THESIS

COMMERCIAL LIGHTING IN OFFICES, STORES AND SHOW WINDOWS

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Commercial Lighting In
Offices, Stores and Show windows

A

Report Subimtted to the Faculty of the

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PREFACE

In this thesis the author has attempted to compile under one cover all necessary information necessary to properly design the artificial illumination for offices, stores and store windows. There are no books on the market to date which combine the theoretical with the commercial side of the designing. As far as possible the author has given concrete examples and illustrations of the different methods in use and their application. Although the greater part of this thesis is not original with the writer, he cannot help but feel that the time has been well spent, since a quick reference library on commercial lighting has been the result.

The author is indebted to Prof. Foltz of the of the electrical department for his preliminary course on illuminations, and for his his many timely suggestions as to available material.

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INTRODUCTION

"Twas a light that made
Darkness itself appear
A thing of comfort."

Light is one of the dominating agencies in life and progress for it is important to our most important educative sense-vision. The possibilities extend into all those activities which make their appeal to human consciousness thru the doorway of vision. The importance of lighting is limited only by the bounds of human activities and its broadest sense, its importance extends even beyond them, for it is one of the most important in the scheme of creation. The activities of primitive man were practically bounded by sunrise and sunset, and darkness was feared as the abode of evil spirits and of lurking dangers. Doubtless light was merely a by-product of the fire whose primary function was to furnish heat, nevertheless we may imagine primitive man with his burning knot exultant in his victory over Nature. This achievement was one of the most important mile stones on the highway of human progress. Man's activities were no longer limited to daylight hours and greater opportunities were before him.

In the early days of lighting as a distinct profession, the engineering aspects were given prominence. In fact, lighting today is practiced largely from this standpoint not withstanding that the efficiency and adaptability of modern illuminants have made possible the realization of lighting to meet very largely all the requirements of the human activities and desires in respect to this agency. With this growing attention to lighting we find as in many other activities, ~~that as in many other activities, that~~ the deeper we delve the more extensive are the ramifications and comparitively smaller is the part of the apparent whole with which we are thoroughly familiar. For this reason ~~and~~ the physiologist and ophthalmologist have been attracted to the problems of lighting which involve the visual organs. The physicist specializes in many of the problems of production and utilisation of light. The psychologist finds an unexplored field for his endeavors for finally the problem of lighting is largely psychological. The artist finds an outlet for his ability in clothing scientific lighting principles with artistic exteriors in lighting fixtures, also in using lighting as a decorative medium by "painting" with light as obtained primarily from the lighting units. As we delve deeper into the problem of lighting we find many intimate relations between lighting and the various sciences and arts all of which must be appreciated by the lighting practitioner before he is worthy of the title of lighting expert.

The illuminating engineer should recognize that the esthetic sense however dormant, is possessed by all human beings as is evidenced by the things about us. Perhaps we would not apply the term, artistic, to many of the scenes that greet us during our daily routine; however, as we critically view any of these scenes and eliminate in our imagination all that is not purely utilitarian, how different they would appear.

Imagine this done to everything on earth and a fair apprecia- tion of the value of the artistic and beautiful is obtained. On theother hand the artist should appreciate that in a broad sense in lighting, utility cannot be divorced from beauty. In fact it is misleading to use these two terms as if they had nothing in common. Beauty is in itself certainly useful as veiwed from the brodd outlook upon life. The philosophy of the beautiful teaches us that beauty is the harmonious en- semble of the various parts, hence in lighting fixtures beauty in a broad sense is the harmony of science and art.

But the consideration of the artistic aspect of lighting should not end at the fixtures. In fact the greater field lies beyond them in the distribution of light on the various surfaces, such as walls and floor, and in the prduction of shadows appropriate to the setting and in the color which best fits the spirit or mood of the occasion. This is one of the most neglected aspect of lighting altho it is one of the most extensive fields for development. Inasmuch as the prime object of the lighting specialist is to safeguard vision he seeks for rules which limit brightness and brightness-contrasts to safe values. Research is contributing much of value by direct attack on these problems. However, a rule which it seems safe to follow, is that if the lighting does not offend the finer esthetic sensibilities it is not likely to be seriously harm- ful in its physiological effects. Such a rule cannot be app- lied safely as a criterion of the best possible illumination but glaring lighting conditions have no place in an esthetic harmony of light, shade and color.

