permit comfortable and accurate vision. The glare from the brilliant illuminants only blinds the customer and thus the installation defeats its purpose.

LIGHTING UNITS, OR LUMINAIRES

In order to direct the maximum amount of light where it will be of service and to shield or soften the brilliant light sources in the range of vision, reflecting and diffusing equipment must be used.

Stores may be satisfactorily illuminated by luminaires of anyone of the three classes into which reflecting equipment is divided, *direct,* including the enclosing and semi-enclosing globes; *semi-indirect,* sending more light upward than downward; *totally indirect,* sending all the light upward. This classification depends upon whether the majority of light rays are transmitted directly to the plane of work or whether they are largely or toally re-directed from the ceilings and walls.

Open bottom reflectors are usually the most economical equipment, but their appearance can hardly be compared to some of the other types. With them there is also the objection of possible glare and specular reflections and it is therefore advisable to use lamps having the lower portion of the bulb of diffusing glass; i.e., diffusing bulb or bowl enameled. On the other hand some direct rays of light are necessary in jewelry store illumination and open prismatic reflectors of an ornamental style

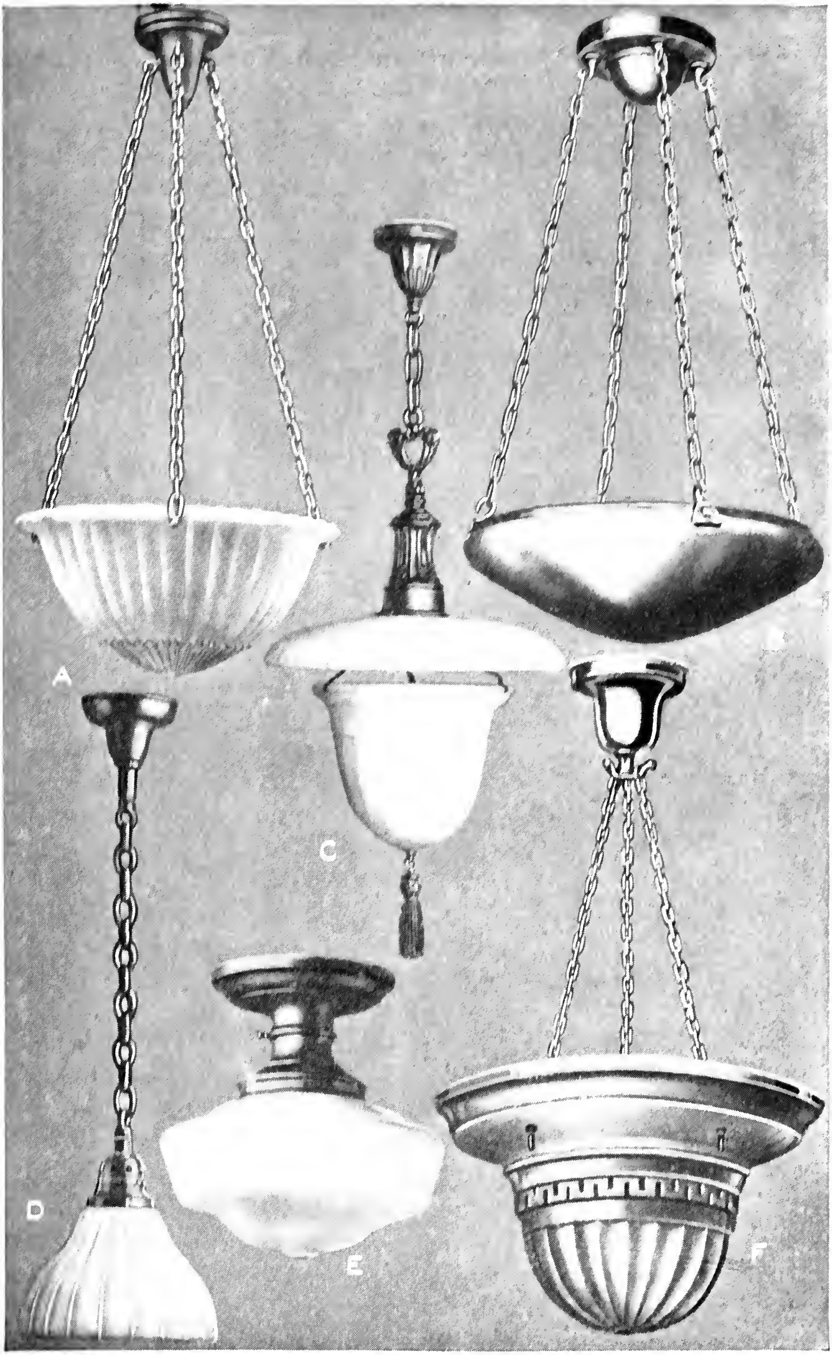


Fig. No. 1—Typical Store Lighting Luminaires

A—Semi-Indirect Bowl
B—Indirect Bowl
C—Covered Bowl
D—Direct Reflector
E—Enclosing Globe
F—Bowl and Upper Plate

Fig. No. 1A—Typical Store Lighting Luminaires

G—Indirect Bowl H—Globe and Cover I—Prismatic Reflector
J—Enclosing Globe K—Semi-Indirect Bowl L—Bowl and Reflector

Fig. No. 1B—Typical Store Lighting Luminaires

M—Bowl and Reflector
N—Semi-Indirect, Enclosing
O—Enclosing, Light Directing
P—Semi-Indirect

using for example, pendant crystal prisms around the reflector, will be found both attractive and appropriate equipment for lighting jewels and cut glass.

The various semi-indirect and totally indirect luminaires are used where light-colored walls and ceilings permit, and when a soft, well-diffused light is desired.

The most popular luminaires for store lighting are the enclosing diffusing globes, the present style for reasons of efficiency as well as decoration being those of the squat shape. These globes are nearly dust-tight and thus require only a relatively small maintenance, besides being capable of softening the discomforting brilliancy of the bare gas-filled Mazda lamps with consequent light absorption losses of not more than 20 per cent.

Table 2

Lamps Recommended for Store Use

Luminaire	MAZDA LAMP Wattage	MAZDA LAMP Type	MAZDA LAMP Finish
Open Reflectors	25, 40, 50 50 100, 150, 200 75	Mazda B White Mazda (C) Mazda C Mazda C	Clear or Diffusing Bulb —— Bowl Enameled Diffusing Bulb
Enclosing Globes, Semi-Enclosing, Semi-Indirect, or Totally Indirect	75, 100, 150 200, 300, 500 150, 200, 300, 500	Mazda C Daylight Mazda	Clear Bulb Clear Bulb
Window Reflectors	75, 100, 150 100, 150	Mazda C Daylight Mazda	Clear Bulb Clear Bulb
Floor and Table Lamps	40, 50 50	Mazda B White Mazda (C)	Diffusing Bulb ——
Show Cases	25, 40 15, 25 15	Mazda B (Tubular Bulb) Mazda B (Round Bulb) Mazda B (Candelabra)	Clear Bulb Clear Bulb Clear or Diffusing Bulb
Wall Brackets With Shade Without Shade	25, 40, 50, 60 75 15 25 25, 40, 50 50	Mazda B Mazda C Mazda B (Flame-Candelabra) Mazda B (Round Bulb) Mazda B White Mazda (C)	Clear Bulb Clear Bulb Diffusing Bulb Diffusing Bulb Diffusing Bulb ——
Candelabra and Decorative Types	25, 40 50 25, 40, 50	Mazda B (Round Bulb) White Mazda (C) Mazda B	Diffusing Bulb —— Diffusing Bulb
Entrance Enclosing Globes and Hemispheres	75, 100	Mazda C	Clear Bulb

ENTRANCE DOORWAY LIGHTS

A well-lighted store requires a brightly illuminated entrance, particularly on a brightly lighted street. The air of welcome and activity is most necessary, and the passer-by who sees a window display should sub-consciously find the entrance clearly defined and attractive. Some merchants find it profitable to light the side walk in front of their store or at least to use an electric sign which can thus serve a double purpose.

An enclosing globe of the ceiling type or a close fitted ceiling hemisphere is recommended for entrance lighting. For the majority of small stores a 75 or 100-watt Mazda C lamp will be sufficient for this purpose. Here, above all else, the luminaire should be dust and insect proof, and when the windows are washed this entrance light should also be cleaned.

NIGHT LIGHTS

As a protection against robbery after closing hours a lamp well placed and burning all night will illuminate the store sufficiently to allow the policeman or watchman to see the whole of the interior. This lamp is usually placed where it will bring into prominence the safe, vault, rear entrance, or specially valuable stocks. As a rule a 50-watt Mazda B lamp or a 75-watt Mazda C lamp is used.

An attractive means of supplementing the display window area and providing night illumination, is to keep a wall case in the rear of the store lighted throughout the night. In addition to displaying merchandise an illuminated wall case will silhouette clearly the figure of anyone moving about in the store.

The cost of burning the 50-watt lamp would not exceed seven cents per night.

COLOR MATCHING AND COLOR QUALITY

The accurate identification of color is often necessary in merchandising. Clothing and Carpet stores, Haberdashery shops, and ladies apparel rooms especially, should be equipped with some means of reproducing daylight illumination. Mazda Daylight lamps will provide a means of approximating daylight quality, as will some enclosing cased-glass globes, one layer of which is blue glass absorbing some of the red and yellow rays emanating from the regular Mazda C lamp.

An effective means of displaying rugs is to install a dual lighting system, one circuit consisting of Mazda daylight and the other of clear bulb Mazda lamps. It is thus possible to show the rug as it appears under both daylight and artificial illumination. Merchants selling rugs under these conditions have less returned goods, and will find many dyes whose tones are visibly enriched by light of a carefully chosen color quality.

The Mazda Daylight lamp can be used very appropriately over mirrors in Clothing stores where suits and dresses are tried on. Flower, Fur, Hat, and even Jewelry stores can use them in connection with clear lamps to bring out blue colors in better relation to the reds and yellows.

For very accurate color matching and identification, there are available specially designed units employing standard clear bulb Mazda C lamps, the light from which is filtered through a specially designed blue glass screen. One type of color matching unit is for counter use in the lighting of small merchandise, such as silks, ribbons, and neckties. There are also pendant types for suspending in front of mirrors in the examination of wearing apparel in clothing stores. Such color quality of illumination is unrivaled for displays of cravats, ribbons, colored buttons, spool silk and cotton, trimmings, and flowers.

SHOW CASE LIGHTING

Show cases, both the counter and wall type, are another means at the disposal of the merchant for *displaying* his goods. They are really miniature show windows and as such should be properly illuminated, else their heavy investment cost and their valuable space is not 100 per cent. capitalized.

Show cases are for *showing* and not *storing* merchandise. If sufficiently illuminated, careful inspection may be made without moving and handling the various articles.

There are two types of reflecting equipment preferable for show case lighting; first, the individual mirrored glass reflectors, and, second, the metal trough reflectors extending the length of the case. The illuminated show case shown in Fig. No. 2 illustrates how inconspicuously these latter units can be installed in an all-glass case. The exception to the usual practice of concealing the units as much as possible is in the lighting of candy displays, wax ornaments, etc., where the merchandise is affected by the heat of the lamps. An attractive method of solving this problem is to use small ornamental lamps on top of the case and thus provide the illumination from outside. The chief consideration is to furnish more illumination in these cases than is supplied for the store itself in order that they will

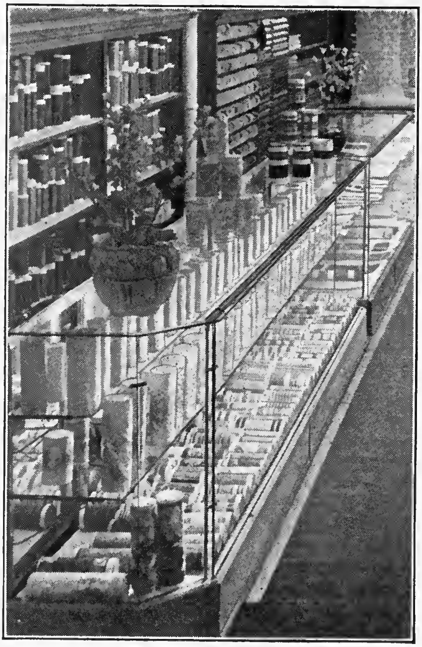


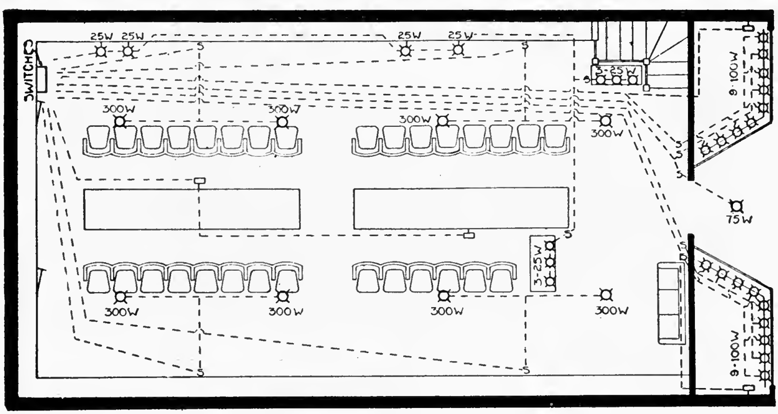
Fig. 2

stand out by contrast; approximately 15 to 25 foot-candles is usually the minimum value.

For the lighting of show cases, 25-watt Mazda lamps on 18 to 24-inch centers will be sufficient. Attention is called to the tubular lamps available, and to the small decorative types whose use, clear or colored, should be better known and more extensive.

Plan A

SHOE STORE—THE INSTALLATION AND THE PLAN



Interior Illumination

Area of Store (48 x 25)	1200 Sq. Ft.
Illumination Desired (Table 1)	9 Ft.-Candles
Utilization Factor	.36
Depreciation Factor (20%)	.80
Number of Outlets	8

$$\text{Lumens Required per Outlet} = \frac{1200 \times 9}{.36 \times .80 \times 8} = 4690$$

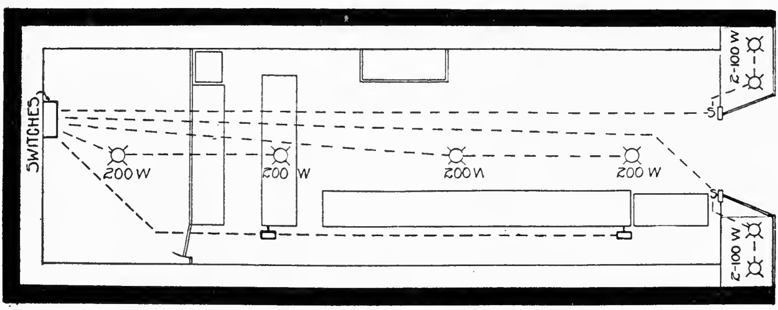
Use 300-watt Mazda C Lamps
Wattage per Square Foot of Floor = 2

Show Window Illumination

100-watt Mazda C lamps on 16-inch Centers.
Wattage per Square Foot of Window Floor = 15

Plan B

GROCERY STORE—THE INSTALLATION AND THE PLAN



Interior Illumination

Area of Store (40 x 12½)	500	Sq. Ft.
Illumination Desired (Table 1)	6	Ft.-Candles
Utilization Factor	.32	
Depreciation Factor (20%)	.80	
Number of Outlets	4	

$$\text{Lumens Required Per Outlet} = \frac{500 \times 6}{.32 \times .80 \times 4} = 2930$$

Use 200-watt Mazda C Lamps.

Wattage per Square Foot of Floor = 1.6

Show Window Illumination

Two 100-watt Mazda C Lamps.

Wattage per Square Foot of Window Floor = 10.

SHOW WINDOW LIGHTING

Merchants endeavor to locate their stores not only on busiest streets but on the busier side of the street. The more people that see the merchandise, the more the sales. Consequently in order to realize more fully upon the large investment in window space, it is essential to light up the windows as soon as dusk falls or perhaps even during the daylight, and to keep them working at 100 per cent. efficiency even after the store is closed, as long as pedestrians are abroad. This can be accomplished by a key switch on the outside of the store, to be operated by a watchman or, in a more satisfactory way, by an automatic time-switch.

There should be enough light so that the windows are not dim by comparison with those adjacent. The lighting must be designed to conceal the light sources from the vision of the spectators and in addition to so shield and place them that there is no direct reflection from the polished wood or glass background of the window. The usual and an excellent method of concealing the lamps and reflectors is by a cloth or a painted glass valance. The prismatic glass reflectors are best suited for illuminating these transparent advertising valances. In case of deep windows with a long side bordering the entrance, or of open-back show windows, it is of equal importance to conceal the units from the back as well as the front by hanging behind them a second cloth valance.

In another style of window lighting equipment the lamps are mounted horizontally in shallow metal troughs lined with mirrored glass. These can be very inconspicuously installed either at the top or bottom of the window and are easily concealed from the rear by having the trough deep, and the metal match the interior trim. Metal partitions fitted across the trough prevent a direct view of bare lamps when the observer is standing at the side of the window.

The care that is given to window lighting approaches that of the theatrical stage. Spot lights are used to accentuate particular features. Footlights of approximately one quarter the strength of the overhead lights are used to soften the shadows. For general use a system of alternate clear and Mazda daylight lamps is recommended. This will provide light close enough to daylight quality and yet warm enough for correct color impressions of most merchandise. Windows trimmers are now employing colored light to produce the more studied artistic effects and to show merchandise to its best advantage, as described in the next section.

The appearance of a show window and the attractiveness of the display may be enhanced by the use of side wall brackets and stand lamps. Relatively small wattage lamps will be ample, as such equipment should not be counted upon to illuminate the window but merely to serve as an added attraction.

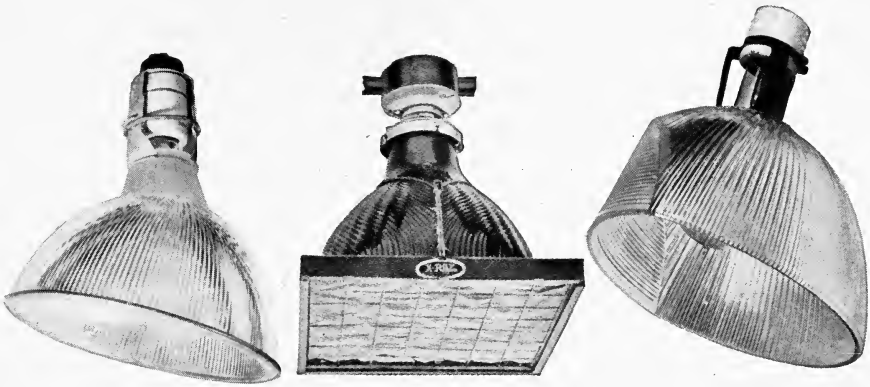
The safe practice in lighting show windows is to use the equipment designed especially for that particular service. There is, however, an exception found in some small stores such as Grocery, Bakery, and Butcher shops. Here the windows do not usually have backgrounds, and displays of merchandise are not given as much decorative consideration as in other types of stores. But non-glaring light is needed and can be excellently provided by locating the outlets as shown in Plan B for the Grocery store. Three or four open deep-bowl glass reflectors mounted at the top of the window about 12 inches from the glass will illuminate the window, supplement the interior lighting and will not be objectionable from the standpoint of glare.

SHOW WINDOW EQUIPMENT

The principal types of window lighting reflectors are shown in Fig. No. 4. In addition to these there is the trough reflecting equipment previously metioned. Both the mirrored and prismatic units can be obtained in various styles suitable, as occasion demands, for high, deep, or shallow windows. In some instances adjustable holders are provided permitting the use of one reflector for various types of windows.

For color effects the mirrored glass unit, Fig. No. 4 (B) is available with the detachable gelatin color screen shown. The prismatic reflector (A) is also furnished with screens of similar material that can be attached by clips to the bottom of the unit. The reflector (C) uses a glass color cap that fits over the lamp, while the trough reflector can be had with screens of natural colored glass, or gelatin.

All of these color-producing devices are easily attached or changed. Combinations of the three primary colors, red, green, and yellow, ordinarily supplied will be sufficient for most needs although with gelatin screens or lamp color dips, there becomes available a large variety of colors.



A B C

Fig. No. 4.—Show Window Reflectors

SHOW WINDOW ILLUMINATION CALCULATIONS

The planning of the lighting for windows, excepting the artistry and the color harmonies, need not involve the calculations required in designing the general interior illumination. The majority of show windows are practically of a standard type and with the specially designed equipment the illumination may be determined simply by the proper spacing of the units. The general practice is to use 100-watt Mazda C lamps spaced 18 inches apart. Outside of metropolitan centers, or on dimly lighted streets, this spacing may be increased up to a maximum of 24 inches. For lower illumination a 75-watt lamp would be used. The tendency, however, is toward higher values and in metropolitan districts 100-watt lamps with 12-inch spacing is considered good practice. In Plan A, page 57, 100-watt lamps are spaced on about 16-inch centers.

As previously explained, in the open-back windows of Grocery, Bakery, and similar stores, the standard window equipment should not be used unless a drop curtain or shield is hung behind them. Here again the calculations involved in the general interior lighting are not necessary. A simple method of planning the lighting on a watt-per-square-foot basis is very convenient and will usually be found satisfactory. This procedure may also be followed and will serve as a check in windows, using equipment as shown in Fig. No. 4.

Using 3 to 5 watts per square foot will produce a moderately high illumination, while 10 watts per square foot is a good average figure for lighting show windows. The present practice, however, in metropolitan centers, is to use 20 watts per square foot, unless spot lights are employed to supplement the overhead units.

On this basis in Plan B, page 58, we will assume 10 watts per square foot. The floor area of each window is 20 square feet, which multiplied by 10 gives 200 watts per window. This is provided by 2 units of 100 watts each.

WIRING AND CONTROL

The lighting switches should be conveniently located and the wiring system so laid out that flexible and easy control is provided. This applies particularly to Furniture, Rug, and similar stores where certain sections are lighted only when a customer is inspecting merchandise. Switches should be located near the entrance to a room or department. In case of more than one entrance, three-way switches permitting control at two points will be found convenient.

In the wiring of show windows two circuits controlling alternate units are frequently advisable. This will permit the use of part of the equipment during the late afternoon when the artificial illumination supplements the failing daylight, or will facilitate the alternation of colors if flashers be connected to one or more circuits.

It is important to provide an ample number of convenience outlets, i.e., wall or baseboard receptacles, column outlets, etc., throughout the store. These will eliminate dangling wires and permit easy connections for fans, vacuum cleaners, portable and stand lamps, decorative festoons, department signs, and electrical display devices. Show windows should also be equipped with auxiliary outlets for fans, electrical displays, etc., and particularly with one or more receptacles at the front edge or corner of the window, top and bottom, for spot lights.

The foresighted merchant must remember that the planning of the lighting, and the part that light is to play in benefiting his sales, begins with the work of the electrical contractor, and with the placing of the outlets.

PART IV
INDUSTRIAL LIGHTING

Requirements of Good Industrial Illumination

The requirements which must be met in the choice of reflecting equipment and in the design of a satisfactory lighting installation for industrial plants are:

1. A steady light of sufficient intensity on all working surfaces whether in horizontal, vertical, or oblique planes;
2. A comparable intensity of light on adjacent areas and on the walls;
3. Light of a color and spectral character suited to the purpose for which is is employed;
4. Freedom from glare and from glaring reflections;
5. Light so directed and diffused as to avoid objectionable shadows or contrasts of intensity;
6. A system which is simple, reliable, easy of maintenance, and reasonable in initial and operating cost.

Complete satisfaction cannot be expected from an installation in which any one of these requirements has been neglected. Thousands of manufacturers have taken advantage of the abundance of light obtained from the high-power Mazda C lamps to duplicate daylight conditions in their plants, but others, either through carelessness or ignorance, have given no thought to the choice of proper reflecting equipment and installation. Naturally, such practice is not only wasteful of light, but the glare from the unshielded lamp filaments detracts in large measure from the effectiveness of the system and, in fact, may prove to be a positive menace to the safety and eyesight of the employees.

Light on the Work

Today, work of many kinds, including the most intricate operations and those requiring the utmost precision, must be carried on throughout the twenty-four hours. If artificial light could be had for the asking, no plant would be content with a lower standard of illumination by night than by day. Table 1 summarizes the minimum values of daylight that operators in typical factories consider sufficient.

Each figure given is the mean of a number of observations and the measurements extended over both clear and cloudy days. The aim was to secure data which represented good aver-

Table No. 1

Intensities of Daylight Illumination in Foot-Candles

Values obtaining when daylight was deemed just sufficient for processes carried on.

Factory Product	Grade of Work		
	Fine	Medium	Rough
Engine lathes — Horizontal Vertical, Min.-Max.	10 6 — 15	7 2 — 15	3 0.5 — 9
Automatic engine lathes	14 2 — 30	12 2 — 30	10 1 — 15
Machine forgings		6 2 — 15	5 1 — 10
Special machinery	10 4 — 20	7 3 — 15	
Lamps	10 5 — 16	9 11 — 15	
Vacuum cleaners	17 7 — 25	11 3 — 20	
Automobiles	5 2 — 11	5 2 — 8	5 3 — 11
Automobiles *	10 6 — 12	3 1 — 3	5 4 — 5
Storage batteries		5 1 — 6	3 0.5 — 5
Machine tools and patterns	6 2 — 16	9 3 — 35	
Sheet iron equipment	10 1 — 20	5 1 — 12	8 2 — 15
Machine gears	7 3 — 16	8 5 — 18	5 1 — 15
Hardware	10 1 — 20	10 1 — 20	4 0.5 — 12
Printing machinery		5 1 — 15	3 0.5 — 5
Sewing machines		4 1 — 8	2 2 — 5
Cloth bags		5 3 — 10	7 3 — 10
Clothing	10 10 — 20	4 7 — 15	
Furniture	5 3 — 20	5 0.5 — 12	
Average	10 4 — 18	7 3 — 15	5 1.5 — 10

*Saw tooth roof.

age working conditions; and factory processes were divided roughly into three groups in accordance with the relative necessity for accurate vision. It will be noted that in general the operations requiring closest attention were ordinarily best lighted, for wherever possible such machines are located near the windows. Just below the data on horizontal illumination there are given in each case the results of readings taken in two vertical planes, toward and away from the windows.

Obviously, the minimum intensity of either daylight or artificial light to be supplied is that which will permit comfortable vision, conserve eyesight, and eliminate accident hazard. Many states, through their Industrial Commissions, are beginning to require the employer to make such minimum provision. In the States Codes, intensities for various classes of operations are specified, depending on the nature and fineness of the detail to be observed, the closeness of application required, and the reflection factor of the working surfaces. These intensities are designed to protect the operative who must work for long hours under these conditions day after day.

However, these governmental requirements are not such as to assure the most economical production, a factor of vital interest to the manufacturer, and to obtain which considerably higher intensity values are found necessary. It is difficult to recommend the exact intensity required in a given plant from the economic

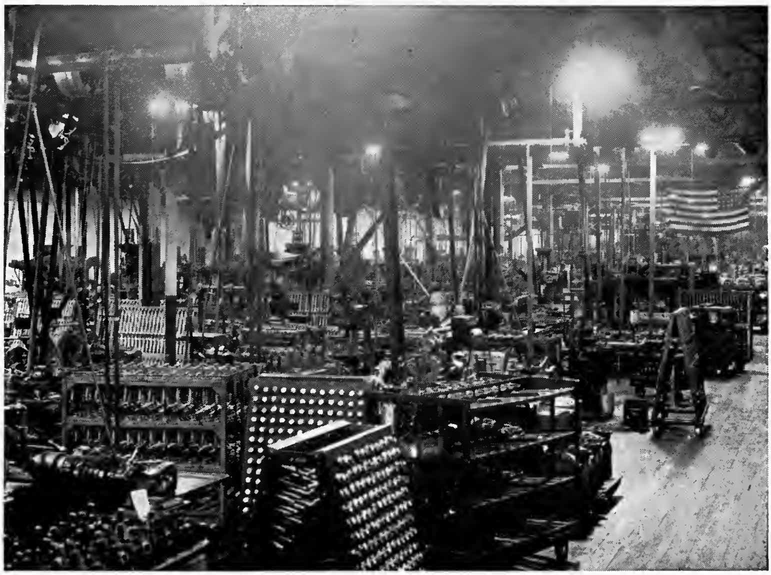


Fig. 1—Successful Application of Properly Directed and Diffused General Lighting to Interiors of this Nature is Gradually Eliminating the Drop Cord System

standpoint. This figure necessarily depends upon numerous factors such as the cost of producing light, the number and wages of the employees, and the value of their output, all of which vary widely in different establishments.

For good vision, the color and fineness of the materials worked upon are important considerations in determining the amount of light which should be supplied. An object is seen by the light which it reflects rather than by the light falling on it; hence textile mills manufacturing dark colored fabrics require higher intensities than those mills which produce light colored goods. Manufacturing processes involving fine machine work or fine assembling require more light than industries where a comparatively low degree of accuracy suffices. The greater alertness and better morale of the workmen in brightly lighted surroundings are at once apparent in the greater production of the plant.

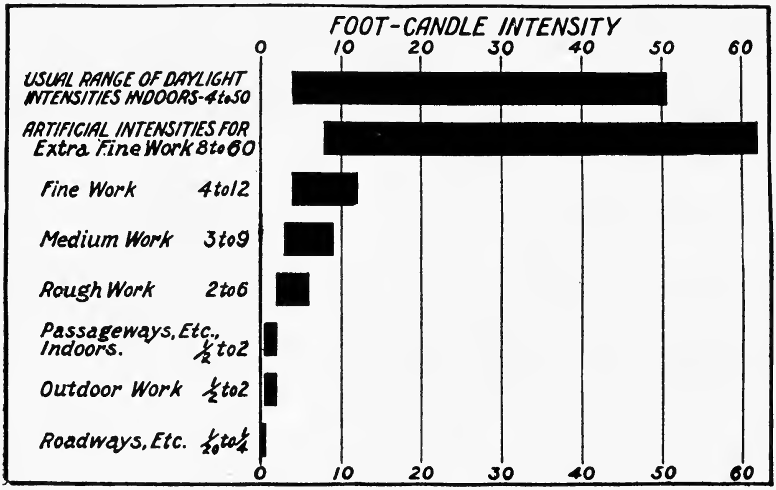


Fig. 2—Artificial Lighting Intensities Compared with Interior Daylight Values

There is a growing conviction that no one should be called upon to work continuously at any occupation under an intensity of less than one foot-candle regardless of how rough the operation may be. Table 4, of Part II, Illumination Design Data, lists the present standards of intensity for different classes of work. There is no doubt that the use of higher values than are there listed will prove profitable in many cases. It is a notable fact that in those factories in which the most study has been devoted to lighting, the highest intensities have been adopted, based upon the experience that each increase has led to still more economical production.

*Tests by Wm. A. Durgin in four Chicago plants where accurate cost and production records could be kept, showed that with illumination of the order of 10 to 12 foot-candles, the production increased from 10 to 35 per cent at a cost for lighting of only

*Electrical World, March 1, 1919. Electrical Review, March 22, 1919.

1 to 5.5 per cent of the pay roll. These shops were engaged in various metal machining and assembling operations and the previous lighting systems were, in one case, individual lamps on drop cords, and in the other three instances, general lighting systems in which the illumination ranged from 2 to 4 foot-candles.

In a consideration of the amount of light necessary for factory illumination, the criterion must be the intensity on all working surfaces, whether in horizontal, vertical, or oblique planes. At one time, consideration was largely confined to light on the horizontal; yet most factory work involves the perception of objects in their three dimensions, and the illumination of all surfaces is important.

Except in especially unfavorable locations, such as near the dark side wall of a room, any of the systems of lighting usually employed can be expected to provide an intensity of illumination on any vertical plane equal to about one-half of that measured in a horizontal plane at the same point. This fact should be kept in mind particularly in designing a lighting system to comply with the State Codes, which usually specify only the value to be provided on the principal plane of the work, which may be vertical, horizontal, or oblique.

The intensity values used in industrial lighting as compared with the usual range of daylight intensities existing in factory interiors are shown graphically in Fig. 2.

Illumination of Surrounding Surfaces

Moderate intensities of illumination in aisles and other spaces intermediate between the working surfaces, on the walls, etc., are necessary to safety, good vision, and a stimulating atmosphere. Light side walls are conducive to a cheerful impression of brightness throughout the room. Sources which direct considerable light to the vertical planes, and light wall colors, aid materially in accomplishing this.

The eyes of the workman looking up from his well illuminated machine or bench are not adapted for vision at low intensities; 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 adapted to the low intensity. Glancing back at his work, he again loses time while the pupils of 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. The general illumination of all intermediate and surrounding areas should be sufficient to allow no marked contrast with the brightness of the working surfaces.

It is considerations such as these that have led to the almost universal adoption of the general or overhead system of lighting in modern industrial plants; they also constitute strong arguments for the use of reflecting equipments which direct a part of the light toward the side walls and ceiling.

Color Quality of Light

As daylight intensities represent the standards which are to be sought in the artificial lighting of industrial plants, so does the color of daylight constitute the standard which should be approached in artificial illumination. Through centuries of use the human eye has adapted itself to function best under a color of light found within the range over which natural light varies, and light within this range will also be found most pleasing and stimulating.

Color discrimination forms one of the most important aids to vision. It defines outlines and edges and serves to identify objects which may be similar in other respects, such as form, texture, and reflection factor. The ideal illuminant therefore emits rays of all colors. While the exact proportions are not the same, still, all of the colors in daylight are contained in the light emitted by MAZDA C lamps, and objects retain their natural appearance when viewed under this light. The MAZDA daylight lamp with its specially selected blue-green glass bulb gives a light which is a further step toward daylight color and extremely valuable in the manufacturing processes requiring closer color identification or better revelation of detail through color contrasts. For dye making and color matching, where extreme accuracy is required, several equipments with special absorbing screens are available which duplicate the standard north-sky light with exactness.

Under certain conditions, on the other hand, as in a foundry, the criterion for the choice of an illuminant is the penetrating power of the light. The appearance of the sun through smoke, haze, or fog evidences the fact that the shorter wave lengths, or the rays near the blue end of the spectrum, are absorbed or dispersed while the longer wave lengths pass through. Hence, under such conditions, light in which red and yellow rays predominate is the most effective, and a clear-bulb MAZDA C lamp will give better service than a MAZDA daylight lamp.

Glare

Glare has been characterized as light out of place. It has been more fully defined as brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision, or eye fatigue. Either definition establishes the fact that glare is undesirable.

Fig. 3—An Installation of Mirrored-Glass Reflectors in a Foundry

The degree to which glare is experienced depends upon six principal factors:

1—Total candlepower emitted by the source in the direction of the eye;

2—Distance from the source to the eye;

3—Intrinsic brilliancy of the source;

4—Contrast in brightness between the light source and the working surfaces and surroundings;

5—Proximity of the light source to the line of vision;

6—Length of time during which the source of glare is present within the field of vision.

It is a matter of common experience that of two sources of equal candlepower, that which has the greater intrinsic brilliancy or candlepower per square inch is the source of greater discomfort. Too frequently, however, the consideration of glare is assumed to be entirely a question of intrinsic brilliancy. Of greater importance than this is the question of total light flux entering the eye. A 10-inch opal globe equipped with a 500-watt MAZDA C lamp hung approximately 10 feet above the floor and 10 feet from the observer, will prove fully as glaring as a bare 75-watt MAZDA C lamp in the same location. Although the intrinsic brilliancy of the opal globe unit is only two or three times that of a candle, its total candlepower—hence the quantity of light which reaches the eye at this close range—is so excessive that its effect is just as bad as that of the filament of the lower candlepower MAZDA C lamp which has an intrinsic brilliancy 400 times as great as that of the globe. On the other hand, the same 500-watt unit at twice the mounting height might be entirely unobjectionable because of the greatly reduced quantity of light which would then reach the eye.

Contrast also is an important factor in causing glare. An unshielded MAZDA lamp hung over a bench near a window causes no glare when viewed against the background of sky by day, yet the same source contrasting sharply in brightness with its background at night will be the cause of extreme discomfort, accentuated by reason of the fact that it is close to the line of vision. The afternoon sun has only a fraction of its noonday brightness; nevertheless, on account of its proximity to the horizon, it is much more likely to be glaring.

Some sources which are not immediately recognized as glaring may cause fatigue when within the field of vision for a considerable period of time. The effect of looking out of a window for a moment is usually not at all unpleasant. But working all day at a desk facing the same window would be decidedly tiring.

Specular Reflection

Wherever highly polished surfaces are present, the reflected images of a light source as seen in these surfaces are more likely to be a cause of discomfort than the lighting units themselves. Glare caused by specular reflection from working surfaces is particularly trying because of the necessity of directing the eyes toward those surfaces, and further, because the eyes are by nature especially sensitive to light rays entering from below. In choosing lighting equipment, it must be borne in mind that, although a given reflector may afford adequate protection against direct glare from the lamp filament, it will not protect against glaring reflections unless the lamp is shielded in such a manner that the filament cannot be seen when the unit is viewed from directly beneath. In many industrial operations including the inspection of finished surfaces, a moderate degree of specular reflection or sheen will be found essential.

Fig. 4—Freedom from Drop Cords is Essential where Motors are Moving Along in Progressive Assembly

Shadows

Differences in brightness of surfaces, that is, light and shadow, are essential in observing objects in their three dimensions. Without such differences, except as variations in color are present, no outlines, edges, or contours would be defined; one could not tell whether an object were rectangular or circular in cross section, whether the faces were flat, convex, or concave. On the other hand, in the factory it is usually necessary to work on surfaces in many planes; hence, while dense, sharp shadows would define edges and outlines most distinctly, they might also be so dark as to interfere with work in the shaded areas.

From successful trials of indirect lighting in offices, some factory managers have drawn the conclusion that the indirect system is ideal for all locations, and that it is simply the matter of operating cost and maintenance which has prevented the universal application of this system. However, the distinction must be recognized that in offices close scrutiny is limited to plane surfaces and that printed words and figures are rendered legible by differences in color and contrasts in brightness with the background, and here specular reflection and shadows are of no aid to vision, but usually do harm.

For satisfactory general illumination in industrial plants, there must be no shadows so dense as to make vision difficult where the direct light from one or two sources is cut off, nor so sharply defined as to cause confusion between a machine part and its shadow. In general, lighting should be so designed that shadows are present, but they should be soft and luminous.

* * * * * *

For a guide to the selection of lighting equipment and for the method to be followed in making illumination calculations, the reader is referred to Part II, Illumination Design Data.

Operations of fine detail may be well lighted by an overhead system. Here the average of 10 Foot-candles is provided by 10′ x 10′ spacing of 150 and 200 Watt Mazda C Lamps in RLM Reflectors

Table 2—Good Lighting for Factories

Good Lighting requires three things:

1. Light of Suitable Quality.
2. Light of the Proper Direction.
3. Light in the Correct Amount.

Good Lighting	Suitable Quality	Absence of Glare. Absence of Reflected Glare. Proper Color.
	Proper Direction	Shadows Soft and Luminous. Uniform Distribution.
	Correct Amount	Lighting for Safety. Lighting for Economical Production. Proper Cleaning of Units.

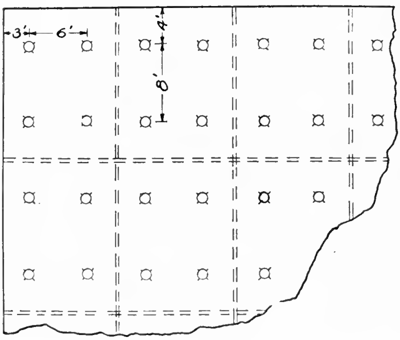
Table 3—Bad Lighting for Factories

Cause	*Effect*	*Remedy*
Bare Lamps.	Glare, eye strain, wasted light, harsh shadows.	The modern efficient type of reflector such as RLM Standard dome.
Miscellaneous local lights dangling on drop cords.	Glare, eye strain, danger of accident, particularly about belting and moving machinery, short circuits, breakage.	General overhead system.
General System—Units too far apart or too low.	"Spotty" lighting; areas between lamps receive very little light; shadows are very black.	Proper relation between mounting height of units and spacing distance.
Clear lamps where polished surfaces are present on material or machinery.	Reflected glare, eye strain.	Bowl-Enameled MAZDA C lamps, or equipment to diffuse downward light from filament.
Too little illumination.	Time lost by workman, particularly on detail work; eye strain; accidents; no incentive to keep place cleaned up.	Larger lamps in suitable reflectors spaced closer together if necessary.
Sharp, black shadows.	Accidents; time lost; eye strain.	RLM Standard dome reflectors properly spaced. Bowl-enameled MAZDA C lamps.
Gloomy and cheerless appearance of room.	Unpleasant contrast between light sources and background; dispirited workmen.	Liberal use of white paint accompanied in some cases where location is suitable by use of glass reflectors.
Dusty, dirty, or broken equipment.	Loss of 40% to 60% of the light paid for.	Institute a regular cleaning schedule.

LOCATION OF OUTLETS IN TYPICAL FACTORY INTERIORS

The following illustrations show how direct lighting units may be advantageously located according to bays in the usual industrial interior. The reader is referred to Page 79 for a discussion of bench lighting.

Design No. 1a. **Bays 12 x 16 ft.**
Ceiling Height—Not Less than 9 ft.
(See also Design 1b.)

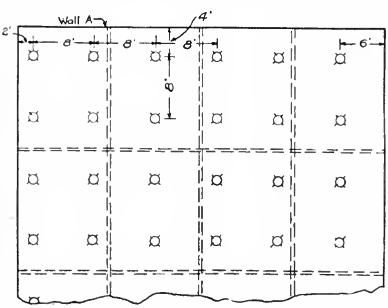


SPECIFICATIONS

Location—4 Units per Bay as Shown (48 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 8½ ft. above Floor; Preferably, somewhat Higher.

Design No. 1b. **Bays 12 x 16 ft.**
Ceiling Height—Not Less than 9 ft.
(See also Design 1a.)

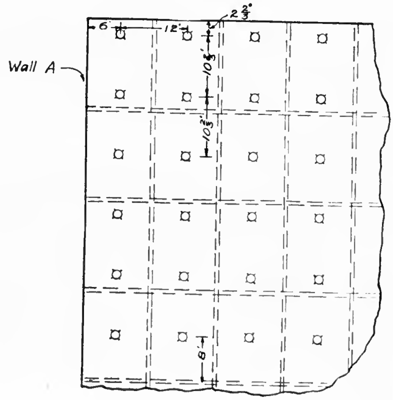


SPECIFICATIONS

Location—4 and 2 Units per Bay as Shown (64 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 8½ ft. above Floor; Preferably, somewhat Higher.

Design No. 1c. **Bays 12 x 16 ft.**
Ceiling Height—Not Less than 12 ft.

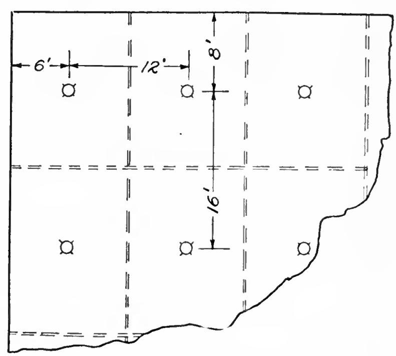


SPECIFICATIONS

Location—2 and 1 Units per Bay as Shown (128 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 11 ft. above Floor.

Design No. 1d. **Bays 12 x 16 ft.**
Ceiling Height—Not Less than 14 ft.

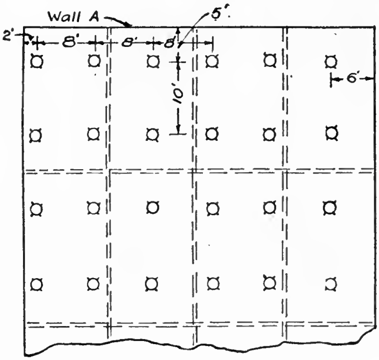


SPECIFICATIONS

Location—1 Unit per Bay as Shown (192 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 14 ft. above Floor.

Design No. 2a. **Bays 12 x 20 ft.**
Ceiling Height—Not Less than 10 ft.

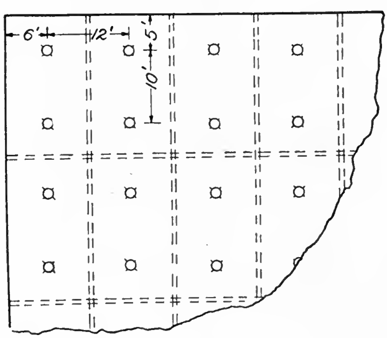


SPECIFICATIONS

Location—4 and 2 Units per Bay as Shown (80 Sq. Ft. per Outlet.)

Mounting Height—Good Practice, 10 ft. above Floor. Preferably, somewhat Higher.

Design No. 2b. **Bays 12 x 20 ft.**
Ceiling Height—Not Less than 12 ft

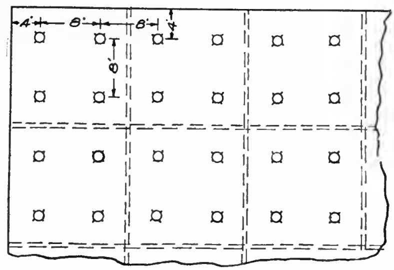


SPECIFICATIONS

Location—2 Units per Bay as Shown (120 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 11 ft. above Floor.

Design No. 3a. **Bays 16 x 16 ft.**
Ceiling Height—Not Less than 9 ft.



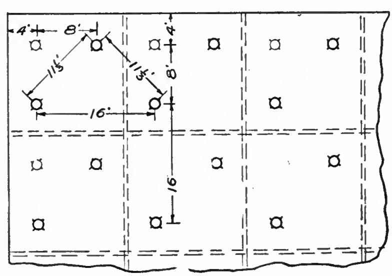
SPECIFICATIONS

Location—4 Units per Bay as Shown (64 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 8½ ft. above Floor; Preferably, somewhat Higher.

Design No. 3b. **Bays 16 x 16 ft.**
Ceiling Height—Not Less than 11 ft.

Where interior is not likely to be subdivided into smaller rooms, 4, 2 and 1 units per bay may be used in the same manner as in Design 6b. There will then be one outlet per 114 sq. ft. of floor area.



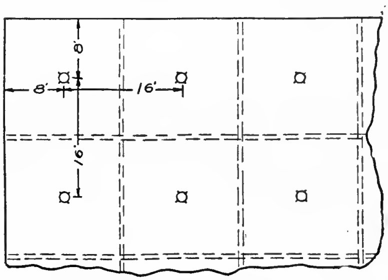
SPECIFICATIONS

Location—2 Units per Bay, "Staggered," as Shown (128 Sq. Ft. per Outlet).

Mounting Height—Good Practice, 10½ ft. above Floor.

Design No. 3c. **Bays 16 x 16 ft.**
Ceiling Height—Not Less than 14 ft.

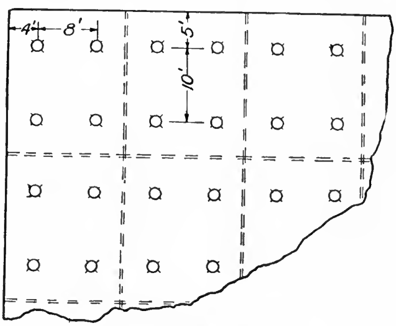
Caution: Any design showing less than 2 units per bay is not recommended for fine operations unless at least 2 rows of units are installed. Otherwise, light will not reach the work from a sufficient number of directions.
Where there is much overhead belting or overhanging machinery to cast troublesome shadows, use Design 3b.



SPECIFICATIONS

Location—1 Unit per Bay as Shown (256 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 14 ft. above Floor.

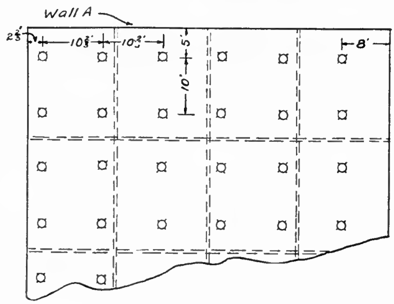
Design No. 4a. **Bays 16 x 20 ft.**
Ceiling Height Not Less than 10 ft.



SPECIFICATIONS

Location—4 Units per Bay as Shown (80 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 10 ft. above Floor; Preferably, somewhat Higher.

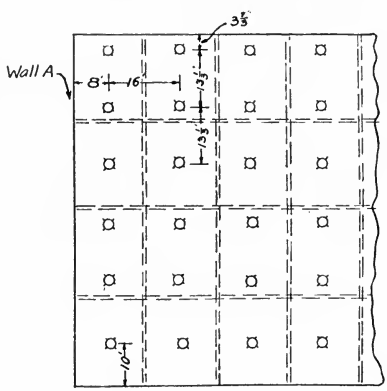
Design No. 4b. **Bays 16 x 20 ft.**
Ceiling Height—Not Less than 11 ft.



SPECIFICATIONS

Location—4 and 2 Units per Bay as Shown (107 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 10½ ft. above Floor.

Design No. 4c. **Bays 16 x 20 ft.**
Ceiling Height—Not Less than 14 ft.

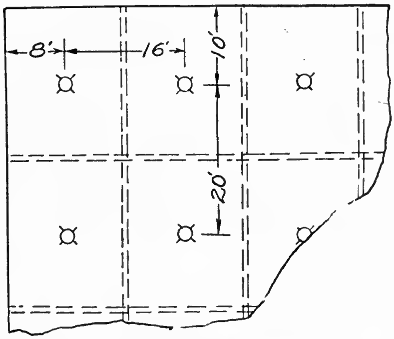


SPECIFICATIONS

Location—2 and 1 Units per Bay as Shown (213 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 14 ft. above Floor.

Design No. 4d. **Bays 16 x 20 ft.**
Ceiling Height—Not Less than 17 ft.

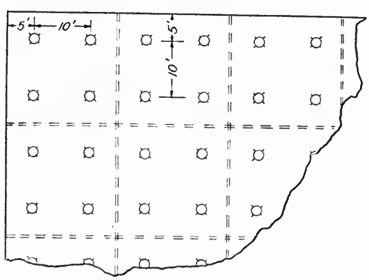
Caution: Any design showing less than 2 units per bay is not recommended for fine operations unless at least 2 rows of units are installed; otherwise, light will not reach the work from a sufficent number of directions.
Where there is much overhead belting or overhanging machinery to cast troublesome shadows, use Design 4c.



SPECIFICATIONS

Location—1 Unit per Bay as Shown (320 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 16½ ft. above Floor.

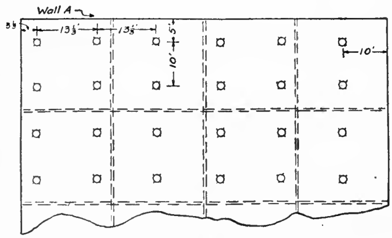
Design No. 5a. **Bays 20 x 20 ft.**
Ceiling Height—Not Less than 10 ft.



SPECIFICATIONS

Location—4 Units per Bay as Shown (100 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 10 ft. above Floor; Preferably, somewhat Higher.

Design No. 5b. **Bays 20 x 20 ft.**
Ceiling Height—Not Less than 12 ft.

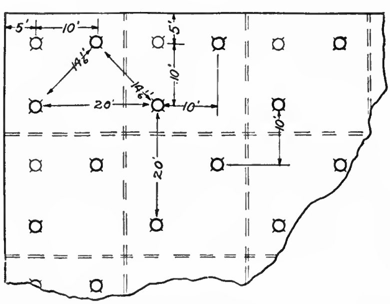


SPECIFICATIONS

Location—4 and 2 Units per Bay as Shown (133 Sq. Ft. per Cutlet).
Mounting Height—Good Practice, 12 ft. above Floor.

Design No. 5c. **Bays 20 x 20 ft.**
Ceiling Height—Not Less than 13 ft.

Where nteror is not lkely to be subdivided into smaller rooms, 4, 2, and 1 units per bay may be used in the same manner as in Design 6b. There will then be one outlet per 178 sq. ft. of floor area.

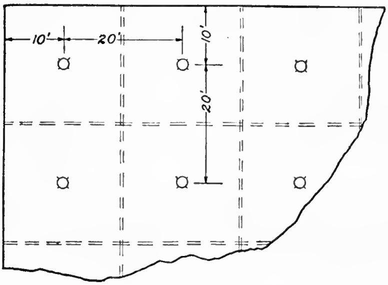


SPECIFICATIONS

Location—2 Units per Bay, "Staggered," as Shown (200 Sq. Ft. per Outlet).
Mounting Height—Good Practicc, 12½ ft. above Floor.

Design No. 5d. **Bays 20 x 20 ft.**
Ceiling Height—Not Less than 17 ft.

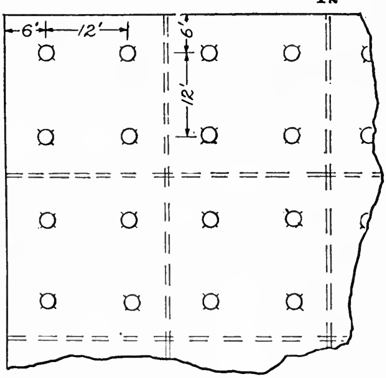
Caution: Any design showing less than 2 units per bay is not recommended for fine operations unless at least 2 rows of units are installed; otherwise, light will not reach the work from a sufficient number of directions.
Where there is much overhead belting or overhanging machinery to cast troublesome shadows, use Design 5c.



SPECIFICATIONS

Location—1 Unit per Bay as Shown (400 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 16½ ft. above Floor.

Design No. 6a. **Bays 24 x 24 ft.**
Ceiling Height—Not Less than 12 ft.

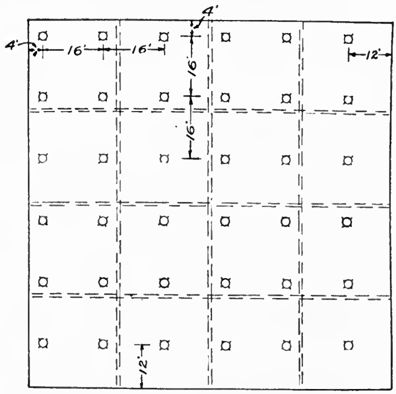


SPECIFICATIONS

Location—4 Units per Bay as Shown (144 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 11 ft. above Floor.

Design No. 6b. **Bays 24 x 24 ft.**
Ceiling Height—Not Less than 14 ft.

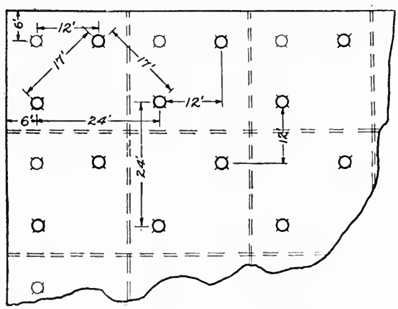
Caution: Where interior is likely to be subdivided, a system similar to 6c is preferable.



SPECIFICATIONS

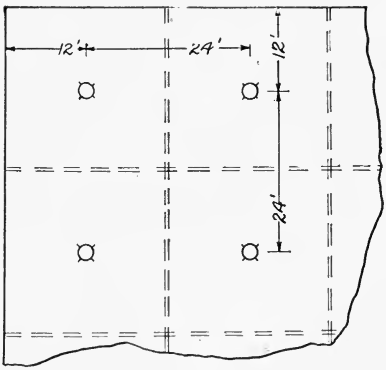
Location—4, 2, and 1 Units per Bay as Shown (256 Sq. Ft. per Outlet).
Mounting Height—Good Practice 14 ft. above Floor.

Design No. 6c. **Bays 24 x 24 ft**
Ceiling Height—Not Less than 15 ft.



SPECIFICATIONS

Location—2 Units per Bay, "Staggered," as Shown (288 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 14½ ft. above Floor.



Design No. 6d. **Bays 24 x 24 ft.**
Ceiling Height—Not Less than 19 ft.
Caution: Any design showing less than 2 units per bay is not recommended for fine operations unless at least 2 rows of units are installed; otherwise, light will not reach the work from a sufficient number of directions.
Where there is much overhead belting or overhanging machinery to cast troublesome shadows, use Design 6c.

SPECIFICATIONS

Location—1 Unit per Bay as Shown (576 Sq. Ft. per Outlet).
Mounting Height—Good Practice, 19 ft. above Floor.

AUXILIARY LIGHTING FOR WORK BENCHES

In general, where more lighting units are employed than one per bay, bench lighting can be adequately cared for by shifting the outside rows of units nearer to the walls along which the benches are placed, as indicated in the notes accompanying the designs. This means, of course, that the spacing distance between the outside row of units and the next is greater than it

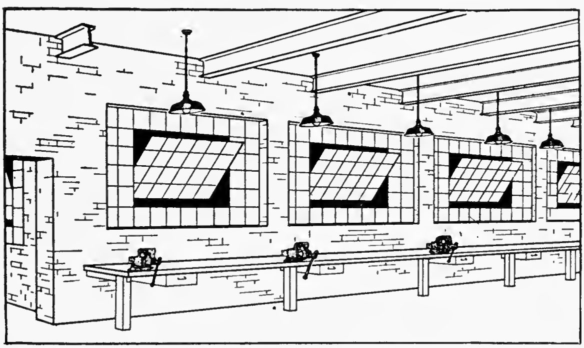


Fig. 5—Good Arrangement of Auxiliary Bench Lighting Units

should be, and the illumination at points between the two rows is correspondingly reduced. However, since this area of low illumination usually covers the aisle between the benches and the first row of machines, the effect is usually not serious. On the other hand, where bays are large and only one unit is employed in each bay, best practice usually requires auxiliary bench lighting units. A typical good arrangement of auxiliary units is shown in the sketch.

100-watt Bowl-Enameled MAZDA C lamps in RLM Standard Dome reflectors, spaced 8 ft. apart and mounted 6 to 8 ft. above the bench tops will provide an average illumination on the bench of about 6 foot-candles; this is, of course, in addition to the light received from the general overhead system. 150-watt lamps so installed will provide an average of about 10 foot-candles.

150-watt Bowl-Enameled MAZDA C lamps in RLM Standard Dome reflectors, spaced 10 ft. apart and mounted 7 to 10 ft. above the bench tops will provide an average illumination on the bench of about 6 foot-candles.

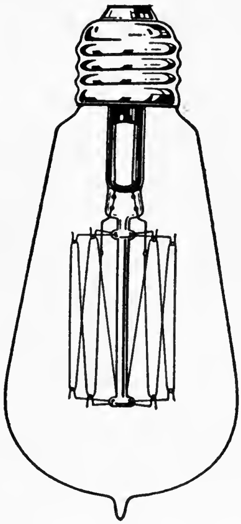
The distance between the units and the wall is governed by the width of the benches. The units should be so located that the lamp is out from the wall a distance about equal to the width of the bench.

115-VOLT vs. 230-VOLT MAZDA LAMPS

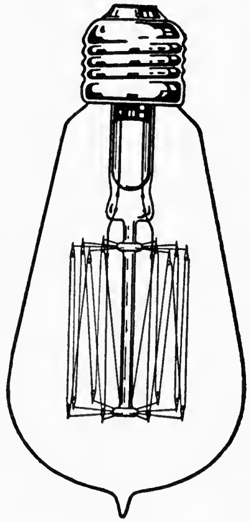
It is true of electrical apparatus in general that as the voltage for which it is designed increases beyond certain limits, the difficulties of manufacture are multiplied. These difficulties are more easily overcome in some types of apparatus than in others. There is no difficulty in manufacturing motors or generators for 220-250 volt service which will operate at as high an efficiency and will give as satisfactory service as those manufactured for 110-125 volt service. The limiting voltage for incandescent lamps is lower, and it has not been found possible as yet to manufacture for voltages ranging between 220 and 250 volts with results as good as for 110-125 volt service. In order that the nature of the difficulties may be more readily understood, a few are discussed in the following paragraphs:

220-250 VOLT LAMPS

In Fig. 6 are shown to scale a 40-watt 115-volt lamp and a 40-watt 230-volt lamp. The filament of the 230-volt lamp is of necessity 1.7 times as long as that of the 115-volt lamp. For this long filament, 17 supports are needed to keep the filament strands separated, whereas 9 suffice for the shorter filament. Each support draws a small quantity of energy which escapes from the bulb as radiant heat and is lost; and, even with 17 supports, the strands of the 230-volt filament have a greater tendency to lock together and short-circuit a portion of the filament. When such interlocking occurs, the portion of the filament which burns receives more than normal current, and premature failure of the lamp results.



115-Volt Lamp



230-Volt Lamp

Fig. 6—40 Watt 115-Volt, and 40 Watt 230-Volt MAZDA Lamps. The 230-Volt Lamp has a Longer Filament and Requires 8 Additional Supports. Illustrations One-Half Scale

The maximum voltage existing between supports in the 115-volt lamp is approximately 92 volts. The supports as they are held in the "button" on the center rod are separated about 0.06 inch. In the 230-volt lamp, the maximum voltage between supports is about 204 volts, and, since the distance between supports is almost exactly the same, a greater current flow through the glass between supports takes place. Likewise, a greater flow takes place between the points where the leading-in wires, with almost the entire 230 volts difference in pressure between them, are sealed into the stem glass. The increase in heat, and, on direct current particularly, the more rapid formation of electrolytic products, which result from the greater current flow, seriously affect the life of the lamp.

It is not practical to employ larger buttons than are at present used in 230-volt lamps and in this way permit greater spacing between supports because of the fact that as their size is increased the mechanical strength of the mount is reduced unless a thick center rod is used. If a thick center rod is used, the connection with the stem is more likely to be faulty and unable to resist a sudden jar or shock. The center rod must be of a size neither too large nor too small if the lamp is to possess maximum strength.

Even with the high degree of vacuum existing in incandescent lamps, a pressure of approximately 230 volts between the first and last strands of filament is sufficient to produce a current transfer through the residual atmosphere in the bulb of considerably more moment than that occurring in 115-volt lamps. On direct current particularly is the effect of this transfer objectionable, for, in some cases, the continual discharge heats the residual atmosphere to a point where it becomes a sufficiently good conductor to allow an arc to form between the filament strands; this arc travels rapidly toward the base of the lamp, and ruptures the stem.

The filaments of the two lamps shown in Fig. 6 have a cross-sectional area ratio of approximately 4 to 9, the 230-volt filament being, of course, the smaller. Aside from the difficulties of drawing, and working with, the finer filament, there is the disadvantage that small filaments must be operated at lower temperatures if they are to show a life performance equal to that of large filaments. The light which a filament gives is dependent upon the temperature at which it operates; for this reason, as well as for those previously mentioned, 230-volt lamps are less efficient than 115-volt lamps of corresponding wattage.

TWO LAMPS IN SERIES ON 220-250 VOLTS

In order to profit by the advantages of lamps of the 110-125 volt class, the practice of operating two lamps in series across the 220-250 volt lines has met with favor in many industrial installations, where severe operating conditions and long hours of service make the use of the more rugged, less expensive, and more efficient low-voltage lamp particularly attractive. Under these circumstances, however, slightly less than normal life is to be expected from the lamps, for although two new lamps usually operate satisfactorily in series, one lamp naturally fails sooner than the other, and when a replacement is made, the resistance of the two lamps will be higher than that of two new lamps and less than that of two old ones, for the resistance of lamps increases with burning. Hence, the new lamp will receive slightly less than normal current and will give less than normal candle-power, while the old lamp will be forced to carry a somewhat heavier current than it would normally carry at that period of its life and will, therefore, fail earlier than it otherwise would.

A more serious disadvantage of operating two lamps in series is that the failure of either lamp means the outage of both; thus a relatively large area is left without sufficient light and the time of several persons may be lost while the defective lamp is being located and the replacement made. Obviously, in industrial plants and shops, accident risk under these conditions is increased over that when only one lamp is out.

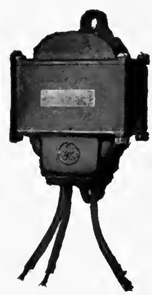


Fig. 7—Typical Balancer Apparatus
Motor-Generator Set on Left; Balancer Coil on Right

PROVIDING 110-125 VOLTS FROM 220-250 VOLT CIRCUITS

Few are the modern installations, at least of any size, where provision is not made for supplying 110-125 volts for the lighting circuits. The larger installations often generate alternating current which is, of course, readily transformed to 110-125 volts for lighting. The energy needed by such apparatus as requires direct current is obtained by converting the alternating current to direct current. In new plants in which direct current is generated and maximum flexibility in the control of motor speeds is desirable, or where the lighting load is a considerable portion of the total load, the present practice is to install a 3-wire generator, which provides between the third wire and either main, half the main line voltage. Where the lighting load is a small proportion of a large total load and a very flexible motor speed control is not essential, the installation of a balancer set will, in general, provide greater economy.

The largest field of the 220-250 volt lamp is, then, in plants where 220-250 volt circuits are already used for lighting circuits. In such cases, except for very small installations, the most satisfactory and the most economical lighting results are secured by providing 110-125 volt circuits by placing a balancer between the 220-250 volt lighting feeders and running a third, or neutral, wire to the main distributing points. The purpose of the balancer is to maintain equal voltages on the two sides of the 3-wire circuit despite unequal loading. For alternating-current circuits, a simple balancer coil suffices; for direct-current, a small mechanically coupled shunt or compound wound motor-generator set is commonly used. Typical apparatus is shown in Fig. 7.

In Fig. 8 is shown the wiring diagram of a typical 230-volt lighting circuit. Attention is called to the fact that power requirements have been cared for by the installation of a separate

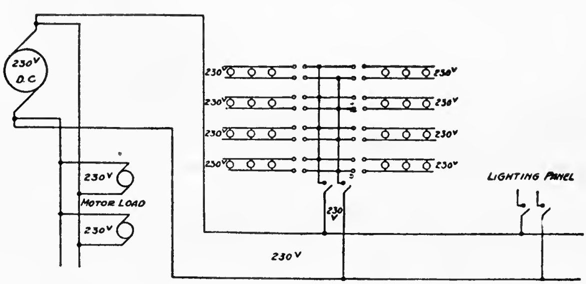


Fig. 8—Wiring Diagram of Typical 230-Volt Lighting Circuit

power circuit. This practice is to be encouraged, for not only are fluctuations in voltage caused by the starting of motors or by the sudden shifting of heavy loads confined at least in part to the power circuit and their effect upon lamp performance thus reduced, but trouble in the power circuit is less likely to cut off the illumination of the plant at a time when light is urgently needed.

Figures 9 and 10 show a method of connecting the balancer for adapting the 230-volt circuits to 115-volt lamps. The motor-generator set, or the balancer coil, is connected between the 230-volt mains, and a neutral wire is run to the panel boxes. The power load connections require no alterations. Three-wire panels can usually be substituted for 2-wire at moderate expense; or, if thought advisable, a 3-pole switch may be substituted for the 2-pole in existing boxes and a small section removed from the center of one of the bus rods. The two outside wires are then connected, through the switch, to opposite ends of the split bus, and the neutral is connected to the continuous bus rod.

For the sake of clearness, a simplified diagram showing the important connections is given in Fig. 11. As long as the lamp loads on each side of the neutral wire are equal, or balanced, all

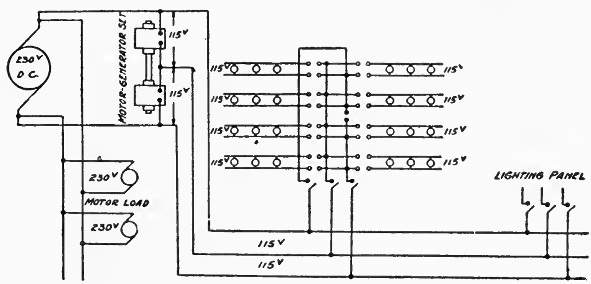


Fig. 9—A Method of Connecting Motor-Generator Set in Direct-Current Circuit

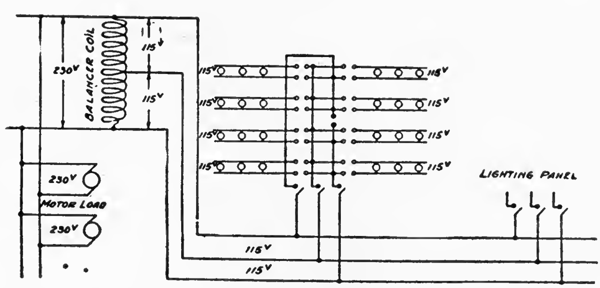


Fig. 10—A Method of Connecting Balancer Coil in Single-Phase Alternating-Current Circuit. Where Three-Phase Lighting Circuits are Used, Balancer Coils May be Connected in Each Phase, but the Neutral Points Cannot be Grounded

the current which flows through one circuit of lamps will flow through the other, the 230-volts will automatically divide into 115-volts across each lamp circuit, and the lamps will operate at normal voltage. If the load becomes unbalanced, the side having the greater load will have less resistance, and the tendency will be for the voltage to divide unequally between the two circuits, the voltage across the heavily loaded side becoming less than half the 230-volts impressed across the two circuits. If this condition obtained, the lamps in the heavily loaded branch would receive less than normal current and would give less than their normal candle-power, whereas those in the lightly loaded side would receive more than normal current and would burn out at less than rated life. However, the balancer set takes care of this unbalancing. Under conditions of perfectly balanced load, the two machines composing the motor-generator set run idly as motors, taking only enough energy to offset the no-load losses.

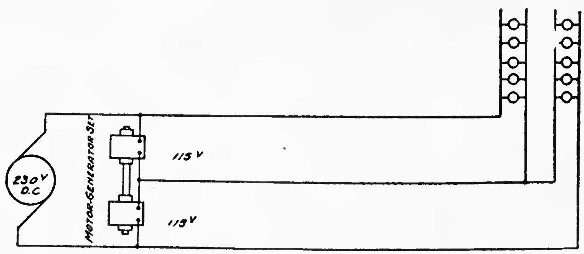


Fig. 11—Simplified Wiring Diagram of Balancer Set Installation

The instant that the load becomes unbalanced and the voltage between one main and the neutral starts to fall below the voltage between the other main and the neutral, the tendency of the machine on the low voltage side is to slow down and run as a motor the same as before the unbalancing occurred. This is prevented, however, because of the mechanical connection between the two machines, and, since the generated voltage of the machine on the low-voltage side is higher than the voltage impressed across its armature, it becomes, automatically, a generator, and, within its capacity, holds the voltage of the heavily loaded circuit at normal or nearly so. The best regulation is secured by cross connecting the fields of the machines—that is, by connecting the field for one armature across the circuits of the other armature and vice versa.

The current which the heavily loaded side carries in excess of that flowing through the lightly loaded side must be carried by the neutral. This neutral current divides at the motor-generator set, half of it, plus the current necessary to offset the losses of the generator, flowing through the motor and the remainder flowing through the generator. If it is considered advisable to protect the balancer against possible overload, a circuit breaker may be arranged to open both sides of the circuit between the balancer and the source of supply or to open all three circuits between the balancer and the lamp load; the precautions taken to guard against a break in the neutral of any 3-wire system should, of course, be applied.

The action of a balancer coil for alternating-current circuts is very similar to that of the motor-generator set. The coil is simply a 230-volt auto-transformer with a mid-voltage tap. As long as the load is balanced, the coil floats on the line. When the load becomes unbalanced, the voltage tends to rise on one half of the coil and tends to drop on the other. Since both halves of the coil are on the same magnetic core, the voltages of the two halves, within the capacity of the coil, must be almost exactly equal. Hence, the voltages of the two lamp circuits are maintained nearly equal.

Since the current which the balancer must carry is determined by the degree of unbalancing, the capacity of the apparatus required in any given case depends upon the magnitude of the lighting load and upon how nearly the conditions of installation will allow the circuits in the panel boxes to be made to balance. Obviously, the greater the number of properly connected circuits, the smaller the chance for serious unbalancing to occur. In practice, the size of the balancer installed ranges from about 10 per cent. of the total connected load to 20 or even 25 per cent., depending upon the size of the lighting load and upon how well the circuits may be divided. The capacity of the balancer set as used here is in terms of the current flowing in either machine multiplied by the total impressed voltage of 220-250 volts, or the current flowing in the neutral multiplied by half the impressed voltage.

* * * * * *

In addition to effecting maximum lighting economy and obtaining superior service performance, the user of 110-125 volt lamps receives the benefits resulting from the use of a more highly standardized product. Lamps of the 220-250 volt range are manufactured primarily to supply a small demand which does not justify the stocking of quantities of lamps to fill emergency requirements. Furthermore, improvements are less readily incorporated because of the greater manufacturing difficulties presented by high-voltage conditions.

PART V
LIGHTING OF OFFICE BUILDINGS AND DRAFTING ROOMS

Introductory

With too low an intensity of lighting the eye is soon fatigued, particularly when engaged in clerical work. With glaring light sources or glaring reflections from the work or surroundings, the efficiency is seriously impaired. With dancing or shifting shadows on the typewriter or ledger, eye strain is introduced. These effects are particularly serious in the clerical or stenographic office where a high percentage of women are employed, for they are by nature particularly sensitive to such effects.

Properly installed high intensity lighting in the office will increase production and reduce the number of absentees.

A careful consideration of the subject shows past standards of intensity to be too low. An analysis of the standards recommended in typical textbooks and handbooks shows the average values set down as desirable to be between three and four foot-candles.

It is possible, of course, to see to read or typewrite with less than one half foot-candle, but severe eye strain is introduced, and no one would think of insisting on prolonged work under such conditions. Where, then, is the economic or critical limit to intensity? One hesitates to say, and can merely report that the most progressive firms are using, and the leading specialists are recommending, from 10 to 15 foot-candles for general clerical work. What the standard will be a decade from now cannot be accurately foretold.

One often hears the criticism that a certain place is over-lighted, and a much quoted report of some medical men who investigated office lighting conditions in lower New York City, characterized the majority of them as "over-lighted." A subsequent casual investigation revealed this same general group of buildings to be even below the standards then prevailing for good office lighting.

Glare is the element of lighting which causes the layman to refer to a place as over-lighted. These offices were in general glaringly lighted. Glare is the element we must guard against if the advantages of higher levels of illumination are to be realized.

Method of Lighting

A few years ago each desk had a portable lamp directly above it and a few overhead units. This is what is termed a combination of local and general illumination. It was a necessary condition, since the lamps were not efficient enough to warrant supplying a sufficiently high intensity throughout the entire

Night View of Totally Indirect Lighting in a Small Private Office. In this installation each outlet supplies 3 75-watt MAZDA C lamps which are placed in inverted mirrored-glass reflectors concealed in a spun metal housing. The intensity of illumination is approximately 9 foot-candles

room. An office with a multiplicity of drop lights is unsightly, the cost of wiring is high, and there is a heavy expense when wiring is changed as the position of the desks are shifted. The employees are likely to change the location of lamps by tying the wire to some stationary object, a practice which is objectionable from a standpoint of safety and forbidden by the wiring codes.

Local lighting is objectionable as there is a great liability of glaring reflections from the desk surfaces and glazed paper; the clerk loses time shifting the light about, breakage of lamps is increased, and there is often marked contrast between the brightly lighted desk area and the rest of the room which does not make an efficient condition. Now, therefore, general illumination is practically standard. Overhead units alone are used—lighting the whole room uniformly—so placing the lamps that they are well out of the ordinary angle of view, equipping with diffusing glassware, and arranging them in such a manner that dense shadows are avoided. This scheme also permits the use of larger lamps, which, as a general thing, are more efficient than the smaller sizes. Since fewer outlets are required the cost of wiring is reduced. A great deal of careful investigation has proved, without doubt, that general illumination is a real economy, all things considered, in comparison with local lighting.

Comparison of Systems of Lighting

Direct lighting with efficient reflectors is unquestionably the most economical, as far as current consumption is concerned, of the three methods, for with it the color of walls and ceilings have less effect on the resultant illumination. Direct lighting, if im-

Semi-Indirect Lighting in Small Office

properly arranged, may produce glare either from the light sources themselves or by reflections from the objects lighted, or it may distribute the light unevenly and as a result produce dense shadows. It is not generally as decorative as the other methods. Nevertheless, thousands of satisfactory installations of good direct office lighting are to be seen, employing translucent glassware rather than opaque reflectors, thus avoiding the undesirable condition of a dark ceiling and the gloomy appearance of the room. Many forms of semi-enclosing glassware of the direct type are giving very satisfactory service.

Totally indirect lighting is probably the most "fool-proof" from the standpoint of a glaring installation. The light is usually

Semi-indirect Installation in Small Office

evenly distributed and comfortable. Objections have been raised that there is a total absence of shadow, making the room appear flat. If the system is properly designed, however, this is not true.

Semi-indirect lighting is an intermediate practice; it is more efficient than totally indirect and much better for the eye than the average direct lighting system. Semi-indirect lighting is not glaring if the proper unit is chosen; it can be made very decorative, the light is quite evenly distributed, and such shadows as are produced are very soft and do not become annoying. The fact that the place where the light originates is readily discernible, has a psychological effect on the average individual and makes many people feel more at ease under semi-indirect lighting than under totally indirect.

A semi-indirect unit, first, should be of quite dense glass; in other words, transmit but a small portion of the light, if the best conditions for the eye are to be obtained. If light density glass is used, the bowl becomes very bright and the system loses many of its advantages, dropping back to the direct lighting class where a number of fairly bright objects are in the field of vision.

Second, the fixture or hanger used should be of such a length and the socket in the proper relative position to the bowl that the light is directed in such a maner as to illuminate the ceiling evenly. Many cases can be noted where the lamp is placed too low in the dish, concentrating the emitted light in a fairly narrow angle resulting in a ring or circle of very bright illumination on the ceiling directly above the unit with the spaces between units

Common Sense Office Lighting of a Modern Type. 150-watt clear MAZDA C lamps are used on 10 ft. centers, 4 outlets per bay. The resultant illumination is slightly over 9 foot-candles

comparatively dark. At other times to get rid of this effect, the lamp is raised so high that from some parts of the room the filament becomes visible, introducing glare. On the introduction of the Mazda C lamp with its rather concentrated filament, this feature became of more importance than formerly.

Third, the glass used should be smooth inside and, preferably, outside, as roughed glass collects dirt very readily and is difficult to clean. Needless to say, all lighting fixtures should be regularly and carefully cleaned to keep the illuminating efficiency at a maximum.

Fourth, the means of suspension of the bowl should be such that there is absolutely no danger of the glassware falling and it is desirable to have some convenient means of cleaning.

The primary purpose of the fixture is to support the lamp and glassware and in most commercial installations should be as simple as possible, of plain, well finished metal. In a decorative interior, such as a director's office, the ornateness of the fixture is of more importance and its artistic value should be given due consideration.

Fifth, in the commercial office the decorations of the glassware, if any, should be very simple, for any appearance of excessive ornateness would be out of keeping with the character of the room. Deep crevices in the glass, although they may be decorative, are objectionable from the standpoint of dust accumulation.

With indirect or semi-indirect systems it is very essential that the ceiling be light in color, white or slightly cream, to secure the maximum efficiency of reflection.

Spacing of Outlets

In practice a rough general rule, "never space outlets much further apart than the ceiling height," works out quite satisfactorily.

In planning the location of outlets, it is desirable to space these symmetrically with regard to the bays or columns. The number of outlets per bay will, as stated above, depend on the ceiling height. Standard construction is tending toward 20-foot bays in office buildings and for the ordinary heights of ceiling 4 outlets per bay are to be preferred. If the bays run larger than this it is often advisable to increase the number of outlets to 6, as future demands may necessitate the dividing of the large space into two or more small offices. The 6 outlets per bay arrangement often meets these conditions without necessitating any additional wiring. In some cases additional outlets are provided, but not fitted with fixtures (the outlet box merely being covered with a neat cap) to make provisions for the future and avoid the necessity of opening the ceiling for rewiring.

In cases where an unsymmetrical arrangement of outlets is necessary, they should be located relatively nearer the windows than the inside wall for the predominating light will then come from the same direction as daylight.

In wiring large offices lamps should be controlled in rows parallel to the windows rather than in groups perpendicular to the windows. In this manner the center of a wide room which has the first demands for artificial light, can be turned on before light is required nearer the window.

A High Intensity of Illumination if Provided in this Room by 300-watt Clear Mazda C Lamps in Deep Bowl, Dense Opal, Inverted Reflectors. This type of illumination gives diffusion and eliminates dense shadows

It is very rarely that an office can be lighted satisfactorily by one outlet, and even a small clerical office should have from 2 to 4 outlets, depending on its size.

Wattage Required

Good practice in office lighting where equipment employing clear bulb lamps is used calls for from 1½ to 3 watts per square foot depending upon the effectiveness of the equipment employed, the size and proportions of the office, the color of the ceiling and walls, etc. Equipments of the enclosing light-directing type in either opal or prismatic glass, the semi-enclosing type, and the semi and totally indirect type, are adapted to the use of either clear or daylight lamps. The use of daylight lamps is preferred by many because of the fact that the artificial light then blends with daylight and the transition from one to the other is made less noticeable. Where daylight lamps are used, about 50 per cent. more wattage is required for the same ilumination, than is required where clear-bulb lamps are employed.

In small rooms, since a greater proportion of the light strikes the walls, a smaller proportion of the illumination will be effective than in a large room with the same size lamps and same equipment.

For private offices, it is often very satisfactory to provide a relatively low intensity of general illumination by some decorative central unit and use a localized light of satisfactory design for the desk. This should be located in such a manner as to prevent glaring, annoying reflections. In any office where glass tops are used on the desks, particular attention must be paid to the type of lighting fixtures to avoid reflections.

Drafting Rooms

Although the lighting requirements of the drafting room are somewhat exacting, they may be readily met if due care be taken in the selection and location of lighting units. The ideal condition is an even distribution of well diffused light of a high intensity. Shadows must be minimized as they make it difficult to follow the fine lines when one is working close to the T square or triangle.

A high intensity of illumination is necessary. Five foot-candles is the minimum and should be supplied only for rough work. For the most exacting work, such as tracing from blue prints, from 10 to 20 foot-candles will be required.

The discussion given under office lighting applies to the drafting room. The requirements are even more exacting as the work is of a higher grade and must be accurate. Semi-indirect systems, where dense glass is employed, or totally indirect systems, are probably the best suited, using from 1.5 to 3.5 watts per square foot.

Direct general illumination of a high intensity using rather close-spaced semi-enclosing units is also used, where the ceilings are so dark as to preclude the use of indirect systems, and found satisfactory. The units should be located with reference to the drawing tables and so arranged that the maximum light will come from the proper direction. Lamps must be hung well out of the angle of vision and every effort made to avoid glare.

In both the direct and semi-indirect systems of illumination due note must be taken of the usual arrangement of boards relative to the windows, locating the lamps so that, as far as possible, the direction of predominant light is the same as that of daylight.

A system which is quite frequently found is the use of a diffused general illumination (1 to 2 foot-candles) supplemented

Lighting of the Drafting Room

by a local lamp for each drawing board. This unit may be of several varieties, fixed or movable, attached to the wall or to the drawing board, opaque or diffusing reflector, and various sizes of lamps; but in any case it is open to the usual objections of local lamps, namely, liability of glaring reflections, loss of time in shifting the lamps, and relatively high maintenance cost.

Tracing may often be satisfactorily accomplished by having the top of the tracing table made of etched glass, and lamps with suitable reflectors placed below the glass, illuminating the work from beneath rather than from above.

PART VI

SCHOOL LIGHTING

Dr. Wm. M. Howe of the New York State Department of Education, states: "I believe that, in time, any school service that does not prevent most of these ocular defects, with which we are meeting so often, will be considered inefficient and derelict in its duty to school children. There is something intrinsically wrong in any educational system that permits from eight to fifteen per cent of our children to acquire defective vision within the few years of their school lives. Few children, as you know, are born with defective eyes."

Proper lighting of the school house should not be considered an expense but an economy. If, due to defective vision, a pupil is forced to spend one extra year at school, the cost of teaching this one student for a longer period than normally, will much more than offset any of the expenditures necessary for proper lighting. Statistics reveal that these cases are legion.

Illumination Values

It is self-evident that the proper amount of light must be supplied for any kind of work. The correct foot-candles are necessary in order that everything which is to be seen may be seen clearly and without fatigue. No matter what system is used, unless enough light actually reaches the desks, then the lighting system is inadequate.

The following table indicates the minimum intensity of illumination it is desirable to provide in the school house.

Classroom	5—10 foot-candles on desks
Study Room	5—10 foot-candles on desks
Office	5—10 foot-candles on desks
Cloak Room	1—3 foot-candles on floor
Corridor	2—4 foot-candles on floor
Laboratory	6—12 foot-candles on tables
Auditorium	4—8 foot-candles on floor
Drawing	10—20 foot-candles on tables

While such values as given above will produce satisfactory results, the higher, rather than the lower intensities are recommended. With the higher intensities, an increased degree of perception is obtained. If increased production in industrial plants and offices can be profitably brought about by high level lighting, why should not increased speed and accuracy of accomplishment on the part of the pupils likewise be worth while?

As an unfortunate result of our ecomonic system, students are usually compelled to work under less light than is provided in industry for similar operations. In reality, more light is needed because the pupil in the process of learning has to give closer visual attention than a workman to whom a process becomes more or less automatic.

Diffusion

The harmful effects of glare cannot be over emphasized. The likelihood of glare from light sources is becoming greater and greater with the development of higher efficiency lamps with their increased intrinsic brightnesses.

We therefore always reduce the brilliancy of the light by means of diffusing globes, shades or reflectors which either effectively enlarge the light sources or actually hide them from view.

Diffusion also softens the shadows so that severe contrasts are less likely to occur. It is not desirable, however, to go to such an extreme diffusion that we entirely eliminate shadows, for they are very essential to show the contour or shape of objects. Over-diffusion or flat illumination is trying to the eyes and unpleasant.

Not only must we take care of the light sources themselves in providing diffusion, but the walls and objects in the room must be given attention as well. Dull rather than polished surfaces are desirable here, and even a depolished or waxed finish is more desirable than varnished or highly polished surfaces on the desk and other furniture, as the latter produce mirrorlike effects in reflecting the light sources.

In this connection, attention should also be given to the desirability of mat rather than glossy finished paper for paper with a glossy finish likewise reflects light in an annoying manner.

GENERAL CONSIDERATIONS

The Classroom

In most interiors we space outlets symmetrically throughout the room, but with the schoolroom, as with the machine shop, the shadow effect is very important, so we have the maximum light coming slightly forward and from the left to diminish the head and hand shadows; as far as possible the direction of daylight is imitated, sometimes much improved.

To accomplish this we arrange outlets as shown in Fig. 1, "favoring the window side."

More outlets are required for direct lighting than for the indirect systems, in order that multi-directional light may be provided. It is always desirable to hang units as high as possible to keep them out of the field of view. No lighting units should come below a line extended from the eye of a student in the rear seat to a point two feet above the blackboard.

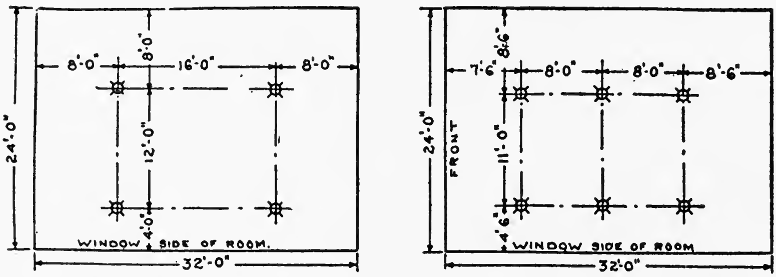


Fig. 1.

Typical Arrangement of Outlets for the Average Size School Room (24 x 32 ft.). The Size of Lamp Specified Represents Good Practice Fulfilling the Intensity Requirements Set Forth in the Text. A—Four 200-Watt Clear Mazda C Lamps in Dense Glass Semi-Indirect Units, Totally Indirect Equipment or Enclosing Diffusing Globes. B—Six 100-Watt Bowl Enameled Mazda C Lamps in Etched Prismatic or Dense Opal Deep Bowl Direct Lighting Reflectors

Blackboards

There is a likelihood of glaring reflections from blackboards and they should, therefore, always have mat rather than polished surfaces. It is sometimes possible to get rid of this reflection by tilting the boards slightly. Blackboards on which colored chalks will be used and those that are more than twenty feet away from the pupil should be especially lighted to an intensity approximately 60 per cent higher than the intensity in the rest of the room. This can be accomplished by the use of properly screened and judiciously placed local units similar to the systems commonly used on outdoor signs and billboards. For clear vision, blackboards should not be located between windows.

Comparison of Various Lighting Systems

Direct, semi-indirect, and totally indirect systems are all employed for school lighting. Each has certain advantages and disadvantages which are outlined below. A number of factors must be taken into consideration which may be briefly stated as below:

Quality of illumination produced.
Convenience of maintenance.
Appearance of the installation.
Efficiency of the system.
Ability to provide the desired intensity.
Cost of installation.

Certain systems may appear to be most desirable from theoretical considerations, but may not work out well in practice. Obviously, the type of lighting unit to select is the one which will give a desirable quality of illumination in as efficient a manner as possible, over a long period.

The proper maintenance of a lighting system in any class of service is of very great importance. Even greater emphasis must be laid on this question in the school, for supervision is at best meager and periods between cleaning are of considerable length. These conditions should not exist but nevertheless, we must recognize that such is the case and take this into consideration when planning the lighting.

Totally indirect lighting produces a very high quality of illumination, but requires a relatively large wattage for a given intensity. With such a system, there is little possibility of glare and the light is very soft and comfortable to work under. Glaring reflections are at a minimum. The inverted bowls, however, tend to accumulate considerable dirt and unless cleaned frequently the light output is materially reduced.

Semi-indirect lighting is an intermediate step, most of the light from the lamps being directed to the ceiling, with a slight amount transmitted through the glassware. It is slightly more efficient than totally indirect lighting, the resultant illumination is well diffused, and such shadows as are produced are very soft and do not cause annoyance. The best forms of semi-indirect units for school work employ dense glass or some other means of reducing the brightness of the lighting unit.

There have recently appeared on the market, a number of totally enclosing, semi-indirect units which are relatively easy to clean and therefore offer special advantages.

In many of the older installations, open bottom, direct lighting units are used. Such a system is obviously efficient from the standpoint of light utilization, but the diffusion is not of the highest quality, shadows and contrast are likely to be rather severe, and direct and reflected glare become serious, particularly if clear bulb lamps are employed. The use of this form of lighting is only advisable where costs must be kept at a minimum and

Class Room Lighting

where secondary consideration is given to the quality of illumination.

Where direct lighting is deemed advisable, dense opal or etched prismatic reflectors should be used. These transmit but a small portion of the light, and they, therefore, are not very bright. The diffusing bulb or bowl enameled Mazda C lamp should always be employed with open reflectors in preference to the clear lamp, as these finishes produce better diffusion, reduce reflected glare and soften shadows.

The flat type reflectors should never be used in a schoolroom, for it is almost impossible to conceal the filament from view when using this style of shade. Opaque reflectors are, of course, generally unsuited, as the ceiling would be very dark when these are used.

In view of the above analysis, the enclosing, diffusing, direct lighting luminaire seems to be, at the present state of the art, the most generally applicable equipment for classroom lighting. If the proper type is chosen, a well diffused illumination, quite free from direct or reflected glare, is produced. Although the major portion of the light is directed downward, a considerable amount is transmitted upward, thus giving a cheerful appearance to the room and a character of illumination closely akin to that produced by semi-indirect units. It is apparent that such equipment does not depreciate as rapidly with the accumulation of dirt as do other fixtures producing the same general quality of illumination. This should not be taken to mean that cleaning can be neglected, for it is always of prime importance.

A typical specification for a suitable school lighting unit of the diffusing enclosing type, might be drawn up as follows:

Class Room Lighting

The glassware shall be of thin blown-opal or cased glass giving good diffusion with low absorption.

It shall be of such a size that the brightness, with recommended size of lamp, is not uncomfortable even when the unit is viewed for long periods of time.

It shall be of such a shape that a horizontal section is greater than a vertical section.

The supporting holder shall be sufficiently strong and of such a type as to preclude any possibility of the glassware falling.

The method of support shall be such that the globe can be readily removed for cleaning.

Similar specifications can be readily drafted for other forms of equipment.

Corridor

The lighting can be accomplished with relatively low wattage lamps, on fairly wide spacings, provided diffusing glassware is employed. Uniform illumination is not necessarily essential. Smaller sizes of the same general type of equipment as used in the classroom can be utilized for the corridor. A row of outlets, symmetrically spaced along the center line of the ceiling, is generally to be preferred, although sometimes the structure is such as to make ceiling outlets inadvisable. In these cases, brackets or wall fixtures must be employed. In general, 75 watt Mazda C lamps on 15 foot centers are adequate. With corridors over 8 feet wide, larger lamps are necessary.

Laboratory

The laboratory requires a relative high level of illumination in order that the progress of experiments may be carefully watched. The general layout suggested for the classroom is satisfactory for the laboratory. In the chemical department, however, acid fumes will attack metal parts of ordinary fixtures and soon make them useless. For this reason porcelain enameled reflectors and porcelain receptacles or sockets are well adapted. The RLM standard dome reflector with bowl enameled Mazda C lamp makes an excellent lighting device for such rooms. It is efficient, durable, inexpensive, and diffuses the light satisfactorily.

Auxiliary Outlets

The stereopticon and motion picture machines, as well as many electrical devices, are becoming important factors in our educational system. Every classroom should have an outlet to which these can be attached.