In the industires and in various other activities in which the vision is taxed the problems of lighting are not solved by providing a sufficient intensity of illumination on the working planes. In each case the various specific activities should be studied in order to arrang at the very best conditions for seeing. Sometimes objects on which the eyes are focused are best seen as high lights on a dark ground and other cases as dark shades against a relatively brighter ground. The character of the shadows which is determined by the position and angular extent ot the light source and by the amount of scattered light reflected from the surroundings, is of importance in distinguishing objects. The color of the surroundings the spectral character of the illuminant and the environment as a whole are factors that should be considered and controlled by the lighting specialist in so far as he is able.

What is Good Lighting?

The answer to the above question depends upon the interpretation of the word "good", and this interpretation depends upon the viewpoint of the observer. An interior may be well lighted from the utilitarian viewpoint, with good uniformity and sufficient intensity and yet badly lighted from the artistic viewpoint. There is a great misunderstanding regarding what constitutes artistic lighting. Some believe that artistic lighting fixtures in the same scale of magnificance as the interior decorations should be considered. In fact, this is the general impression of "artistic lighting" and it has become so prevalent that those who are not skilled along this line have come to feel that, for the average store or home, artistic lighting is an extravagance far beyond realization. This misunderstanding has arisen because no general information has been circulated regarding the true relation of esthetics to lighting. This relation is so important that to neglect it is positively detracting from the complete value of lighting to the consumer, a detraction which no electrical salesman should allow to exist in his community, and one which it is possible to avoid, providing a little consideration is given to the subject. Every salesman who has to come in contact with the consumer realizes that the consumers' satisfaction is the biggest asset in the salesman's and his company's favor. Satisfied customers do not complain, and become "boosters" instead of "knockers," and every corporation needs as many friends as it can get.

Satisfaction from lighting depends on something more than economy. The consumer who si continually subjected to the "economy" argument is alway s anticipating, and demanding greater economy. And economy, like everything else, has its limit, although it is difficult to draw the dividing line in such cases. For example, the proprietor of a drug store was dissatisfied with the lighting of the glass urns filled with colored solutions, suspended in his window, and requested a local electrical salesman to suggest some method of improving same. The salesman after a superficial study of the conditions recommended that larger Mazda lamps be used. In accordance with the usual method of lighting such urns the lamps were placed in sockets attached to flexible and adjustable tubing so that they were placed directly behind each urn, constituting a miserable ineffective and inefficient arrangement, for the contents of the urn could only be effectively illuminated when the observer was standing in one position--directly in front. The view from the side dis closed the lamp and the glare was so great that the whole effectiveness of the urn and its color was destroyed. In addition, the larger lamps increased the current consumption and at the end of the month the druggist became infuriated, upon receipt of a bill considerably in excess of his average amount. The salesman in his anxiety to satisfy his customer went from one extreme to another and installed Mazda lamps of the smallest possible type, which failed utterly to reveal the coloring matter in the urns, leaving the druggist thoroughly dissatisfied despite the reduction of his bill which ensued. By chance a lighting expert in the employ of the lighting company was consulted and suggested that lamps of the original size be used in a new way. The novelty of his suggestion immediately aroused the interest of the druggist and it was carried out. The colored solutions were removed from the glass urns and their inner surface was stained with ordinary lamp coloring. The lamp was then placed inside and the effect when lighted was that of a uniformly colored urn, equally attractive from any viewpoint, either by night or by day. The opal coloring which was used gave translucency without transparency and neither the lamp itself nor its filament could be seen through the colored glass. The druggist was not only satisfied but enthusiastic and became a first-class "booster" for the company, assisting their district representative on more than one occasion to close a prospect. This is an example of good lighting and good business combined, and where you find one you will usually find the other.

The Practical Side of It.

There is such a wide variety of lighting equipment available to-day that there is positively no excuse for not specifying the right thing. It is just as easy to give a customer what he needs, instead of what he thinks he needs, if you can present the facts to him so he can grasp them. Don't make the mistake of letting a man buy the wrong fixture because he thinks it's right, for eventually you will be blamed for the transaction. Be careful as to the size of a fixture with reference to the interior or space it is to occupy. Nothing is more crude or inartistic than a massive fixture in a small interior or ceiling area, and a very small delicate fixture in a large room. After you have determined your watts per square foot distribute them so that the effect to the eye will be harmonious and pleasing. Never specify lighting systems with direct a great deal of light upon a ceiling unless the ceiling is a good condition and will stand such exposure.

Avoid gaudy ornamentation on glassware and fixtures. Those festoons, wreaths, and medallions stamped out of cheap metal and soldered to cheap fixtures should be blacklisted. They are the stock in trade of the alley-way electrician and junk man. Obtain some photographs showing examples of good taste in lighting for large and small stores and residences. Show these but don't make the cistake of copying exactly--inject some originality into each particular case, and tell your prospect why he should be determined to have something different.