The auditorium should have a well equipped motion picture booth for exhibiting standard films. The Mazda lamp for motion picture projection, with its economy and convenience of operation, is a boon to the school.

PART VII
RESIDENCE LIGHTING

Introduction

When we realize the amount of time that we are dependent on artificial light, it is not surprising that devices which give proper illumination are receiving more and more attention. In the home, the useful and decorative phases of lighting must be combined, neither one being emphasized at the expense of the other. The decoration of a room may be absolutely spoiled or given the final touch of perfection by the lighting effect. Time, care, and considerable money are spent in establishing harmony of the furniture, hangings, and room finish, and avoiding any discord between the styles of furniture used. But of what use are these refinements in the matter of the decorations and furniture unless the lighting is such that these elements can be appreciated? It must be remembered that, as a general rule, it is during the hours when we need artificial illumination that we wish the house to appear at its best. Comfortable lighting makes pleasant surroundings enjoyable, but with poor illumination the carefully planned details of the room are ineffective.

Fortunately, with the wide range of sizes of efficient lamps and the number of styles of standard lighting equipment available it is possible to have extremely effective lighting. The intensity of light desired for any particular purpose can be obtained without the objectionable feature mentioned above. No longer is it necessary to have only one light source in a room. The more reasonable way is to have a lighting system that can be readily adapted to the requirements of the people rather than making it necessary for them to adapt themselves to such lighting as happens to be available.

As an example of this, let us consider the living room of an average home. In this room many recreations are enjoyed. Reading requires more light than talking, but music is more enjoyable in what is known as a "half light." If then, we are able to have the room softly lighted by decorative table lamps with the help of wall brackets, we can produce a general atmosphere of quiet contentment, the portable lamps furnishing illumination for those reading beside them. For a comfortable game of bridge, it is a necessity that each player be able to see his cards easily, without holding his hand to avoid shadows. The most efficient way to furnish equal light for all is to make use of a ceiling luminaire of the semi-indirect type, which will light the whole room to an even intensity. The advantages of variable lighting are readily appreciated, not only in the living room, but in all other rooms of the home.

Systems of Lighting

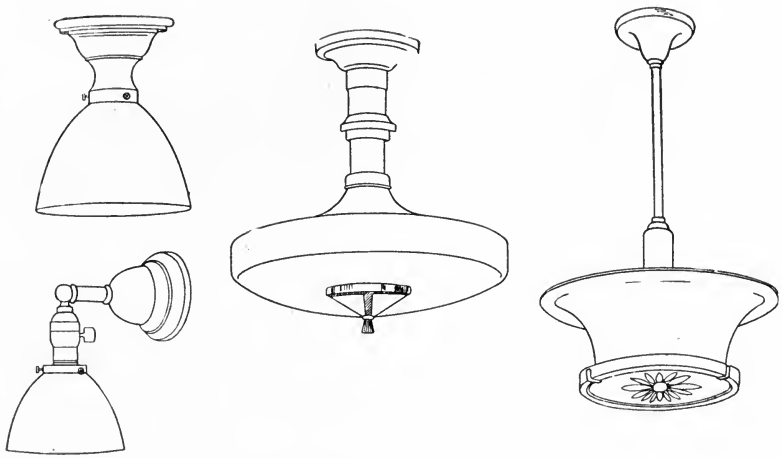
There are three general ways of lighting a room, i.e., by direct, totally indirect, or semi-indirect illumination. With luminaires of the first class, shades are used that send the dominating light directly down where it is to be used. The dining room dome, the shower fixtures, the pendant wall brackets, and the ordinary table lamp, all are examples of this type of lighting.

Just the opposite effect is obtained by using the indirect system because, in that, all the light is directed to the ceiling which in turn acts as a large reflector and distributes the light throughout the room. No dense shadows are created because the light, being reflected from such a large surface, is well diffused. This type of lighting can be obtained from special portable lamps, with inverted reflectors on the tops of bookcases or in wall urns, as well as from ceiling luminaires.

Now, if the inverted bowl instead of being opaque allows some of the light to be transmitted through it, still reflecting a greater portion to the ceiling, we have an example of semi-indirect lighting, another form of this being a translucent reflector on an upright wall bracket.

Kitchen

The unfortunate part of the ordinary kitchen luminaire is its inability to be adapted to much improvement. The combination gas and electric stem luminaire places the lamp so low that the only thing it can do is to cast the shadow of the worker on the work. The designer of such a luminaire seems to have the mistaken idea that the light is wanted on the floor in the center of the room rather than on the stove or sink. Then, too, the glassware that is used is ineffective. There is really little that can be done to improve this luminaire save by the substitution of diffusing bulbs for clear lamps. If satisfactory lighting is desired, this luminaire should be replaced by one which carries the lamp close to the ceiling and is furnished with a glass reflector that will assist in distributing the light around the sides of the room. Of course, if the room is large, this ceiling light will have to be aided in its efforts by wall brackets in the darker parts. The shades used should be of dense opal glass with smooth, easily cleaned surfaces. For places of average dimensions, a 75-watt white



Typical Luminaires for the Kitchen Which Will Provide Suitable Lighting if Properly Applied

or a 100-watt bowl enameled MAZDA C lamp in an 8-in. diameter reflector should be used in the ceiling unit, while 25-watt all frosted MAZDA B lamps in 6-in. reflectors will serve on the bracket luminaires. Such a combination will do away with objectionable glaring reflections that a bare light source will give when bright pans are used.

When the ceiling is painted a light color, a semi-direct system of lighting is effective. With this installation, only the ceiling luminaire is necessary and yet the shadows are reduced to a minimum. A 100- or 150-watt clear MAZDA C lamp in such a luminaire will provide adequate intensity in the typical kitchen.

A wall switch near the doorway is a most desirable feature, but its absence will not prevent the use of a luminaire hung out of reach, for chain pull sockets with a length of cord and luminous indicator may be used to control the light.

Whatever form of lighting is employed, it is highly important that convenience outlets for the iron, percolator, or fan be provided. The position of the outlet to which the iron will be connected merits consideration and should be such that the minimum of shadows is cast on the board both in the daytime and at night.

Another way to make the kitchen as comfortable and as easy to work in at night as it is in the daytime, is by the use of Mazda daylight lamps. The daylight quality of the light not only makes a cleaner looking kitchen, but, just because it is like daylight, stains are more readily visible and therefore the kitchen actually is cleaner.

Butler's Pantry

If the outlet is not already in place, it is preferable to have it installed directly over the sink. A direct lighting opal reflector, 50-watt Mazda lamp, close ceiling luminaire, with pull chain socket, may well be used here. When the outlet is already in the center of the room, this type of lighting is not advisable becuse of the shadows that will be cast by the worker on the sink. Under such conditions, semi-indirect lighting is preferable and a harp type holder may be used that suspends an opal glass reflector under the lamp. A convenient outlet near the sink is desirable for attaching a small motor for polishing silver or other time-saving devices.

Laundry and Work Bench

As a usual practice, the washing machine is installed in the basement and artificial illumination will probably be necessary whenever the machine is used. High level illumination is a desirable factor here and Mazda daylight lamps make it easier to detect stains on linen. The 100- or 150-watt bowl enameled Mazda C lamps in RLM Standard dome reflectors make an efficient luminaire giving the desirable quality of diffusion and distribution. The type of direct luminaires suggested for the kitchen is also applicable where the laundry is "finished off."

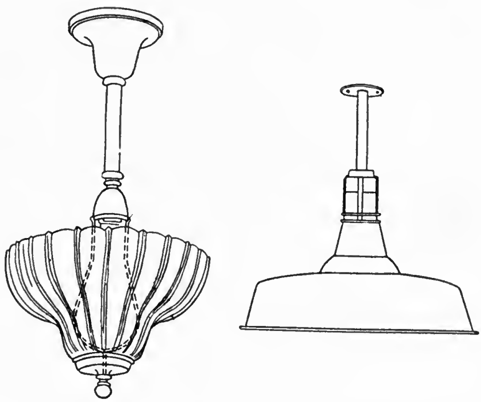
The location of convenience outlets for the washing machine and ironer should be considered with respect to the position of the light source. For hand ironing, an outlet on a drop cord is preferable to one in the side wall or baseboard in giving greater latitude in the work.

The lights for the cellar proper should be so distributed as to illuminate the foot of the stairs, the furnace, coal bins, and cold pantries. If the ceiling is finished in a light color, flush or surface receptacles with diffusing bulb, low wattage lamps without reflectors will give a wide spread of light at a low cost of installation.

At least one of the cellar lights should be controlled from the head of the stairs and it is desirable to have some sort of a pilot device to indicate whether or not the lamps are burning.

Den or Sewing Room

The lighting requirements of these two rooms are so similar that they can well be discussed together. For close work, either in sewing or keeping records, a high intensity of illumination is necessary. For ordinary purposes, however, we do not want to have the whole room as light as this. A combination of lighting is desirable, a central diffusing luminaire to furnish general illumination of moderate intensity, and a portable luminaire for the close work.



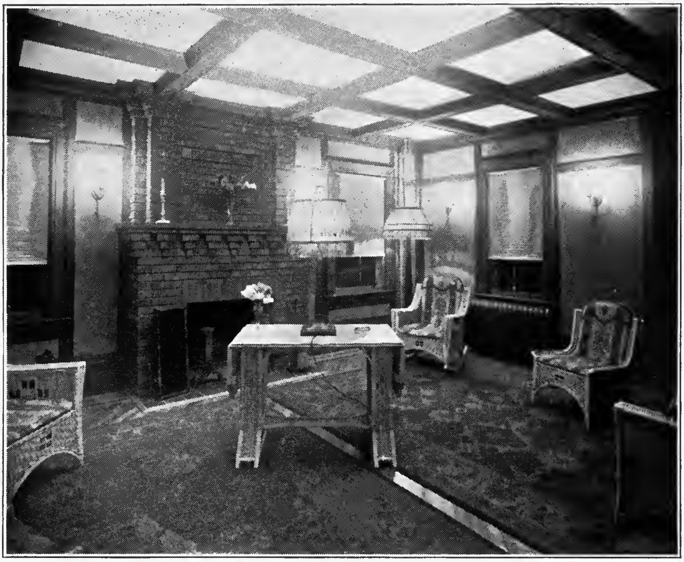
A Simple Means of Obtaining Semi-indirect Effects from a Direct Lighting Luminaire and the Efficient RLM Standard Dome Reflector for Lighting the Basement and Garage. The porcelain enamel resists attacks of moisture

Living Room

The living room is the scene of the social life of the house, and the lighting of such a room should receive special attention. It must be agreeable and bring out the especial points of the decorative scheme. It will not be a full success if it makes people look tired, old, or unattractive, by bringing out sharp facial shadows. Into this room novel effect may be introduced that vary the monotony of ordinary lighting. Small lamps burning inside translucent vases render them luminous and show beauties that would otherwise not be noticed. The possibilities in the way of special effects can be utilized only when an adequate number of convenience outlets are available. Ingenuity will soon indicate many expedients by means of which the little touches of color, that aid so much in the appearance of the room, can be introduced at will.

For general lighting, when only one outlet is available, a semi-indirect luminaire will more nearly meet the average requirements than any one type. A lamp of sufficient size can then be used to furnish the necessary intensity and the light will be comfortable and devoid of glare, provided a proper design is chosen.

A 100- or 150-watt Mazda C Lamp will usually provide a de-



Adaptability is the Keynote of the Lighting Shown in This Room. 150-watt Mazda C lamps are used in inverted reflectors in the portables. 15-watt all frosted Mazda lamps in the brackets are concealed by shields harmonizing with the wall coverings

sirable intensity of illumination with semi-indirect luminaires in rooms of average dimensions.

There are innumerable period styles of luminaires suitable for the living room. A few typical examples are indicated in the accompanying sketches. In choosing luminaires of this nature, the cardinal points in regard to distribution of light, contrast, and direct glare must be kept in mind. Very rarely is it feasible to use lamps without some sort of a shade or diffusing medium.

With a suitable number of wall and convenience outlets it is good practice to light the living room without a central or ceiling luminaire, and, in this event, table and floor lamps may be used to advantage.

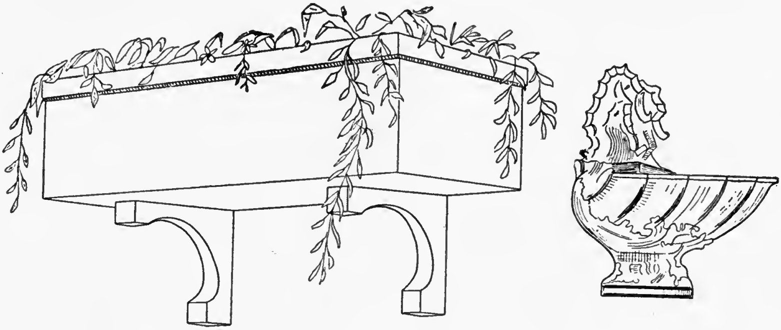
The Styles of Portable Lamps Giving Good Results Are Innumerable. These are just a few suggestions

All portable lamps should be chosen with particular thought given to the shades. It is always objectionable to be forced to look at a lamp and the shades must conceal the light sources from one sitting near them. The materials used should be dense enough that the filaments do not show through and as pointed out before, it is always desirable to use diffusing bulb lamps in any kind of direct luminaire. With skillful selection, a shade will become an integral part of the color scheme of the room in the evening, as it is during the day. Sometimes, however, a color is used that harmonizes well enough with the drapes and furniture covering but when the shade is lighted, the effect is far from desirable. This danger is most likely to be present when green or blue color schemes are employed. The best solution for such a condition is to have the exterior layer of particularly thin material, such as chiffon or georgette crepe and the lining a rather heavy rose, buff, or cream. The resultant light will be toned by the lining and ghastly effects eliminated.

A wall switch is the most desirable for controlling the lights in the living room, and it is generally advisable to have the

A Few Styles of Direct, Semi-Indirect and Totally Indirect Ceiling Luminaires Suitable for the Living Room Under Various Conditions
Glass shades for candle fixtures are now available in very rich and decorative designs

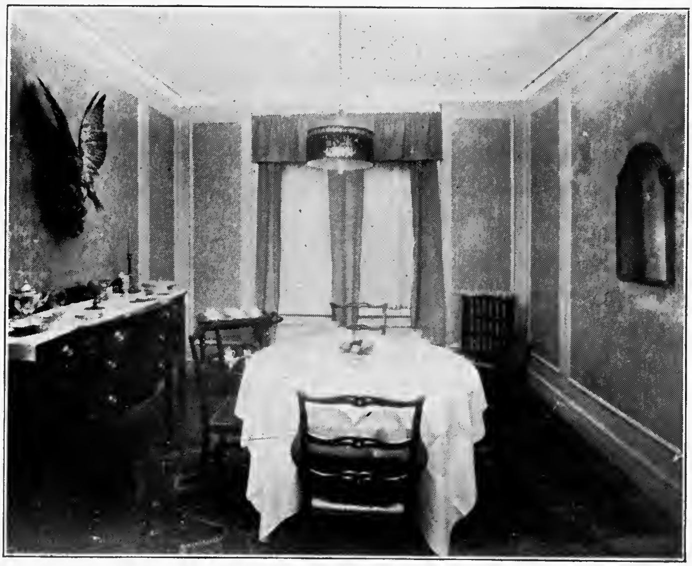
central outlet and wall brackets on separate circuits. Absence of a wall switch will not make it impossible to use semi-indirect illumination, for small switches can be neatly concealed in the canopy fitting and operated by a fine cord. The living room requires the maximum number of convenience outlets for attaching the portable lamps, electric fan, phonograph motor and special decorative lighting effects.



Various Means for Lighting the Living Room from the Sidewalls

Dining Room

This room has lighting requirements peculiar to itself; rarely



This Night View of the Dining Room illustrates the Even Illumination and Absence of Shadows Characteristic of Semi-indirect Lighting

is it used as anything but a place to eat. The interest therefore is primarily centered on the table and this interest may be increased by having the table lighted to a higher intensity then the rest of the room.

It is a matter of personal taste which way the dining room shall be lighted, whether by direct or indirect methods. The old style dome, while often crude and inartistic, provided a most desirable distribution of light. The table was the brightest spot in the room, yet enough light was transmitted through the glass to illuminate the corners of the room, preventing too great a contrast. There are several requirements which must be fulfilled where a dome is employed. It must be hung high enough that one can see the person on the opposite side of the table and yet not so high that the lamps are visible. This will place the bottom of the dome about 56 inches above the floor. A dome can often be made more effective by using a small direct lighting reflector inside of the fabric or glass to send the light downward and conceal the lamp from view. A number of styles of domes have recently appeared on the market much more artistic than those produced in the past, and hence more generally applicable to the home where harmony is sought. A 50-watt White Mazda lamp will give the desirable intensity on the table top when a dome is employed although in individual instances, higher or lower values are considered more pleasing.

Some people prefer the room more uniformly illuminated and this can be accomplished by the use of the semi-indirect system. By choosing the proper density of glass, a suitable amount of light will be transmitted, the table receiving more light than the surroundings.

For this system, 75-, 100-, and 150-watt Mazda C lamps are applicable, depending on personal preferences as to intensity and on the color of surroundings. It is often possible to provide two circuits in a semi-indirect luminaire, one giving the low illumination for setting the table.

Luminaires should not serve as sources of current for cooking devices. A convenience outlet should be installed under the edge of the table, and this in turn, attached to a floor plug. A baseboard convenience outlet near the buffet or serving table permits the percolator, toaster, or grill to be used without the unsightly collection of cords dangling from overhead, as is too commonly the case.

Hall or Reception Room

Every room in the house has a particular meaning and, as the hall is the first one entered, a feeling of hospitality should prevail. Lighting can be of great assistance in attaining this end.

There are two kinds of halls just as there are two varieties

Some Well Designed Dining Room Units. It is of interest to note the tassel at the bottom of the semi-indirect bowl. This conceals half of an attachment plug for use with cooking devices. The wicker dome carries an opalescent reflector indicated by dotted lines

of porches. One is merely a space between the front door and the rest of the house, the other is of the reception room type. In the first class a moderate intensity of illumination suffices and a 25-watt Mazda lamp in a suitable diffusing globe close to the ceiling will furnish enough light for removing one's wraps. The upstairs hall has generally the same requirements and may be similarly lighted.

The methods of lighting the living room are quite generally applicable to the hall of the reception type. Urn shaped enclosing globes are also harmonious with many interiors.

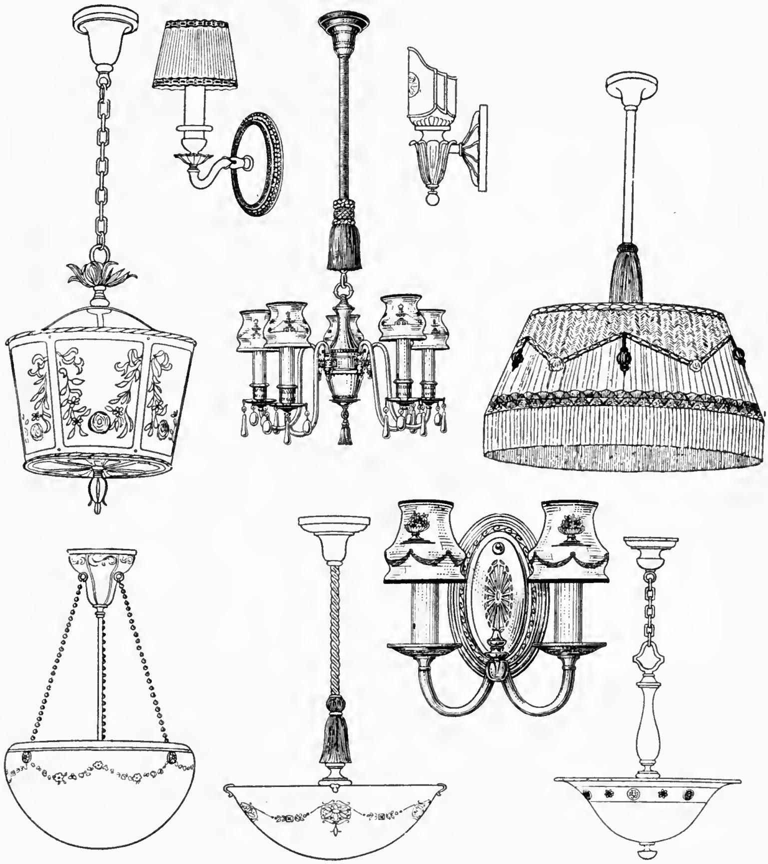
The control for hall lighting is important. Three-way

These Examples are Typical of the Variety of Luminaires that are Suitable for the Reception or Formal Hall

switches are most desirable, one near the entrance doorway and the other at a convenient point in the second floor hall. The slight additional expense in installing these is more than offset by the security and comfort gained.

Bedroom

The general arrangement of lighting outlets in the bedroom will depend upon the placement of the furniture. In most cases it is desirable to provide a low intensity of general illumination from a central luminaire, preferably of the semi-indirect type, although frequently silk-shaded direct luminaires are suitable; from 40 to 75 watts are desirable in this unit. It should be controlled by a wall switch near the entrance doorway to avoid stumbling about in the dark in search of the key-socket.



Dainty Decorative Luminaires Suitable for the Boudoir are Numerous. One should be chosen which blends with the color treatment of the room. Candle fixtures shaded with richly colored glass give good illumination together with pleasing color effect

A higher intensity of illumination is required at the mirrors or dressing table and this can be obtained by wall brackets or pendant dresser lights harmonizing with the central unit as well as the room decoration. A pendant dresser light should be placed slightly in front of the person using the mirror. A convenience outlet near the bed makes it possible to attach a heating pad, or portable lamp for reading in bed. Another near the dresser is useful for attaching an electric curling iron, heater or fan.

The harmony of equipment in the boudoir is very important.

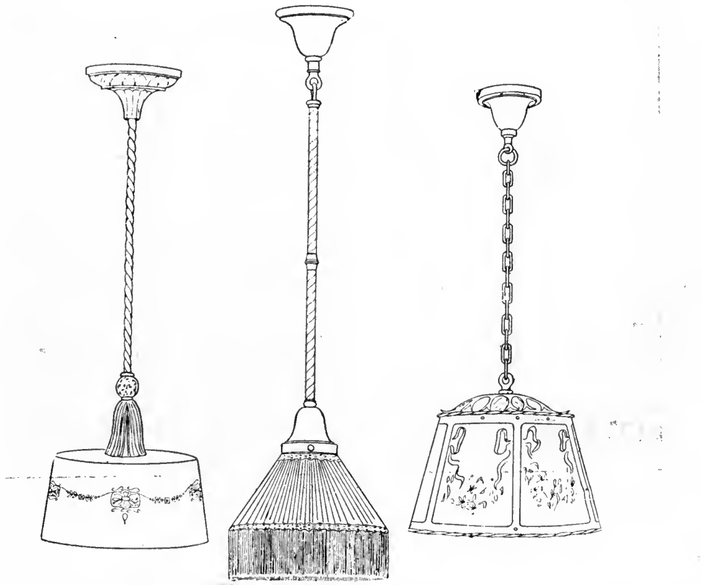
Where the closet is in such a position that it does not receive light from the room itself, a simple type of receptacle should be provided close to the ceiling with a low wattage, diffusing bulb Mazda lamp. A door switch for such a position is a convenience and an economy.

The Day View of This Bedroom Gives a Good Idea of How Different Materials May be Used in the Lighting Equipment and the Results be Harmonious. The fact that all lamps are concealed from view is indicative of comfortable conditions

Bathroom

The mirror is the point of particular interest in this room and the lighting must be planned with this in mind. The face must be well illuminated before it can be viewed in the mirror. Wall luminaires, one on each side, will provide satisfactory illumination for shaving. The 15-watt diffusing bulb Mazda lamps in either pendant or upright shades may be used. A lamp in a simple diffusing globe close to the ceiling may be used for general illumination where additional light is necessary. Care should be taken in locating the lighting outlets in the bathroom in order that shadows of the occupant of the room will not be cast on the window. Convenience outlets are necessary for the electric heater, curling iron, hot water mug, or vibrator.

Neatness and Simplicity are Expressed in Such Luminaires as These Applicable to the Bathroom, Closets and Passageways Respectively



Parchment, Silk, and Glass are Media for Directing and Diffusing the Light. Here they are Applied in Neat Dresser Luminaires

Porch

In order that the home may invite one's friends and repel intruders, the porch should be well illuminated. A porch often serves merely as an entrance, but may act as an outdoor living room. Of course in these two cases radically different lighting will be employed. In the first type, only a small amount of illumination is required for safety and to enable one to see the name plate, doorbell or button. A 10-watt Mazda lamp will burn for a long period at a very low cost and serves excellently on the porch in a weatherproof enclosed type globe, lantern fixture, or luminous house number. An outlet is also necessary at the rear porch or service entrance. In the large porch or sunroom, much novelty can be introduced. Indirect luminaires of metal or actual wickerwork lined with cretonne or tinted glassware are suitable in introducing a touch of color harmony. Artificial or natural flowers or vines can be effectively applied. Convenience outlets on the porch for attaching portable lamps or other devices should be of the

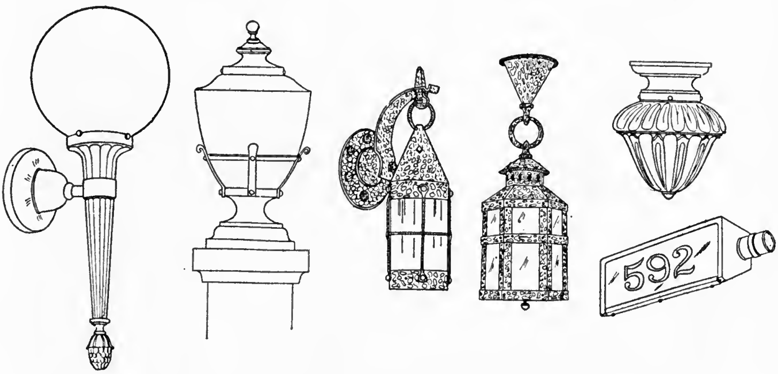
The Indirect Light Sources in This Sunroom Are Inconspicuous by Day and Add to the Decoration When Lighted. 40-watt lamps in metal reflectors are concealed by the artificial flowers in the wire baskets

weatherproof type and located in such positions that they will not collect moisture.

Grounds

While the subject of lighting the grounds is particularly of interest to those having suburban homes, there are still many parts of cities where the street lighting may be supplemented by a lamp at the entrance of the driveway. This light acts as a welcome to guests, as a means of protection, and also will contribute to the appearance of the property. The use of an ornamental standard that matches the architectural style of the house, with an opalescent glass globe or lantern type luminaire, is good practice. A 50-watt Mazda lamp in this will enable the driver of an automobile to see the entrance clearly.

When the driveway is of considerable length, it becomes necessary to place lights at least at sharp curves or particularly dark spots. The size of the lamps used will depend upon the surroundings but Mazda lamps ranging from 25 to 75 watts should fulfill all requirements. It is necessary that these lamps be used on standards that will raise them above the direct line of view of the driver. The glassware used should minimize glare in the driver's or pedestrian's eyes.



The Luminaire for the Porch Need Not be of a Crude Afterthought Nature, but can be Distinctive at a Small Additional Cost

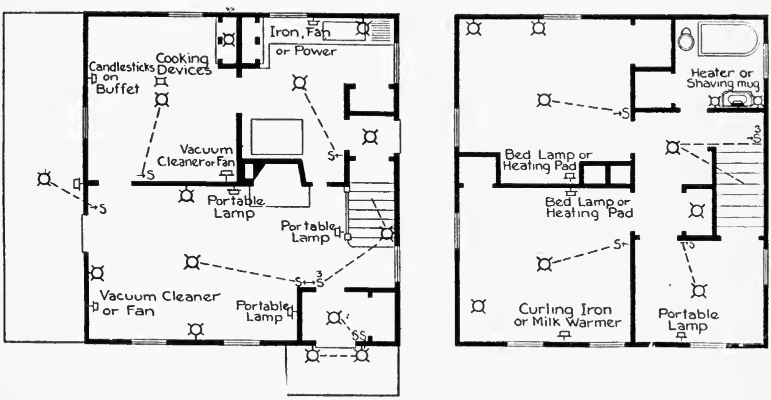
Garage

Electric light is a necessary adjunct to the garage in reducing the fire hazard, promoting safety and making adjustments and repairs in a satisfactory manner. General illumination should be furnished by one or more overhead luminaires, depending on the size of the structure. Bowl enameled Mazda C lamps in steel reflectors, porcelain enameled, of the dome type, are desirable for this service. They should be controlled by a wall switch near the entrance. Several convenience outlets are also necessary with a number of re-enforced cords, Mazda mill type lamps and wire guards, as portable lights. In working on the engine and transmission, such equipment proves of value.

Wiring

The standards for proper wiring from a protective basis are established by local underwriter's codes and ordinances. These must be adhered to. The choice between different systems is governed largely by economic considerations and need not be discussed here.

Attention should be directed to the desirability of making the initial installation complete. A given amount of installation work can be done at much less expense when doing the original work than at a later date. The mistake is often made of omitting convenience outlets and wall switches in order to keep



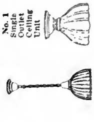
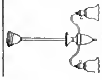
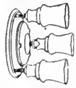
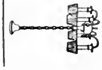
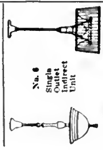
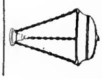
Layout of Outlets for a Typical Small House

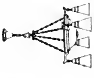
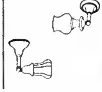
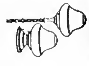
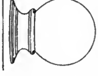
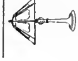
down the cost of wiring. This will certainly be regretted when one begins to appreciate that some of the real advantages of electric service are lost.

The statement can be made with a reasonable degree of certainty that "one cannot have too many outlets." The errors in practice are all in the other direction. A satisfactory layout for the average home would be such as pictured above.

A feature which should be incorporated in each house wired in the future is the use of the Elexit or the standardized luminaire receptacle. This device makes it possible to "hang a fixture like a picture" and one can change bracket or ceiling luminaires at will, without the often prohibitive delay and ex-

pense of calling in an electrician to make any connections.
It will be as simple to move a fixture from one room to an-

GENERAL TYPE OF LIGHTING FIXTURE	RECOMMENDED SIZES OF MAZDA LAMPS for Small Room (9′ x 12′ or less)	Medium Room (Approx. 12′ x 15′)	Large Room (15′ x 20′ or more)
 No. 1 Single Outlet Ceiling Unit	75-watt Bowl Frosted MAZDA C LAMP	100-watt Bowl Enameled MAZDA C LAMP	150-watt Bowl Enameled MAZDA C LAMP
 No. 2 Double Outlet Ceiling Unit	40-watt All Frosted MAZDA B LAMPS	50-watt WHITE MAZDA LAMPS	Fixture is not suitable for a room of this size. If necessary use 50-watt WHITE MAZDA LAMPS
 No. 3 Three Outlet Ceiling Unit	25-watt All Frosted MAZDA B LAMPS	40-watt All Frosted MAZDA B LAMPS	50-watt WHITE MAZDA LAMPS
 No. 4 Four Outlet Ceiling Unit	25-watt All Frosted MAZDA B LAMPS	40-watt All Frosted MAZDA B LAMPS	50-watt WHITE MAZDA LAMPS
 No. 5 Four or Five Light Candlestick Unit	25-watt Round Bulb All Frosted MAZDA B LAMPS When supplemented with wall brackets, 15-watt round bulb all frosted MAZDA B LAMPS.	25-watt Round Bulb All Frosted MAZDA B LAMPS	25-watt Round Bulb All Frosted MAZDA B LAMPS
 No. 6 Single Outlet Indirect Unit	75-watt Clear MAZDA C LAMP	100-watt Clear MAZDA C LAMP	150-watt Clear MAZDA C LAMP
 No. 7 Three Outlet Indirect Unit	25-watt Clear MAZDA B LAMPS	40-watt Clear MAZDA B LAMPS	50-watt WHITE MAZDA LAMPS

 No. 8 Indirect and Four Outlet Pendant Type Unit	For pendant type outlets: 15-watt All Frosted MAZDA B LAMPS | 25-watt All Frosted MAZDA B LAMPS | 40-watt All Frosted MAZDA B LAMPS For indirect outlets Same size of lamps should be used as in other indirect units
 No. 9 Dome Fixture	Single outlet—50-watt WHITE MAZDA LAMP Double outlet—40-watt All Frosted MAZDA B LAMPS Three outlet—25-watt All Frosted MAZDA B LAMPS Four outlet—15-watt All Frosted MAZDA B LAMPS
 No. 10 Side Wall Brackets	When no ceiling fixture is used—50-watt WHITE MAZDA LAMP When ceiling fixture is used—25-watt All Frosted MAZDA B LAMP For passage-ways, halls or decorative lighting—10 or 15-watt All Frosted MAZDA B LAMP
 No. 11 Side Wall Candlestick Bracket	Single outlet—25-watt Round Bulb, All Frosted MAZDA B LAMP Double outlet—15-watt Round Bulb, All Frosted MAZDA B LAMPS
 No. 12 Enclosing Units	For halls and passage-ways—15 or 25-watt MAZDA B LAMP
 No. 13 Porch Fixtures 197	If used for general porch lighting—40 or 50-watt MAZDA B LAMP If used as marker or entrance light—10 or 15-watt MAZDA B LAMP
 No. 14 Table Lamp	Single outlet—50-watt WHITE MAZDA LAMP Double outlet—40-watt All Frosted MAZDA B LAMPS Three outlet—25-watt All Frosted MAZDA B LAMPS.
 No. 15 Floor Lamp	Double outlet—50-watt WHITE MAZDA LAMPS Three outlet—40-watt All Frosted MAZDA B LAMPS Four outlet—25-watt All Frosted MAZDA B LAMPS

The fixtures illustrated above, or units of a similar general type, are typical of those most commonly used in homes today. The lamps recommended will produce the best lighting effects possible with these units.

other as it now is to move a table lamp. A person living in a rented home need not be content with the lighting that happens to be installed but can use his own distinctive, individual fixtures, just as he does his pictures, draperies, and furniture.

The special wiring devices which add materially to the convenience of the installation are almost innumerable. Among them might be mentioned:

The switch handle or small indicator on a pull chain socket provided with luminous material which glows in the dark, making it possible to locate the control readily.

Switches with small lamps concealed in their mechanism which serve to indicate that the attic or cellar lights are burning. Buzzing devices serve the same purpose.

Switches which can be attached to the ceiling or concealed in a canopy where wall switches are missing and it is not deemed advisable to do any extensive wiring.

Three-way switches for controlling the light from two points.

Two or more circuit switches in one mechanism to produce various degrees of lighting by pushing or turning the button a certain number of times.

Switches which operate automatically when a closet door is opened or closed.

Master switches for lighting the whole house from the owner's bedside in case of emergency.

Convenience receptacles which can be installed in the wall, baseboard, floor, or under a table. These should be of the standard type to take a plug with ¼-inch parallel blades spaced ½-inch apart so that all plugs are interchangeable.

Bell ringing transformers which do away with maintaining batteries for this purpose.

Toy transformers which can be used to provide a low voltage circuit that can be safely used in the nursery for children's electric toys.

Sockets to convert candlesticks so that they will serve as electric lamps.

New devices of this nature are constantly being developed and the adaptability of electric service continually broadening in scope.

PART VIII
CHURCH LIGHTING

General Requirements

No set rules can be laid down for designing church lighting as the structures vary widely in type and the artistic effect plays such an important part. In other words, this class of lighting cannot be standardized as that for the industrial plant, office, or store. In attempting to discuss the subject, one can only outline the conditions likely to be encountered and schemes which have proven satisfactory in service.

The illuminating engineer must co-operate with the architect and bear out the latter's ideas with respect to the lighting effect to be attained, and specify such location of units, types of fixture and distributions of light as to meet these criteria. If care is taken in selecting and locating the lighting fixtures, these edifices can be very satisfactorily lighted, for they seldom have brilliant interior finishes to cause glaring reflections; the ceilings usually are high, thus permitting hanging the lamps out of ordinary view.

Observation of actual installations reveals that, if our homes were as poorly lighted as many of our churches, it would soon have a serious effect on our vision. As we are in the church for only a few hours every week, the matter is not given sufficient thought.

In the church, in contrast to the theatre, or assembly hall, the lights are turned on the entire time that the congregation is present, and particular attention must be paid to the arrangement of lighting units, concealing the lamps from view or equipping them with diffusing glassware.

As pointed out, the lighting units should be in architectural conformity with the structure, yet utility of the lighting must be given consideration. By this is meant—first, use every precaution to prevent eyestrain, which leads to drowsiness and attendant discomfort; second, provide enough light in all parts of the room for easy reading. Experience has shown that, if there is no annoying glare or bad contrast, an intensity of from 0.75 to 1.5 foot-candles is sufficient for reading at short intervals, as for instances, during the singing of a hymn or psalter responses.

It is impracticable to specify the wattage necessary to obtain the desired illumination or give figures on the utilization constants for the different systems suggested, due to the wide variation in character of surroundings.

Methods to Avoid in Church Lighting

Huge chandeliers, unless very carefully designed, have no architectural significance, and, as ordinarily employed, create severe glare. The tendency seems to be to hang these fixtures too low and use a large number of small lamps. With this arrangement, it is almost impossible to avoid glare, and many a church otherwise pleasing is spoiled by such lighting. In a number of instances, fixtures originally intended for gas jets or low powered lamps have been modified to accommodate the brilliant high efficiency modern lamp and are decidedly objectionable. Where such fixtures are employed, special precautions must be taken to see that the light sources are of low brilliancy.

Studded lights around the capitals of the pillars, along the beams and on the corbels are also objectionable for it is almost impossible to avoid annoying images. While this system sometimes brings out the architectural beauties of the building, it is difficult to maintain, and each burned out lamp will make a break in the continuity and spoil the effect sought. The use of this system will occasionally produce freak effects. For instance, a row of small lamps around the capital of a pillar may give the appearance of an open space and leave the roof and its arches without visible means of support. The efficiency of this system is low and renewal cost high.

Bracket units at the front of the church and decorative lighting around the pulpit and organ are particularly objectionable, for anyone giving attention to the speaker will be looking toward these bright spots. This is one of the most common causes of unsatisfactory church lighting.

Feasible Schemes for Lighting

Churches fall in two distinct groups—the ritualistic and the evangelical. In the former, the sanctuary or altar is the center of attraction and symbolically demands the higher intensity of illumination. In the evangelical church, the maximum illumination should be provided for the speaker, pastor or minister.

The very structures of the buildings devoted to these two groups still further separate their lighting requirements. The ritualistic church is generally of the Gothic type of architecture with the nave and transept forming a cross. A high peaked roof is also characteristic of this form of structure and dark surroundings are likely to prevail. In the evangelical church, the Basilica type of structure is frequently followed. The ceiling is more likely to be light in color and also flatter. Even where the Gothic style of architecture is employed, it is usually modified and presents less of a lighting problem.

Ritualistic Churches

As mentioned before, in many cases the ceiling is too dark in color to warrant the use of indirect systems of lighting and the nave and transept must be lighted by direct overhead units. The following systems of lighting are applicable to the ritualistic church with dark surroundings; those buildings with light surroundings can be well lighted by the methods discussed under evangelical churches.

A. Direct lighting fixtures consisting of clear Mazda C lamps and reflectors enclosed in some sort of an ornamental housing. This housing can be made up of art glass and wood, or metal work in the form of a lantern to enclose one or more equipments. The multiple unit fixture offers certain advantages in that the failure of one unit will not leave an entire section in shadow. Mirrored glass reflectors are excellent here, but must be supplemented by a few low wattage lamps inside of the fixture to illuminate the art glass. Translucent, prismatic or dense opal reflectors are also effective and the transmitted light serves the purpose of the small lamps. Such fixtures as these can be relatively large suspended from the peak of the arch or smaller in size dropped from the hammer-beams.

B. Diffusing bulb Mazda lamps in simple direct lighting opalescent glass reflectors can be suspended from the hammer-beams and form a very inexpensive method of lighting. If possible, a Gothic type of decoration should be secured. As an alternative to open type reflectors, simple types of enclosing globes of Gothic design can be used in the same position. Opalescent glass, of course, gives good diffusion but the whiteness of the glass shows up in contrast with the background. It is desirable, therefore, to employ units with a spray of light brown or similar color. The slight absorption of the toning is offset by the improved appearance of the installation.

C. Direct lighting angle or symmetric reflectors, with clear Mazda lamps, can be placed behind the hammer-beams, sending the light downward. These should be on the side toward the altar, not in the general view of the congregation, and if the proper type of reflector is chosen, they will not be annoying to the speaker.

A Combination of Direct and Indirect Illumination is Employed in This Gothic Structure of Light Gray Stone. Deep bowl mirrored reflectors are recessed at the crossings of the arches of the main and side aisles. These are the 300 and 200-watt sizes respectively

D. In the Gothic structure, with light surroundings, a combination of direct and totally indirect lighting is often applied with excellent results. In this building the utilization of light from an indirect system would be of a very low order due to the great height, in comparison with the width. Direct lighting reflectors are recessed at the crossing of the arches and the indirect units eliminate severe contrasts in brightness.

Evangelical Churches

Since the ceilings of many of these buildings are light in color and nearly flat, there is considerable latitude in the choice

The Smooth Light Colored Ceiling of This Auditorium Lends Itself to the Semi-indirect System. 500-watt MAZDA C lamps are used in the four large central units and eight 200-watt units of similar design are placed above the balcony

Night View of a Church with Totally Indirect Fixtures of the Luminous Bowl Type. General illumination is furnished by 500-watt MAZDA C lamps in inverted mirrored glass reflectors and 75 watt MAZDA C lamps, in smaller angle units at the capitals of lighting equipment. In contrast to the pure Gothic structure, all three systems of illumination—direct, semi-indirect, and totally indirect—have their uses. Frequently the architectural features of the building offer certain logical places for the attachment of lighting fixtures, at the crossing of the nave and transept, for example, or at symmetrical points along the main peak. Balance is usually desirable in the location of outlets.

Many forms of direct lighting devices suggest themselves. They should generally be of the enclosed, rather than the open type, as the likelihood of glare is then diminished. Decorated, opalescent glass, parchment, and painted mica are among the materials which can be effectively used for this purpose. A very wide latitude exists in the choice of equipment. The funds available for fixtures will govern this factor. As an example of extreme simplicity, inexpensive enclosing units with clear Mazda C lamps can be placed at the apex of the arches separating the side aisles from the main aisle in the modified Gothic structure. A sufficient spread of light will be obtained and lighting units will be well out of view.

Semi-indirect units symmetrically spaced are applicable to the church with a light colored ceiling and are available in a wide variety of decorations which will harmonize with the architectural design.

Totally indirect illumination can be accomplished in a number of ways. Hanging ceiling fixtures with clear Mazda C lamps in mirrored glass reflectors are simple to install. Smaller lamps in mirrored glass individual or trough reflectors can be located in a cornice, or groups of such units placed in recess at the tops of the columns or capitals. Wall boxes with suitably designed mirrored glass reflectors have also been employed for this method of lighting. Occassionally, recessed windows offer logical locations for such equipment.

Many churches are provided with an art glass ceiling to admit natural light. Excellent artificial illumination can be accomplished by properly placing direct lighting reflectors and clear Mazda C lamps above the skylight. Where the skylight is limited in area it is often necessary to supplement illumination received from this by overhead units placed between it and the side walls. A combination of semi-indirect or totally indirect illumination and the diffused direct light through the sky window proves effective.

For balconies, the general overhead lighting of the auditorium will usually take care of the balcony itself. Lighting beneath the balcony can be accomplished by the use of the wall type indirect lighting box previously mentioned, close ceiling hemisphere or flat plates attached to the lower side of the balcony. The glass should be of an opalescent character giving good diffusion with minimum absorption.

In order that the place occupied by the minister or speaker may be illumined to a higher degree than the rest of the church, it is desirable to have some means of projecting light on the pulpit. The suspension type spot lamp with concentrated filament Mazda lamp is compact and can be hidden from view. One of these units located above the speaker will produce the desired result. It should be focused so that a rather widely spread beam, not a sharply defined spot, is obtained.

Special Lighting Requirements

Chancel

On account of the desirability of concentrating the attention on the elaborate ritual held in the sanctuary, this must be the most brightly lighted portion of the church, and yet no lights should be visible, for the congregation faces in that direction. In the Gothic structure there is usually an excellent opportunity for locating the units behind the chancel arch. Steel or mirrored glass, angle reflectors simplify the problem remarkably.

The sanctuary should have plenty of light to bring out its decorative value, and yet the altar should not be uniformly bright, for shadow effects are then lost and the elaborately carved portions appear flat and dull, with consequent absence of detail. It is usually better to light the altar from the sides, simulating the daylight values, rather than from the top, to avoid any deep shadows without entirely eliminating them.

The lamps should be so arranged that the choir stalls are well illuminated, and it is often desirable to have the units on several switches, to meet the demands of the different portions of the services.

In the synagogue, the scroll kept in a cabinet at the rear of the altar should be illuminated by a few low wattage concealed lamps placed to furnish uniform illumination. A switch turning these on automatically as doors are opened is a desirable accessory. An outlet above the altar or a low wattage lamp for the "Light Everlasting" and convenience outlets for the imitation candlesticks on the altar are also necessary features.

Choir Loft

In the evangelical church, this occasionally presents a problem, often being located at the front. The light from the main auditorium units is both low in intensity and from the wrong direction.

A practice is often followed of placing a few brackets on the organ and shielding the lamps with some sort of diffusing shade. These units are continually in the vision of the congregation and are extremely annoying. One solution is to place the lamps in recessed boxes in the overhanging portion of the organ, and diffuse the light through glass plates. If the organ structure will not permit of this, bowl shaped steel reflectors painted on the outside to harmonize with the organ finish can be used on brackets. While these are not especially decorative, a strong light is provided on the books of the choir, and, as the reflectors are opaque, the eyes of the congregation are protected. Reading lamps on music racks, as in the orchestra pit of a theatre, are also applicable and possess many advantages.

A local lamp is, of course, provided for the organist, and in many instances it is advisable to have a small lamp below the keyboard to illuminate the pedals. All these lamps should be separated from the main circuits and be readily controlled for use during rehearsals.

Windows

Most churches have at least one elaborate stained art glass memorial window. By day this is a thing of beauty, but at night, when viewed by reflected rather than transmitted light, it appears as a dark, dull space. In most cases it is not difficult to illuminate the window. Weatherproof type, enameled steel, angle reflectors with clear lamps have proved of use. In most cases it is necessary to make a point by point illumination calculation to determine the type of unit and its location for the even distribution of light, and this can often be supplemented by some slight experimentation to determine the final result.