Remember that the efficiency of the Mazda lamp is so great that energy cost need not restrict you from planning and carrying out any lighting scheme which may occur to you, providing same is based upon the recognized principles of efficient direct indirect, or semi-indirect illumination. Don't expect to use the lamp inefficiently and obtain an artistic effect, tthat is where the principles of illuminating engineering must be carefully observed. When inexpensive bowls are used, avoid "brassy" finishes (even brushed brass is becoming too common,) and other finishes can be obtained even in the cheapest kind of fixtures.

Under conditions where blending or toning a fixture's metal work in with the ceiling is not possible you will get the best results from a bronze finish, which is lasting and does not depreciate so quickly from the effects of dirt and general wear and tear. The idea of "matching" a fixture with the radiators and steam piping is a mistaken one from an esthetic viewpoint. Pipes and radiators are never objects of art, and their ugliness should be concealed by painting them (in a dead finish) to blend exactly with their background. Then they are unnoticeable.

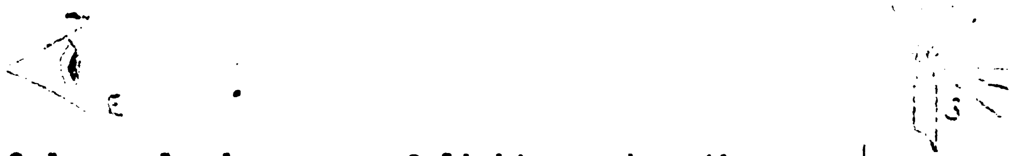
The same treatment applies to wall switch plates and panel boxes, lighting men seldom have the power to make such changes but they ought to know about them, and make suggestions whenever possible. Do not recommend silk shades which are so thin that the filament of the lamp shows throught If you are obliged to recommend such lamps, instruct thepurchaser how to cut a slit in the inside lining and introduce therin a filler of thin white paper (between the inner and outer lining) which will eliminate this defect.

Fundamental Concepts *

A mastery of the principles of illumination can ge gained only by studying the subject from the ground up. In this, as in other scientific subjects, it is necessary at the outset for us to familiarize ourselves with the various terms used in the art, especially those terms which designate units of measurement, for these terms constitute the foundation work upon which the final structure is to be built. Just as we once had to learn that there is a unit called the yard which is used to measure length and that this unit has been subdivided into three feet and each of these in turn into twelve inches, that the gallon is a unit used to measure quantity and contains 231 cubic inches, so in illumination we have certain fundamental units to study before measurements can be made and before definite relations of cause and effect can be comprehended or expressed. Basic definitions have a very academic and sometimes a very technical sound, although the units themselves, once their definitions have been assimilated, and not merely learned by rote, are comparatively simple. The definitions which appear from time to time in this bulletin need not, therefore, be committed to memory but should be thoroughly digested so that the reader will grasp the distinction between the different units and obtain a working knowledge of what each stands for and the quantity it represents. The school-

* N. L. Wks of G. E.

boy may be able to define an acre very accurately, but a farmer may not even know how many square feet there are in an acre and still have a better conception of the extent of an acre; the one point they both must first appreciate is that the acre is a unit of area rather than oflength or volume. Very few electricians or electrical engineers could off-hand give a basic definition of the ampere, although they might all know that it is a measure of the rate of flow of electric current and have a practical conception of the magnitude of the unit. In illumination it is of more practical value to have a conception of the quantity of light represented by one lumen--to



Only a slender cone of light reaches the eye.

know that, for example, 75 of these units represent the quantity of light given off by a 10-watt lamp--than it is to be able to tell precisely what a lumen is. If the unit of length which we call amile were arbitrarily made shorter, the distance between New York and Chicago would still be the same, or if the day were divided into ten equal parts instead of 24 hours the planets would not change their speed of travel or rate of rotation. Obviously, it is of advantage to standardize certain units so that relations of magnitude can be expressed and understood with precision, although the value we arbitrarily assign as a standard is of little importance except from this standpoint.

Units of Measure

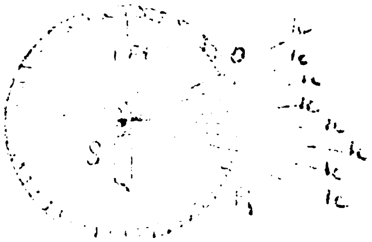
The Candle

A generation or two ago when new light sources began to supersede the candle, it was most natural that the illuminating power of these new sources should be expressed in terms of the candle familiar to all. It is probable that the very first comparisons of two light sources were made by setting up the two lamps in the line of vision and gauging them by means of the eye, the most natural direction in which to look at the sources being the horizontal. The eye is capable of measuring only a very slender cone of light at one time; in fact, if the eye is an appreciable distance from the source, the cone of light coming from a light assumes a straight line. While there are an infinite number of directions from which the eye might look at the source, the light-giving power in a horizontal direction was made the basis of comparisons, and the strength of the light in this direction from a candle made according to certain definite specifications, was arbitrarily chosen as the unit of intensity and called a candle. The newer illuminants appearing on the scene were rated according to their strength in this same direction and were stated to give so many candles, so that when we say a lamp gives 10 candles we really mean that its intensity or strength in a horizontal direction is equal to that of a group of ten standard candles. This rating of a lamp is made by means of an instrument called a photometer, a description of which will follow later. One essential point to remember in this connection is that the candle-power of a lamp represents the intensity in one direction only. In practice it has been customary for years to rotate the lamp about a vertical axis while the candle-power was being determined and the result was known as the mean or average horizontal candle-power, but even this determination gives an average value of the intensity in the horizontal directions only. It should be stated, however, that in compar-

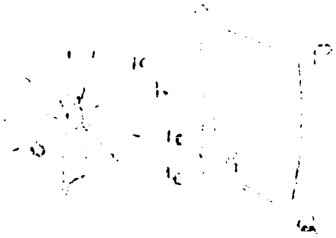
The Candle-Power in the Direction of the Photometer is Not Changed by Partially Surrounding the light Source With a Non-Reflecting Surface.

ing lamps on the basis of their horizontal candle-power, the light in directions other than the horizontal was not really ignored, for it was taken into consideration that most sources of light then in use gave off their light in about the same proportions in the different directions and that for this reason the candle-power in a single direction furnished a criterion sufficiently accurate for the needs of the time.

To carry our conception of candle-power a little further, let us assume the conditons existing as the diagram above. In Case A we have on the left a standard candle and on the right a photometer pointed toward the candle. From what has already been stated, it isobvious that when the photometer is balanced it will indicate an intensity of 1 candle. In Case B we have surrounded the candle with a sphere having a moderately large opening. The inside of the sphere, we will say, has been painted a dead black so that none of the rays striking it are reflected but are absorbed and cease to be light--in other words, are thrown away as far as our experiment is condemned. In this case the photometer will still indicate an intensity of one candle in spite of the fact that a great deal of light has been thrown away. In Case C, we have used a sphere with a much smaller opening and are therefore wasting still more of the light, but even in this case our photometer will indicate an intensity of 1 candle. In fact, our reading will be 1 candle regardless of the size of the opening, that is, regardless of the quantity of light we allow to be emitted, provided the direct rays from the candle to the photometer are not obstructed. The proverbial candle hidden under a bushel will still give an intensity of 1 candle if there is a small hole in the bushel for a beam to escape, although as far as its illuminating value is concerned, it is still "hidden under a bushel". This leads us to the important conclusion that the candle-power of source gives noindication of the total quantity of light emitted by that source. Candle-power, we may say, is



A



B

A. Opening OR has Area of 1 square foot and emits 1 Lumen

B. one Lumen falls on Surface OPQR

analogous to a measurement of the depth of a pool of water at a certain point on its surface--a measurement which is useful for certain purposes but in itself gives no indication of the quantity of water in the pool.

The first fundamental concept we have to deal with in illumination, then, is candle-power, which is the measure of strength of a source to produce illumination in a given direction, and thepower in a horizontal direction of a candle made according to certain specifications and burning under certain conditions has been arbitrarily chosen as the unit for measuring this strength.

The mean spherical candle-power os a lamp is simply the average of all the candle-powers in all directions about that lamp. A source giving one candle in every direction would have a mean spherical candle-power of 1, or if a source gave off various candle-powers in different directions but if the average of all these candle powers were 1, this source would have a mean spherical candle-power of 1. We must remember, however, that the infinite number of directions in which a source ordinarily emits light do not all lie in the same plane, but extend into space on all sides about the source, like the pricks of a chestnut burr.