As a general rule, the window should be evenly illuminated, and it is bad practice to have the light source visible through the glass. Sometimes, however, there is a point in the design which logically demands a higher itensity of light, as for example, the sky in a landscape scene, and this feature must be given attention.

For large windows a very effective method is to project from a distance a beam of light having sufficient spread to cover the entire window area with a uniform intensity. There are available weatherproof floodlighting projectors which are especially applicable to this class of work. They can be mounted on a post or other convenient location, from 25 to 300 feet from the window, and the beam trained on to the window and its spread varied as necessary. The 500-watt unit is sufficient to cover 20-foot windows with the unit mounted 100 feet away.

Suggestions Regarding Wiring

In many respects the demands of the church are similar to those of the theatre and it is advisable to have a conveniently located central control. Dimmers are an especially desirable feature, both on the main and chancel circuits. During the sermon, the dimming of lights produces an excellent effect.

An experiment with colored lighting is now being carried on in "St. Mark's Church in the Bowurie," New York City. Direct lighting lantern type fixtures are used to produce red, amber, blue, and green toned illumination. During the prayer one combination is employed, during the sermon another, at the offertory still another. The psychological effect is taken into consideration at each point, blue green for meditation, red and amber for stimulation, and so on. There are undoubtedly wonderful possibilities to this, and the future will see great developments. Such manipulation of the light requires a number of circuits with the necessary switching and dimming controls.

Standard convenience outlets at certain points about the building are a necessity. In some churches entertainments are given requiring the use of a stereopticon. A stage pocket at the rear of the auditorium with sufficient capacity for the lantern is a feature worthy of attention.

The moving picture is becoming a factor in church work and a suitable booth for the machine is of course necessary.

Convenience outlets throughout the auditorium make it a simple matter to attach vacuum cleaners.

On various occasions decorative lighting is called into play as, for example, at Christmas time when a tree might be illuminated by small lamps. A receptacle on the rostrum or stage is necessary for such occasions.

Many pastors use notes and a reading lamp providing a strong localized light is often necessary.

In Catholic churches there are certain services and part of the service which require special lighting effects, and for grand celebrations, as at Easter or Christmas, special decorative effects are brought into play. Adequate capacity in convenience outlets must be provided for these purposes.

In some churches candles have been replaced with imitation candlesticks and all frosted Mazda candelabra lamps. In most services, however, the candle has a symbolic value which should be retained.

A feature often overlooked in designing a lighting system is the fact that reflectors and lamps become covered with dust which very materially reduces the light output as discussed in another section. In many cases complaints of poor illumination are due to this cause alone. In the church, with its high ceiling, fixtures are very likely to be most inaccessible and the sexton accordingly is hesitant about risking his safety for the sake of cleaning the units. If one wishes the installation to give continuous satisfaction, he should keep the question, "Will it be easy to clean reflectors and replace burned out lamps?" constantly in mind. Equipment should be located so that it is directly accessible or lowering devices provided. Automatic cutout hangers are of assistance here and suitable windlasses for massive fixtures are a necessity.

PART IX

LIGHTING OF PUBLIC BUILDINGS

Armories

The drill shed is, of course, the most important part of the armory and should receive the most attention. As a general proposition the usual form is a large open space with an arched roof. The size of those investigated varied from 600 feet by 300 feet (180,000 square feet), 120 feet high to 76 by 92 (7,000 square feet), 38 feet high. The roof is often partly glass to admit daylight and usually the iron work is exposed.

Many drill sheds have balconies for the seating of spectators, necessitating special lighting below to prevent dense shadows which would result if only the general lighting was provided. The floor varies considerably depending on the branch of service, cavalry having a very dark brown tanbark; infantry, light hard wood. Comparing the cavalry drill shed having a floor of low reflecting coefficient, with a shed having an ordinary wooden floor, approximately twice the wattage will be required to produce corresponding lighting effects.

On account of the simplicity of operation and maintenance, the high efficiency of light production, the pleasing color of light, and the steadiness and adaptability to reflectors giving any desired distribution of light, the Mazda C lamp has become practically the standard illuminant supplanting all other forms of equipment, for lighting drill sheds. The large areas permit the use of high candlepower units and the lofty ceilings give hanging heights such that lamps are always well out of the ordinary angle of vision.

The uses to which the drill hall is put are somewhat varied. The drilling of raw recruits takes place on only a portion of the floor and does not require the entire area to be lighted; battalion and regimental drills and reviews necessitate full illumination for ease of manoeuvres and inspection; gun drills in the coast defense and artillery sometimes need all lights out; or the armory is often rented to charitable organizations and the like for fairs and bazaars, which demand brilliant lighting as well as special decorative or spectacular effects. In any event sufficient light must be provided in all parts of the room to meet the most exacting conditions.

In most cases it is advisable to use either a translucent reflector or a unit which permits some of the light to escape above the horizontal, for if the ceiling is totally dark the room seems unpleasant. Occasionally, however, the floor is light enough to reflect sufficient light back to the ceiling even if opaque bowl reflectors are employed.

The type of distribution will vary with conditions. If the side walls are quite dark a unit giving a wide curve is inadvis-

Night View of an Infantry Armory (185 by 275 ft., 40 ft. to Peak) Green Side Walls, Green Ceiling, Light Wood Floor, Lighted by 28 1000-watt Clear Mazda C Lamps in Two-piece Prismatic Enclosing Units, Steel Cable Suspension

able as far too much flux will be wasted by wall absorption. With light walls, however, the diffuse reflection will assist in the general illumination and concentration of the light is not as necessary.

In compiling the material for this section a total of thirty armories were investigated as to equipment and spacing of units, condition of surroundings, etc. In regard to the reflecting equipment, the following applies:

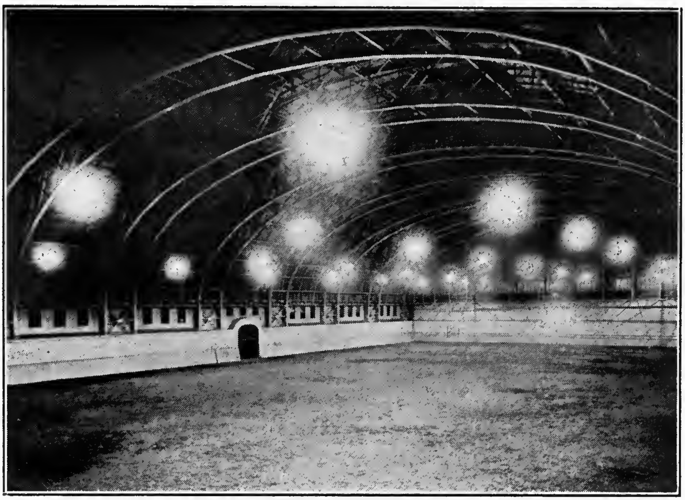
Ten were provided with deep bowl dense opal direct lighting reflectors. This type of unit is low in first cost and efficient in directing light downward. It transmits a certain percentage of the light which serves to illuminate the ceiling.

Six were equipped with enclosing globes of opalescent glass with an external porcelain enameled steel reflector. This equipment is comparatively inexpensive, gives good diffusion and pleasing light. As a considerable portion of the light is in a horizontal direction the utilization constant is rather low.

Five of the armories employed deep bowl large mirrored glass reflectors which are very efficient in redirecting the light, although introducing comparatively little diffusion. They are rather high in first cost.

Four buildings utilized deep bowl prismatic glass direct lighting reflectors. These are efficient, of moderate price, and have the property of transmitting a small proportion of the light upward.

On account of the high hangings employed, some sort of a lowering device should be provided. Most of the single unit fixtures weigh so little that a simple steel cable will safely support them, a cut-out hanger with lowering rope or wire simplifies this phase of building maintenance. In some cases the cut-out is omitted and the cable passed through a pulley, then down the sides of the room, the current-carrying wires hanging in loops.



Night View of a Cavalry Drill Shed (175 by 310 ft., 70 ft. to Peak) Cream Side Walls, Cream Ceiling, White Sand, Shavings and Loam as Floor, Lighted by 31 750-watt Clear MAZDA C Lamps in Deep Bowl Dense Opal Direct Lighting Reflectors, Steel Cable Suspension

The automatic cut-out hanger is a desirable feature where lamps are hung very high and where it would cost considerable to build scaffolding for renewing and cleaning lamps. In some armories, a walk is provided around in the roof trusses above the units from which they can be maintained. These trusses are usually very high and the construction of the walk must be carefully considered as the danger element is large.

Intensity of Illumination Desirable

From general considerations the cavalry and field artillery armories would require less light than those of the other branches of service, as they are not likely to be used for social purposes. This is counteracted, however, by the fact that the tanbark or loam floor absorbs a great deal of light and makes the place appear abnormally dark.

As indicative of modern practice the actual power consumption for the armories with wooden floors varies from .25 to .55 watt per square foot, the average figure being .37 watt per square foot. The illumination, therefore, varied from 2 to 5 foot-candles with the average in the neighborhood of 3 foot-candles. Actual tests in two of the armories investigated showed approximately 2½ foot-candles of illumination quite uniform in character.

In the armories with tanbark floors, the actual watts per square foot varied from .23 to .55 with an average of .34. The average generated lumens per square foot were 6.2. A test in one of these showed the illumination to vary between 2 and 4 foot-candles with an average of 3.25.

GYMNASIUM

General Considerations—Main Exercising Floor

This is usually rectangular in shape with a moderate height of ceiling. The arrangement most frequently used has the running track as a balcony 6 to 8 ft. wide around all four sides of the room. In the center of the main floor are the principal pieces of apparatus, horses, bucks, jumping standards, and parallel bars, while the flying rings and horizontal bars hang from the main ceiling. These can usually be pushed aside or drawn up out of the way for basketball, indoor baseball and wrestling matches, or practice. Below the balcony are found the exercisers of the various types and racks for wands, dumb-bells and Indian clubs.

The center part of the space requires even illumination of a moderate intensity with lamps so located that the hanging apparatus will not cause dense shadows. Particular attention should be paid to the shielding of the eye from the lamp filament, for one is forced to look upward a great deal when playing basketball and often faces the ceiling in ring and bar work. A blinding effect is particularly serious at such times and may cause a bad accident.

The illumination on the apparatus attached to the side wall below the track need not be as high as in the open space, yet in

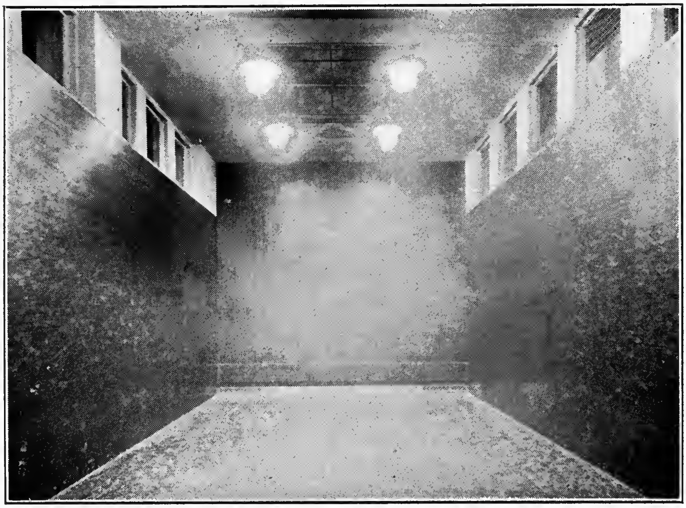
Night Photograph of a Gymnasium 60 by 120 ft., Lighted by 400-watt Clear MAZDA C Lamps in Semi-enclosing Units Consisting of a Diffusing Glass Dish Suspended Beneath a Large Porcelain Enameled Steel Reflector

Night View of a Tennis Court Showing Lighting Effects Obtainable with a Combination of Semi-indirect and Totally Indirect Lighting. Eight 750-watt MAZDA C lamps are used

many cases it is necessary to provide a few outlets here with small lamps properly shaded to prevent dense shadows.

The general discussion on choice of a unit given under armories applies here also.

In investigating the lighting of gymnasiums, data were collected on the equipment utilized in 42 typical Y. M. C. A., high school, and college buildings. It was unfortunate that nearly 50 per cent of those examined employed old style equipment consisting of 3, 4 or 12 lamp cluster bodies with flat white glass or



Night View of a Squash Court Lighted by Eight 400-watt Mazda C Lamps in Opalescent Semi-enclosing Units. The wattage consumption is 5.55 watts per square foot and the intensity is approximately 10 foot-candles

enamel steel reflectors. These were, in general, placed close to the ceiling and surrounded by wire cages or guards. This type of fixture is unsightly, gives a very poor distribution of light and is inefficient, as light from one lamp must pass through the adjacent partially blackened bulbs. These flat clusters have the particular objection that they expose the entire filament.

Of the twenty-two gymnasiums with modern equipment, the following types were employed; their properties are discussed under armories.

Enameled Steel, Dome Shape—7
Enameled Steel, Deep Bowl Shape—1
Mirrored Glass, Deep Bowl Shape—4
Prismatic Glass, Deep Bowl Shape—2
Opalescent Glass, Flat Type—2
Opalescent Enclosing Globe—3
Opalescent Enclosing Globe with Enamel Steel Reflector—2
Opalescent Glass Semi-Indirect Dish—1

In these twenty-two buildings the minimum watts per square foot was .42; the maximum 2.0; the average .78. The average generated lumens per square foot was 9.0. As most of the equipment employed is of an efficient character and side walls are generally light in color varying from white to natural brick and the ceiling, in contrast to the dark ceiling of the armory, usually also light, a fair average figure for the intensity of illumination provided is between 4 and 5 foot-candles.

Swimming Pool

This room, from a lighting standpoint, is practically a modified Ulbricht sphere, for the side walls and ceiling are generally white tile. The type of reflecting device employed makes but little difference in the illumination. Care should, of course, be taken to insure satisfactory eye protection.

Swimming Pool, 35 x 130 feet, Lighted by 7 200-watt Diffusing Bulb MAZDA C lamps in Dome Enameled Steel Reflectors

Running Track

Although in most cases this extends about the main exercising room and the general illumination is sufficient for the track, sometimes a long track is installed in the form of a low tunnel. For such conditions, angle type reflectors pointing in the direction the runner is proceeding avoid any likelihood of glare and direct the light where it is required.

Miscellaneous Exercising Rooms

These comprise the wrestling, boxing and fencing rooms, together with the medical director's office. Fencing requires a relatively high intensity of illumination and it is probable that one room only will be provided for all these sports. In such cases the lighting layout must be considered from the standpoint of fencing.

Since the action is rapid, it is essential that the light be well diffused and of high intensity in order that all movements may be readily followed.

The finish of these rooms is usually light in color with smooth ceilings, making indirect and semi-indirect systems of illumination quite feasible. Approximately 1 watt per square foot of floor area with MAZDA C lamps proves satisfactory with semi-indirect lighting. As the rooms are often decorated with prizes, pennants, etc., the decorative element of the fixture is important.

In the medical director's office, the ordinary requirements for office lighting are experienced, as well as the necessity for plenty of light in all parts of the room for physical examinations. Totally indirect or dense glass semi-indirect units are suitable.

Shower and Locker Rooms

In the shower room, there is no special problem in regard to lighting, but on account of the high percentage of vapor present in the air, it is advisable that moisture-proof electric fittings be employed.

In the locker rooms, double rows of lockers with aisles between in most cases extend to the ceiling. The athletes dress in these aisles. Mirrors are ordinarily placed at the ends of rows on the main aisle. Low ceilings of light color make practical the use of low candle-power, all frosted lamps without reflectors, with sockets set flush. In a number of the installations examined 25-watt lamps are used on 8 ft. centers. Larger lamps with suitable reflectors localized near the mirrors on the main aisle are essential. A 60-watt lamp with bowl-shaped dense opal reflectors between pairs of mirrors proves satisfactory.

Lighting of Art Galleries

Proper lighting of the art gallery is both an important and interesting subject. The buildings themselves represent a large expenditure, are more or less monumental in character and dignity, and consequently require artistic and harmonious lighting. In the second place, priceless collections of paintings and sculpture are exhibited here, and these must be well lighted so that the public may view and study them in comfort. And third, in order that these works of art may be presented so that the details will stand out as the artist conceived them, we must not only have ample light, but direction and color values must be carefully considered.

Paintings

The logical arrangement of the paintings is to place those of a dark nature at the top, for, with predominant light from above, the higher intensity will naturally be on the paintings which require it. We see by reflected light and, when this fact is considered, it at once becomes apparent that by this arrangement a more uniform and attractive gallery is the result.

A Night View of a Well Known Painting Gallery Illuminated by 40-watt MAZDA Lamps in a Continuous Rippled Mirrored Glass Reflector. The lamps are spaced on 12-inch centers and produce an intensity of 6 foot-candles on the paintings

The background, or walls, should be of a neutral tone, non-glossy in character and of low reflecting power, so that reflections from the walls are eliminated and there is consequently nothing to distract the attention from the exhibit. The neutral tone is of special importance as a brilliantly colored background may reflect enough light to modify the color value of the paintings quite materially.

There are two general methods commonly employed in the illumination of galleries—one, where the lighting is accomplished from the sides, and the other, where the direction of light simulates actual daylight conditions and comes from overhead. Whatever system is used, the intensity should be sufficient to illuminate the dullest piece in a collection, and care should be exercised to see that specular reflections from the painted and glass surfaces are minimized. The reader has often had the experience when viewing a collection of being annoyed by a multiplicity of reflections which distract greatly from the interest of the exhibit.

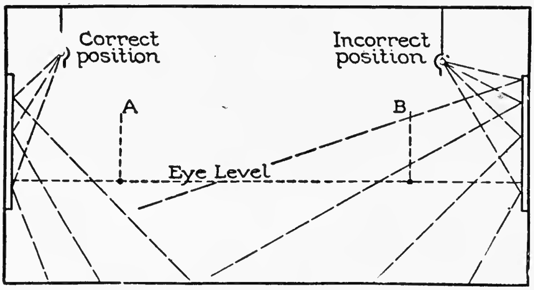


Fig. 2

Section of a Painting Gallery, Showing How an Incorrectly Placed Fixture May Result in Annoying Specular Reflections

This condition is most frequently encountered where the side system is employed as evident in Fig. 2. Here the paintings are represented as illuminated by lamps in a continuous trough reflector, and the light rays are indicated by the broken lines. The collections are usually viewed from the area between A and B, and eye level is shown by the dotted line. It can be readily seen from the sketch that any slight divergence of the fixture from the correct position will cause the light rays to be reflected into the area from which the paintings are viewed, causing annoying specular reflection.

Mirrored glass offers certain advantages in the flexibility of control of distribution, but plain or smooth mirrored surfaces should never be employed on account of image reflections. For temporary installations, white paint enamel gives excellent results from the standpoint of reflective properties and diffusion, but for permanent installations is quite out of the question, as it turns brown from the heat of the lamp, blisters and peels, as well as accumulates dust, thus having its reflecting power considerably lowered. For ordinary conditions, from 40 to 60 watts per running foot of wall space will provide an intensity of approximately 6 foot-candles on the picture.

It is certainly desirable, when the construction of the building permits, to utilize the skylight as a method of illuminating paintings, for not only can a better lighting effect be obtained, but the appearance of the room without fixtures is much more attractive.

In a system of this type, the hanging height of the units above the skylight will depend upon the wattage of the lamps used, and upon the glass in the skylight. The lamps and reflectors should be so arranged that the glass presents a uniform appearance from the room below, and the glass itself should be of such a nature that the lighting source cannot be discerned through the glass.

In some instances angle units can be so suspended as to direct the light on the opposite wall and are generally preferable on account of their higher vertical components to reflectors giving a symmetrical distribution of light. Projector units have also been successfully applied to this service, their advantages being accurate control of light distribution and compactness. To avoid spotted appearance of the glass it is sometimes necessary to employ opaque shields to obstruct the direct light. With an installation of this type it is advisable to employ a glass which, while concealing the location of the lamps, does not materially affect the distribution of light by introducing a great amount of diffusion.

Another factor which requires consideration when the gallery is equipped with a skylight, is the continually changing quality of daylight so that some system or method of modifying the intensity should be provided for. This may be effectively accomplished by installing a system of adjustable louvres between the sub-skylight and the main skylight. The louvres may be of thin metal painted white, or may be of cloth on wooden frames, and in either case they should be controlled either pneumatically or electrically from the room below. Thus, when the sun is in such a direction as to light one wall to a higher intensity than the opposite, the attendant may adjust the louvres until more uniform illumination is obtained.

A much simpler method is to provide a white diffusing curtain between the two skylights which can be drawn across the skylight when the intensity is too high. This system is, of course, less expensive, but is by no means so satisfactory or flexible as the former.

The question of proper color quality of artificial light for an art gallery can be viewed from many angles. All of us know that a distortion of hue results when lights of different spectral characteristics fall on colored objects.

From a theoretical standpoint in displaying a painting, it seems most logical to attempt to reproduce conditions under which it was conceived. A picture painted by daylight obviously transfers the artist's conception best under natural light, while those painted in artificial light should have similar treatment.

In an art gallery, however, we find all types in the same group, and even the position of individual works may be changed from time to time. It is scarcely expedient to be constantly shifting the lighting.

It is probable that the majority of pictures were produced under daylight conditions and the MAZDA Daylight lamp is a suitable light source for the art gallery. It is a compromise between unmodified artificial light and average daylight, sufficiently efficient to warrant its use. When lamps of this character are used, the transition at nightfall is much less noticeable.

There is another phase of the question which is not generally applicable to the large gallery and is possibly open to objections on the part of the true connoiseur, that is, special lighting by tinted lamps of individual pictures. Many paintings appear to better advantage when so lighted. Certain colors or tones may be accentuated or subdued with skillful treatment. Again, each picture may be illuminated by light with a certain predominating direction, coincident with the general direction of light in the picture, thus heightening the contrast. This field presents many varied and interesting problems and, in general, needs specialized study of each individual work.

Statuary

The sculptor may choose the most perfect piece of marble and model it into a sublime work of art, a perfect reproduction of his inspired vision, yet a careless arrangement of the work with reference to predominent light may cause unseemly distortions and a shattering of the expressed ideals.

The beauty of statuary lies in the relation of high-lights and shadows. The desirable density, sharpness, and quantity of shadows, depend upon the emotion to be depicted. Tragedy demands sharp contrast and bold shadows, as exemplified in the Laocoön group. On the other hand, a piece of work similar to Aphrodite, portraying soft, subtle modelling, and a face of radiant pleasure, needs a softer light to bring out the effect of the more quiet emotion. Shadows are troublesome in sculpture only when they tend to produce false impressions.

Under artificial light, the degree of shadows produced depends upon the type of unit used. If a direct lighting system is employed, the sharpest of shadows are produced with little diffusion, except that reflected from surrounding surfaces, such as walls and floors. With a totally indirect system, of course, a minimum of shadows is obtained and this lighting is scarcely of service. With semi-indirect units, however, we have a particularly fortunate condition. The proportion of direct to diffuse or reflected light is dependent on the density of the glass of the bowl or, with a given density of glass, these factors can be varied by tinting and toning the ceiling, increasing its absorption. Enclosing or semi-enclosing diffusing units having similar properties to semi-indirect units are also useful in producing a suitable combination of direct and diffuse light.

A systematic arrangement of either of these two latter types of units, providing an intensity of from 4 to 6 foot-candles, gives good results. Since a greater amount of direct light is usually produced immediately beneath the outlet, it is quite logical to locate in such positions objects requiring well defined shadows and those of "softer" lines in the more diffusely lighted areas.

Thus, artificial light, on account of the possibility of readily changing the intensity, color and direction, is one of our best mediums of artistic treatment. Crude, stagey effects should be avoided and one must realize that, while lighting cannot make art, it can certainly mar it.

Lighting of Museums

Our museums contain priceless collections of natural, scientific, and literary curiosities, conveniently exhibited where the public may view and study them at leisure. It is important that the specimens be arranged and displayed to their best advantage, and this cannot be accomplished unless the exhibit is properly illuminated to facilitate careful study.

There must obviously be good general lighting, special lighting of a high intensity for small objects in show cases, and more or less of stage lighting effects where a group is presented in its natural setting.

Glaring light sources and reflected images must be avoided, for there is no one factor which tends to reduce the effectiveness of a museum more than annoying reflections in the glass surfaces of the cases. A well diffused, general lighting is required, of an intensity of 6 to 8 foot-candles, so arranged that it will not cause objectionable shadows on the exhibits. The indirect systems or diffusing direct lighting units of neat simple lines meet these demands. The fixture itself should be dignified and in conformity with the architecture of the building. In the foyer and similar places, massive ornamental standards or multiple unit fixtures are frequently necessary for their decorative value.

The lighting of exhibit cases is obviously an important feature. In general, they may be divided into two distinct groups —those constructed entirely of glass and readily illuminated by the general system, and those which have an opaque top, or are of such a nature as to require local illumination. The wall cases usually have a cornice at the top behind which lighting equipment may be readily installed in an inconspicuous manner. As most of the cases are air-tight in order that they may be dust-proof, it is important that low wattage lamps be employed to prevent excessive heating. Small mirrored glass or metal individual reflectors or continuous trough equipment can be utilized.

The most interesting phase of museum lighting is that of providing special effects for cases or alcoves containing objects in their natural surroundings. The principles of stage lighting have been applied to the show window with excellent results. They are especially applicable here. The method of handling individual exhibits will depend on the construction of the case and the ingenuity of the designer.

The laboratory and workshops of the museums, where figures of the groups are cast or modelled specimens mounted, magnified copies of objects made in glass and wax, and models of all sorts repaired, offer no problem distinct from those of the ordinary industrial plant, with similar demands on vision. A high intensity of general illumination with efficient direct lighting units, such as RLM Standard dome reflectors and bowl enameled Mazda C lamps, will permit accurate work amid pleasing surroundings. Convenience outlets to which suitably shielded local lamps can be attached are necessary along the benches in order that the very high intensity necessary, when working on minute objects, can be available.

Lighting of Libraries

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

Libraries may be divided into two quite distinct classes—one, the monumental building of the large city where the rooms are spacious, ceilings high, corridors handsomely finished in marble, and where the element of decoration plays a large part. Reading rooms in this class of building are generally separate from the stack room. The other is represented by the branch, public school, or town library, unpretentious in nature, where the books are stored in cases around the room. Here the decorative feature is secondary and utility of light plays a more important part.

It is quite common practice to install decorative fixtures in the high ceiling reading room of the first class of buildings. These supply a moderate intensity of general illumination, necessary for supervision and to prevent severe contrasts of brightness, but are seldom designed to supply enough light for continued reading. All too frequently, the decorative value is apparently the only element of design given sufficient weight, and examples are well known of glaring and hence ineffective installations. Unshaded lamps are studded in huge clusters, sometimes unfortunately in the field of view. It is quite out of the question to lay down specific rules on this phase of lighting, for individual taste varies, and earnest co-operation between the architect, fixture specialist, and illuminating engineer is advisable.

In addition to the general illumination of from 2 to 4 foot-candles, local lighting should be supplied on the tables. These lamps should be very carefully chosen, so placed, and of such a character that direct or reflected glare is minimized. Many standard types in wide use are most inappropriate and productive of eye fatigue. An even distribution of light on the table top of an intensity of 6 to 8 foot-candles, is suitable, although higher intensities are sometimes necessary where faded manuscripts or books with very fine type are likely to be used.

In many respects proper table lighting is an economy, producing a high intensity over the working area while a lower intensity is sufficient in the rest of the room. This is particularly important in the library at night where but few readers are likely to be present. Each reader will then control his own local illumination; the attention will be concentrated upon the work.

As mentioned, in the reading room of the second class of buildings are located the book stacks, and general lighting with the indirect systems is the most logical method of meeting the requirements. With the present-day high efficiency lamps, it is perfectly advisable to supply from 6 to 8 foot-candles throughout the room. This eliminates the necessity and bother of local or table lights. The diffuse character of the illumination thus produced gives excellent lighting on the vertical surfaces of the stacks.

The catalog room of the city library is generally lighted by massive ornamental fixtures and the remarks relative to the reading room apply to this part of the building. Simple brackets, attached to the filing cabinets, carrying relatively low wattage lamps in deep bowl or angle reflectors increase the intensity of illumination in that region to 6 or 8 foot-candles.

The periodical rooms and special reading rooms are similar in nature to the small library, and the type of lighting suggested for use there fits these conditions.

In the stack room, the titles and numbers on the books must be readily discernible, and an average intensity of from 2 to 4 foot-candles is desirable. Twenty-five or 50-watt Mazda lamps with deep bowl opalescent glass reflectors, attached to a line of overhead conduit over the aisles, on 6 to 10 foot centers, will fulfill the demand. Where the aisles are of considerable length, three-way switches at both ends are an economy in enabling the attendant to switch on the required lights and to extinguish them after the desired book has been obtained.

Lighting of Municipal, County, and State Buildings

The larger portion of these structures is devoted to private and clerical offices, the illumination of which has been thoroughly discussed. Entrances, corridors, and reception rooms are similar in demand to those in the museum, and, where inscriptions and mural paintings prevail, care should be taken to see that the type of unit chosen for lighting permits these to be seen in a clear and effective manner.

Committee and jury rooms have the same general requirements as the office, although a lower intensity (3 to 5 foot-candles) is sufficient. In many instances, however, these rooms are finished in dark wood, which makes the lighting problem considerably more complex. Bracket units with unshielded lamps must be avoided, and diffusing enclosing globes, well out of the angle of view, offer probably the best solution. The character and design of the supporting fixture will depend on the elaborateness of the decoration.

Figuratively speaking, light and justice are always associated, and yet an investigation of the lighting in our court and assembly rooms shows them to be, in many instances, dark and dingy. When necessity arises for proving physical facts by visible evidence, it is often difficult to observe the details of the exhibit. During a court trial, it is certainly desirable that the judge and jury should see the witness with the utmost distinctness as testimony is being given, and it is evident that proper lighting is essential.

Many of our court rooms are still illuminated by open burner gas jets, or by old gas fixtures which have been slightly altered to accommodate such electric lamps as would go inside the globe, without any forethought from the standpoint of intensity, distribution, or diffusion.

The general lighting requirements are similar to those of an auditorium, and lighting units even though of a decorative nature, should be suspended well out of the line of vision. Wall brackets at the front of the room are especially objectionable, as they are continuously in the field of view, and one's attention is naturally directed toward the judge and witness.

While stage effects are not in especially good taste, there is no reason why advantage should not be taken of some of the principles utilized so effectively on the stage. If the director desires to focus the attention of the audience on a particular part of the scene or on one actor, he illuminates this area to a higher intensity by the use of a spot lamp of some sort. If the construction of the building is such as to permit a suspension type spot lamp to be concealed from view, it would seem fairly logical to direct the light from this on the witness stand. A sharply defined spot would not be desirable, but on the other hand, one which shaded off gradually would produce the desired effect without being noticed by the casual observer.

There are many cases which come to trial where the verdict depends on a close examination of the evidence, as in the case of forgery, or an erasure in a document. Much time may be lost if the case has to be adjourned to an adequately lighted room in order to view the exhibit. If convenience outlets are provided to which local lamps giving a high intensity of illumination can be attached, this work can be carried on without loss of time. The accurate type of color identification unit, providing illumination of a high intensity over a small area of a true daylight value, should be useful.

Lighting of Banks

The lighting system in the bank should be such as to impress

A Well Lighted Bank Using 300-watt MAZDA Lamps in Semi-indirect Bowls on Centers 18 by 32 feet. The fixtures are simple yet dignified and provide a uniform intensity of 5 foot-candles throughout the main banking space

the patrons with the dignity of the institution, and yet eliminate any idea that the building is simply a cold storage place for currency, by making the interior comfortable and inviting. A high intensity of illumination will eliminate eye fatigue and thus prevent opportunities for errors, and will increase the speed of the clerical force. It is an asset in advertising the bank, and many deem it advisable to leave the light burning at night for this purpose, as well as for protective value.

With the high efficiency of the present-day illuminants the old form of local or drop lighting is gradually being eliminated, and the multiplicity of unsightly cords and tin shades, which formerly occupied the space behind the cages, is becoming a thing of the past. The main banking space should be equipped with general lighting of an intensity of from 4 to 5 foot-candles. Almost any form of fixture which harmonizes with the architectural features might be used, providing it fulfills the general requirements as to distribution and diffusion. If the general lighting is not sufficient, patrons' desks should be equipped with local units producing an intensity of from 8 to 10 foot-candles. The general type of these units should be similar to those recommended for reading in the library, and they should be so located as to prevent direct and reflected glare. The exterior of the fixture obviously should harmonize with the other metal work.

The general lighting system is often supplemented by cage grill fixtures to raise the intensity at the various wickets to a

A Night View Showing a Typical Cage Grill Fixture Employing 25-watt MAZDA Lamps Spaced about 14 Inches Apart

value of approximately 10 foot-candles. The distribution of light should be such as to prevent glares and a diffusing glass plate over the opening should be used to prevent annoying reflections of lamp filaments.

The vaults are used primarily for the storage of valuable documents, and little actual work is carried on here. A lower intensity (3 to 4 foot-candles) suffices. In most instances it is inadvisable to pierce the armor plate of the safe to furnish electric current for lighting purposes. A convenient arrangement to overcome this difficulty is to locate one receptacle outside of the vault connected to the power supply, and another inside of the vault feeding the lighting circuit. When the steel door is opened, a flexible cable with a plug at each end connects the two receptacles. A circuit breaker installed on the line is sometimes used as an economy.

PART X
LIGHTING OF HOSPITALS AND DENTAL OFFICES

Wards

The ward is essentially a sick room for accommodating a number of patients at the same time. The size is determined largely by the purpose for which the hospital is used. In private

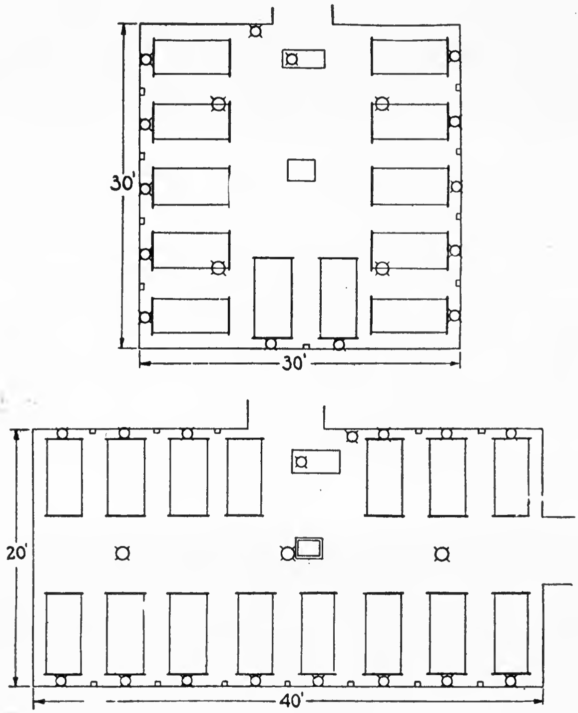


Fig. 1—Sketch Showing Typical Arrangement of Outlets in Wards of the Square and Rectangular Type. Ceiling outlets for general illumination and baseboard receptacles for local lighting, together with a drop lamp over the nurse's or attendant's desk will be noted

hospitals, most of the patients occupy private or semi-private rooms, and the wards are designed to accommodate only a few patients. Public institutions, however, as a rule, are composed entirely of large wards accommodating upward of 40 patients.

Wards, therefore, vary in size and shape, but generally are provided with hard surfaced walls and ceiling of light color and floors of glazed surface which may be readily cleaned. Typical wards of square and rectangular shapes with the usual arrangements of beds are shown in Fig. 1.

Owing to the fact that patients' eyes are directed toward the ceiling for hours at a time, the lighting must be of a nature that will not strain or tire the eye.

In the ward there are three distinct requirements for lighting as outlined below:

(A) In the evening hours, visitors are received who desire to move about or sit and talk with the patients; at this time also, nurses and doctors perform their routine duties in preparation for the night.

A well diffused system of general illumination is necessary to provide lighting that will be sufficient for the ordinary purposes as described above.

(B) Local lights over the beds, additional to the general system are necessary. These should be of a character which will permit the patients to read or pass the time at other occupations requiring close vision, without eye strain. It also is frequently necessary for the doctors or nurses to attend a patient at night and they need a high intensity of illumination for the use of instruments, etc.

(C) All hospitals require the lights in wards to be extinguished after a certain hour, but a night light is necessary to enable the nurse or others to move about with ease and exercise the necessary supervision.

Analyzing these requirements we find that the totally indirect system is probably most suitable for the general illumination, although semi-indirect units may be used if equipped with heavy density bowls. The direct method using totally enclosing globes may be utilized in small wards or in remodeled buildings where conditions are not favorable for indirect lighting.

Two or more rows of ceiling outlets are necessary to provide even distribution of general illumination in wards which are square in shape but the long narrow type require only a single row of fixtures as shown in the diagram, Fig. 1.

The proper intensity of general illumination for wards has been the subject for considerable discussion. The consensus of opinion, however, is that an intensity of two foot-candles on the bed level is desirable.

If the indirect system is used with light surroundings the above intensity will be obtained by an allowance of one-half watt per square foot floor area. If surroundings are dark this should be increased slightly.

Outlets with a bracket type fixture for local lighting should be provided over or between the beds to furnish sufficient illumination for special purposes, as explained above.

There are several type of wall bracket fixtures available for this purpose. One fixture which reduces wiring costs and is very desirable combines the light and an extra receptacle in the same base. This base of flat white glass is attached to the wall; an opalescent reflector conceals the source and directs the light on the bed. Below the lamp is located a flush receptacle to which portable lamps, heating appliances, or instruments may be attached.

The importance of providing an extra receptacle cannot be over-emphasized. It is obviously undesirable to remove the lamp from the lighting fixture every time current is desired for these purposes and unless equipment such as that just described is provided, baseboard outlets at frequent intervals are essential.

A common method of providing the night lighting is by use of low wattage lamps, wired on a separate circuit in the fixtures for general illumination, which are kept burning when all other lights are out. A very modern method for night lighting of wards is the placing of lights in the floor within trough reflectors, covered by clear plate glass. Their light is, of course, sent to the ceiling and diffused downward. This arrangement gives a light of low intensity and precludes all possibility of annoyingly bright fixtures.

A somewhat more elaborate night lighting system uses individual floor lights such as found in the modern Pullman sleeping cars. Small pockets lined with reflecting material are recessed in the baseboard. The light from low wattage lamps shining through a set of baffles or louvres is cast in a narrow streak onto the floor between the beds, not visible to the patient, yet making all objects readily discernible.

As a night light is intended to furnish just enough light to discern the large objects, such as beds and doors, an intensity of one-quarter foot-candle is sufficient. An allowance of one-tenth watt per square foot floor area will give this. Thus in the sketch, Fig. 1, of the square ward, the dimensions 30 by 30 give a total area of 900 square feet, an allowance of one-tenth watt per square foot would indicate that a total of 90 watts was required for night lighting. A 25-watt MAZDA lamp in each of the four indirect units shown is the solution.

The location of the nurse's desk is generally at some convenient place near the entrance, and an outlet should be provided for a portable desk light to be used by the night nurse in making up the records, etc. A wall bracket or other suitable light should also be provided over the chart rack to permit its examination at night.

The medicine cabinet should be provided with suitable light during the night so that the nurse may select the proper container without groping or making mistakes. The medicine cabinet is sometimes placed under a fixture and a drop light with rather dense translucent reflector is suspended over its glass top.

Private Room

The private room in the hospital resembles a bedroom which has been especially equipped for the care of the sick. In many instances it is highly decorated with luxurious surroundings, similar to one in a private residence.

A well diffused general illumination and local illumination similar to that previously described may be used. The intensity need not be so high as in the ward owing to the fact that it is used by fewer persons. The fixtures employed in lighting may be somewhat elaborate and decorative to suit any particular interior. The indirect systems are preferable for general illumination where conditions are favorable.

The direct system may also be used for this purpose, where indirect methods are not practical, care being taken to provide suitable diffusing media. A central ceiling fixture should be supplemented by wall brackets or table lamps near the bed. These should be fitted with reflectors or decorative shades which will diffuse and direct the light where needed.

Corridors

The hospital corridors or passage ways are usually provided with hard surfaced walls, ceilings of light color, and white tile floors which can be readily cleaned, and to be in keeping with the modern sanitary conditions, the lighting fixtures should be of a simple construction, easily cleaned, and no-dust collecting. They should be so arranged that direct rays will not strike the eyes of the patients and cause annoyance.

The totally indirect method is very desirable for lighting corridors of buildings where the highest standards prevail; the lighting is comfortable and artistic.

The system of direct lighting, employing a compact ceiling fixture with a suitable diffusing reflector also furnishes good illumination and is widely used for corridor lighting. There are many types of sanitary fixtures designed exclusively for hospital use, being dust-proof, with enamel finish.

As only sufficient light need be furnished to permit easy passage, an intensity of one foot-candle is adequate. For direct lighting an allowance of one-quarter watt per square foot will give the required illumination, providing surroundings are light in color. This value should be increased slightly if surroundings are dark.

Operating Rooms

The lighting requirements discussed thus far do not differ materially from those ordinarily encountered. In the surgery, however, very special demands exist as to lighting.

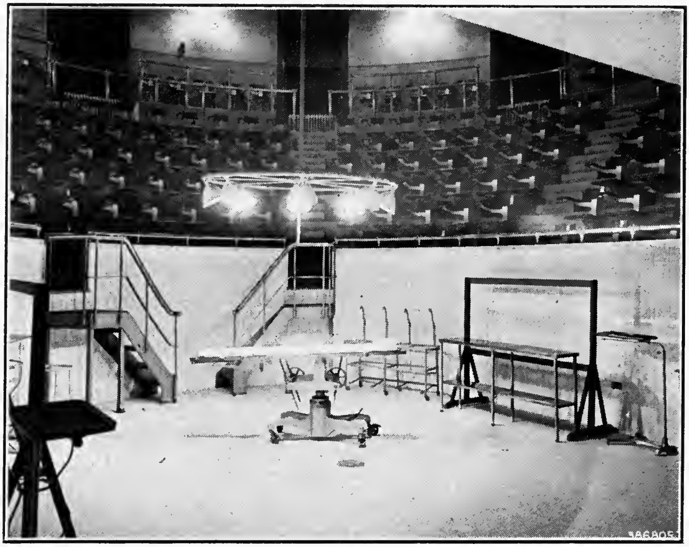
There are two general types of operating rooms which require slightly different treatment in their lighting. The first is the type of room used in the city or private hospital, which is relatively small in size and contains merely the operating table, sterilizer, and a few necessary pieces of apparatus. The second is the operating room of the hospital connected with some educational institution and is made in the form of an auditorium for the purpose of holding lectures or clinics accompanied by demonstrations. Walls and ceiling are, or should be, pure white and in the more modern hospitals, the walls are constructed of tiling and the floor of smooth white marble for ease of cleaning and sanitation.

In the first type of room, strong illumination is needed over the operating table with local lighting for the sterilizer and accessory appliances. There will, in general, be sufficient light reflected from these units to enable the surgeon and attendants to move about with facility.

In the auditorium type of operating room, the "pit" may be treated as just discussed, but general illumination must also be provided in the balcony to enable the class to take notes with ease. An intensity of three or more foot-candles is desirable here and may be provided by the use of wall brackets at the rear of the top tier of seats, supplemented by properly spaced ceiling units of standard types. Wall bracket or overhead units should also be provided for general illumination of the "pit" to be used when preparing for an operation and at other times when general illumination is necessary here.

The lighting equipment used in the operating room must have the general sanitary and ease of cleaning qualities necessary throughout the hospital.

The main question is that of lighting the operating table proper and the requirements for both types of room are identical in this respect. In the auditorium type of operating room, it is common practice to conduct operations at night making the demands for this class of buildings especially important. In the smaller institutions, the majority of the operations are performed



The Operating Amphitheater of a Large Municipal Hospital. The concentrating reflectors with 60-watt MAZDA lamps direct the light at the working point

in the daytime and it is only on special occasions or emergencies that artificial light is called into play.

The operating table requires a very high intensity of well diffused light of the proper color coming from several directions. High intensity is required on account of the minute details which must be observed at all times. Diffusion is necessary to eliminate shadow effects. Light of approximate daylight color is desirable in order that the blue veins, red arteries, or yellow bile ducts can be distinguished one from the other. It is also essential to have light coming from several directions in order to illuminate the interior of an incision properly. Many classes of work require light from nearly a horizontal direction for penetration.

The fixture itself must be of such construction that there is no danger of dirt accumulating and falling into the wound, and must be so placed as to minimize the possibility of this action. It should radiate the minimum amount of heat in order that the surgeon and attendants may work in comfort and without danger of perspiring.

The natural illumination of the operating room should be a subject of careful study and to secure the best results the surgery is usually located on the north side of the top floor of the institution where minimum obstructions exist. Skylights with semi-diffusing glass constitute a part of the north wall and a considerable part of the ceiling. North light is generally well diffused and more uniform in quality and quantity than that from other points of the compass, and for this reason is preferred.

The surgeon endeavors to conduct the most important operations under daylight conditions, yet he realizes that in times of emergency dependence must be had on artifiical illumination. Without giving the matter careful thought, many medical men would make the claim that it is impossible to secure thoroughly satisfactory artificial lighting. This statement may be justly combated, for with discretion in the choice of equipment and with the application of sufficient electrical energy transformed into light, daylight effects can be readily simulated. The uninitiated might think that such a procedure was too costly to be practical. Such is not the case. Suppose, for example, it required a total of 3,000 to 5,000 watts to illuminate an operating room properly. (This is far more than necessary in most cases.) At the customary rates for electrical energy, this might cost from 25 to 50 cents an hour. The operating room is customarily charged for and it will be seen that this figure represents but 1 to 2 per cent of the rental of the room. Certainly proper lighting is worth this percentage.

North skylight can be imitated by placing daylight Mazda lamps in suitable reflectors outside of, and above the skylight, illuminating the room with light of the same character, of the same general direction and with sufficient intensity. This method is actually used in some of the more modern buildings. It is true that there is a certain amount of absorption in transmission through the glass and that the construction work is rather costly, but the splendid results obtained justify such expenditures. For general illumination of this character an intensity of 30 to

50 foot-candles is desirable and would be attained by providing from 10 to 15 watts per square foot of floor area depending on the structural arrangement, density of the glass of the skylight, type of reflector, size of lamp used, and similar details.

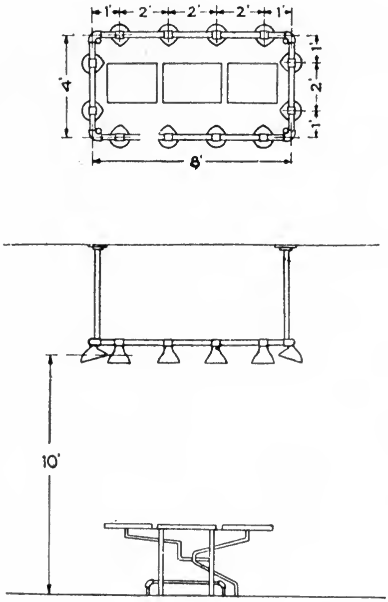


Fig. 2. Arrangement of Angle Type Prismatic Reflectors with 75-watt Bowl Enameled Daylight MAZDA lamps for Illuminating the Operating Table

If such a scheme as this is not feasible, a number of other methods represent good practice. Totally indirect illumination may be used if the ceiling is light in color and of a character suitable for reflecting the light. Mirrored glass units equipped with daylight MAZDA lamps are efficient and produce evenly distributed, very well diffused (practically shadowless) illumination. Instances have been reported where indirect lighting has proven unsatisfactory for this purpose but analysis generally reveals that inefficient wattage was used and hence an inadequate intensity of illumination secured. It must be borne in mind that work of the character carried on in the surgery demands a high degree of illumination and to secure this, sufficient power must be used.

Where conditions preclude the application of the skylight method of general illumination by the indirect systems, special direct lighting fixtures are available. Such a device provides diffused light of a high intensity from directly above the table. The large area of the source tends to eliminate shadows, has the advantage of simplicity and compactness. A unit of this character is entirely adequate for the less exacting operations and maternity work. It is often necessary to supplement a unit of this type with a portable lamp stand and suitable reflector to direct light on vertical surfaces.

In the attempt to obtain light from a number of directions twelve prismatic angle type reflectors are mounted on a framework or directly attached to the ceiling about 10 feet above the floor. These are fitted with 75-watt bowl enameled daylight MAZDA lamps. A splendid distribution of light on the table from all directions is secured. The light is of a suitable quality, units are hung at a sufficient height so that the heat is not objectionable, the fixture construction is simple and reflectors are not located directly above the table and any dust which might have accumulated will not fall in the wound. Since the prismatic reflectors transmit a certain percentage of the light no general illumination is needed in addition. Measurements of the illumination produced by such a layout indicate the following intensities: between 40 and 50 foot-candles on the horizontal plane, from 20 to 30 foot-candles on the 45 degree plane and from 10 to 20 foot-candles on vertical surfaces above the table.

Wiring and Signal Systems

The source of current supply in any public building must be dependable. This is particularly important in the hospital where the occupants are in a critical physical condition. The most exacting demands exist in the operating room where the failure of illumination might have a fatal result.

Whether the hospital has its own plant or whether the current is supplied by a Central Station, the building should be so wired that the blowing of a fuse will not extinguish all of the lights in any section of the building. The circuits in wards and corridors, for example, should be so arranged that part of the lights are on one circuit and part on another. In some instances, duplicate panel boards with emergency switching and plugging arrangements are installed to make possible a quick change over.

An emergency system in the operating room is particularly important so that even the failure of the entire electric supply will not throw the room into darkness. Gas as an auxiliary is at best a makeshift for it is not likely that suitable equipment will be installed to give satisfactory illumination with gas. As ether is used as an anaesthetic, it is not particularly safe to have an open flame near the spot where this is being administered. A small storage battery of sufficient capacity to light the operating room for a given period of time is a most desirable feature. The mere throw of a switch in such an installation takes care of any emergency. The care required by a storage battery is not excessive and most hospitals have a plant engineer who is thoroughly competent to maintain the battery. Smaller lower voltage batteries are also very useful for furnishing current for miniature surgical lamps and microscope illumination.

The signal system in the hospital, an important element, also employs the storage battery for its operation. The modern type of signal devices are noiseless and the old bell or buzzer for calling the nurse or attendant is a thing of the past. Two general methods are employed for the purpose, one utilizes a semaphore or small arm which drops from a vertical to horizontal position over the door or nurse's desk. The latest system has a push button by the patient's bed which when operated lights a signal lamp over the nurse's desk and one by the bed, or outside of the door in the case of a private room. When the signal lights, the nurse glances down the ward or corridor and locates the patient who requires attention. These lights are left burning until the nurse responds, who extinguishes them by inserting a special key in the push button switch. This system is not so unsightly and not as likely to get out of order as the semaphore or annunciator system.

Dental Offices

The *waiting room* of a dental office and the reception room of a hospital present similar lighting problems. The more attractive and soothing the lighting conditions are made, the more readily the patient will await his appointment. Floor and table lamps may be used to supplement the general lighting advantageously.

There are two systems in vogue for securing proper illumination in the *office* for the actual dental work; one supplies a high intensity of general illumination enabling the dentist to work under conditions approximating natural lighting and the other involves the use of only a small beam of light focused directly upon the mouth by some form of special illuminator or spot lamp. As with any class of lighting, general illumination is more effective in most cases and offers wider possibilities.

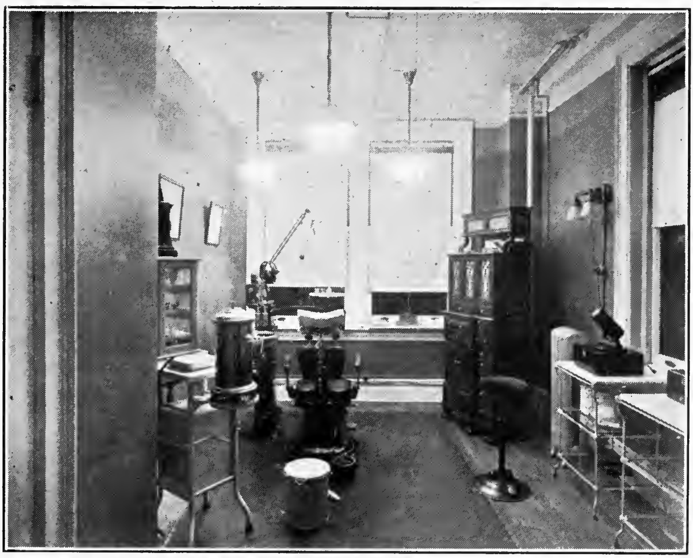
It is obvious that the desirable results are secured with such a system when, no matter where the dentist is standing or working, neither he nor his instruments will cast shadows on the working point. The ideal light would reach every portion of the mouth and with the assistance of the mirror, illuminate the deepest recess. In order to minimize shadow effects, it is obvious that light must come from more than one direction which necessitates the use of more than one light source or a unit having a very large reflecting or diffusing surface. The semi-indirect and totally indirect fixtures which direct the major portion of the light to the ceiling produce such an effect. Since the details to be observed are extremely minute, high intensity is an essential element. Since the color of teeth must be compared and the condition of various tissues noted light approximating daylight is desirable.

Where structural considerations prevent, or where the color of surroundings is such as to preclude such lighting, its effects can be simulated by the use of an adjustable diffusing fixture. Since the dentist usually works from the patient's right side, this outlet should be located at the front and slightly to the left. Where the fixture is adjustable, the swing of the supporting arm should be regulated for this position.

A fixture having the same general characteristics as the one described, although not quite so simple, utilizes four lamps in prismatic enclosing globes on a swinging arm fastened to the window casing. The simplicity of installation of these units is one of the great points in their favor. On the other hand, a certain amount of time is involved in adjusting the device to suit particular conditions, which is not necessary with the overhead general lighting scheme.

The *spot lamp* falls in the same class as the local lamp over the tool in the machine shop. It is inconvenient, and valuable time is wasted in adjusting it. Most machine shop illumination can be secured much better from the high intensity general method, yet there are a few special processes, such as the machining of the interior of deep castings which make a local lamp a necessity. Just so in the dental office. The greater proportion of the work can be more satisfactorily performed with proper general lighting, yet for some very special conditions, the mouth lamp is a very valuable adjunct. Continuing the analogy, many forms of drop lamps in the industrial plant are practically useless and objectionable from the standpoint of glare. The dental lamp which employs a low wattage unit with a half shade reflector on a flexible or adjustable arm throws much light in the patient's eye, is cumbersome and if not specially constructed may soon become mechanically weak.

The carefully designed lens type spot lamp, illuminated



A Small Dental Office Lighted by Three 200-Watt MAZDA Daylight Lamps in Simple Type Semi-indirect Bowls. A uniformly distributed high intensity illumination of suitable color is produced. The diffused character of the light is particularly valuable for illuminating the recesses of the mouth

mouth mirror and head band type of equipments, not only keep the stray light from annoying the patient, but are useful in root canal work and for trans-illumination in the detection of dead teeth. At best, the local lamp is only an accessory and dependence should not be put on it alone. Good general illumination is necessary to enable the operator to pick up readily any instrument on his stand or cabinet, for in the poorly lighted room the contrast between a brightly illuminated area and the dark surroundings is a source of much confusion to the eye.

PART XI
FLOOD-LIGHTING

Dignity and beauty combine with the spectacular to provide in flood lighting one of the most effective forms of electrical display. A stately building, a national monument, a scene of great natural beauty, bathed in light against the darkness of the night, may be made to compel attention and to inspire admiration. Without a suggestion of garishness, yet with attracting power which is irresistible, flood lighting accomplishes its purpose.

The application of flood lighting, however, is not limited to the producing of striking and unusual effects. There are many applications for it in industry. The time required for outdoor construction work may be considerably reduced by a flood lighting system which will permit work to be continued throughout the night; the flood lighting of railroad yards, docks, wharves, and the yards of industrial plants, permits night work to be done efficiently and with increased safety. An application is found in the lighting of traffic intersections to facilitate the movement of vehicles and pedestrians and to promote safety. The illumination of large outdoor spaces devoted to pageants or sports, including bathing beaches, drill grounds, and open-air theatres, is being most satisfactorily accomplished by flood lighting. Bulletin boards and painted signs located high up on water towers or chimneys are examples of the application of flood lighting to electrical advertising. New uses are being constantly found as the possibilities of this form of lighting are becoming better understood.

The Problem

The design of a flood-lighting installation is governed by the purpose which the illumination is to accomplish. In the case of a bulletin board or painted sign, the aim should be to provide a uniform level of illumination over the entire surface of the display. One or two projectors, if properly located, will often be sufficient for this purpose. Outdoor construction work and railway and industrial yards require, of course, ample light at all working points and yard thoroughfares, but of very great importance is the requirement that long, heavy shadows, which present a constant menace to safety, be avoided. This requires that light be received from several directions and a number of projectors located advantageously about the grounds are therefore necessary. The flood lighting of buildings and monuments is largely a problem of aesthetics. Here uniform, shadowless lighting often defeats the purpose of the installation. Shadows are essential to relief, and contrasts in intensity or in color of light can be used advantageously to bring out important details and to suppress others; extreme care must, however, be exercised to see that shadows will not be formed which distort the appearance of the structure and produce a grotesque result. The aim should be to light the surface to produce the most

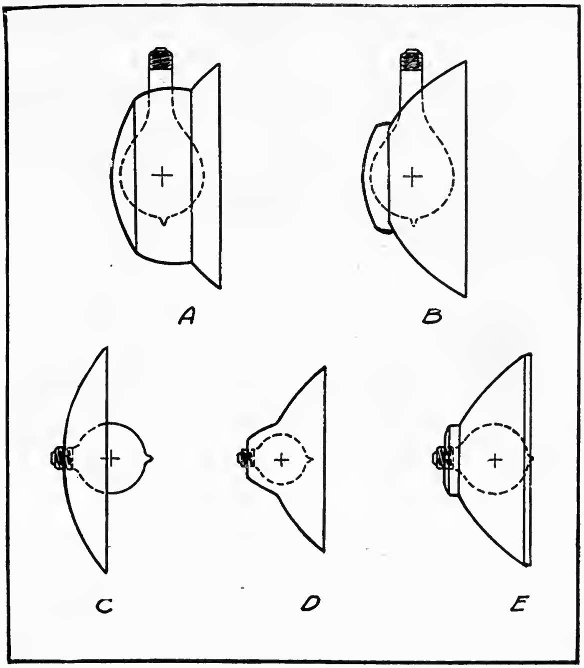


Fig. 1—Typical Floodlighting Reflector Contours
A and B, for use with ordinary multiple MAZDA C lamps, give moderate and wide spread of beam.
C, D, and E are for use with MAZDA C floodlighting lamps
C—Shallow parabola, narrow spread of beam
D, E—Deep reflectors, moderate spread of beam

pleasing and desirable effect. To permit this to be done, a number of units, or banks of units, are required.

Flood Lighting Equipment

Since a specularly reflecting surface is necessary in order to direct the light into a relatively narrow beam, as is desired for flood lighting, polished-metal or mirrored-glass reflectors must be employed in such equipments. Because of their high initial reflection factors and maintenance of efficiency in service, the mirrored-glass units have been widely adopted.

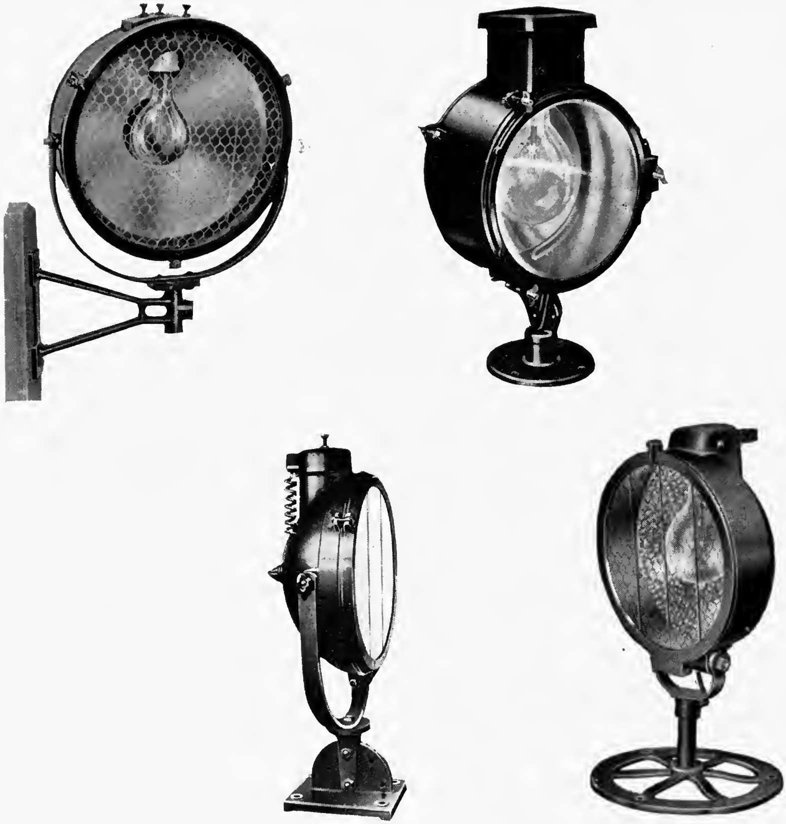


Fig. 2—Typical Projectors for Use with Ordinary Multiple MAZDA C Lamps

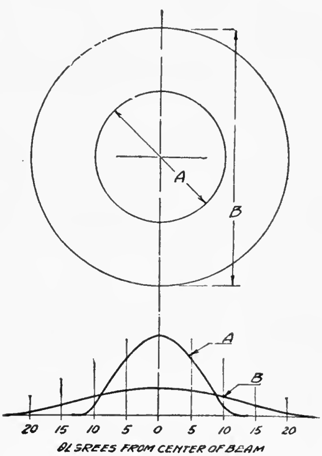


Fig. 3—Typical Distributions of Light Flux from Units of this Class. Circles represent relative areas of surfaces illuminated

A—Medium spread of beam
B—Wide spread of beam

Note—With some floodlighting equipments, several reflectors giving beams of various concentrations are interchangeable in one housing.

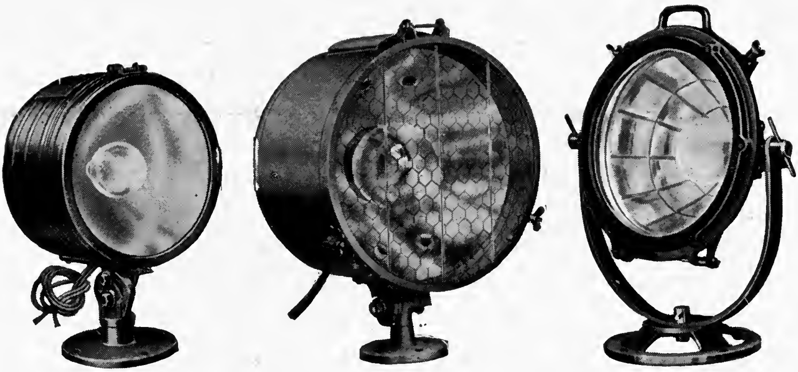


Fig. 4—Typical Projectors for Use with MAZDA C Floodlighting Lamps

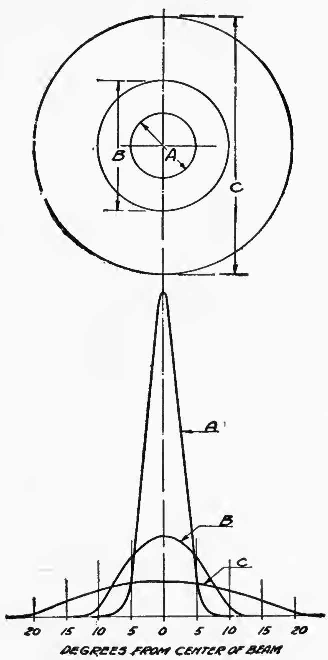


Fig. 5—Typical Distribution of Light Flux from Units of this Class
Circles represent relative areas of surfaces illuminated

A—Narrow spread of beam
B—Medium spread of beam
C—Wide spread of beam

Note—With some floodlighting equipments, several reflectors giving beams of various concentrations are interchangeable in one housing.

The equipments available may be divided into two general classes: those which in various sizes employ 100 to 1000 watt Mazda C lamps of the regular construction and those which are designed for use with flood-lighting lamps, having specially concentrated filaments, of the 250 or 500 watt sizes. The smaller light source of the latter permits more accurate control of the beam. The use of the former equipments simplifies the stocking and supplying of lamps. One limitation in their use is the fact that the larger sizes of Mazda C lamps should not be operated with the tip tilted more than 30 degrees from vertically downward.* On the other hand, the concentrated filament flood-lighting lamps are so constructed that they may be operated at any angle except within 45 degrees of vertically tip downward. The equipments using these lamps usually have the axis of the lamp in the axis of the reflector.

The spread of the light from a projector, that is, the angle of divergence of the beam, depends upon the size of the source and its distance from the reflecting surface (in other words, the angle which the light source intercepts at the reflector) and upon the contour of the surface. Obviously, the narrower beam of light can be obtained with the concentrated-filament flood-lighting lamps. Equipments employing these are available with a beam spread of as low as 8 degrees, and in other designs, of as high as 50 degrees. With the ordinary multiple lamp equipments, the minimum spread of beam is about 15 degrees and the maximum about 50 degrees. With a given contour of reflector, some variation in the spread of beam is obtained by moving the lamp filament backward or forward along the axis of the reflector. The maximum spread so obtainable is usually less than twice the minimum angle of divergence.

The percentage of the light from the lamp directed into the beam depends primarily upon the amount intercepted by the reflector and also upon the contour of its surface. The equipments available direct from 20 to 50 per cent of the light into the beam. For all ordinary multiple lamp equipments, however, and for the flood lighting lamp projectors of medium and wide beams, an output of 40 to 50 per cent may be obtained with reflectors of proper design. Fig. 1 shows typical designs of the reflectors for both the regular and flood-lighting lamp equipments.

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* For any other position of burning, lamps must be specially ordered.

TABLE No. 1

FLOOD LIGHT CALCULATION DATA

		2 B = 8°			2 B = 12°		
H Feet	C Deg.	L Feet	W Feet	A Sq. Ft.	L Feet	W Feet	A Sq. Ft.
25	0	3.50	3.50	10	5.26	5.26	22
	15	3.75	3.62	11	5.64	5.44	24
	30	4.67	4.04	15	7.03	6.08	32
	45	7.03	4.96	27	13.13	9.23	95
	60	14.19	7.04	79	21.73	10.08	172
	75	56.01	13.98	615	92.72	22.23	1619
50	0	6.93	6.93	38	10.51	10.51	87
	15	7.50	7.24	43	11.27	10.89	96
	30	9.34	8.08	57	14.06	12.16	130
	45	14.06	9.91	109	26.26	18.46	381
	60	28.39	14.09	314	43.45	20.17	688
	75	112.02	27.95	2459	185.44	44.46	6476
75	0	10.49	10.49	86	15.77	15.77	195
	15	11.25	10.86	96	16.91	16.33	217
	30	14.01	12.12	133	21.10	18.24	292
	45	21.08	14.87	246	39.38	27.70	857
	60	42.58	21.13	707	65.18	30.25	1548
	75	168.03	41.93	5533	278.15	66.69	14567
100	0	13.99	13.99	154	21.02	21.02	370
	15	15.00	14.48	171	22.55	21.77	386
	30	18.69	16.16	237	28.13	24.32	518
	45	28.11	19.83	438	52.51	36.93	1523
	60	57.77	28.18	1256	86.90	40.33	2753
	75	324.04	55.90	9836	370.87	88.92	25902

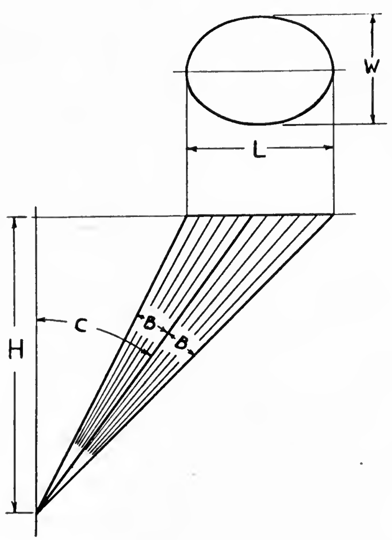


TABLE No. 1

(Continued.)

FLOOD LIGHT CALCULATION DATA

		2 B = 16°			2 B = 20°		
H Feet	C Deg.	L Feet	W Feet	A Sq. Ft.	L Feet	W Feet	A Sq. Ft.
25	0	7.03	7.03	39	8.82	8.82	61
	15	7.54	7.29	43	9.45	9.12	68
	30	9.43	8.14	60	11.88	10.24	95
	45	14.34	10.03	113	18.20	11.38	181
	60	29.86	14.53	342	38.90	18.52	566
	75	114.71	31.91	3633	232.14	45.25	8251
50	0	14.05	14.05	155	17.63	17.63	244
	15	15.08	14.58	170	18.89	18.23	271
	30	18.86	16.28	241	23.76	20.47	382
	45	28.67	20.06	452	36.40	22.76	724
	60	59.71	29.06	1367	77.79	37.04	2263
	75	229.42	63.80	14531	464.28	90.50	33002
75	0	21.08	21.08	349	26.45	26.45	549
	15	22.63	21.88	383	28.34	27.35	609
	30	26.29	24.42	543	35.63	30.71	859
	45	43.01	30.09	1016	54.59	34.14	1629
	60	89.57	43.58	3076	116.68	55.55	5091
	75	344.13	65.80	32694	696.41	135.76	74255
100	0	28.11	28.11	641	35.27	35.27	977
	15	30.17	29.17	680	37.79	36.46	1082
	30	37.73	32.56	965	47.51	40.95	1528
	45	57.35	40.12	1807	72.79	45.52	2896
	60	119.42	58.11	5468	155.57	74.07	9050
	75	458.84	127.61	58122	928.55	181.01	132009

Flood Lighting Design Data

Four factors must be considered in the design of a flood-lighting installation. These are:

1—Location of equipment;
2—Choice of equipment;
3—Illumination desired;
4—Size and number of units.

Location of Equipment

The necessity, in many cases, of locating the lighting units where they will be inconspicuous, as in the lighting of monuments, frequently leaves little choice of position. Advantage may be taken of neighboring buildings, columns, porches, and ledges on the structure itself, neighboring trees, and other possibilities which suggest themselves in each particular problem. Similar locations may be used for the lighting of bulletin boards and painted signs.

TABLE No. 1

(Continued.)

FLOOD LIGHT CALCULATION DATA

		2 B = 30°			2 B = 50°		
H Feet	C Deg.	L Feet	W Feet	A Sq. Ft.	L Feet	W Feet	A Sq. Ft.
25	0	13.40	13.40	141	23.42	23.42	431
	15	14.43	13.91	158	25.39	24.33	486
	30	18.30	15.66	226	33.52	27.95	826
	45	29.64	20.19	456	59.64	37.31	1747
	60	68.30	30.25	1623	268.24	79.07	16659
	75	.....	.....	....	.....	.....	.....
50	0	26.80	26.80	564	46.83	46.83	1722
	15	28.87	27.81	631	50.77	48.66	1944
	30	36.60	31.32	902	67.03	55.91	3302
	45	59.29	40.39	1825	119.28	74.61	6990
	60	136.61	60.49	6490	536.49	158.15	66638
	75	.....	.....	....	.....	.....	.....
75	0	40.19	40.19	1269	70.25	70.25	3875
	15	43.30	41.72	1419	76.16	72.99	4374
	30	54.90	46.97	2030	105.46	83.86	7430
	45	88.93	60.58	4107	178.91	111.92	15727
	60	204.91	90.74	14603	804.73	237.22	149935
	75	.....	.....	....	.....	.....	.....
100	0	53.59	53.59	2256	93.66	93.66	6890
	15	57.74	55.62	2522	101.54	97.32	7776
	30	73.21	62.63	3609	134.06	111.81	13092
	45	118.57	80.78	7301	283.55	149.23	27959
	60	273.21	120.99	25961	1072.98	316.30	266551
	75	.....	.....	....	.....	.....	.....

TABLE No. 2

WATTS PER SQUARE FOOT RECOMMENDED FOR FLOOD LIGHTING

Subject to be Illuminated	Poorly Illuminated Surroundings	Brightly Illuminated Surroundings
Buildings and Monuments:		
White or Cream	0.50—1.00	0.75—1.50
Light Yellow and Buff	0.75—1.50	1.50—3.00
Medium Buff	1.50—3.00	2.50—5.00
Billboards and Painted Signs	1.25—3.75	2.50—7.50

Bathing Beaches	0.05—0.5
Buildings:	
Construction	0.5 —1.00
Excavation	0.10—0.50
Docks, Wharves and Bridges	0.25—0.75
Drill Grounds	0.10—0.75
Outdoor Athletics: Football Practice, etc.	0.50—1.50
Outdoor Stage	0.50—1.00
Playgrounds	0.25—0.75
Yards for Mills, Factories and Railroads	0.05—0.25

TABLE No. 3.

FOOT-CANDLE ILLUMINATION RECOMMENDED FOR FLOOD LIGHTING

Subject to be Illuminated	Poorly Illuminated Surroundings	Brightly Illuminated Surroundings
Buildings and Monuments:		
White or Cream	2—4	3—6
Light Yellow and Buff	3—6	6—12
Medium Buff	6—12	10—20
Billboards and Painted Signs	5—15	10—30
Bathing Beaches	0.25—2	
Buildings:		
Construction	2—4	
Excavation	0.5—2	
Docks, Wharves and Bridges	1—3	
Drill Grounds	0.5—3	
Outdoor Athletics: Football Practice, etc.	2—6	
Outdoor Stage	2—4	
Playgrounds	1—3	
Yards for Mills, Factories and Railroads	0.25—1	

TABLE No. 4

LUMEN OUTPUT OF MAZDA LAMPS USED FOR FLOOD LIGHTING

Watts	Lumen Output
Mazda Lamps of the Regular Construction	
100	1300
150	2100
200	3000
300	4900
500	9000
750	14000
1000	20000
Mazda Lamps for Flood Lighting Service	
250	3250
500	8100

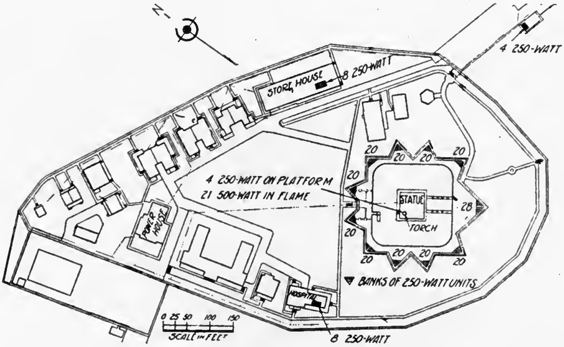
In the lighting of yards and outdoor construction work, units may sometimes be located on surrounding buildings, poles, or towers; frequently, however, it will be necessary to erect poles especially for the units in order to obtain locations which will allow light to be delivered from sufficiently different angles to destroy dangerous shadows. In order to avoid serious glare from the units, the projectors should be mounted high,—at least 30 feet above the ground. Mounting heights of 40, 50, or even 60 feet are usually to be preferred.

Choice of Equipment

The choice of equipment is largely determined by the dimensions of the area to be lighted and by the location of the equipment with respect to the area. Frequently, two or more forms

Floodlighting Liberty

252, 250-watt projectors in 15 separate banks located as shown in the diagram are used for this illumination



Plan of Bedloe's Island, Showing Location and Number of Lighting Units of equipment can be used advantageously for a single installation.

The beam of light from a projector is conical in form and hence when striking a surface perpendicular to its axis illuminates a circular area. If the beam strikes a surface at an angle, the resultant spot of light is, of course, elliptical in form. By overlapping the beams it is possible to obtain an approximately uniform illumination and avoid striations, or images of the filament, projected by the specularly reflecting surface of the reflector. Ribbed or fluted cover glasses are available by which the spread of the beam may be greatly extended in one direction.

In flood lighting, it is often found necessary to eliminate spill light in order to avoid glare or to confine the light to a certain definite area. For this purpose some manufacturers supply spill-shields to be placed within the projector or it is not difficult to equip the projectors with cylindrical tubes or baffle plates.

Table 1 gives the dimensions and area of the spot illuminated by projectors having various spreads of beam located at various distances from the surface illuminated and directing the light to it at different angles. By means of this table, the location of the units having been decided upon, the choice of the correct beam spread may be made and the equipment selected accordingly.

Illumination Desired

In deciding the desirable amount of illumination for the specific installation under consideration, it is necessary to take into account such factors as the color of the surface to be lighted or the nature of the work to be performed, the brightness of surroundings, and in the case of advertising displays, the attracting power of high illumination. There is seldom danger of overlighting if the installation is properly made. On the other hand, it should be recognized that to make a structure stand out in the midst of bright surroundings, light must be projected in quantity,—literally layer upon layer; halfway measures have no place in flood lighting for artistic effect. The ideal subject for flood lighting is the one of great beauty in an isolated spot. The data of Tables 2 and 3 are representative of modern practice, although, as mentioned, individual conditions will lead to considerable departures from the ranges given. Unquestionably, the use of higher values than here shown is desirable in many cases.

Size and Number of Units

There are two simple methods of determining the size and number of units required, first, by using the data in Table 2

The Wheatena Factory, Rahway, New Jersey—Lighted with 32 500-watt projectors with an average of only 0.41 watts per square foot

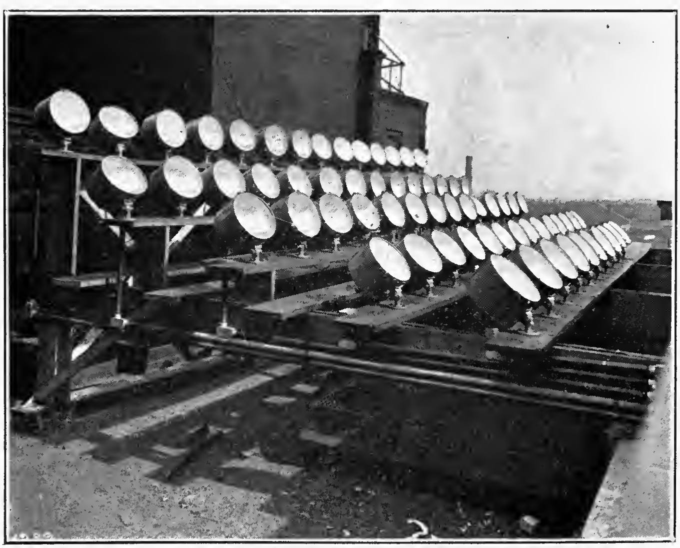
A typical bank of projectors used to light the Wheatena Factory, illustrating the substantial construction of mounting frame, which is made of 2-inch pipe set in concrete, painted dark green to harmonize with surroundings

which gives the average watts per square foot that experience has found satisfactory for this service. A second method is to work from the other extreme, basing the calculations on the illumination desired, i.e., the flux of light method. The values recommended for this are shown in Table 3.

In either method there are several general points to be remembered. A dark object is always an extremely difficult subject to illuminate regardless of the quantity of light provided. Table 3 shows light yellow or buff objects require double the illumination necessary for white surfaces, while a medium buff requires three times as much. An equally important consideration is the brightness of the surroundings. A building in a poorly lighted section would require only a fraction of the wattage per square foot to produce the same effect as an installation in the midst of brightly lighted surroundings.

Problem No. 1

Let us assume that a factory yard is to be flood lighted to permit work to be done at night. If the yard is 175 feet by 320 feet we would have an area of 56,000 sq. ft. to light. From table 2 we see that 0.05 to 0.25 watts per sq. ft. are required. Assuming moderate activity and allowing for ordinary accident hazard a figure of 0.10 could be taken. Then 56,000 $\times$ 0.10 gives 5,600 watts required. The number of projectors required depends upon local conditions and can be determined from Table 1. If neighboring buildings permit the equipment to be mounted relatively high, 12 units of the 500 watt size would be sufficient.



One of the Batteries of 500-watt projectors that floodlight the Wrigley Building

The Wrigley Building, Chicago—An excellent example of floodlighting employing 198 500-watt and 16 250-watt projectors

Problem No. 2

Calculations for the size and number of flood-lighting units required can be made much more accurately in essentially the same way as for interior lighting. The first step is to multiply the area in square feet of the surface to be illuminated by the foot-candles illumination decided upon. The product is the total lumens which must be delivered to the surface. This value is then increased by about 30 per cent. or more, to provide for depreciation between periods of cleaning and making lamp renewals. The result obtained is the number of lumens which must be received initially upon the surface.

The next step is to refer to Table 1 and with the location of the units with respect to the surface in mind, estimate what percentage of the total light projected by the units will actually strike the area to be illuminated. Dividing the percentage, expressed as a decimal, into the lumens required initially upon the surface itself as determined above, gives the total number of lumens which must be supplied in the projected beams.

As has been stated, flood-lighting projectors of medium and wide beam are available in which from 40 to 50 per cent of the light of the lamp is directed into the beam. The actual values for the equipments under consideration should be obtained from the manufacturer. Dividing this value (as a decimal) into the total lumens required in the projected beams, as determined above, gives the total lamp lumens required for the installation.

The lumen outputs of the lamp ordinarily used in flood lighting are listed in Table 4. The total lamp lumens required divided by the lumen output of the size of lamp used gives the number of projectors required for the installation.

Suppose, for example, it is desired to flood-light the front of a bank building from a distance. The surface is 75 feet high and 60 feet wide and is of white terra cotta. It is located amid dark surroundings.

Area to be lighted: 75 x 60 = 4500 sq. ft.

From Table 3 it is decided that 4 foot-candles will give effective results; 4500 x 4 = 18,000 lumens.

This value is increased by 30 per cent to provide for depreciation; 18,000 x 1.3 = 23,400 lumens.

From a consideration of the location of the units and their beam characteristics, it is estimated, by reference to Table 1, that 90 per cent of the light in the projected beams will strike the surface; 23,400 divided by 0.9 = 26,000 lumens necessary in the beams.

The manufacturer's data shows that the equipment it is desired to use directs 45 per cent of the lamp lumens into the beam; 26,000 divided by 0.45 = 57,800 lamp lumens required, with no allowance for absorption of the clear glass cover plate.

Assuming that a further allowance of approximately 15 per cent must be made for absorption of the clear glass cover plate, multiplying 57,800 x 1.15 = 66,500 total lamp lumens required.

If it is desired to use the 500-watt flood-lighting lamp, the lumen output is found from Table 4 to be 8100 lumens; 66,500 divided by 8100 = 8.2 (or 9) units required.

Pennsylvania Freight Yards, Chicago—Two-pole tower mounting eight 1000-watt Floodlight Units. Two such towers are employed 3000 feet apart, with beams opposed.

Pennsylvania Freight Yards, Chicago—Lighted by two banks of eight 1000-watt floodlighting units, mounted on towers 75 feet above the tracks. The two towers on which they are mounted are 3000 feet apart with beams opposed

PART XII
LIGHTING FOR OUTDOOR SPORTS

Tennis Court Lighting

The conditions to be met in the lighting of outdoor courts present problems not encountered in other fields of illumination. In the office, for instance, the desk level is usually assumed to be the working plane and all illumination calculations may be made with this plane as the basis. In the case of the tennis court, however, this condition is materially changed. There is no fixed plane and the light must be distributed in such a manner that the ball is well lighted during its entire travel.

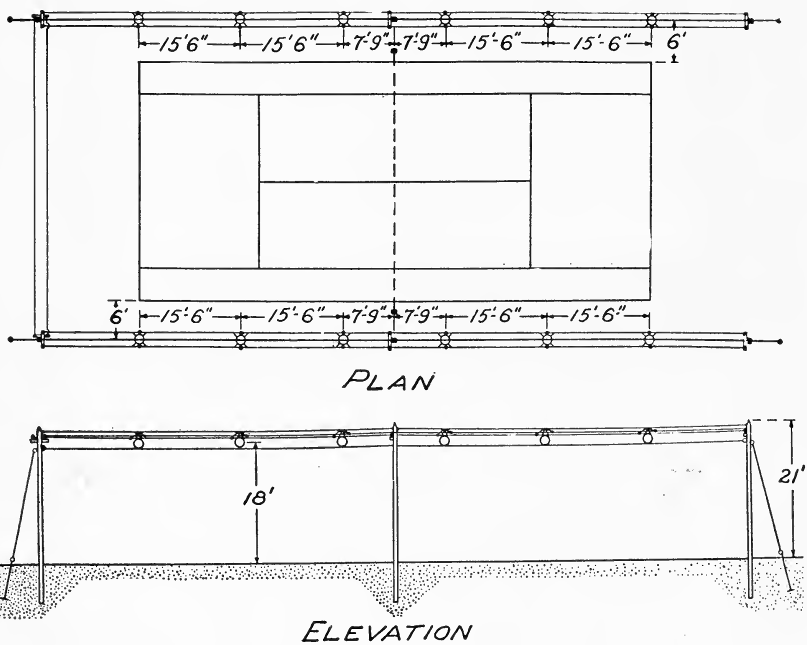


Fig. 1
The Arrangement of 500-watt Mazda C Lamps with Angle Type Enameled Steel Reflectors in the Side Lighting System for Tennis Courts

In the side lighting system, as the name implies, units are hung at a moderate height along the sides of the court, while in the overhead system they are placed far above the ground over the center line of the court. These two systems are the result of considerable experimentation, and have been found very satisfactory in service, as is evidenced by the number of courts throughout the United States and foreign countries which use these forms of lighting.

The United States National Lawn Tennis Association en-

Effect of Lighting as Shown in Fig. 1 on Preceding Page

dorses night tennis when the installation is properly laid out to obtain the desired playing conditions. The maintenance of the system is practically nil, save for an occasional cleaning of lamps and reflectors.

Night playing overcomes the limitations of daylight and makes one court do the work of two. Any man who cannot stand the heat of the day for such a strenuous game as tennis, enjoys night playing in the open. Lighted courts are an added attraction—a valuable asset to any club in interesting prospective members. It proves as interesting for spectators as daytime playing. It enables the busy man to get more practice during the week so that he will be in better form for week-end matches.

The side lighting system is shown in plan and elevation in Fig. 1. It calls for twelve units, six on each side of the court, spaced and hung as shown. 500-watt Mazda C lamps are used with suitable angle type porcelain enameled reflectors and weatherproof holders.

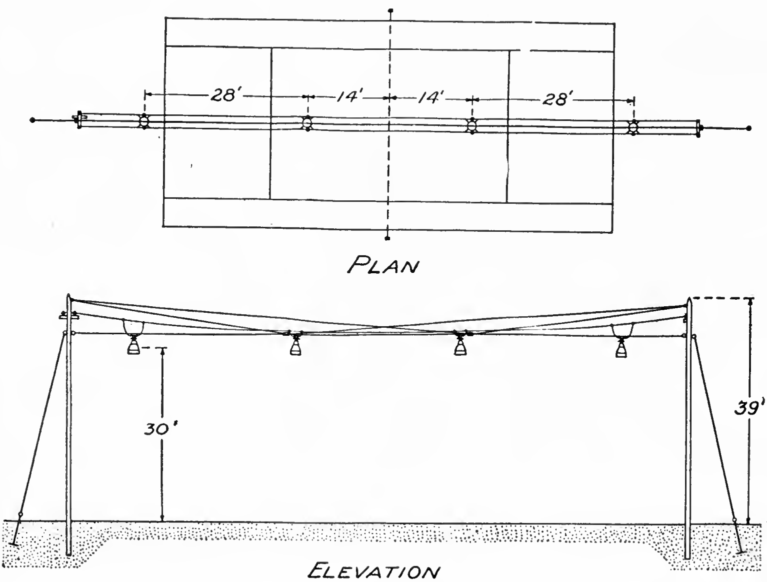
Some of the courts are surrounded by netting, the supporting structure of which is of sufficient strength to allow mounting the units from brackets attached thereto. Under other conditions, it is advisable to suspend the lighting units from cables stretched between posts or poles. Three of these on each side are desirable.

The supporting cable should consist of ⅜-inch galvanized stranded steel wire. The lamps and reflectors may be attached to this by any suitable hanger.

List of Material Needed for Side Lighting System

	Amount Necessary
500-watt MAZDA C lamps	12
Porcelain enameled steel 45-degree angle reflectors	12
Holders	12
Hangers	12
25-ft. wooden poles	6
⅜-in. galvanized stranded steel wire	350 ft.
No. 12 galvanized iron wire	250 ft.
No. 8 weatherproof copper wire	600 ft.
No. 14 weatherproof copper wire	75 ft.
Double-pole, single-throw, 60-amp. switch	1
Weatherproof service box	1
Cross arms with pins, insulators, lag screws and braces	8
Guy anchors with turn and clamps	4

The overhead lighting system in plan and elevation is shown in Fig. 2. This system calls for four 1,000-watt Mazda C lamps equipped with deep bowl enameled steel reflectors and special skirt with weatherproof socket holders. They should be placed as indicated in the dimensioned drawing. The fixtures should be suspended from galvanized stranded cable,



⊙ *Location of 1000-watt MAZDA C Lamp with Bowl-shaped Enamel Steel Reflectors*

Fig. 2

Location of 1000-watt Units in the Overhead System for Tennis Courts stretched between 45 foot posts. The hangers may be the same as those used for the side lighting system, or preferably automatic cut-out hangers which make it possible to lower the units for replacement of lamps.

List of Material Needed for Overhead System

	Amount Necessary
1000-watt MAZDA C Lamps	4
Porcelain-enameled steel deep bowl reflectors	4
Skirts	4
Holders	4
Hangers	4
45 ft. wooden poles	2
¼ in. guy and messenger cable	450 ft.
No. 8 weatherproof copper wire	325 ft.
No. 14 weatherproof copper wire	25 ft.
Double-pole, single-throw, 60-amp. switch	1
Weatherproof service box	1
Guy clamps	10
Anchors	2
Strain insulators	2
Cross arms with pins, insulators, lag screws and braces	2

Clock and Court Golf Lighting

Although not as exacting, the conditions to be met in this class of lighting are similar to those of the tennis court.

There must be sufficient light to enable the player to follow the ball after the stroke and to make out easily the outline of the hole on the putting green. The illumination should be fairly even in order that one will not be misled in judging distances and in sizing up any irregularities on the green. The distribution of light from the lighting units should be wide so that one may find the ball in case it is driven off the fair green.

The lighting accessories must be so located as not to interfere in any way with the play.

By artificially lighting a clock and court golf course the ardent golfer need not confine his activities entirely to the daytime. He is enabled to extend his practice in approaching and putting during the evening hours, thus enabling him to devote his day's playing to the game proper.

Each particular court is, to a certain extent, a problem in itself and thus requires special attention. One club met the lighting requirements by using units suspended from cross arms attached to iron poles embedded in concrete. The spread of the cross arms is eighteen feet and the units are fourteen feet above the ground, six 750-watt Mazda C lamps are used equipped with steel reflectors.

Night View of Sheepshead Bay Speedway Taken from End of Grand-stand. The Illumination of the Track and Field is accomplished by MAZDA C Flood-lighting Lamps in Form L-1 Projectors

The Lighting of Motorcycle and Bicycle Racing

Motorcycle and bicycle racing have become so popular in the past few years that many races are held at night. This, of course, means that artificial light must be provided.

Racing, especially with motorcycles, has a certain element of danger even under the best conditions. Unless the track is properly lighted this danger will be greatly increased.

The scheme outlined in Fig. 3 meets the requirements for this class of service. Medium-sized Mazda C lamps (300- or 500-watt) should be used, equipped with enameled steel angle reflectors that project the maximum light at approximately

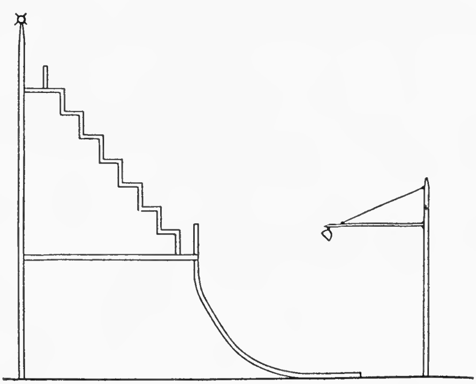


Fig. 3
Section of Motordrome Showing Location of Units for Lighting Track and Seats

forty-five degrees from the vertical. The units should be so located as to project the maximum light a little above the central portion of the track. Where it is necessary to locate the units above the lower portion of the track they should be suspended from brackets in order that the supporting posts may be removed several feet from the track to eliminate danger. The posts should be spaced approximately every twenty feet. The height of the units will depend on the contour and height of the track.

This system has the following advantages:

A number of small units produce more uniform illumination than fewer large units. The failure of one unit does not leave a comparatively large section of the track in darkness.

The light is absolutely steady.

There is no glare for either the riders or spectators. This feature adds to the safety of the former and the comfort of the latter.

In addition to the units required for the track proper, there should be additional low wattage lamps at the back of the spectators to aid in finding seats and reading programs.

The Lighting of Outdoor Arenas

The illumination of outdoor areas sufficiently large to be used for auto polo, drilling, foot-ball, hockey, skating, playgrounds and athletic contests in general, offers exceptionally interesting problems.

Three methods of illumination are employed as follows:

(1) Suspending units over the area by messenger cable strung between poles. The units must be hung at a sufficient height to eliminate any danger of glare to either the observers or players. The spacing must be such that for the hanging height and type of reflector employed the illumination is reasonably uniform.

(2) Lighting from units located at the sides employing standard angle type reflectors. These must be suspended at such a height and in such positions as to prevent the possibility of annoyance to the players and to observers in the stand.

(3) The employment of floodlighting projectors located on the roof of the grandstand, adjacent buildings, special poles, or even trees.

Night View of a Drill Field Lighted by Nine 750-watt Mazda C Lamps in Angle Steel Reflectors on Poles Around the Edge of the Field

Each particular system has certain advantages. The one to be selected will depend upon the area to be lighted and local structural conditions.

If the field is comparatively small and only a low intensity is required, as for example, a small drill field, skating pond, or playground, poles can be erected without difficulty. The overhead system employing medium size Mazda C lamps with standard distributing reflectors is probably the most simple installation.

Where there is a grandstand or similar structure and the area to be lighted is comparatively narrow, angle type reflectors fitted with standard Mazda C lamps are inexpensive and easily installed.

For lighting areas too wide to permit the use of the overhead system, and when only a low intensity is required, angle type units located on poles around the edge of the field prove satisfactory. They are much less expensive than floodlighting equipment.

Where the area to be lighted is wide and a relatively high intensity of illumination is desirable, floodlighting equipments offer the best means of solution. The type of floodlighting projector employed will depend on the available means of support and the distance between units.

The following table gives the desirable intensity for various outdoor sports.

	Intensity in Foot-candles	Watts per Square Foot*
Drill Fields	0.5—3.0	0.10—0.75
Football	2.0—6.0	0.50—1.50
Hockey	4.0—6.0	1.00—1.50
Polo	2.0—4.0	0.50—1.0
Skating	0.5—2.0	0.10—0.50
Playgrounds	1.0—3.0	0.25—0.75

* Based on use of high power MAZDA C lamps and efficient reflectors.

Lighting of Bathing Beaches

Bathing beaches have always been a popular place of assembly at night. This is the only time when a large majority of the people can enjoy them. The pleasure of bathing, however, is usually denied because of the danger of being lost in the darkness.

It is a relatively simple matter to light the beach so that it is safe for night bathing. Artificial illumination of the bathing beach will materially increase its patronage, and prove a boon to the working class.

The nature of the average beach is such that the lighting units must be placed a considerable distance from the water and for this reason floodlighting projectors offer the best solution. They should be placed thirty feet or more above the beach and, when possible, located in two banks about one hundred feet apart so as to provide light from more than one direction. Hotels or other buildings adjacent to the beach usually provide convenient means of mounting the projectors. From ¼ to 2 foot-candles of illumination should be provided.

The Lighting of Trap Shooting Ranges

As difficult as the problem may seem, the successful lighting of ranges for trap shooting is an established fact. In a recent day and night meet all of the contestants made as good scores by night as during the day, while some made better scores. In another meet held in the middle west, one of the entrants made ninety-nine hits out of a possible one hundred under artificial lighting.

One method of lighting this particular sport is shown in Fig. 4. Four projectors are used, located behind the shooter's stand or handicap positions twenty feet above the ground. Each of the projectors is equipped with a 1,000-watt Mazda C lamp. The lamps should be focused so that the spread of the light will be approximately thirty degrees. After installing the units they should be pointed in the direction indicated by the lines on the diagram at such an angle vertically that the illumination on the ground at the limit of travel of the clay pigeons will be even. Having obtained this condition each projector should be

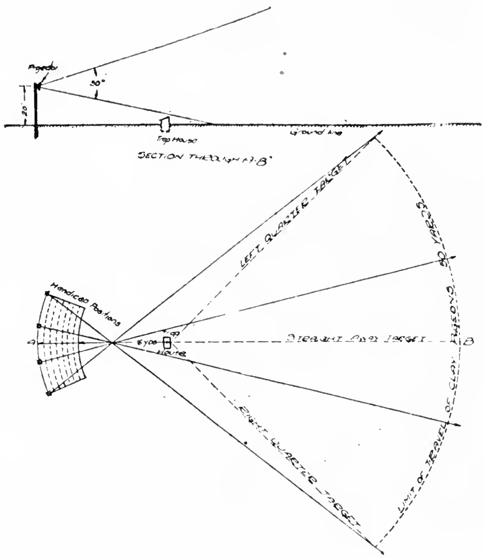


Fig. 4
Method of Lighting Trap Shooting Ranges in Plan and Elevation

pointed upward the same amount until the lower edge of the beam of light is approximately as shown in the elevation, (Fig. 4).

This method has the advantage of simplicity of installation and operation. There is sufficient direct light from the units to illuminate the shooter's stand. The light covers the entire area over which the pigeons will be thrown with sufficient intensity to make them very conspicuous. The cost of operation is low. The energy required is 4,000 watts which at ten cents per kilowatt hour will cost forty cents for each hour.

PART XIII
LIGHTING FOR INDOOR RECREATIONS

Pool and Billiard Parlors

When considering the lighting requirements for pool and billiard tables, two important points must receive careful attention. These are a high intensity and extremely good diffusion. The necessity for these is easily seen from the fact that the playing area is rather small and distances and angles must be

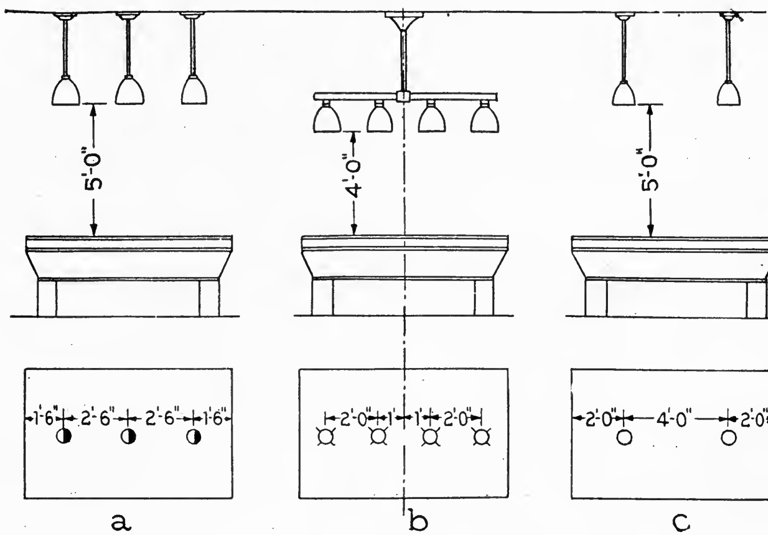


FIG 1

THREE COMMON METHODS OF LIGHTING BILLIARD TABLES

a = 3–75 or 100 watt bowl enameled Mazda C lamps in heavy density glass intensive type bowl reflectors.

b = 4–50 or 75 watt diffusing bulb Mazda lamps in heavy density glass intensive type bowl reflectors.

c = 2–100 or 150 watt bowl enameled Mazda C lamps in heavy density glass intensive type bowl reflectors.

carefully gauged. A shadow cast by a ball is very apt to mislead players in gauging distances, or otherwise disconcert them causing them to fumble the shot. No shadows cast by players standing in the immediate vicinity of the table should be allowed to fall on the table, unless these shadows are so soft as to be imperceptible.

There are three methods by means of which these requirements can be met in a satisfactory manner:

A—Individual units located over each table supplemented by a low intensity of general illumination.

B—Translucent reflectors placed over each table which serve both as local light for each table and general lighting for the entire room.

C—Straight general system employing semi-indirect, indirect or enclosing diffusing units.

Individual lighting of tables is by far the most common. This is due no doubt to the fact that the grouping of low wattage lamps over tables in order to secure a desirable intensity was inaugurated before the advent of high wattage lamps. It is customary with this type of installation to use opaque deep bowl reflectors mounted approximately four or five feet above the table. Metal reflectors are best suited because no light is transmitted through them, with the result that little direct light reaches the eye.

With such a system, it is necessary to use some means of general illumination, as otherwise the room will be very gloomy and cheerless. Unless care is exercised in designing the installation and choosing the fixtures, the lighting system is apt to be unsightly.

The units should be hung high enough so that they do not interfere with a player's movements, and are not likely to be struck with a cue. It is necessary for the reflectors to be of such type that the angle of cut-off light from the lamp is fairly sharp and no direct light is permitted to enter the player's eyes. As stated before, a medium intensity of general illumination is necessary with such a system and this can best be obtained by using 100 or 200-watt Madza C lamps in indirect, semi-indirect, or enclosing units, spaced to provide from one-quarter to one-half watt per square foot of floor area.

With the indirect system, because of the diffusely reflected light from the ceiling and walls, the placement of tables with regard to the lighting units is not important.

The semi-indirect system requires more careful placing of units with respect to tables in order to keep shadows short and soft. Best results are obtained with this system when a group of tables are to be lighted, as the units can then be so placed as

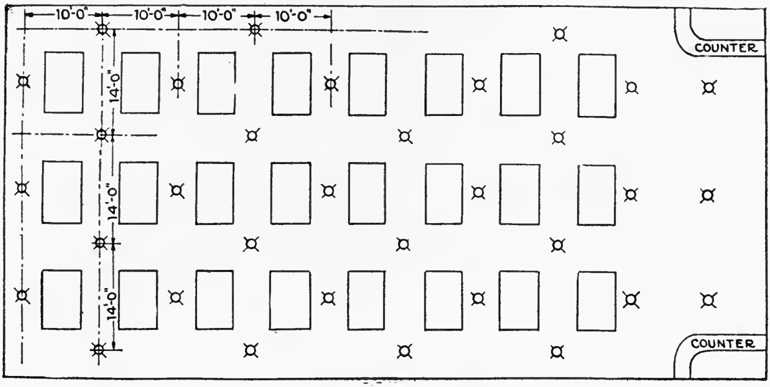


Fig. 2

PLAN OF BILLIARD ROOM LIGHTING INSTALLATION
¤ = 300 watt Mazda "C" lamp in enclosing glassware

to make tables receive predominating light from several directions.

While enclosing units diffuse the light to a certain extent, still most of the light received under such a system is direct light, and hence particular care must be used in placing the units so that objectionable shadows will not interfere with the player's aim. Fig. 2 shows a method of locating units in order to obtain the desirable effect.

With totally indirect lighting, and with light surroundings, from 2.0 to 3.0 watts per square foot should be provided; with enclosing units from 1.5 to 2.0 watts per square foot are desirable; the value for semi-indirect lighting falling between these two and being dependent of the type of unit and room finish.

Bowling Alleys

The very nature of bowling is such that unless careful consideration is given to the proper shielding of light sources, it is very likely that the pastime cannot be carried on with any degree of enjoyment. Bowling alleys, by virtue of their construction, are long, narrow areas with comparatively low ceilings, which practically limit the spacing of outlets to the region above the alleys themselves, where the lighting units are most conspicuous. It is obvious that unless they are properly shielded the resulting glare may be such as to render the player unable to aim his ball effectively.

The intensity on the alley itself should be fairly high, while at the end, on the pins, the intensity should be approximately double that on the alley. Deep bowl reflectors with 75-watt Mazda lamps are often placed in a single line down the alley. In some cases the spacing between units is too great

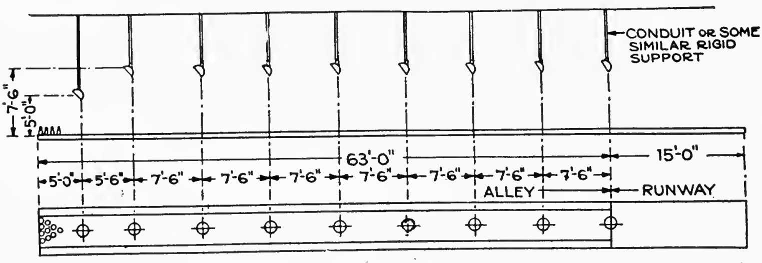


Fig. 3

STANDARD METHOD OF BOWLING ALLEY LIGHTING

⌖ = 75 watt Mazda C lamp in angle steel reflector

and the resultant illumination very uneven, creating light and dark areas or striated effect, which proves very annoying. Then again, with an installation using deep bowl reflectors, the reflected glare from the polished floor surfaces is likely to prove troublesome.

The best method of obtaining an evenly distributed light on the surface of the bowling alley and a high intensity on the pins, free from glare or glaring reflections, is to utilize 75-watt Mazda lamps in angle reflectors mounted in a single line over the center of the alley, as shown in Fig. 3.

When using this system, which is rapidly becoming standard, it is necessary to use conduit or some similar rigid support for the units, as otherwise they are likely to twist or turn, thus either throwing the light on a neighboring alley or else in the player's eye.

This system can be used for lighting two alleys, and when so employed, outlets for 75 or 100-watt Mazda lamps with the proper size angle reflectors should be spaced in a single line, midway between the two alleys, with individual units on each alley at the pins.

Indoor Tennis Courts

Indoor tennis is popular among those adherents of the game, as it is free from the vagaries of the weather and differences in seasons. The entire area housed by the structure should be lighted to a fairly high intensity, and not only must the floor surface be lighted, but the units must be hung sufficiently high to enable a ball, traveling 20 feet in the air, to be clearly visible at all times. If the intensity is markedly uneven over the court, light and dark patches will be present and the ball in traveling from a lighter to a darker area will appear to slow down; conversely, when traveling from a darkened area to a lighter area, it will appear to gather speed. This apparent variation in the ball speed may render the player unable to gauge properly the speed of the ball in order to make a return. With constant repetition, this will defeat the primary purpose of the lighting installation, which is to enable the game to be played as effectively at night as during the day. Glaring light sources will render the players more or less ineffective in making returns.

All three of the general systems of lighting are applicable to this problem. The direct system is the most efficient, but, if it is not carefully designed, the installation may easily become glaring. The semi-indirect system can be applied where the

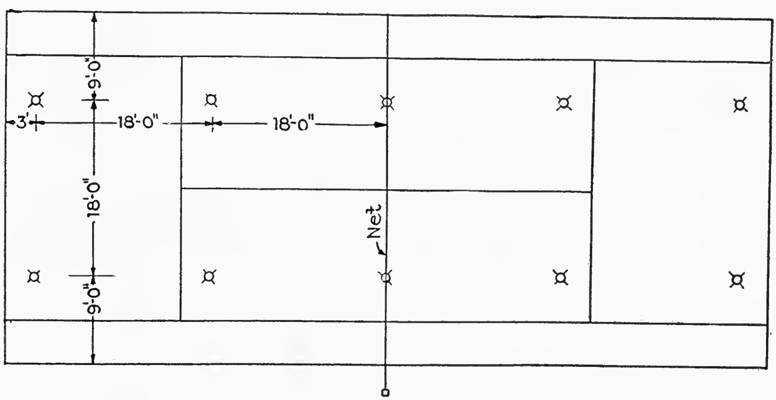


Fig. 4

PLAN OF TENNIS COURT SHOWING LOCATION OF LIGHTING UNITS

¤=500 watt Mazda C lamp in semi-indirect or enclosing diffusing globe

NOTE: Minimum hanging height 20 feet

wall and ceiling finish of the building is comparatively light in color, thus permitting a good portion of the light to be reflected from these surfaces. The totally indirect system can be applied only where the wall and ceiling finish is such as to have a high coefficient of reflection. This system gives the best diffusion with little or no likelihood of glare, but since all of the light must be reflected from the ceiling, it requires approximately double the wattage required for a direct lighting system.

For all practical purposes, enclosing or semi-enclosing diffusing units are to be recommended, where the ceiling height is 25 feet or more. High wattage Mazda C lamps placed on wide centers are preferable to low wattage lamps more closely spaced, as there is less likelihood of several units being in the field of view. Light colored walls and ceilings will eliminate any difficulty with uneven lighting.

Squash Courts

The principal requirements for lighting a squash court are a high intensity, good diffusion and absence of glare. The game of squash calls for rapid play with close attention, inasmuch as the movements of a small ball must be closely followed.

The room in which this game is played varies from 50 to 30 in length, and from 20 to 15 feet in width. The walls and floor are hard and smooth. There are usually two finishes applied to the walls and ceiling. In some cases a dark finish, such as mahogany, is used in conjunction with a white ball, so as to get the proper contrast between the ball and walls.

In other cases, particularly in England, the walls are painted a flat white and a black ball is used. It is evident from this that the dark finished court makes the greatest demand on the lighting installation inasmuch as it posseses a very low reflection factor.

Occasionally the construction of the ceilings of these courts is such as to permit the hanging of deep bowl direct lighting units, so as to conceal them from view, save when looking directly upwards. That is, they can be hung along side of drop beams. In other cases, it is possible to set these so that the mouth of the reflector is flush with the ceiling and provide a slight metal shield on the side generally faced by the players. Angle reflectors are scarcely suitable, for the play is likely to progress on all sides and unsymmetrical distribution of light is not effective.

Where the fixture must be in full view, semi-enclosing units of the diffusive and decorative type find use. The precaution must always be taken of carefully guarding the glassware from balls struck upwards. As mentioned, the power required properly to light the court will vary with the room finish. From three to four watts per square foot with the deep bowl direct lighting installation, in a darkly finished room, will prove satisfactory, while with the enclosing units, under the same conditions, upwards of five watts per square foot is necessary. With light surroundings the values can be greatly decreased.

Skating Rinks

Of all indoor recreations that of ice skating meets with most popular favor. This is so because the sport is not limited to a small number of people and there is practically no age barrier.

The pleasure afforded is nearly equivalent to that of outdoor skating and in many ways indoor ice skating is more to be pre-

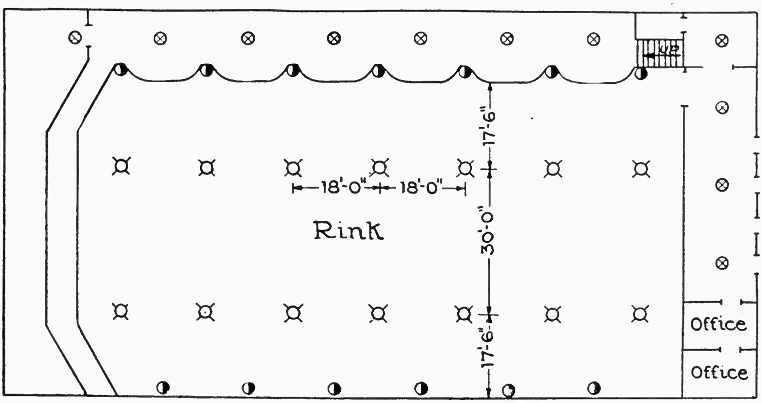


Fig. 5

PLAN OF ICE SKATING RINK

⌑ = 300 watt Mazda "C" lamp in semi-indirect unit

⊗ = 75 watt Mazda "C" lamp in semi-indirect unit

◑ = 3-25 watt Mazda "B" lamps, wall-bracket

ferred inasmuch as its enjoyment is not dependent on weather conditions.

When considering the lighting of skating rinks, two types come to mind—one, purely utilitarian, non-decorative, for use in such rinks as are devoted mostly to hockey playing and similar contests; the other less efficient, more decorative, harmonizing and blending with the finish and appointment of the rink. In the first type, as stated before, the primary consideration is adequate diffusion. In a hockey game the shadows cast by the players, either when separated or in a scrimmage, must not be dense enough to cause the players to lose track of the hockey puck.

If direct lighting is to be employed, it is necessary to space outlets quite closely together to eliminate any shadow difficulties. In choosing the type of reflector, we must consider the question of efficiency, appearance, and cost. Bowl enameled Mazda C lamps in RLM Standard Dome reflectors or clear Mazda lamps in deep bowl mirrored glass reflectors represent one extreme, diffuse enclosing units the other. A practice which has much in its favor is the use of dense opal deep bowl reflectors, transmitting some light to the ceiling, permitting a fairly ornamental appearance, and yet relatively effective in redirection of light.

The size of lamp to be used will vary somewhat with the ceiling height. For ceiling heights of 20 feet or under, 100-watt Mazda C lamps, heavy density opal glass reflectors, spaced approximately on 10 by 10 foot centers, will provide a good intensity on the rink, together with a high degree of diffusion. Where the ceiling height ranges between 20 and 30 feet, 200-watt bowl enameled Mazda C lamps in the same type of reflector spaced on 15 by 15 foot centers will provide approximately the same intensity.

Where rinks are employed purely for general skating purposes in large cities, they should be well appointed and critical attention given to their interior finish. The lighting of these rinks must necessarily be of a more ornamental character in order to harmonize with the surroundings. The intensity here need not be so high as that required on rinks devoted to skating contests. Diffusion, however, must be of a fairly high degree inasmuch as exhibition matches are sometimes staged which necessitate comparative freedom from dense shadows.

The two systems which work out best for this service and are commonly employed, are the semi-indirect and enclosing unit systems. The diffusion under each is very good, and a fairly high intensity can be obtained at a reasonable consumption of power.

PART XIV

MAINTENANCE OF INTERIOR LIGHTING SYSTEMS

To account for the poor attention which lighting systems as a whole receive, it is necessary to believe that most persons fail to realize with what rapidity or to what extent dust and dirt cut down the effectiveness of a lighting system; or that, knowing the extent of the depreciation, they undervalue the light allowed to go to waste; or that, with the value of the wasted light known, they believe a maintenance system to be difficult and costly to operate.

Extent of Lighting Depreciation

In calculating the wattage for a modern lighting system, the illuminating engineer uses a "depreciation factor" to compensate for normal average depreciation in service. Good practice calls for an allowance of 30 per cent more light initially than is expected in service in fairly clean locations and fairly clean operations (23 per cent loss); in dirty locations and dirty operations 50 per cent or even 100 per cent is really necessary (33⅓ or 50 per cent loss). These figures doubtless seem high but the illuminating engineer uses them with the knowledge gained from experience that unless the maintenance of the system is handled in better fashion than is usually the case, the system will in a short time be giving less light than it was designed to furnish.

There are six principal causes of lighting depreciation. These are: (1) dirty reflectors and lamps; (2) darkened walls and ceilings; (3) depreciation of lamps; (4) empty sockets; (5) unobserved burnouts; (6) improperly made replacements. In general, when installed in relatively favorable locations, open reflector units show a depreciation in total light output of from 10 to 25 per cent in four weeks' time. Where excessive smoke and dust are the rule, the depreciation over this same period may be as high as 40 per cent. The effect of darkening of the ceiling and walls due to smoke and dust depends upon the type of unit, the location, i.e., whether clean or dirty, and the original color and finish; typical data are given in Table 1. MAZDA C lamps throughout life average above 90 per cent. of their initial output. Blackened bulbs are continually decreasing in number, but where inspection shows a bulb to be considerably darkened the lamp should be replaced with a new one. Empty sockets and unobserved burnouts in indirect and multi-light fixtures are fre-

TABLE 1—Effect of Darkening of Ceilings and Walls on Illumination at the Work

Ceiling:	Very Light			Fairly Light			Fairly Dark	
Walls:	Fairly Light	Fairly Dark	Very Dark	Fairly Light	Fairly Dark	Very Dark	Fairly Dark	Very Dark
Type of Unit	Foot-Candles Illumination in Per Cent							
RLM Standard Dome	100	96	92	98	94	90	94	90
Deep Bowl, Steel	100	96	91	98	95	91	95	91
Semi-Enclosing	100	90	80	95	85	78	83	76
Light Density Semi-Indirect	100	87	76	82	71	63	55	50
Indirect	100	90	83	73	63	57	37	33

quently found when complaints of inadequate illumination are investigated. Replacement of burned out lamps with new ones of a wrong size or of an incorrect voltage rating is often found to be the cause for dissatisfaction with the lighting.

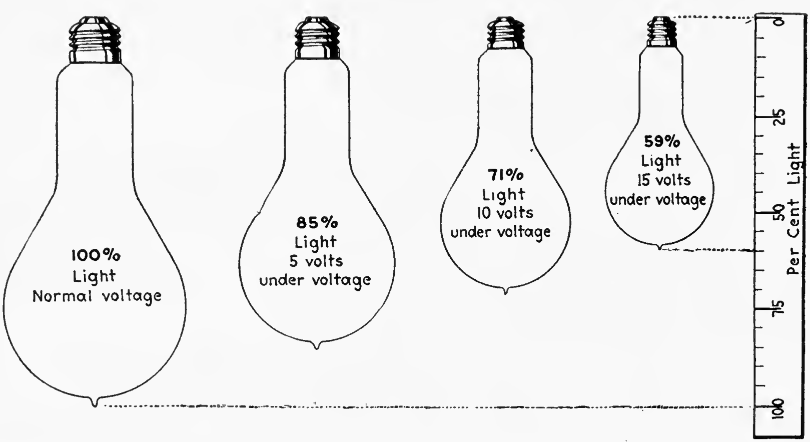


Fig. 1.—Loss of Light When Lamps are Operated Undervoltage. The data are for 110-volt MAZDA lamps

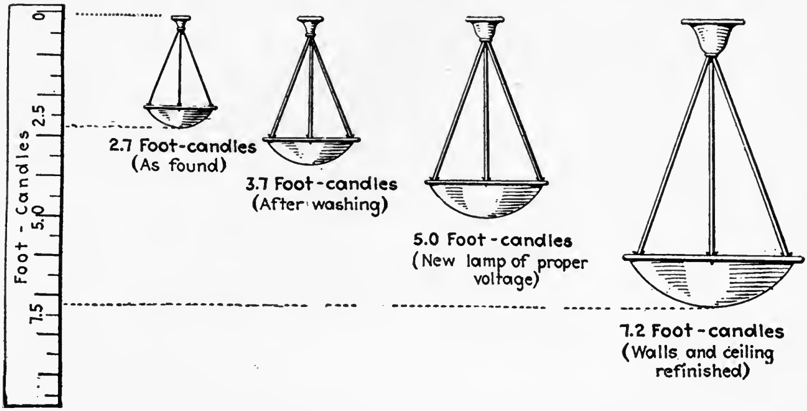


Fig. 2.—Effect of Proper Maintenance in Building up the Illumination from a Depreciated Lighting System. The data were obtained in investigating a complaint on an indirect system

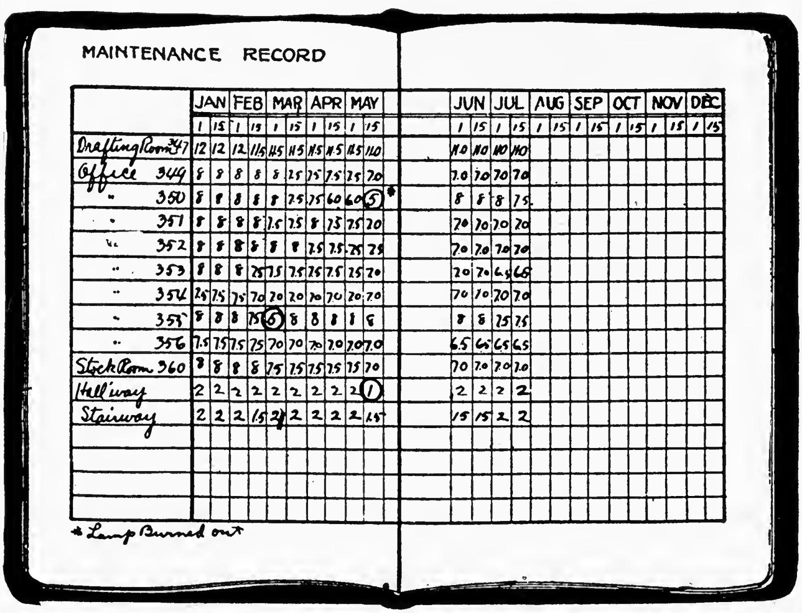
When one considers the combined effect of the different causes of depreciation, it is easy to understand why it is that the illumination at the work will often be reduced very seriously in a relatively short space of time. The reason that this waste goes unsuspected is twofold: First, because depreciation is gradual and, second, because the eye adjusts itself to changes in illumination automatically. Changes in intensity which when brought about gradually pass unnoticed by the eye would be extremely annoying if made so rapidly that the eye did not have time to adjust itself. Usually a falling off of illumination is not apparent until a point is reached where complaints begin to be made of inaccuracies in the work or where the trouble manifests itself in lowered production.

Even then inadequate maintenance is rarely suspected as the cause for the dissatisfaction. A case in point is that of an office lighting installation investigated in response to a complaint. A system of indirect lighting had been installed two and one-half years previously. The ceiling had been painted a flat white and the walls finished in a light buff. At the time the installation was put in, the illumination was adequate.

Measurements made in response to the complaint showed that only 2.7 foot-candles were being obtained on the desk tops. A thorough washing of the lamps and reflectors brought the illumination up to 3.7 foot-candles—an increase of more than 35

Fig. 3.—The Foot-candle Meter Measures Light at the Work and Reveals the Combined Effect of all Possible Causes of Depreciation

per cent—and this in spite of the fact that the reflectors had been wiped out at fairly regular intervals. The lamps had been in service more than two years and their rating was several volts higher than the average voltage of the circuit. New lamps of proper rating increased the illumination to over 5 foot-candles.



MAINTENANCE RECORD

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15
Drafting Room 347	12	12	12	11.5	11.5	11.5	11.5	11.5	11.5	11.0	11.0	11.0	11.0	11.0										
Office 349	8	8	8	8	8	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0										
" 350	8	8	8	8	8	7.5	7.5	6.0	6.0	(5)*	8	8	8	7.5										
" 351	8	8	8	8	7.5	7.5	8	7.5	7.5	7.0	7.0	7.0	7.0	7.0										
" 352	8	8	8	8	8	8	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0										
" 353	8	8	8	7.5	7.5	7.5	7.5	7.5	7.5	7.0	7.0	7.0	6.5	6.5										
" 354	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0										
" 355	8	8	8	7.5	(6)	8	8	8	8	8	8	8	7.5	7.5										
" 356	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0	7.0	6.5	6.5	6.5	6.5										
Stock Room 360	8	8	8	8	7.5	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0										
Hallway	2	2	2	2	2	2	2	2	2	(1)	2	2	2	2										
Stairway	2	2	2	1.5	2*	2	2	2	2	1.5	1.5	1.5	2	2										

* Lamp Burned out

Fig. 4.—Lighting Maintenance Record
(From I.E.S. Transactions)

Refinishing the ceiling and walls in their original tones brought the illumination up to slightly more than 7 foot-candles. The effect of the several steps in the restoration process which increased the illumination from 2.7 to more than 7 foot-candles is shown graphically in Fig. 2. Experience indicates that in general more than 30 per cent of the light which is paid for is allowed needlessly to go to waste. In many individual cases one-half or even two-thirds is being thrown away through lack of attention to simple maintenance requirements.

Value of Light Wasted

If the value of the light needlessly wasted were arrived at simply by calculating its cost in ratio to the total cost of the lighting system, the figures might seem insignificant in relation to the total operating cost of an office or of a factory building; for the total cost of the light is itself a small item when so considered. To obtain a correct valuation it is necessary to consider to how great an extent the work carried on is dependent upon artificial illumination and to what degree this work is affected by a decrease in the quantity of light.

In industrial lighting is found a basis upon which to formulate an idea of the value of higher levels of illumination. For a number of years prior to the war, factories had been getting along on just slightly more than enough light to "see." State Codes to establish mandatory minimum values of illumination in industry were being talked about because of the need for assuring workmen sufficient light for safety. That light in quantities which would make seeing entirely involuntary, that would greatly minimize accident hazard, and that would make surroundings bright and cheerful, might be employed to advantage in industry was hardly more than a theory. Since that time, experiments* have been conducted which show how vision is improved by increased illumination and tests† have demonstrated that startling increases in production have accompanied improvements in the artificial lighting systems in factories. These increases have been accomplished at an additional cost on the average of only 2 or 3 per cent of the payroll. They are men-

*Ferree and Rand, Transactions I. E. S., Vol. XV, No. 9, p. 769.
Ferree and Rand, I. E. S. Convention Paper, 1921.
Luckiesh-Taylor-Sinden, Electrical World, Oct. 1, 1921, p. 668.
†Durgin, Electrical Review, Mar. 22, 1919.
Harrison-Haas-Dopke, Electrical World, Oct. 15, 1921, p. 763.
Stickney and Mahan, General Electric Revew, Dec., 1921, p. 1023.

TABLE 2—Suggested Schedules for Cleaning Reflectors

Where direct lighting systems are used, i. e., where there are no reflecting or diffusing surfaces concave upward to invite dirt accumulation, the interval of cleaning should be about as follows:

Characteristic of Location	Interval in Days if Units are Wiped out*	Interval in Days if Units are Thoroughly Washed
Very Dirty	3	5
Dirty	7	10
Average	15	20
Clean	30	40

Where open semi-indirect or totally indirect units are used:

Characteristic of Location	Interval in Days if Units are Wiped out*	Interval in Days if Units are Thoroughly Washed
Dirty	5	7
Average	10	15
Clean	20	30

*Washing every third or fourth interval assumed.

tioned here to show that the light wasted through inadequate maintenance is not simply light over and above that which is needed for efficient operation of the plant; it is light which has an important effect on production and as such has a potential value far in excess of its purchase price.

Another effect of inadequate maintenance which is almost always entirely overlooked is that of increasing glare and of making shadows sharper and heavier. A bright bulb against a dirty reflector, or a bright unit against a blackened ceiling accentuates glare. The density of shadows depends, among other things, upon the area of the light sources, and where reflectors are dirty, their contribution of diffused light is lost.

Systematic Maintenance

Because the rate of depreciation depends so greatly upon individual conditions, it is difficult to formulate schedules which do more than roughly indicate suitable cleaning periods. The schedules of Table 2 are, however, representative of good practice. By far the best check on the illumination is obtained by frequent foot-candle reading at various stations throughout the plant. These readings are easily and quickly made by means of the foot-candle meter, illustrated in Fig. 3. A simple record of readings such as that shown in Fig. 4 will reveal at a glance the condition of the lighting system and will indicate where trouble is brewing before it becomes serious.

There is a considerable difference between merely wiping out a unit and washing it thoroughly. The difference is more marked in some units than in others. With the exception of mirrored reflectors, and of plaster or composition units (which are readily cleaned with sandpaper or a stiff wire brush) all require a thorough washing at least as often as every third or fourth cleaning period. Warm water and soap or any of the prepared cleaners used in the bathroom of a home are effective in nearly all cases. Mirrored units require special attention to avoid injury to the backing.

Inspection of lamp bulbs for possible blackening should be made at the regular cleaning period, and if a bulb appears considerably darkened it should be replaced. The cleaning should not be considered complete until the unit has been lighted to insure that it operates. The cleaner should carry a supply of lamps of the proper size and voltage with him so that failures may be replaced immediately.

Where proper cleaning is rendered hazardous because of the difficulty of getting at the units, disconnecting hangers, of which there are several types available, may be used to advantage. Where these are employed, the work can sometimes be entrusted to employees who could not otherwise safely handle it.

The walls and ceiling will have lost much of their reflecting effectiveness before they appear badly in need of refinishing and the consideration of lighting economy often dictates the refinishing of an interior before the expenditure from an appearance standpoint suggests itself. The foot-candle meter, which measures the combined effect of all possible causes of depreciation, will enable the maintenance men to watch the gradual depreciation as shown on their records and to determine when refinishing is necessary. A white paint or plaster surface absorbs less light than any other interior finish, and the former is particularly adapted to factory interiors. The color of the side walls for the 5 or 6 feet next the floor has no material effect upon either the color or quantity of the illumination, and a dark color is preferred because it is restful to the eyes and because it does not show dirt and smudge readily.

The cost of maintaining a system properly is largely one of labor and will, of course, vary considerably. In large industrial plants a small maintenance department is necessary for accomplishing effective results. In small buildings one employee may be able to handle the work satisfactorily. Where the responsibility is definitely assigned to a reliable employee and he is given sufficient authority to see that the work is properly done, the entire routine may be placed upon a systematic basis. In a building or plant of sufficient size to require the entire time of at least one man, the cost of proper cleaning should not exceed 3 cents per unit per cleaning in the case of open reflectors. With open semi-indirect or totally indirect fixtures, the cost will be considerably higher. The enclosed semi-indirect units which have recently appeared on the market are slow to collect dirt and compare favorably with direct lighting open reflectors in cleaning. In some cases, it will be desirable to have the cleaning done by window cleaning companies, some of which have established definite departments to handle this work as a part of their regular service.

TO RESTORE A LIGHTING SYSTEM

1. Wash reflectors and lamps thoroughly at least every third or fourth cleaning period. See Cleaning Schedule, Table 2.

2. Fill empty sockets and replace burned-out and blackened lamps with new ones of the correct size and proper voltage rating. The voltage rating of the lamp should be at least no higher than the voltage at the socket when the system is in use. Avail yourself of the service of the lamp manufacturer in determining what the voltage rating of your lamp should be.

3. Refinish ceiling and upper part of side walls in white or in a very light cream color.

4. Make some reliable employee responsible for the maintenance of the lighting system and give him sufficient authority to enable him to get the work done.

PART XV

MODERN PRACTICE IN STREET LIGHTING

In considering a plan of street lighting for a city it is necessary to observe carefully the different requirements of each class of street to the end that the most efficient result possible may be obtained from the expenditure. It is obvious that the thoroughfares of the principal business district will require the greatest amount of illumination, for in this section there is congestion of foot, vehicle, and street car traffic. The principal thoroughfares leading outward from the center of the city and the streets in the wholesale and manufacturing districts likewise carry much traffic of a high speed nature and must be lighted accordingly. In the residential streets, which do not carry through traffic to any extent, requirements for illumination from the standpoint of traffic are, of course, much less severe. In certain outlying districts appropriation allowances sometimes make it necessary to reduce the lighting to a system of small marker lights for corners only.

It should be recognized, of course, that the highest intensity of illumination in the principal business streets of large cities at the present time is not greater than would be desirable for all streets of the city, except for the cost. However, because of the very great areas to be covered, and the limited appropriation available, it may be possible to provide, perhaps, only 1/10 as much light on residential side streets as in the principal business section. In consequence of these very low levels of illumination which must suffice for all except the limited White Way district, it becomes especially necessary to exercise the greatest care to see that the available illumination is so placed and directed that it contributes most effectively toward safety from crime and accident, toward the comfort and convenience of those using the streets, and toward improving the day and night appearance of the street.

Not only are there differences in local conditions to be considered in planning street lighting, but also the developments in the power of lamps and in the efficiency of equipment have been so rapid that there are not as yet fully definite standards of design which are generally adhered to for the different classes of streets. However, there are certain tendencies which have come about as a result of experience with different types of installations under various conditions. Table 1 contains a summary of practice as to lamp size, mounting height, and spacing applicable to the different classes of streets.

Principal Business Streets

For important business streets in cities, the most widely favored method of lighting consists in the use of single light or-

Table No. 1—Summary of Modern Street Lighting Practice

Street Class	Size of Lamps*	Mounting Height	Spacing
Business District	600, 1000, 1500, and 2500 C.P.	14-18 ft.	80-125 ft.
Boulevards and Parks	250, 400, 600, and 1000 C.P.	14-20 ft.	80-200 ft.
Wholesale and Manufacturing Districts and Thoroughfares	400, 600, 1000, and 1500 C.P.	20-25 ft.	150-300 ft.
Residential	250, 400, and 600 C.P.	14-20 ft.	150-300 ft.
Outlying Districts and Alleys	100 and 250 C.P.	14-20 ft.	150-300 ft.
Highways	250 and 400 C.P.	25-35 ft.	300-600 ft.

The lower mounting heights should be adopted only with the smaller lamps and at the closer range of spacings. For the larger lamps and the wider spacings the upper range of mounting heights is preferable.

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* The rated lumen output of street-series Mazda lamps is equal to ten times the candle-power rating.

namental standards mounted at heights from 14 to 18 feet and spaced opposite each other at distances of 80 to 120 feet. For very narrow streets the lamps may be placed on one side only or staggered at the same spacing. An important increase in efficiency is secured by the use of lamps of 600, 1,000, 1,500, or 2,500 candlepower instead of the 3, 4, or 5 light clusters using small lamps which were the vogue before the introduction of the high-powered gas-filled incandescent lamp. Typical equipments of modern character are shown in Fig. 1. There is at present a very noticeable tendency to depart from the use of the opal ball or globe, and to use instead a lantern structure, which by many, is considered more pleasing in appearance. Cleveland was the first large city to adopt equipment of this character and has something over 1,500 lantern standards, using 1,000 and 1,500 candlepower incandescent lamps.

Instead of the single lamp standards spaced relatively close together, some cities have adopted standards carrying two or even three high-powered lamps mounted 20 to 30 feet above the street and spaced 150 to 200 feet apart. The resultant effective illumination is not greatly different from the more usual arrangement and the exceptionally high mountings minimize any possibility of glare from the lamps. On the other hand, there appears to be much weight on the side of those who contend that on business streets the surrounding brightness of buildings, show windows, etc., is such that there is no possibil-

Fig. 1.—Typical Ornamental Lamp Equipments. These Designs Accommodate 600 to 2500 Candlepower Lamps for Business Streets. Equipment of the Same General Character, but Designed for Smaller Lamps, is used for Ornamental Boulevard or Residence Street Lighting

ity of serious glare even with the large lamp at the lower mounting of 15 to 18 feet and that the desirable "White Way" effect is enhanced by lanterns at these heights spaced 80 to 90 feet apart.

The demand for higher levels of illumination on business streets has led in some cities to the consideration of lamp standards carrying two or three 1,000 or 1,500 candlepower lamps each and spaced no more widely than previous single lamp installations. It is quite possible that there will be an increased development of this tendency, especially in the larger cities where the crowds from evening business and amusements have become such that in many cities "White Way" systems, which were installed quite largely as an ornamental or advertising feature, are even now barely adequate from the standpoint of lighting for safety.

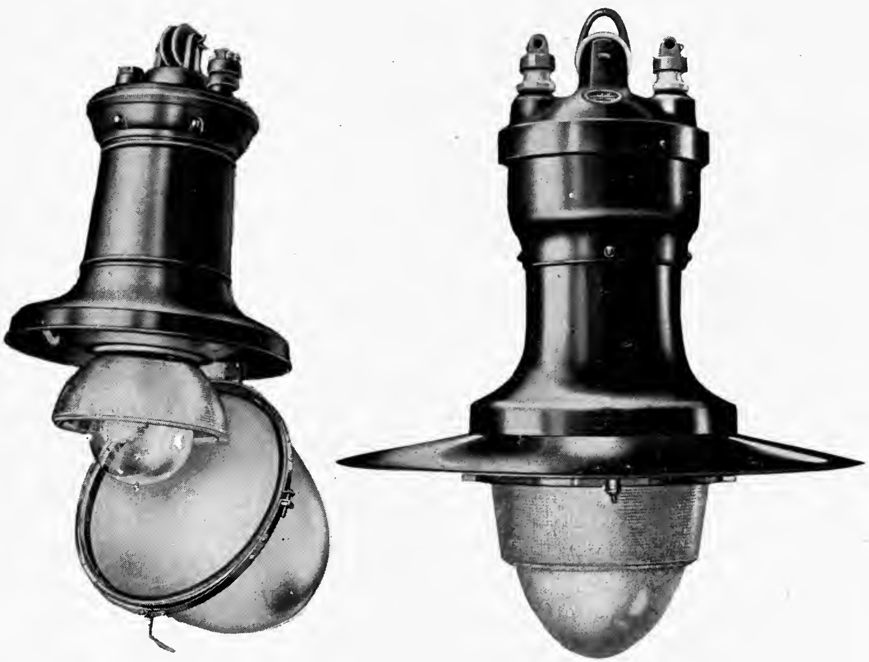


Fig. 2—Types of Pendant Refractor Fixtures for Mast Arm Suspension

Thoroughfares

The thoroughfares leading out from the business section and the streets in the wholesale and manufacturing districts have developed severe requirements for lighting under the new conditions of transportation. These streets carry high speed traffic and are the location of a large percentage of street accidents, particularly at night in those cases where a proper provision for lighting has not yet been made. In some instances it is found practical to extend the high intensity lighting of the business district to include these streets. However, this usually involves a greater expenditure than is permissible, and in any event the light colored building surroundings characteristic of the business section are lacking in most of these thoroughfares and for this reason as well as because of the wider spacing, it is desirable to use a greater mounting height for the lamps in order to avoid the blinding effect of glare. A fair provision for thoroughfares outside the business district is an arrangement of lamps of 600, 1,000, or 1,500 candlepower spaced from 150 to

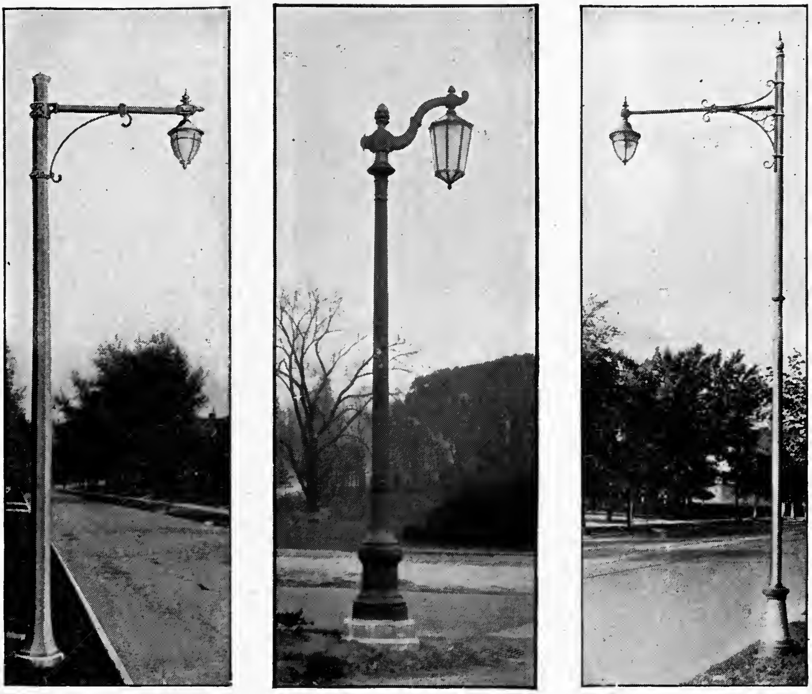


Fig. 3.—Ornamental Bracket Standards for Lighting Thoroughfares and Boulevards. In These the Height to the Lamp is Approximately 20 ft. Similar Designs for Smaller Lamps are Made with Heights of About 16 ft. for Residence Streets

250 feet apart. or, at a maximum, 300 feet. If the street is very wide it may be necessary to consider each side as a separate street and provide lighting accordingly. The mounting height should be 20 or preferably 25 feet in order to remove the bright light sources farther from the line of vision, and also in order to obtain a better spread of illumination. In the past, especially where there were wooden pole lines on the streets, it has been common practice to use a lighting fixture such as illustrated in

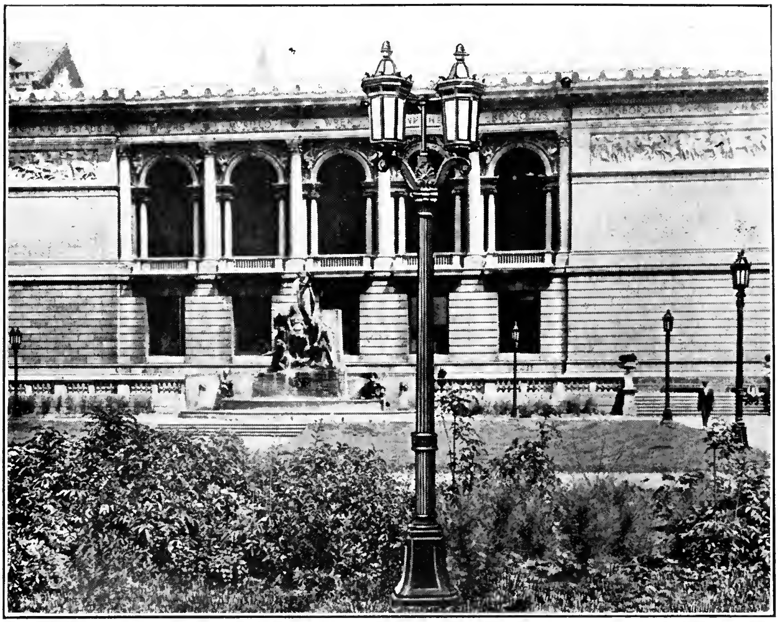
Fig. 2, suspended from a mast arm. The mast arm has the virtue of bringing the lamp out over the street surface, thereby causing the light rays to clear low hanging foliage of adjacent trees. Bringing the lamp over the pavement also increases the possibilities of seeing objects by silhouette against the bright spot of light beneath the lamp or against the bright streak or glint reflections from the pavement. This is an especial advantage in the case of much traveled streets which soon become blackened from oil, but are polished by wear and have a glossy surface when wet. Under these conditions, a very large dependence must be placed upon seeing objects in silhouette against the glint from the pavement on account of the low level of general illumination.

The fixture in Fig. 2 is equipped with a prismatic refractor and this feature is usually incorporated in the equipment for this type of lighting, since, by means of the refractor, the candle-power of the lamp at angles directed to the zone midway between the lamps may be increased practically 100 per cent. Therefore, the light delivered on the street is much greater than with equipment which does not take full advantage of the upward rays from the lamp filament.

Recent designs of lighting equipment for thoroughfares and boulevards have shown the results of efforts to retain the efficiency of light distribution of the mast arm pendant refractor unit type of lighting, and, at the same time, to obtain a construction which would add to the appearance of the street. Some of these bracket type lighting standards for thoroughfares or boulevards are illustrated in Fig. 3.

Residence Streets

Where residence streets carry a large amount of through traffic they are in effect thoroughfares and should be lighted as such. However, in every city there is a large percentage of street mileage not used for through travel and, therefore not subject to a large amount of high speed traffic. Even in these streets, however, sufficient illumination must be provided to enable discernment of objects and obstructions in the pavement by one traveling at a moderate rate of speed. Illumination for sidewalks must also be provided which is adequate for comfortable walking and which does not leave such dark shadows behind tree trunks as might serve as possible hiding places for footpads. Residence streets are very commonly well pro-



Ornamental Two-Light Post to Harmonize with the Building

Euclid Avenue, Cleveland, Illuminated by 1500 Candlepower Incandescent Lamps in Ornamental Lanterns Spaced 85 feet apart.

Prospect Avenue, Milwaukee, Wis. 15 foot concrete posts, 120 feet apart, 42 lumens per lineal foot of street. Average intensity, 0.2 foot candles

Albany-Schenectady Highway Illuminated by 250 Candlepower Mazda Lamps in Parabolic Units Spaced 300 to 500 Feet Apart and Mounted 30 Feet Above the Ground vided with trees; hence, unless the lamp is suspended over the center of the street, it is often necessary, in order to avoid a large loss of light, to use somewhat lower mounting heights than would be desirable on streets without trees. However, in view of the lower candlepower of the lamps commonly used (250 candlepower), they may be placed as low as 15 feet above the street without undue glare, provided the light is properly diffused and directed. When larger lamps are used and at wider spacings, heights of 18 or 20 feet are considered preferable prac-

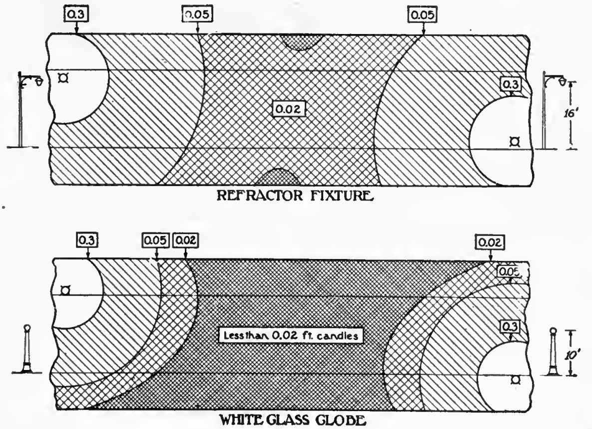


Fig. 4.—Illumination from 250 Candlepower Lamps Computed for Residence Streets
Top: Refractor Lantern Bracket 16 ft. Above Street
Bottom: Opal Globe on 10 ft. Post

tice. In this matter of adequate height the ordinary wood pole bracket installations have been better than many systems of ornamental standards supplied from underground wiring. Some of these systems have used globes mounted on upright posts only 10 or 11 feet in height and while tree foilage is successfully avoided, the units are likely to prove very glaring in the eyes of drivers, pedestrians, or of people on porches. Furthermore, a very close spacing must be adopted if all sections of the street are to be illuminated. Particularly on a curved road, glare from lamps placed too low may so interfere with vision that the lamps may actually become a source of danger to automobile drivers. In view of this, in recently designed systems, there has been a tendency to adopt a minimum height of 15 feet for ornamental posts on residence streets. Also ornamental bracket designs have been developed, bringing the lamp 16 feet or more above the street and with a bracket length of 4 or 5 feet to assist in clearing the foliage. When these equipments carry well designed refractor fixtures, the light utilization is as great as from the efficient but often unsightly wood pole brackets. Fig. 4 illustrates the remarkable increase in effectiveness from equipment of this character compared with a system of low mounted upright ball globes.

Lamp spacings on residence streets vary greatly. Where overhead wood pole distribution is used and the appropriation allowance is very limited, spacings of the order of 300 feet may be used to give fair lighting, provided there are no trees to obstruct the spread of light. On the other hand, spacings of 100 feet or even less are not uncommon for underground distribution supplying low-mounted ornamental units. Unless the interference from trees is excessive, spacings of 150 to 200 feet are found satisfactory. The lamps are customarily staggered to reduce tree trunk shadows.

Outlying Districts and Alleys

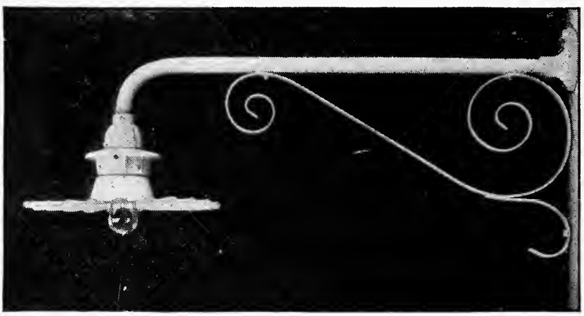


Fig. 5.—Radial Wave Reflector and Bracket for Small Lamps

Fig. 5 illustrates a typical bracket, with a radical wave reflector suitable for attachment to wooden poles or buildings in outlying districts or alleys. This equipment using the 100 candlepower lamp and mounted 15 or 20 feet above the streets forms a very inexpensive type of equipment for those locations where small lamps are all that can be provided and where, consequently, a wide spread of light and the matter of protection against glare is of less importance.

Highways

Where it is desired to illuminate only the roadway without particular regard for the surroundings, special types of equipment are available.

In one design, the unit is made up of nested parabolic construction so as to direct a high intensity up and down the road with very little side lighting. If mounted high, say 25 to 35 feet, and spaced from 300 to 600 feet apart with 250 or 400 candlepower lamps, equipment of this kind provides an illumination which is of very great assistance to night drivers in avoiding accidents.

The Necessity of Maintenance in Street Lighting

If the full effectiveness of a street lighting system is to be secured, it is fundamental that a regular and adequate maintenance schedule be adopted. As the following investigation strikingly brings out, it is quite possible for an installation to depreciate to such an extent as to deliver only one-third the amount of light on the street which it would be expected to deliver under good operating practice.

When the system on which the following data were obtained was first placed in service, it was considered to be one of the best designed installations in the country. However, after it had been in operation for approximately one year, to even the casual observer the amount of light emitted by the fixtures was far below that emitted when the system was first turned on.

The appearance of the units when lighted indicated that the glassware was dirty, and also that the lamps were burning considerably under rated efficiency. In order to determine just what percentage of the decrease in candlepower should be attributed

Table No. 2

	Per Cent Normal Candlepower	Per Cent Increase in Light	Equivalent Size of Lamp
As found	31	...	185 C.P.
Unit thoroughly cleaned	67	116	400 C.P.
New lamp of proper rating	87	30	520 C.P.
Rated current in new lamp	100	15	600 C.P.

to the various factors involved, photometric and electrical measurements were made on two of the units. Candlepower measurements of the equipment as found, and when thoroughly cleaned with soap and water, were taken. The current through the lamps was checked, and the old lamps found in the fixtures were brought into the laboratory for lumen rating. The electrical measurements showed that the lamps were burning below rated amperage. An inspection of the lamps indicated that some had burned much longer than their rated life, and the consequent blackened bulbs and sagged filaments gave evidence that they were operating at a very low efficiency.

The accompanying chart (Fig. 6) and the tabulation in Table

No. 2 plotted for one of the units, indicates the weight of the various factors accountable for the decrease in efficiency of the system. Although 600-candlepower lamps are used in this installation the photometric measurements show that the light output of the fixture as found was only equivalent to the output which would be obtained with a 185-candlepower lamp operated at rated current in a clean fixture. By washing the lamp and glassware the equivalent lamp size was increased to 400-candlepower, an increase of 116 per cent. The substitution of a new lamp of proper rating raised the equivalent lamp size to 520-

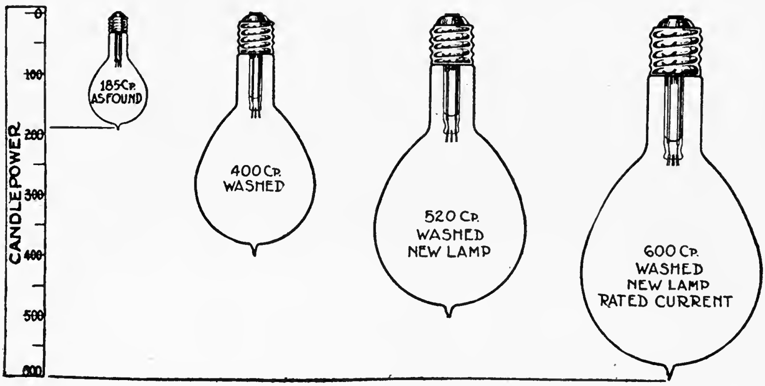


Fig. 6.—Equivalent Candlepower of Lamp, which, if Operated at Rated Current in a Clean Fixture, would Duplicate Performance of Unit Tested

candlepower, an increase of 30 per cent. With the correct current through the lamp the light output was increased still another 15 per cent and was brought up to the rated value, 600-candlepower.

The above data forcefully bring out the necessity of a rigidly-adhered-to maintenance schedule, such as the following, if it is desired to secure an installation which will be satisfactory from the standpoints both of appearance and illumination effectiveness.

1. A systematic and regular cleaning schedule should be in operation.

2. Lamps which have lived far beyond their rated lives and whose filaments have sagged or whose bulbs have become blackened should be removed from the system.

3. The current through the lamps should be maintained at the rated amperage.

PART XVI
ELECTRICAL ADVERTISING

Statistics obtained in Cleveland, Ohio, in which the sign development may be considered fairly typical of large cities in general, show that in the past two and one-half years, in spite of a falling off in the total energy supplied by the central station, the electrical advertising load has more than doubled. That

Fig. 1—The growing appreciation of electrical advertising is attested by the increase in the energy required. (Data obtained in Cleveland.)

this has occurred without an organized selling effort and at a time when the total expenditure for all forms of advertising was being sharply cut, is significant of the growing appreciation of the value of electrical advertising. The return of business to a competitive basis—the necessity for aggressive sales effort—is an influence which, aided by the increasing skill and cleverness of the sign designer, insures a rapid development in sign application.

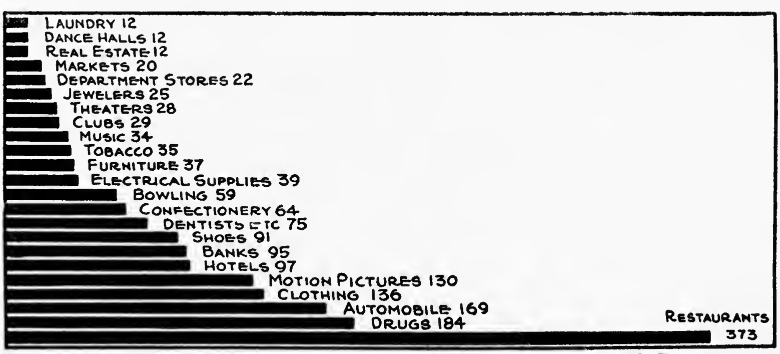


Fig. 2—Distribution of Signs According to Classes of Users. (Cleveland Electric Signs.)

FORMS OF ELECTRICAL ADVERTISING

There are four principal forms of electrical advertising. These are:

1. Electric signs of the exposed or enclosed lamp type;
2. Illuminated Bulletin and Poster Boards;
3. Building Outline and Marquee lighting;
4. Floodlighted advertisements.

A display of whatever form must have: first, attracting power, or the ability to gain attention; second, selling power, or the ability to impress a message and make it endure. In the majority of displays, a third essential is legibility, or the property of showing word or picture in well defined, clean-cut lines.

Brightness and motion are, of course, two of the major characteristics of electrical advertising by which the designer obtains attracting and selling power. In no other form of advertising does he have the opportunity to capitalize these features to so great an extent. Originality, beauty, and color are tools which the designer uses according to his ability and the extent of the funds available. The picture, border, size, and position of the sign are factors which, obviously, bear tremendously on the effectiveness of the display.

Exposed Lamp Signs

Of all the requirements of an exposed lamp sign, none is more important than legibility. Whether the message is carried by word or by picture, clear-cut, sharply defined lines of light are essential.

The distance at which a sign will appear legible depends upon the dimensions of the letters or pattern, the candlepower of the lamps, the color of the light, and the brightness of the background.

Maximum legibility distance is directly proportional to size, and, for a given pattern, is determined by the separation of the distinguishing strokes. When these strokes appear to approach each other so closely that they blend, the pattern becomes illegible. This blending occurs when details lie closer together than approximately one minute of arc.

The effect of illuminating a letter or pattern is to decrease the maximum distance at which it is legible. The reason for this is that a bright object always appears larger than a dark one. An exposed incandescent filament viewed at close range against a dark background will appear perhaps one-third as large as the glass bulb; as the observer moves away the spot

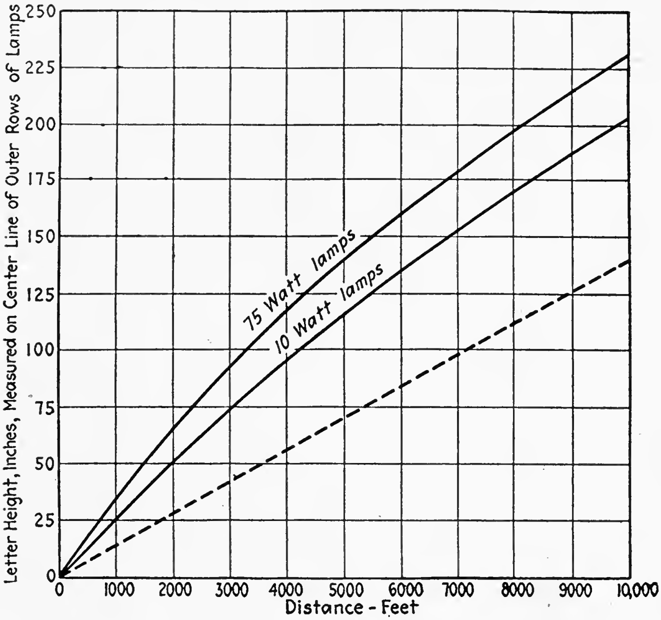


Fig. 3—Maximum Legibility Distance of Signs of Average Number of Letters

Based on average street illumination and clear air when seen by normal eyes and when the determining letter is a Gothic E or its equivalent. The dotted line shows a theoretical maximum distance ordinarily unattainable even under the best conditions encountered in service

of light apparently increases in size, expanding until it fills the bulb, and continuing to grow larger and larger. The effect of this irradiation, as it is called, is to increase the width of the strokes in a pattern, decrease the separation between strokes, and hence reduce the legibility distance of the sign. The apparent size of a spot of light from an exposed filament depends upon the distance of the lamp from the eye, the tip candlepower of the lamp, and the brightness of the background against which the lamp is seen.

The effect of increasing the tip candlepower of the lamps in a sign is, first, to increase the attracting power, and second, to decrease the maximum legibility distance. Unquestionably, the bright sign is more effective than the dim one. The proper procedure in design is therefore to use lamps of a size which will compel attention and to make the letters large enough with these chosen lamps to obtain the desired legibility distance.

Increase of background brightness and surroundings such as the light from a border of lamps about a sign, other displays, or the street illumination, has the effect of reducing the apparent spot size and so of increasing legibility distance. This means, of course, that a sign in a brightly lighted district, where competition is keener, may be made brighter and more attractive than a sign of the same size in a darker district and yet be legible over as great a distance.

The color of the light in a sign affects the legibility distance but it is used chiefly to obtain greater attracting power and more artistic and spectacular effect. As usually applied, its effect upon legibility distance is of secondary importance.

From information obtained in extensive tests, it is possible to evaluate the effect of the factors discussed above and present

Table 1

Lamp Spacing to Provide Unbroken Lines of Light

Clear Glass Lamp Spacing Inches	Distance to Observer in Feet When the Surrounding Illumination is: Comparatively Bright					Comparatively Dark				
	10 Watt Lamps *	25 Watt Lamps *	50 Watt Lamps *	75 Watt Lamps *	100 Watt Lamps *	10 Watt Lamps *	25 Watt Lamps *	50 Watt Lamps *	75 Watt Lamps *	100 Watt Lamps *
3 .	480	420	*	*	*	290	*	*	*	*
4 .	630	560	500	*	*	390	330	*	*	*
5 .	790	700	620	570	*	490	410	*	*	*
6 .	950	840	740	680	610	590	500	420	*	*
7 .	...	990	870	800	720	690	580	490	440	*
8 .	...	...	990	910	820	790	660	560	500	*
9 .	...	...	...	...	920	880	740	630	570	500
10 .	...	...	...	...	...	980	830	700	630	550
11 .	...	...	...	...	...	...	910	770	690	610
12 .	...	...	...	...	...	...	990	840	750	660
13 .	...	...	...	...	...	...	...	900	810	720
14 .	...	...	...	...	...	...	...	970	870	770
15 .	...	...	...	...	...	...	...	...	940	830
16 .	...	...	...	...	...	...	...	...	1000	890

* For distances less than the lowest given in the table, it is impossible to obtain the appearance of a continuous line of light. If the exposed lamp design is used for signs in such locations, the spacing should be made as small as mechanically possible.

data which is applicable to practical sign design. From the curve of Fig. 3, the maximum legibility distance of signs having an average number of letters (5 to 10), when made up in different heights may be readily approximated. In Table 1 are given the spacing distances required between lamps of various sizes to present an unbroken line of light when located in bright surroundings and when located in dark surroundings. A chart, Table 2, suggests which sizes and kinds of lamps are best suited to the various applications.

Table 2

Selection of the Proper Lamp for Sign and Display Lighting

	Surrounding Illumination: Dark → Medium → Bright							
FOR DISTRICTS OF HIGH CIRCULATION								
Small Exposed-lamp Signs, 25 feet or less from ground	10 Watt Mazda-B Clear	25 Watt Mazda-B Diffusing	50 Watt Mazda-B Diffusing	50 Watt White Mazda				
Exposed-lamp Signs 25 to 75 feet from ground	10 Watt Mazda-B Clear	25 Watt Mazda-B Diffusing	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda Daylight	50 Watt Mazda-C Clear		
Large or Roof Exposed-lamp Signs, 75 feet or higher	10 Watt Mazda-B Clear	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda Daylight	50 Watt Mazda-C Clear	75 Watt Mazda Daylight	75 Watt Mazda-C Clear	
Enclosed Lamp Signs	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda Daylight	50 Watt Mazda-C Clear	75 Watt Mazda Daylight	75 Watt Mazda-C Clear		
Marquees	25 Watt Mazda-B Diffusing	50 Watt Mazda-B Diffusing	50 Watt White Mazda	75 Watt White Mazda				
Building Outline Lighting	25 Watt Mazda-B Diffusing	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda-B Diffusing	50 Watt Blue Mazda Sign	50 Watt Mazda Daylight	50 Watt White Mazda	75 Watt White Mazda
FOR DISTRICTS OF LOW CIRCULATION								
Small Exposed-lamp Signs, 25 feet or less from ground	5 Watt Mazda-B Clear	10 Watt Mazda-B Clear	25 Watt Mazda-B Diffusing					
Exposed-lamp Signs 25 to 75 feet from ground	5 Watt Mazda-B Clear	10 Watt Mazda-B Clear	25 Watt Mazda-B Diffusing	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear			
Large or Roof Exposed-lamp Signs, 75 feet or higher	10 Watt Mazda-B Clear	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda Daylight	50 Watt Mazda-C Clear			
Enclosed Lamp Signs	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda Daylight	50 Watt Mazda-C Clear				
Marquees	25 Watt Mazda-B Diffusing	50 Watt Mazda-B Diffusing	50 Watt White Mazda					
Building Outline Lighting	10 Watt Mazda-B Clear	25 Watt Mazda-B Diffusing	25 Watt Blue Mazda Sign	25 Watt Mazda-B Clear	50 Watt Mazda-B Diffusing			

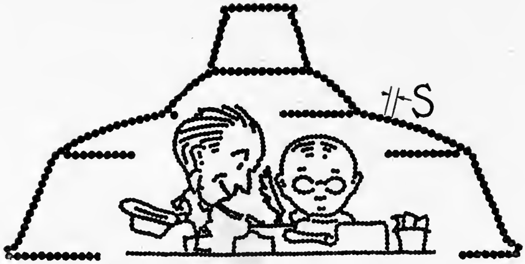


Fig. 4—An Example of the Pattern of a Sign with the Spots of Light Almost Touching

Enclosed Lamp Signs

From Table 1, it will be seen that 10-watt lamps spaced as closely as mechanical considerations will permit will not provide an unbroken line of light when viewed at distances of less than about 300 feet. While illuminated translucent letter signs do not have the brightness and sparkle of the exposed lamp sign, the smoother, more even, and clearer-cut outline of the translucent letter sign gives it a distinct advantage for the shorter effective distances.

The appearance of signs of this type is greatly influenced by the lamp spacing behind the letter, the depth of the box, and the color of the interior surface. If the lamps are spaced too far apart, the pattern will appear spotty. If they are placed too far inside the edge of the pattern, the outline will be ragged and indistinct. A 6-inch spacing from lamp to lamp and a 3-inch spacing from lamp to projected edge of pattern will prove satisfac-

Fig. 5.—A Very Effective Exposed Lamp Sign

Fig. 6.—Building Outline Lighting with Exposed Lamps

tory in signs of ordinary construction providing the interior surfaces are finished in white.

For signs with 6-inch letters, or larger, of uniform height, it is preferable to use the same number of lamps behind each letter. The proper number may be found by determining the number of square inches contained in a rectangle outlining the letter, dividing this number by 40, and using the nearest whole number. Letters 12 inches high and 8 inches wide, for example, would require two lamps.

Suggestions as to the best sizes and kinds of lamps to employ in enclosed lamp signs under various conditions of service are given in Table 2.

Importance of Beauty in Sign Displays

Fully as important as the mechanics of sign design discussed above, are the factors which affect the artistic appeal of the display. The sign which attracts but does not hold attention is low in advertising value no matter how legibly the message is displayed. It is through the intelligent use of color and proportion, the grouping of lamps, and the control of brightness that the designer is able to produce a result which is effective as an advertising medium and which has the additional attribute of beauty. Displays of this type not only build good-will

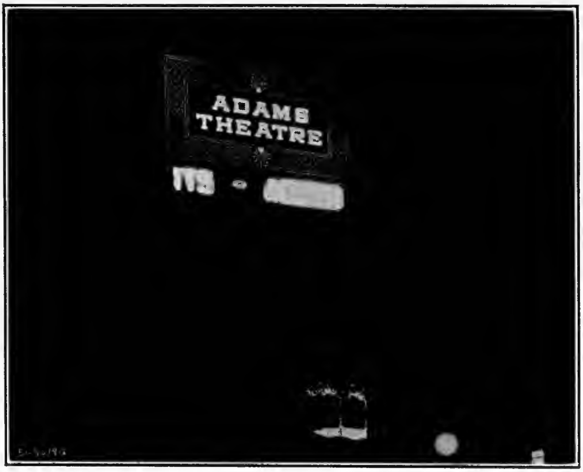


Fig. 7.—The Beautiful Border Adds Greatly to the Effectiveness of this Sign

for the advertiser but they promote the development of the sign industry as well.

Bulletin and Poster Boards

In order that bulletin and poster boards may be illuminated to the best advantage, it is necessary that the light sources be concealed from the eye, that glare caused by the direct reflection of the lighting units from the painted surface be minimized, and that the illumination be fairly uniform and of an intensity high enough to cause the sign to stand out prominently. Glare may be avoided by mounting the units so that the light is thrown upon the sign from below, in which case, since the angle of incidence is equal to the angle of reflection, direct reflection cannot enter the eye of the observer unless he is looking down upon the sign from above. This arrangement is shown diagrammatically in Fig. 8. If, as is sometimes the case, the sign is so located that the observer looks down upon it, it is evident that glare may be avoided by reversing the arrangement, that is, by lighting the sign from above. Such installations are applicable chiefly to signs which are so situated that floodlighting projectors may be used to project the light from the roof or windows of a neighboring building upon the face of the sign, for if the units were mounted close to the sign in the usual manner, their supports would in most cases obstruct a view of the sign.

Another method of mounting the units which overcomes a large part of the trouble from glare is to mount them well

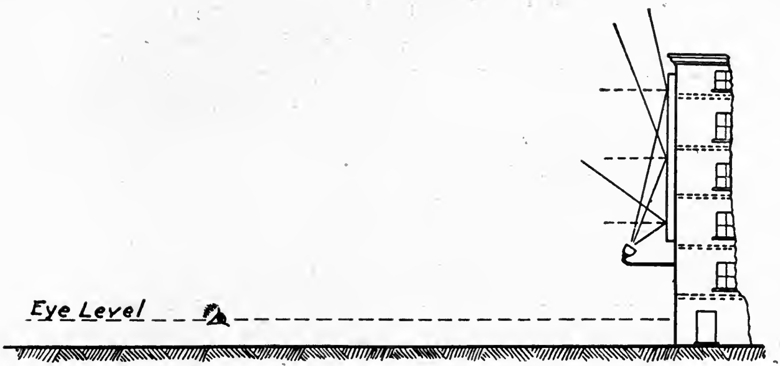


Fig. 8.—Location of Units to Avoid

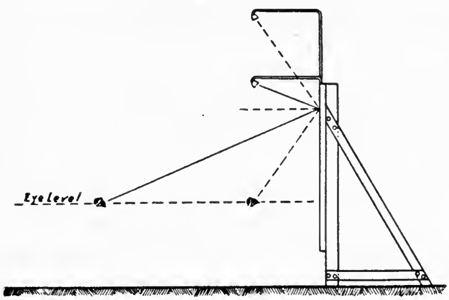


Fig. 9

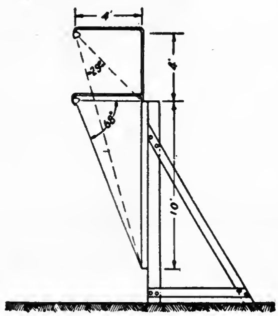


Fig. 10

The Higher the Unit is Mounted Above the Sign, for a Given Distance in Front of the Sign, the Less will be the Distance Through Which Glare will be Apparent; However, a Highly Concentrating Reflector Becomes Essential

above the sign. If this is done, the observer will have to approach the sign closely before the glare is apparent. Fig. 9 shows that the higher the unit is mounted above the sign for a given distance in front of the sign the less will be the distance through which glare will be apparent. However, it will be noted from Fig. 10 that the higher the unit, the more concentrated the distribution must be to be effective; in this case, raising the reflector 4 feet reduces the effective zone from 68 degrees to 29 degrees.

There is no moderate priced reflector for outdoor service at present manufactured which when mounted high above and close to the sign will satisfactorily illuminate it except at a very considerable sacrifice of efficiency. Obviously, were such reflectors to be had, another difficulty would be experienced in spacing units so as to obtain a uniform distribution lengthwise of the board.

With the present reflector equipment, the most practical illumination of bulletin and poster boards is accomplished by means of Mazda lamps equipped with porcelain-enameled steel angle reflectors mounted in front of, and somewhat above, the top edge of the sign. Such reflectors, if well designed, waste little of the light above and below the sign, and direct the beam of maximum intensity toward the bottom of the sign, which is important not only because this part of the sign is farthest from the light source but also because of the acute angle at which the rays strike this part of the sign. They have also the decided

Fig. 11

Two Groups of Well Designed Properly Maintained Billboards as Found in California. The lighting equipment is neat and inconspicuous. Advertising of this character is an asset to the community

advantage of being small in size and light in weight, which permits them to be hung far enough out from the sign to give uniformity of light distribution with little strain on the mechanical supports, and with a relatively small amount of shadow thrown upon the sign in the daytime. The porcelain-enameled surface is weatherproof, does not collect dirt easily, and is readily cleaned.

The data given in Table 3 apply to bulletin and poster board lighting under usual conditions, that is, for boards situated in well lighted districts. Where the surrounding intensities are

Table 3

Specifications for Billboard Illumination

Height of Board, Feet	Mounting Dimensions of Lighting Units: Spacing, Feet	Distance Out, Feet	Distance Above, Feet	Size of Lamp, Watts	Av. Illumination, Foot-Candles
3-5	5	4	1	75	9
6-8	6	5	1	100	9
9-12	6½	7	1	200	10
13-17	9	8	1½	300	11
18-21	12	11	2	500	10
22-25	16	15	2	750	11
25	20	18	2	1000	10

particularly high, larger units than those specified should of course be employed in order that the board will be at least as brilliant as its surroundings.

The tendency is to mount units too close to the board, causing poor illumination. The advantage gained in mounting the units far out from the sign offsets the cost since the distances from the unit to the top of the board and from the unit to the bottom of the board are more nearly equalized, thus the light is more evenly distributed, and the highest intensity is directed toward the bottom of the board without the necessity of tilting the reflector at such an angle that the top of the board is in shadow.

In installing lighting equipment for a bulletin board, accessibility of the units should always be given consideration. The units should be so mounted that they can be reached regardless of the weather conditions as by this means much time and labor can be saved. The mounting should be of such a character that the supports will withstand any wind pressure that tends to displace them from their proper positions.

Bulletin and poster boards located in inaccessible places or at considerable distances from the power supply are usually illuminated by floodlighting projectors. These employ concentrated filament lamps in properly designed reflectors of the parabolic type and direct a concentrated or spread beam, as occasion demands, on the sign.

An interesting and effective innovation in bulletin lighting is the application of color effects. Colored objects present different appearances when illuminated by various colors of light. Red light falling on a blue object makes it appear black; green light falling on a yellow object makes it appear green. A red object on a white background, if illuminated by red light, is practically invisible, for both the object and the background are equally luminous. Similarly, green light would cause a green

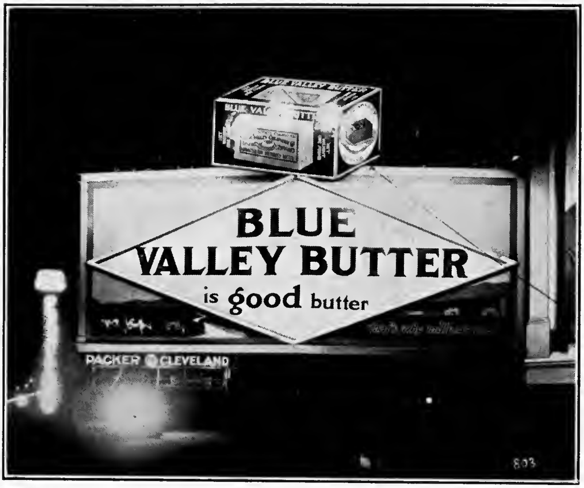


Fig. 12.—The Combination of Bulletin Board and Exposed Lamp Display is New and Quite Effective

object to blend with the background and be invisible. It can be readily seen that by proper painting of the sign and the application of suitably tinted light, complete changes are possible as the light is changed by means of a flasher.

Building Outline and Marquee Lighting

The problem involved in this form of electrical advertising is one of good taste more than of sign engineering. The effect produced should be in keeping with the character of the building. The garish effect which might be desirable for an amusement park would not be in keeping with the dignity of an impressive bank or public building. The best result can be obtained only when full co-operation exists between the architect and the sign designer.

Table 1 shows the proper lamp spacing to be employed to obtain unbroken lines of light; Table 2 suggests the sizes and kinds of lamps suitable for outline and marquee lighting.

Floodlighted Advertising

Building fronts,* bulletin and poster boards, and signs on water towers and chimneys are some of the advertisements which may often be floodlighted advantageously. To accomplish this, projectors are used to throw the light from a distance

* See also Part XI, Flood-Lighting, page 166.

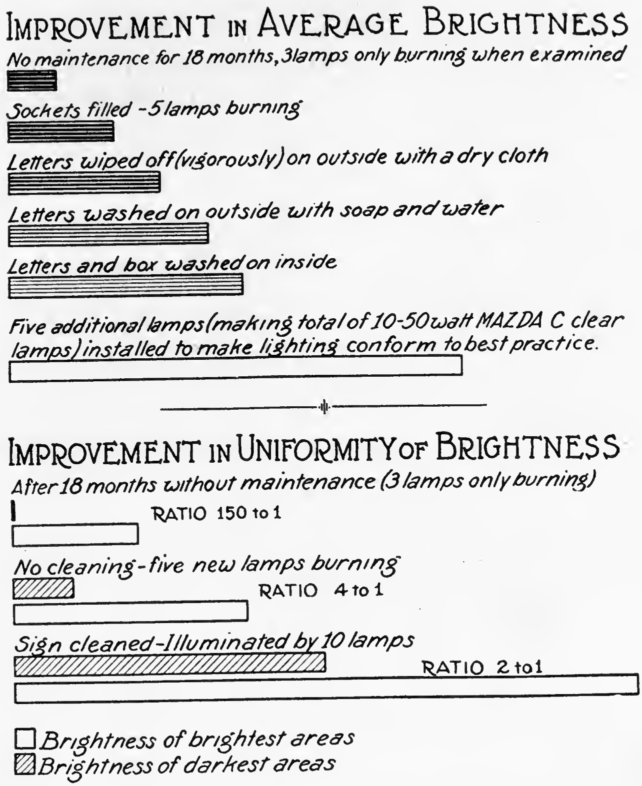


Fig. 13.—Importance of Adequate Maintenance

upon the surface to be illuminated. The number and type of projectors to be used depends upon the size of the advertisement and its position with respect to the projectors.

SIGN MAINTENANCE

In general, better advertising value over a period of a year or more will be obtained from a small sign which is washed and cleaned just as often as the show window is washed, and which is painted and has a change of lamps say three or four times a year, than will be obtained from a sign twice the size which is neglected until it is dirty and five or ten per cent of the lamps are burned out.

While the need for adequate maintenance exists for all signs, it is more important for the small ones than for the large ones, and it is especially needed for enclosed lamp signs. In such signs there are three surfaces to be kept clean. One only of these is exposed to the street dust but although the others are inside and somewhat protected they are never washed by the rain as are the lamps in an exposed lamp sign. Practically all of these signs have a neat and clean appearance when new but show slight deposits of dirt quickly. For this reason enclosed lamp signs should be so constructed that the inside of the letters may be easily reached or, preferably, that the letters may be removed and washed in soap and water, not merely rubbed off, but washed in the water frequently. Making box signs with removable letters similar to theatre feature boards increases their cost only 20 per cent and makes it possible to have a sign which always looks like new.

To evaluate the effect of cleaning a translucent letter sign, such a sign was examined recently. The brightness in five positions was measured both before and after cleaning, and after replacing the lamps with the proper number of new ones of the correct size. The results are shown in Fig. 13. The average brightness of the sign was increased twelve times, the ratio of the brightness of the bright spots to that of the dull spots in the sign was reduced from one hundred and fifty to one to two to one. It is probably true that, in these lower ranges the attracting power of a sign is increased at least in proportion to that of the average brightness and the selling power inversely as the variation in brightness.

PART XVII

Code of Lighting Factories, Mills and Other Work Places

Prepared under the direction of and issued by the Illuminating Engineering Society, New York, N. Y. Reprinted through the courtesy of the Society.

INTRODUCTION

THE accompanying Code of Lighting for factories, mills and other work places has been prepared and issued by the Illuminating Engineering Society in order to make available authoritative information for legislative bodies, factory boards, public service commissions and others who are interested in enactments, rules and regulations for better lighting. The Code is intended also as a guide for factory owners and operators in their efforts to improve lighting conditions in their factories.

Part I contains Rules arranged in convenient form for legal enactment or governmental regulations.

Part II contains a discussion of the rules of Part I; that is, the legal requirements which must be met where a Code is in force; and also suggestions and general information as to desirable practice in factory lighting.

Part III takes up the advantages of proper and adequate illumination, both natural and artificial, and discusses such lighting particularly from the standpoint of economics.

Since the first edition of this Code was issued, a number of the states of the Union, recognizing the beneficial effects of adequate illumination on the health and safety of the employees, have adopted factory lighting codes. As a rule, these codes stipulate the minimum illumination permissible for different classes of industrial operations. They also indicate the desirable, as distinguished from the minimum illumination values, and the kinds of lighting equipment which will avoid glare and give a good distribution of light.

The preface to the Wisconsin Industrial Lighting Code explains as follows why the state is concerned in the regulation of Factory Lighting:

"Insufficient and improperly applied illumination is a prolific cause of industrial accidents. In the past few years numerous investigators, studying the cause of accidents, have found that the accident rate in plants with poor lighting is higher than similar plants which are well illuminated. Factories which have installed improved lighting, have experienced reductions in their accidents which are very gratifying.

Of even greater importance, poor lighting impairs vision. Because diminution of eyesight from this cause is gradual, it may take the individual years to become aware of it. This makes it all the more important to guard against the insidious effects of dim illumination; of glaring light sources shining in the eyes; of flickering light; of sharp shadows; of glare reflected from polished parts of the work. To conserve the eyesight of the working class is a distinct economic gain to the state, but regardless of that, humanitarian considerations demand it.

Finally, inadequate illumination decreases the production of the industries of the state, and to that extent the wealth of its people. Factory managers, who have installed improved illumination, are unanimous in the conviction that better lighting increases production and decreases spoilage."

Mr. R. E. Simpson of the Travelers Insurance Company is authority for the statement that during the year 1919 there were more than 2,000,000 industrial accidents causing loss of time; of this number 25,000 were fatal. The following extract from an article in the *Travelers Standard* by Mr. Simpson gives some interesting data on the relation between lighting and safety:

"There is some foundation for assuming that 18 per cent of our industrial accidents are due to the defects in lighting installations. On that basis the services of 108,000 men for one year are lost annually because the illumination provided is not adequate for the safety of the workmen. That this condition could exist year after year is all the more reprehensible, because of the fact that the remedy is so easily applied, and has beneficial results in many ways other than the safety involved. Accidents caused by carelessness, inattention or ignorance can be eliminated only by a long continued, painstaking, educational campaign, often involving a change in long established habits. Elimination of accidents, due to inadequate or improper lighting is simply a matter of purchasing the proper equipment, and installing it under competent directions. In fact, it seems proper to include illumination in the list of mechanical safeguards, for the reason that the lamps and reflectors provide a guard; illumination points out the hazards just as effectively as a railing points out the danger of, and provides protection against, the hazard of a revolving flywheel."

PART I.

RULES.

Note: Attention is called to the fact that the requirements given in the Rules are minimum specifications and are not to be interpreted as sufficient to insure good lighting. See PART II—Suggestions and General Information.

General Requirement. Traversed spaces, during the time of use, and work in process, shall be supplied with light in accordance with the following rules:

Rule 1. Illumination Required. The illumination maintained shall be not less than given in the following table:

TABLE I.

		Minimum foot-candles On the space or at the work
(a)	*Roadways; Yard Thoroughfares*	0.02
(b)	*Storage Spaces;* aisles and passageways in workrooms excepting exits and passages leading thereto	0.25
(c)	*Where Discrimination of Detail Is Not Essential* Spaces, such as:—Hallways, stairways; exits, and passages leading thereto; toilet rooms; elevator cars and landings. Work, such as:—Handling material of a coarse nature; grinding clay products; rough sorting; coal and ash handling; foundry charging.	0.5
(d)	*Where Slight Discrimination of Detail Is Essential* Spaces, such as:—Stairways, passageways and other locations where there are exposed moving machines, hot pipes, or live electrical parts. Work, such as:—Rough machining, rough assembling; rough bench work; rough forging; grain milling.	1
(e)	*Where Moderate Discrimination of Detail Is Essential* Work, such as:—Machining; assembly work; bench work; fine core making in foundries; cigarette rolling.	2
(f)	*Where Close Discrimination of Detail Is Essential* Work, such as:—Fine lathe work; pattern making; tool making; weaving light colored silk or woolen textiles; office work; accounting; typewriting.	3
(g)	*Where Discrimination of Minute Detail Is Essential* Work, such as:—Watchmaking; engraving; drafting; sewing dark colored material.	5

Rule 2. Avoidance of Glare: Diffusion and Distribution of Light. Lighting whether natural or artificial shall be such as to avoid glare, objectionable shadows and extreme contrasts, and to provide a good distribution of light; in artificial lighting systems, lamps shall be so installed in regard to height, location, spacing, and reflectors, shades or other suitable accessories, as to accomplish these objects.

Bare light sources, such as exposed lamp filaments or gas mantles located within the ordinary field of the worker's vision, are presumptive evidence of glare.

For a specification of definite requirements under this rule, reference should be had to Tables III, IV, V and VI in Part II.

Rule 3. Exit and Emergency Lighting. The lighting to be provided under Rule 1 in all stairways and exits of factories and in the passageways appurtenant thereto shall be supplied so as not to be subject to failure because of the failure of the room or work space lighting from internal causes, and preferably from an independent connection extending back to the main service entrance for the building. 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 ensured by connecting to a separate source of supply without or within the building.

PART II.

SUGGESTIONS AND GENERAL INFORMATION

Notes on Rule 1—Illumination Required.

THE illumination values given in Table I are minimum requirements dictated from the viewpoint of safety. Table II given below is intended to indicate the order of illumination values that are considered desirable for different classes of work. Letters in parentheses following foot-candle values, refer to the corresponding sub-divisions of Table I. Persons of advanced years and those with defective eyes require more light than those having perfect vision. The foot-candles in good lighting practice are as a rule several times those specified as minimum requirements. A range of foot-candle values is given in Table II for each group of operations; in modern practice it will usually be found desirable to select values in or even beyond the upper portion of the range.

TABLE II.

APPROXIMATE FOOT-CANDLES IN GOOD LIGHTING PRACTICE ON THE SPACE OR AT THE WORK

1/20 TO 1/4 FOOT-CANDLES (a)

Roadways and Yard Thoroughfares.

1 TO 2 FOOT-CANDLES (b)

Storage Spaces: aisles and passageways in work rooms, excepting exits and passages leading thereto.

2 TO 5 FOOT-CANDLES (c) and (d)

Auditoriums and Assembly Rooms.

Assembling: rough.

Boilers, Engine Rooms and *Power Houses:* boilers, coal and ash handlings, storage-battery rooms, auxiliary equipment, oil switches and transformers.

Chemical Works: hand furnaces, boiling tanks, stationary driers, stationary or gravity crystallizing, mechanical furnaces, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizing, bleaching.

Clay Products: grinding, filter presses, kiln rooms, molding, pressing, cleaning and trimming.

Elevator, Cars and *Landings:* (freight and passenger).

Forge Shops and *Welding:* rough forging.

Foundries: charging floor, tumbling, cleaning, pouring and shaking out.

Glass Works: mix and furnace rooms, casting.

Hallways: stairways, exits and passages leading thereto.

Leather Manufacturing: vats, cleaning, tanning and stretching.

Locker Rooms.

Meat Packing: slaughtering.

Machine Shops: rough bench and machine work and rough assembling.

Milling and Grain Foods: cleaning, grinding or rolling.

Packing: rough.

Paint Shops: dripping, spraying, firing.

Paper Manufacturing: beaters, machine grinding.

Plating.

Receiving and Shipping.

Soap Manufacturing: kettle houses, cutting, soap chip and powder.

Steel and Iron Mills: charging and casting floors, muck and heavy rolling, shearing (rough by gage), pickling and cleaning, soaking pits and reheating furnaces.

Store Rooms and Stock Rooms: rough.

Textile Mills: (Cotton) opening and lapping, carding, drawing-frame, roving, dyeing; (Woolen) carding, picking, washing and combing.

Toilet and Wash Rooms.

Woodworking: rough sawing and rough bench work.

5 TO 10 FOOT-CANDLES (e) and (f)

Assembling: medium, fine.

Chemical Works: tanks for cooking, extractors, percolators, nitrators, electrolytic cells.

Clay Products: enameling, coloring and glazing.

Cloth Products: light goods.

Electric Manufacturing: storage battery, molding of grids, coil and armature winding, mica working, insulating processes.

Engine Rooms and Power Houses: switchboards, engines, generators, blowers, compressors.

Forge Shops and Welding: fine forging and welding.

Foundries: fine molding and core making.

Glass Works: grinding, glass blowing machines, cutting, polishing, inspecting.

Glove Manufacturing: light goods: sorting, stitching, trimming and inspecting.

Hat Manufacturing: dyeing, stiffening, braiding, cleaning and refining, forming, sizing, pouncing, flanging, finishing and ironing; sewing: light goods.

Ice Making: engine and compressor rooms.

Inspecting: rough, medium.

Leather Manufacturing: cutting, fleshing and stuffing, finishing and scarfing.

Leather Working: pressing and winding, grading, matching, cutting, scarfing; sewing: light goods.

Machine Shops: medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing.

Meat Packing: cleaning, cutting, cooking, grinding, canning, and packing.

Milling and Grain Foods: baking, roasting.

Office: private, general

Packing: medium, fine.

Paint Shops: rubbing, ordinary hand painting and finishing, fine hand painting and finishing.

Paper Manufacturing: calendering, finishing, cutting and trimming.

Polishing and Burnishing.

Printing Industries: matrixing and casting, miscellaneous machines, presses, proof-reading, lithographing, electrotyping.

Rubber Manufacturing and Products: calenders, compounding mills, fabric preparation, stock cutting, tubing machines, solid-tire operations, mechanical goods building, vulcanizing, bead building, pneumatic tire building and finishing, inner-tube operation, mechanical goods trimming, treading.

School: class room, study room, library.

Sheet Metal Works: miscellaneous machines, bench work, punches, presses, shears, stamps, welders, spinning.

Shoe Manufacturing: hand turning, miscellaneous bench and machine work, inspecting and sorting raw material, cutting, lasting and welding: light goods.

Soap Manufacturing: stamping, wrapping and packing, filling and packing powder.

Steel and Iron Mills: bar sheet and wire products; automatic machines, rod light and cold rolling, wire drawing, shearing (fine by line).

Store Rooms and Stock Rooms: medium, fine.

Structural Steel Fabrication.

Textile Mills: (Cotton) spooling, spinning, drawing in, warping, weaving, quilling, inspecting, knitting, slashing. (Silk) winding, throwing, dyeing, quilling, warping, weaving and finishing. (Woolen) twisting, and dyeing; drawing in, warping; weaving; knitting machines: light goods.

Wood Working: sizing, planing, standing, machine and bench work, gluing, veneering, cooperage, finishing.

Assembling: extra fine.

Cloth Products: dark goods.

Glass Works: glass cutting (cut glass); inspecting, fine.

Glove Manufacturing: dark goods: sorting, stitching, trimming, and inspecting.

Hat Manufacturing: sewing: dark goods.

Inspecting: fine.

Jewelry and Watch Manufacturing: engraving, stone setting, fine repairing.

Leather Working: grading, matching, cutting, scarfing, sewing: dark goods.

Machine Shops: fine bench and machine work, fine automatic machines, fine grinding, fine buffing and polishing.

Office: drafting room.

Paint Shops: extra fine hand painting and finishing (automobile bodies, piano cases, etc.).

Printing Industries: linotype, monotype, typesetting, imposing stone, engraving.

Shoe Manufacturing: inspecting and sorting raw material, cutting, stitching: dark goods.

Textile Mills: woolens; weaving: dark goods.

In Tables I and II the illumination requirements are specified in foot-candles. The term "foot-candle" may be explained by saying that it represents the illumination on a surface one foot distant from a standard candle; two foot-candles would represent the illumination supplied by two candles at the same distance, etc. In this illustration it is assumed, of course, that in each case the surface is perpendicular to the direction of the rays of light falling upon it.

At first sight it might appear from Tables I and II that there is a sharp line of demarcation between those operations for which one foot-candle is specified and those which require two foot-candles, etc. In reality no such well defined classification exists and in applying the Tables the inspector will find that in certain cases, because of the degree of fineness of the work carried on in a particular plant, one grade higher or one grade lower than that which first suggests itself may be a more reasonable requirement.

Again, it should not be overlooked that there are occasional operations which need to be performed practically without light, such as photographic and photometric processes in dark rooms. Again, there are some operations which are best observed by their own light, as in certain parts of the process of working with glass. In all cases in which work must be performed under very low illumination, special precaution should be taken to safeguard the workers from accident.

In applying the illumination requirements as given in Tables I and II the foot-candles specified should not be construed as referring only to a horizontal plane; the illumination should be measured on whatever plane the work or operation is carried on, whether it is on a horizontal, vertical or intermediate plane. With most artificial lighting systems the foot-candles measured on a vertical plane are about one-half the illumination in the same location measured on a horizontal plane. Attention is also called to the fact that the values in Table I are minimum values; that is, they apply to measurements of the lighting system in ordinary operation, not simply when the lamps and reflectors are new and clean.

Natural Lighting—The foot-candle values given apply to natural as well as to artificial lighting. In practice it will be found that the natural illumination on clear days is frequently many times these figures; in fact, an illumination of a hundred foot-candles can be found in almost any shop if measurements are taken near the window, and very often mechanics find it worth while to avail themselves of this illumination by walking over to the window whenever extremely accurate measurements are to be made. In this connection it is of interest to note that the range of illumination under which the eye can function with some degree of success is extremely wide, varying from a few hundredths of a foot-candle in the moonlight up to as much as ten thousand foot-candles out in the sunlight on a clear day. However, wide extremes in illumination are ordinarily not conducive to best vision.

Most factory owners are particularly interested in making the best possible use of their daylight facilities, so as to render useful and valuable all parts of the floor space; and also, to shorten the periods when artificial lighting is needed. The saw-tooth sky-windows of modern factory construction (Fig. 1), permit of an adequate and nearly uniform daylight illumination of the entire floor area, and are desirable when practicable. When rooms are illuminated through side windows, it is often difficult, or impossible, satisfactorily to light all parts of the floor space, or to furnish adequate illumination to some of the workers without furnishing too much to others, or without subjecting the latter to objectionable glare. In some cases the use of prismatic glass which redirects the rays of light so as to admit more daylight into the room, especially into the parts of the room remote from the windows, is worth while. As a rule it is better to confine the prismatic glass to the upper sash of a window, as its use in the lower sash is likely to cause objectionable glare; moreover it cuts off all view of out of doors.

Windows should be equipped with adjustable devices so that the illumination may be accommodated to changing exterior conditions. Translucent window shades of light tones constitute the most important of these devices. Window shades or other daylight adjusting devices should not be left to the mercy of those workers who may be nearest the windows, but should be controlled by the room foreman. He should readjust the window equipment for the varying daylight conditions and he should, also, decide when the use of artificial light to make up for a deficiency in daylight in any location, is permissible.

Because of the time required for the adaptation of the eye to its surroundings special danger is present when one steps from outdoor sunlight into a dimly lighted storage space; for example, a passageway connecting two well-lighted areas must be well illuminated. Again, where the eye has been afforded the advantages of a high level of illumination throughout the day and artificial light is turned on to reinforce the failing natural light, a higher total illumination is ordinarily needed than at night under artificial lighting alone.

Maintenance of Illumination—The proper and adequate maintenance of equipment for both natural and artificial lighting is essential. Systems which are adequate when first installed will soon deteriorate unless properly maintained. The factory owner should establish a regular, definite system of maintenance so as to insure that sky windows, side windows, lamps and accessories are at all times kept clean, in proper

Fig. 1.—Saw-tooth roof construction, with glass facing the north sky, usually results in well diffused daylight illumination.

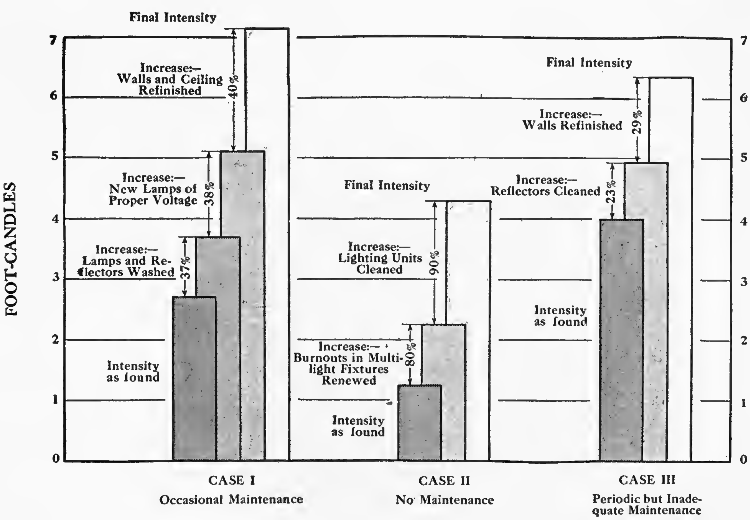


Fig. 2.—Chart showing the importance of prompt renewal of burned out lamps and systematic cleaning of the lighting equipment. These particular tests were on semi-indirect and indirect lighting systems.

adjustment and in good repair. Means should be provided for easy access to all lighting units by the employee in charge of their maintenance. Walls and ceilings should be repainted, preferably in light tones, at regular intervals, particularly where, as in indirect systems of lighting, a large part of the illumination comes from the ceiling. It should be kept in mind that the illumination requirements given in the tables apply to the lighting equipment under adverse operating conditions, not simply new and clean as when first installed.

Figs. 2 and 3 show the very considerable loss in illumination which results from the collection of dirt on lamps and lighting fixtures. To insure that a given level of illumination will be maintained even where conditions are favorable, it is necessary to design the system to give initially at least 25 per cent more light than the required minimum. In locations where the dirt will collect rapidly and where adequate maintenance is not provided, the initial value should be at least 50 per cent above the minimum requirement, and it is evident from a study of the charts that even this allowance may prove insufficient.

Especially in connection with the maintenance of lighting systems attention is called to the desirability of having available in the factory some instrument with which the foot-candles of illumination received at any point can actually be measured. There are a number of such instruments on the market, some of which, in the hands of experienced men, are capable of a high degree of accuracy. One instrument, the foot-candle meter (Fig. 4), is not designed for precise measurements, but nevertheless, has a considerable field of usefulness because its determinations are easily made and are accurate enough for many practical purposes. The foot-candle meter is small, light in weight, and does not require technical training for its operation; foot-candle illumination is read directly from the scale without computation or adjustment. In one large establishment where the superintendent uses a foot-candle meter systematically as a check on his maintenance department, readings of illumination are taken at regular intervals at fixed stations throughout the plant. These readings are recorded in such a way that the successive readings are readily comparable. When any inconsistency appears in the records an

MAINTENANCE RECORD

	JAN 1	JAN 15	FEB 1	FEB 15	MAR 1	MAR 15	APR 1	APR 15	MAY 1	MAY 15	JUN 1	JUN 15	JUL 1	JUL 15	AUG 1	AUG 15	SEP 1	SEP 15	OCT 1	OCT 15	NOV 1	NOV 15	DEC 1	DEC 15
Drafting Room 347	12	12	12	11.5	11.5	11.5	11.5	11.5	11.5	11.0	11.0	11.0	11.0	11.0										
Office 349	8	8	8	8	8	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0										
" 350	8	8	8	8	8	7.5	7.5	6.0	6.0	(5)*	8	8	8	7.5										
" 351	8	8	8	8	7.5	7.5	8	7.5	7.5	7.0	7.0	7.0	7.0	7.0										
" 352	8	8	8	8	8	8	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0										
" 353	8	8	8	7.5	7.5	7.5	7.5	7.5	7.5	7.0	7.0	7.0	6.5	6.5										
" 354	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0										
" 355	8	8	8	7.5	(6)	8	8	8	8	8	8	8	7.5	7.5										
" 356	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0	7.0	6.5	6.5	6.5	6.5										
Stock Room 360	8	8	8	8	7.5	7.5	7.5	7.5	7.5	7.0	7.0	7.0	7.0	7.0										
Hallway	2	2	2	2	2	2	2	2	2	(1)	2	2	2	2										
Stairway	2	2	2	1.5	2	2	2	2	2	1.5	1.5	1.5	2	2										

* Lamp Burned out.

Fig. 3.—Lighting Maintenance Record.

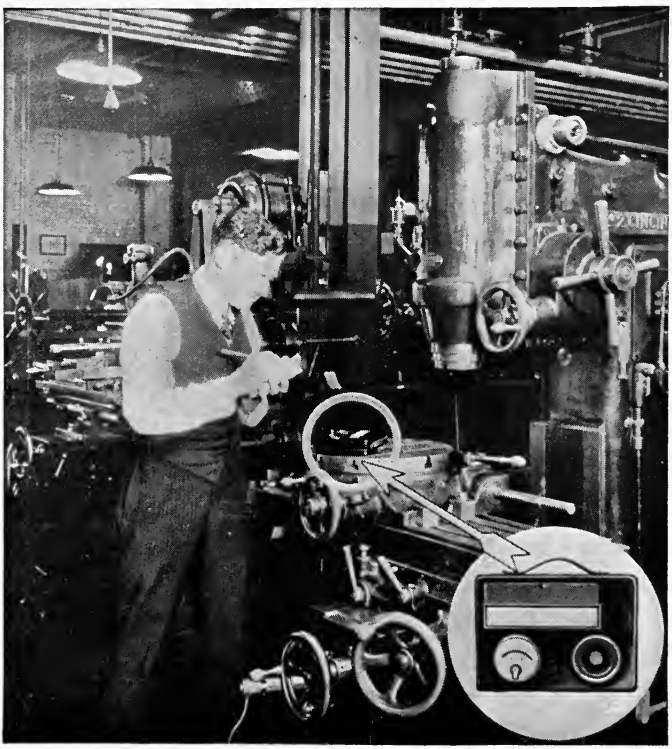


Fig. 4.—A survey of actual lighting conditions can readily be made with the foot-candle meter. This instrument is very useful in "checking up" a lighting system to see that it is being properly maintained.

investigation is made and the remedy applied. The illumination in that establishment is never allowed to fall below 6 foot-candles without immediate correction. By measuring light actually delivered to the work the foot-candle meter automatically reveals the combined effect of all possible causes of depreciation. Ignorance of the magnitude of depreciation has often been the cause of inadequate maintenance. Soap and water cost less than gas and electrical energy.

Locating Switches and Controls—The switches which turn on and off the light in the entrances and halls of a building should be located near the points of entrance. Likewise switches which control at least one circuit of lamps in a room should be located near the principal points of entrance to that room.

In locating switches or control devices in factory and mill aisles, care should be exercised to arrange them systematically; that is, on columns situated on the same side of the aisle and on the same relative side of each column. This plan materially simplifies the finding of switches or control devices, by those responsible for turning on and off the light.

Control Parallel to Windows—The light from the lamps most distant from the windows will usually be required at times when the natural light near the windows is entirely adequate, thus making it advantageous to arrange the groups of lamps in circuits parallel to the windows. The advantage of this method is further apparent when it is considered that if the lamps are controlled in rows perpendicular to the windows, all lamps in a row will necessarily be on at one time, while a portion only may be required.

Notes on Rule 2—Avoidance of Glare.

Glare may be defined as any brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision, or eye fatigue. Always a hindrance to vision, it often, like smoke from a chimney, represents a positive waste of energy as well. It is one of the most common and serious faults of lighting installations; the Code properly requires the shading of lamps in industrial plants to guard against glare.

Glare is Objectionable because (1) when continued it tends to injure the eye and to disturb the nervous system; (2) it causes discomfort and fatigue and thus reduces the efficiency of the worker; and (3) it interferes with clear vision, and thus reduces the efficiency and in many cases, increases the risk of accident or injury to the worker. From both a humanitarian and a business viewpoint, the owner or operator of a factory should be interested in avoiding glare, whether caused by daylight or by artificial light. On the other hand, in interpreting and enforcing the glare rule the inspector is not expected to insist upon what he may believe to be desirable practice in the given case; his duty is only to insure the absence of a condition which is prejudicial either to the health or to the safety of the worker.

If a simple instrument were available for measuring glare the task of the inspector would be comparatively easy. However, there are so many factors entering into the situation that it has not been found practicable to develop any instrument which will properly evaluate them all. To arrive at an intelligent judgment in any given case, therefore, the inspector must be reasonably familiar with the principal factors in or causes of glare.

CAUSES OF GLARE—There are five principal causes of glare:

1. *Brightness of Source*—The light source may be too bright; that is, it may give off too high a candlepower per square inch of area.

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 for example, 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.

2. *Total Volume of Light*—The light source may be too powerful for comfort; that is, it may give off too great a total candlepower in the direction of the eye.

Too frequently glare is assumed to be entirely a question of the brightness of the light source; of equal importance is the question of its total candle-power. Experience has shown that a 500-watt lamp in a 10-in. opal globe, or a mercury-vapor lamp of an equivalent light output, 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 unit is only a few times that of a candle flame, but its total candle-power and consequently the quantity of light which reaches the eye is altogether too great, so that its effect is worse than that of the bare filament of lower candle-power, although the latter may have a brightness as high as 3000 candle-power 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.

3. *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.

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 ft. Again, the same light source would probably be found quite unobjectionable at a distance of 8 ft. from the eye provided this distance was obtained by locating the lamp 4 ft. ahead of the observer and 7 ft. 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 worker should be freed from the annoyance caused by glare. Glare is the 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 at 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 of vision 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.

4. *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 some 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 high side walls and a paint of medium reflecting power for the lower side walls will ordinarily be found most satisfactory under both artificial and natural lighting.

Fig. 5.—Whenever local lighting is used, it should be supplemented by some general illumination. Note the absence of glare and contrast between light and dark areas in this room as compared with Fig. 7 where there is no general illumination. In the above photograph although a local lamp is supplied for each machine, the individual sources of light are scarcely apparent, because of the general illumination.

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 workman 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 adapted 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.

5. *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.

Where an operator is seated and his field of vision is fixed for several hours at a time, light sources of lower brightness and lower candlepower are required than where the operator 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 eye strain 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.

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.

In Table III a means of rating light sources (into Grades I to X) has been provided which takes into account both their brightness and their candlepower. Light sources in Grades I and II may be termed soft or well diffused; those in Grades VIII, IX and X are harsh and likely to cause glare. It is seen from Table III that a light source of high intrinsic brightness but of low candlepower,—for example, one that would be classified under the fifth line of the first column (less than 20 cp.—and 100 to 1000 cp. per sq. in.) has the same rating, Grade V, as a source of lower brightness but of greater total candlepower, (2-5 cp. per sq. in. and 500 total cp.) which falls in the second line of the fifth column.

TABLE III.

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	TOTAL CANDLE POWER IN DIRECTION OF EYE.				
(Apparent candles per sq. in.)	Less than 20	20 to 50	50 to 150	150 to 500	500 to 2000
	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 1000	V	VI	VII	VIII	IX
1000 and up	VI	VII	VIII	IX	X

In accordance with the plan of Table III measurements of brightness and candlepower have been made on a number of light sources found in every day practice, both natural and artificial, and grades have been assigned to them as shown in Table IV. While engaged in his work, the inspector will, of course, find other light sources in use which are not included in the Table; however, from those which are given he should be able to estimate closely in what grades the others should be placed. In cases of doubt, it is, of course, possible to have actual measurements made to determine both the brightness of the lighting unit and its total candlepower. The unit can then be rated in accordance with Table III.

TABLE IV.

SPECIFIC CLASSIFICATION OF LIGHT SOURCES FROM THE STANDPOINT OF GLARE AS DERIVED FROM TABLE III

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

OPEN GAS FLAMES II

INCANDESCENT MANTLE GAS LAMPS

	Mantles Consuming 2-5 cu. ft. per hr.	Mantles Consuming 5-8 cu. ft. per hr.	Large Single Mantle or Cluster 8-12 cu. ft. per hr.	Large Single Mantle or Cluster 12-20 cu. ft. per hr.	Cluster or High Pressure Lamp consuming above 20 cu. ft. per hr.
Clear Glassware	Grade V	Grade VI	Grade VII	Grade VIII	Grade IX
Frosted Globes	III	IV			
6-in. Opal Globe	II	III			
8-in. Opal Globe*	I	II	IV-VI		
10-in. Opal Globe*			III-V	V-VII	
12-in. Opal Globe*					VI-VIII
Dome Reflector					
Mantle Visible	V	VI	VII	VIII	IX
Mantle not Visible	I	II	III	IV	IV
Bowl Reflector					
Mantle Visible	V	VI	VII	VIII	IX
Mantle not Visible	II	II	III	V	V
Totally Indirect*			I-II	II	III
Semi-Indirect Bowls*			II-III	II-IV	III-VI

*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.

TABLE IV.—Continued

ARC LAMPS

	Grade
Enclosed arcs, clear globes	IX
Flame arc, clear globes	X
Flame arc, opal globes	VII-VIII

MERCURY VAPOR TUBES	VI

CARBON AND METALLIZED FILAMENT INCANDESCENT LAMPS

8 c. p.	V
16 c. p.	V
32 c. p.	VI

TUNGSTEN FILAMENT INCANDESCENT LAMPS

WATTS	10-25	40-60	75-100	150-200	300	500-1000
Bare Lamps	Grade VI	Grade VII	Grade VIII	Grade IX	Grade IX	Grade X
Frosted Lamps or Frosted Globes	II	III	VI	VII	VIII	
8-in. Opal Globes*	I	I-II	II-IV	IV-VI		
12-in. Opal Globes*			II-III	II-V	IV-VI	VII-VIII
16-in. Opal Globes*				II-V	IV-VI	V-VII
Flat Reflectors—Filament Visible	VI	VII	VIII	IX	IX	X
Dome Reflectors—Steel or Dense Glass						
Filament visible from working position	VI	VII	VIII	IX	IX	X
Filament not vis. from working position	I	I	III	III	IV	VI
Bowl Reflectors—Steel or Dense Glass						
Filament visible from working position	VI	VII	VIII	IX	IX	X
Filament not visible from working position	II	II	III	IV	VI	VII
Dome Reflectors—Bowl-Enameled Lamps			IV	V	VI	VI
Semi-Enclosing Units*			III-IV	IV-VI	IV-VII	VI-VIII
Totally Indirect Lighting*			I-II	I-II	II	III
Semi-Indirect Bowls*			I-III	II-III	II-IV	III-VI

*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.

TABLE V.

CHART OF THE FIELD OF VIEW

Classification of Position of Light Source Which Takes into Account the Distance from the Eye and the Angle of the line of Vision. (See Fig. 6).

Height above Floor in Feet	HORIZONTAL DISTANCE OF LIGHT SOURCE FROM OBSERVER IN FEET															
	1	2	3	4	6	8	10	12	16	20	25	30	35	40	50	60 & up
6.5 or less	A*	A*	A	A	A	A	A	A	A	A	A	A	B	B	B	B
6.5 - 7	G	E	D	C	C	B	B	B	B	B	B	B	B	B	B	C
7 - 8	G	G	F	E	D	D	C	C	C	C	C	C	C	C	C	C
8 - 9	G	G	G	F	F	E	D	D	C	C	C	C	C	C	C	D
9 - 10	G	G	G	G	F	F	E	E	E	D	D	D	D	D	D	D
10 - 11	G	G	G	G	G	F	F	F	E	E	D	D	D	D	D	D
11 - 12	G	G	G	G	G	F	F	F	F	F	E	E	D	D	D	D
12 - 13	G	G	G	G	G	G	F	F	F	F	E	E	E	E	E	E
13 - 14	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E	E
14 - 15	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E
15 - 16	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E
16 - 17	G	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E
17 - 18	G	G	G	G	G	G	G	G	G	G	G	G	F	F	F	F
18 - 19	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	F
19 - 20 and up	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

*Classified as A unless light source is so nearly above the head of operator as to be quite outside of field of view in which case classify as E.

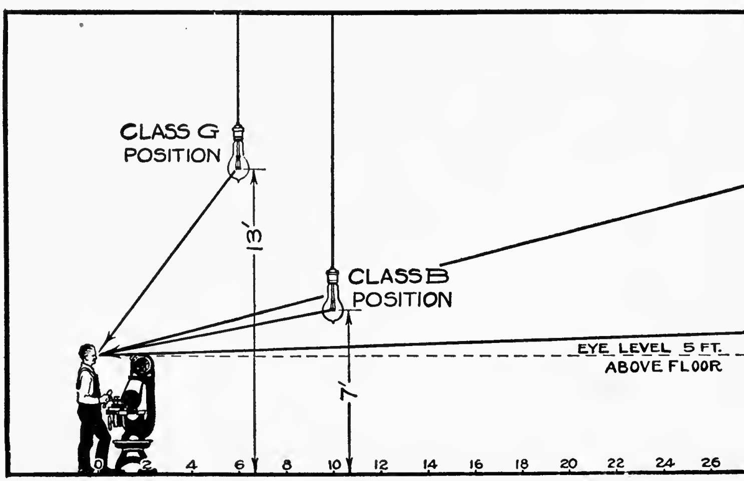


Fig. 6—Diagram illustrating typical position given—

TABLE VI.

SHOWING LIMITING GRADES OF LIGHT SOURCES PERMISSIBLE FOR VARIOUS CONDITIONS

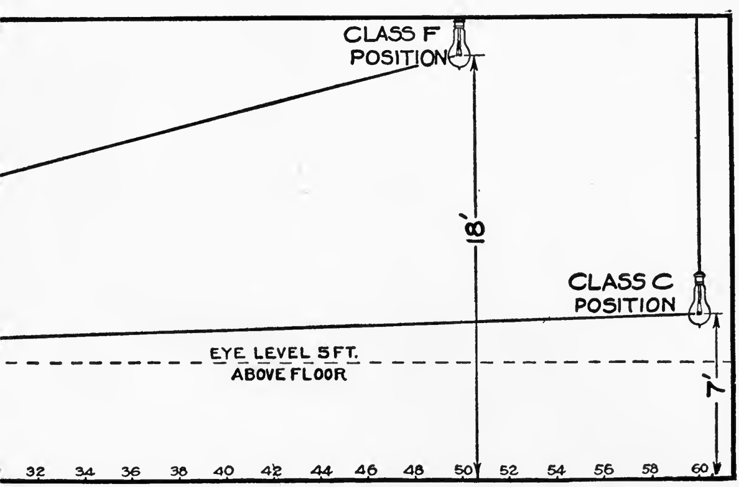
Classification of Position.	Space or work to be lighted.			
	Roadways and Yard Thoroughfares	Storage spaces, Aisles, Stairways, Handling Coarse Material	Ordinary Manufacturing Operations†	Offices and Drafting Work and Certain Mfg. Operations*
	Limiting Grade	Limiting Grade	Limiting Grade	Limiting Grade
A	VI	V	III	II
B	VII	VI	V	IV
C	VIII	VII	VI	V
D	IX	VIII	VII	VI
E	IX	IX	VIII	VII
F	X	X	IX	VIII
G	X	X	X	X

BACKGROUND

Where the background and the surroundings are very dark in tone, a light source of one grade softer than that specified in Table VI may be required. Where the background and surroundings are very light in tone one grade more harsh than that specified in the table may sometimes be permitted.

†For the present the limits set in this table cannot be rigidly applied to portable lamps used for temporary work such as setting up machines, repairing automobiles, etc.

*Those operations in which workers are seated facing in one direction for long periods of time.



he chart of the field of view, see Table V.

From a study of Table IV it will be observed that incandescent lamps equipped with reflectors which do not completely hide the light source have been assigned to the same grade as the corresponding sizes of bare lamps. It is true that the addition of a reflector somewhat increases the total candlepower in the direction of the eye and therefore the argument might be advanced that a 100-watt lamp with a flat reflector should be classified in Grade IX whereas the bare lamp is Grade VIII. On the other hand, from the standpoint of glare, the effect of the light background furnished by the reflector at least compensates for the increased candlepower which it gives; the rating is therefore kept at Grade VIII.

Charting the Field of View—It has already been pointed out that the distance between a light source and the eye, and its angle to the line of vision have much to do with determining how bright a light source may be used without discomfort. In Table V, which is a chart of the field of view, the possible locations of light sources are classified in seven groups, A to G inclusive, depending upon their distance from the eye and their proximity to the line of vision. Light sources in positions designated A, B or C, are close to the eye or close to the line of vision; hence they are most likely to be the cause of discomfort, and the greatest care must be exercised in their selection. In positions F and G, on the other hand, the use of relatively bright sources is much less harmful.

Limiting Grades for Specific Installations—Table VI shows the harshest grade of light source which should be permitted within the field of vision for fixed conditions as to location of lamp, brightness of background, and character of work performed.

The grades named in Table VI are definitely limiting values and in each case the use of softer light sources is to be recommended; that is, where Grade IV is permitted, the installation of a lighting unit of Grade II or of Grade III will be conducive to better results as regards both accuracy of vision and eye comfort.

From Table IV the majority of bare incandescent lamps are seen to have a relatively poor rating; that is, most of them fall in Grades VII to IX, and it is evident from Table VI that Grades VII to IX are never to

Figs. 7 and 8.—Adjoining rooms in the same factory. The upper figure illustrates a strictly local lighting system of the poorer sort. The lower figure illustrates a lighting system consisting of 150-watt bowl enameled lamps equipped with dome reflectors spaced 10 feet apart; the average illumination is 9 foot-candles.

be permitted in work rooms in positions A, B or C. That is, the use of bare incandescent lamps is prohibited in working areas except when they are located at considerable heights above the floor or when they are so placed as to be out of the field of vision. At the present time it will be found necessary from a practicable standpoint to delay the strict enforcement of this provision in a very few instances, particularly in the case of extension cord lamps used in temporary work, such as in setting up machinery and in repairing automobiles, etc.

It will be noted from Table IV that the sources of natural light, side and ceiling windows, usually fall in Grade IV. This means (see Table VI) that no mandatory rules are established as to the use of shades, awnings, etc., except in those cases where the sky is visible through portions of the sash in position A, that is, less than 6.5 ft. above the floor, or where the sun itself comes within the range of vision.

However, Grade II is the limiting value for light sources less than 6.5 ft. high, in offices, and other locations where the workers are seated facing in one direction for considerable periods of time. Hence, in these cases, to comply with the Table, the work must be so arranged that the employees are not required to face windows where the sky is visible through the lower sash; that is, less than 6.5 ft. above the floor.

Prism glass when so located as to catch the sun's rays ordinarily has a very much poorer rating than clear glass; hence, where it is used the installation of window shades or curtains should ordinarily be required.

The question naturally arises why, if glare is so objectionable, should not all sources capable of producing glare be prohibited everywhere. The answer is that to attain a maximum softness of light sometimes entails a sacrifice in efficiency and an increase in operating expense. If a worker chooses unnecessarily to gaze directly upward at bright skylight or at an artificial lighting unit so located that it is not a factor in glare under ordinary circumstances, it is scarcely within the province of a code of lighting to protect him from the consequences.

Fig. 9.—Glaring light from unshaded local lamp which is a menace to safety and to vision and is one of the evils which the Lighting Code is expected to eliminate.

Fig. 10—Lighting an office by means of indirect units. Illumination approximately 6 foot-candles.

How to Use Tables IV, V and VI—To determine whether a given lighting installation is within the glare limits specified, proceed as follows:

(1) Select what appears to be the most glaring light source within the field of view of any of the employees when at work. Measure the height of that light source above the floor and its horizontal distance from the worker.

(2) With the height and distance find in Table V how this location in the field of view is classified, (Position A, B or C, etc.).

(3) With the classification of the position fixed from (2) determine from the proper column of Table VI the harshest grade of light source ordinarily permissible for this location.

(4) If surroundings are very light or very dark, apply a correction of one grade (plus or minus) to the value found in (3).

(5) From Table IV find the classification of the light source in use and compare with (4). (If the particular source is not listed, its grade may be estimated or may be determined by actual photometric measurements.)

Glare by Reflection—Another way in which glare is produced is by the reflection of light from polished surfaces in the field of vision. The difficulty experienced in protecting the eyes from this kind of glare is sometimes very great. The brightness of the image on the working surface is, of course, proportional to the brightness of the light source above it, and hence, one way in which to minimize this effect is to diffuse the downward light; that is, to use a bowl-frosted, or bowl-enameled lamp or an enclosing fixture, or to employ semi-indirect or totally indirect lighting fixtures. In some cases the light source can be so located that its reflection is directed away from, rather than towards, the eyes of the workers. The avoidance of highly polished surfaces in the line of vision is another good way to minimize reflected glare.

There are some instances, on the other hand, where sharp shadows and specular reflection from the materials worked upon actually assist vision. For example in sewing on dark goods the thread is much more easily distinguished when illumination is secured from a concentrated light source, such as a brilliant lamp filament, which casts sharp shadows and gives rise to a distinct glint from each thread. However, in these

Fig. 11.—Drafting room lighting using dense semi-indirect units and 200-watt lamps. The glazed or shiny ceiling will not increase useful illumination and is frequently a source of glare.

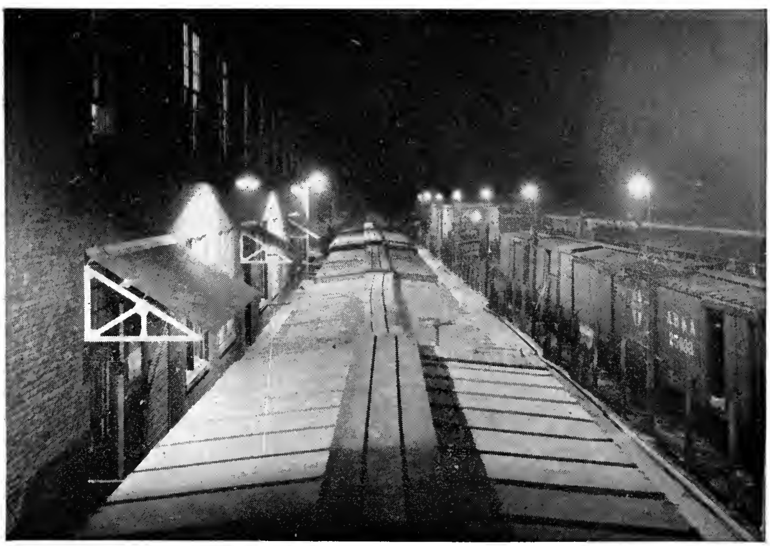


Fig. 12.—A yard lighting installation consisting of 150-watt lamps in shallow bowl reflectors, mounted 20 ft. from the ground. The units in each row are spaced 60 ft. apart, and the two rows are 30 ft. apart.

cases the light source must be particularly well shielded from the eyes of the worker.

Notes on Rule 3—Exit and Emergency Lighting

The employer is to be held responsible for the proper lighting of passageways, stairways and exits, in so far as his premises are concerned; which means such parts of buildings, floors or rooms as are controlled by the employer, including entrances thereto, but excluding hallways, passageways and stairways giving access to other floors, or to spaces on the same floor, and used in common by the tenants of the building. These latter shall be lighted by the party or parties in control of the building, in accordance with the Code, and the following provisions and interpretations thereof:

"Exit and Emergency Light-Sources" are to be understood as those artificial illuminants which are necessary only to make clear to the occupants or employees the regular places of exit, or to enable them to pass to and along safe exits with reasonable speed and assurance of footing. Such lighting is never assumed as being necessarily sufficient for the proper performance of regular working operations.

The circuits for exit and emergency electric lamps should be wired to be independent of the working lamps, back at least as far as the branch panel or distributing board, and should be separately fused, so that any failure of the regular working lamps through causes arising within that working space will not also cause failure of the exit, stairway, or passageway lamps.

No fuses smaller than those of the emergency branch circuits shall be used back of (that is, on transformer, meter or generator side of) such circuits, and no power machinery, portable extension cords or convenience outlets shall be on such emergency circuits.

The "main service entrance" may be interpreted to mean the entrance point (meter or distributing panel) of lighting feeders for the building, floor, loft or particular space in question. In gas lighting, it may be considered to be the main gas feeder for the building, or the main gas riser for the floor or loft in question. Where several factory spaces are grouped in the same building, each with its own exit or exits, the emergency electric circuits for any one space are not required to run to the main build-

Fig. 13—Lighting of steel rolls. Illumination provided by five mantle inclosed gas arc lamps, equipped with opaque reflectors.

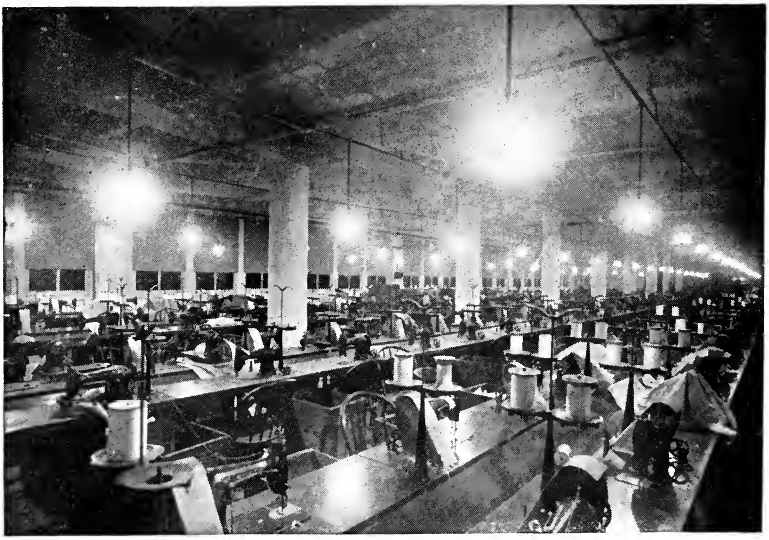


Fig. 14—Shirtwaist factory, sewing machine lighting. Illumination provided by single mantle gas lamps, equipped with prismatic reflectors. Lamps spaced 9 feet apart with a clearance of 5 feet above working plane.

ing panel board or main switch nor are the emergency gas pipes expected to extend to the main gas meter nor to the building feeder from the street main, except as explained below.

Under specially dangerous conditions, where in the opinion of the recognized authorities the failure of the main and entire regular lighting supply would leave the employees without assured means of seeing the outgoing passageways, the exit and emergency lamps should be fed from an entirely separate source of energy, such as a storage battery, or, in case the regular lighting system is electric, from gas or other reasonably dependable illuminant. Under normal conditions, however, the phrase "separate supply" shall, in electric service, be interpreted to mean a separate branch circuit which will afford lighting as long as transformers, generators or main lighting feeders are intact; and in gas service, interpreted to mean branch piping extending back to a sufficiently large feeder to insure a gas supply unless stoppage occurs near or outside of the main gas meter.

As indicated in the general requirements under Part I of this Code, the exit and emergency lamps should be lighted whenever artificial lighting is required in the work spaces.

It is the obvious intent of Rule III to insure reduction of accident hazard, and inasmuch as this end is as beneficial to the industrial operator or owner as to the State, the detailed interpretations of this order, for the various and sundry types and situations of working spaces, must be reached through mutual co-operation of the owner and the State authorities.

PART III.

ADVANTAGES OF GOOD ILLUMINATION.

WHILE the advisability of good natural and artificial illumination is so evident that a list of its effects may seem commonplace, these effects are of such importance in their relation to factory management that they are worthy of careful attention. The effects of good illumination, both natural and artificial, and of bright and cheerful interior surroundings, include the following:

1. Reduction of accidents.
2. Greater accuracy in workmanship, resulting in improved quality of goods.
3. Increased production for the same labor cost.
4. Less eye strain.
5. Greater contentment of the workmen.
6. More order and neatness in the plant.
7. Supervision of the men made easier.

While it is difficult to place a definite money value on the savings effected in increased production and improved quality, by good illumination, it by no means follows that such savings are insignificant or unsubstantial. The factory owner who ignores them neglects his own interests. Other items in the foregoing list, even more difficult to value definitely, are none the less real; taken together, they constitute a powerful argument in favor of the best available illumination in the factory.

The following estimate, conservatively based on practical conditions, gives an idea of the relative costs of good illumination by artificial means, and of labor, in the factory.

Assume that the lamps are so spaced that one 100-watt incandescent electric lamp will take care of one operator; that in this particular case the lamp burns on the average two hours per day, three hundred days per year; that the life of the lamp is one thousand burning hours; and that the operator works eight hours per day, 300 days per year.

Investment:

Cost of lamp (list price)	$1.10
Cost of enameled steel reflector (list price)	2.50
Cost of wiring per outlet	8.00
Total Investment	$11.60

Cost of Operating per Annum:

Interest on Investment, $11.60 at 6%	$0.70
Depreciation on reflector and wiring at 12½%	1.31
Renewal of lamp $\frac{600}{1000}$ x $1.10	0.66
Cleaning, at 3c. per cleaning, two per month	0.72
Energy at 5c. per kw-h	3.00

Total Annual Cost of Maintaining Good Illumination:

Per man per year	$6.39

Cost of Labor: Annual Wages per Man per year

Eight hours at 45c. per hr.; 8 x 300 x $.45	$1080

If an operator, because of the good illumination, saves—in more production, or better quality of product—the equivalent of only three minutes per day for 300 days, he will offset the annual cost of the illumination. Good illumination is, relatively speaking, inexpensive, and its introduction and maintenance are good investments on the part of the factory owner.

These estimated figures, illustrating the low cost of good lighting compared with the cost of labor, also illustrate how large may be the losses unconsciously sustained by the factory owner from the use of a poor lighting system. An operator losing, say, 30 minutes per day, loses more than $60.00 per year, or about ten times the cost of giving him good illumination.

The factory owner, when approached by the gas or electric lamp salesman, should weigh carefully any argument in favor of a change in his lighting system which is based solely upon a resultant saving in energy consumption. The example given above shows how greatly the gain in increased output, due to good lighting, overbalances any possible saving in energy consumption effected by changes in the system of illumination. If the proposed new system sacrifices anything in the quality of illumination, or if it merely substitutes one inadequate system for another, it should be rejected, and the factory owner should insist that if his lighting installation is changed, the new system must meet the requirements of good illumination even though this involves the consumption of more

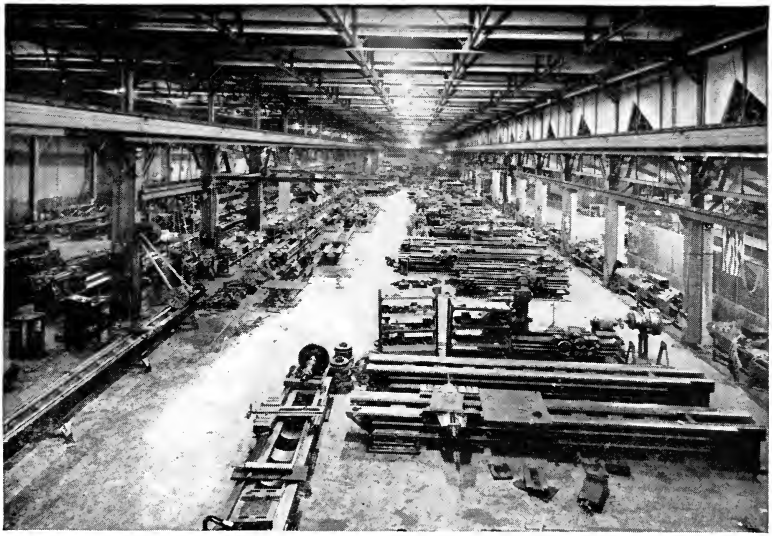


Fig. 15.—A plant where machine tools are manufactured, using mercury vapor lamps spaced 20 feet apart at a height of 25 feet above the floor; approximately 1-watt per sq. ft.

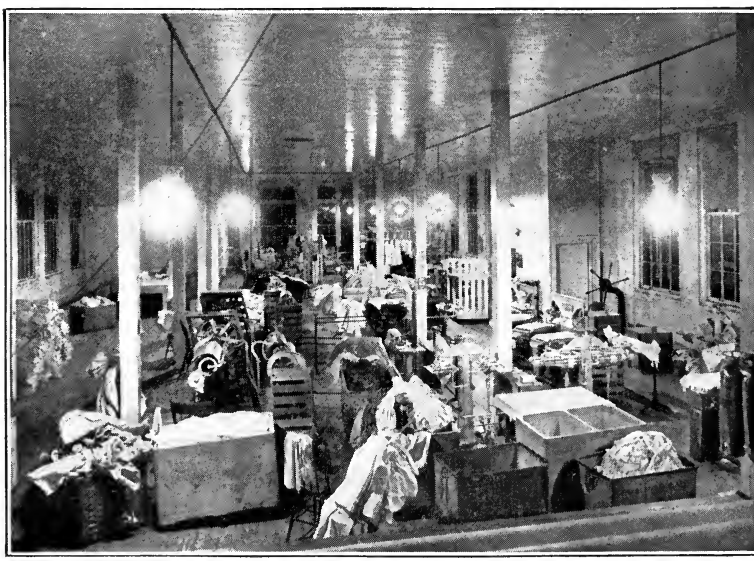


Fig. 16—Laundry lighting—Illumination provided by five mantle gas arc lamps, inclosed type; equipped with diffusing glass globes.

energy than before. First a good lighting system, and then as much economy in energy consumption as is consistent with the illumination requirements—such a policy is the wise one for the factory owner.

Accident Insurance Costs

Compensation insurance premiums for a given plant are based on the amount of the payroll, and the rate is determined by the accident experience of a given industry, modified by the experience of the particular plant under consideration. With a rate of one per cent the annual premium in the case of 1000 employees at an average wage of $40.00 per week would be $20,800.

An insurance carrier might pay the claims resulting from two accidents per month (on an average) in this plant, and meet his own overhead costs, and still have a slight margin of profit. An experience of three accidents per month, one-third of them due to poor lighting (a not unlikely event), would probably leave the insurance carrier no option but to increase the rate, by say, 50 per cent. The premium would then be $31,200—an increase of $10,400. If the lighting costs only $3.00 per employee or $3,000 per year total, the owner's annual expense for poor illumination actually amounts to $13,400—of which $10,400 is required by the insurance company to meet accident claims. An expenditure of $6.00 per year per employee for lamps and energy might save a large portion, if not all, of the latter amount.

An Argument Supplementary To The Code, Showing The Safety Feature of Good Illumination

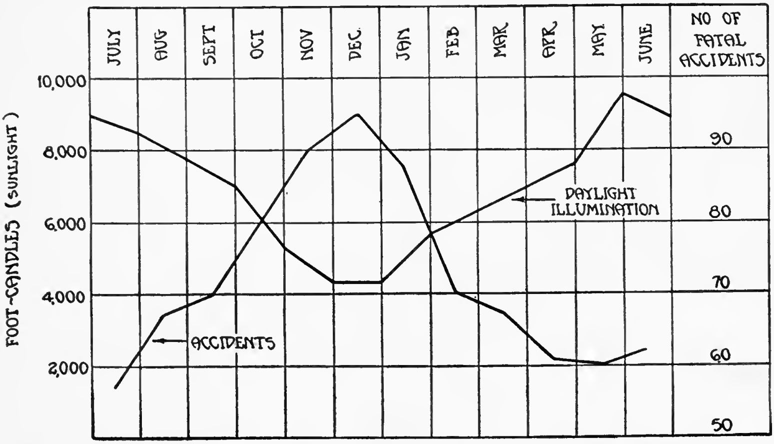


Fig. 17.—Chart of the accidents occurring in a typical group of industries, indicating a higher accident rate when light is inadequate.

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