The Lumen

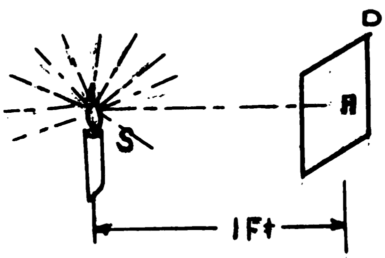
We have seen from Fig. 2 that candle-power along gives no indication of quantity of light. It is necessary, therefore, for us to develop a unit whereby we can measure the quantity of total flux of light emitted by a source. For this purpose let us assume a source giving one candle in every direction, and that this source is placed at the center of a shere painted black on the inside and having a radius of, say, 1 foot, as shown in Sketch A, Fig. 3. OR represents an opening in the sphere through which some of the light may escape. The quantity of light allowed to escape may be varied by varying the size of the opening, with the candle-power of the source and the radius of the sphere remaining fixed; if we decide on some definite size of opening at OR we shall have a definite quantity of light which we can use as our unit for measuring quantity. The simplest area or unit to assume for OR is 1 square foot and if we do make this opening of an area of 1 square foot, the amount of light that escapes is considered to be the unit of quantity, and called a lumen. Thus we have established a permanent unit for the measurement of quantity of light; the mathematical relations used to fix it serve only the same purpose as two scratches on a platinum-iridium bar in the International Bureau of Weights and Measures, the distance between which at a definite temperature is called a meter.

If the area of OR is made 1/4 square foot, the light escaping will amount to 1/4 lumen; if the area of OR is doubled, the light escaping will be 2 lumen. On the other hand, if we have a uniform source of 2 candles instead of 1, 2 lumens will be emitted through an opening of 1 square foot in this particular sphere. We know by arithmetic that the total surface of the sphere having a radius of 1 foot is 12.57 square feet. In other words, removing the sphere entirely, we would have the equivalent of 12.57 openings the size of OR; t that is, if the candle gives 1 candle in every direction, with the sphere removed it would give 12.57 lumens. This means that if we know the mean spherical candle-power of a lamp by multiplying this value by 12.57 we obtain the number of lumens emitted by that lamp. A value of 12 1/2 is sufficiently accurate for most practical purposes and is somewhat more convenient for calculation inasmuch as it is necessary only to divide the mean spherical candle-power by I, with proper regard to the decimal point, to arrive at the lumen rating. A lumen may also be defined as being equivalent to the quantity of light intercepted by a surface of 1 square foot every point of which is at a distance of 1 foot from a source of 1 candle.

Whiâå the foregoing definitions establish definitely the quantity of light that we use as our basic unit, it must be remembered that a lumen, in order to be a lumen, need not necessarily conform with these specifications if the quantity of light represented is equivalent to that prescribed by the definition. A bushel might be defined as the quantity of any commodity contained in a cylindrical measure having a diameter of 18 1/2 inches and a height of 8 inches; however, a bushel of potatoes spread out in the field is just as much a bushel as though the shape of the pile conformed in every respect to the dimensions just mentioned.

The Foot Candle.

Light is a cause and illumination the effect or result. Both the lumen and the candle are used to measure the cause, these units applying to the light source itself and not to the point where the light is utilized. To measure the illumination on a newspaper, desk or other working plane, we empliy a unit called ahe foot-camdle. A foot-candle represents an intensity of illumination equal to that produced at a point on a plane which is 1 foot distant from a source of one candle and which is perpendicular to the light rays at that point. In Fig. 14 if the source S gives an intensity of 1 candle along the line SA and if A is 1 foot distant from the source, the intensity of illumination on the plane CD at the point A is 1 foot-candle. The intensity of illumination, measured in foot-candles, is the unit of measurement most intimately associated with our everyday use of light, and a measurement which the eye either consciously or unconsciously is making whenever the faculty of vision is being employed, for the number of foot-candles we have on the



working plane, other things being equal, determines directly whether or not there is sufficient light. A working idea of a foot-candle of illumination can be obtained by considering the intensity on a newspaper being read by the light of a candle, the paper being held approximately one foot away from the candle. The foot-candle is a unit applying to a point on a surface; by averaging the foot-candles at a number of points on a plane, we get the average intensity of illumination on that plane.

Care should be taken to avoid confusing the intensity of illumination on a surface as indicated by the foot-candles with the appearance as regards brightness of the surface. A grey surface lighted to an intensity of one foot-candle will not appear so bright as a white one, for a greater proportion of the light falling upon the plane is absorbed and lost. The brightness of an object depends upon both the intensity of illumination on it and the percentage of light that it reflects.

Having defined the foot-candle as a unit of intensity of illumination, we are naturally interested in seeing how the illumination, varies as the candle-power of the source varies, and also as the distance of the plane from the source varies. It is obvious that if in Fig. 4 instead of an intensity of 1 candle along the line SA we have an intensity of 2 candles, the illumination at A would be twice as great, and that if we have an intensity of 5 candles the illumination at A will be five times as great. Now, if we consider a source of 1 candle as shown in Fig. 6, we know that the intensity of illumination on A which is 1 foot distant is 1 foot-candle. If, however, we remove the plane A and allow the same beam of light that formerly was intercepted at A to pass on to the plane B, 2 feet away, we find as shown in the diagram that

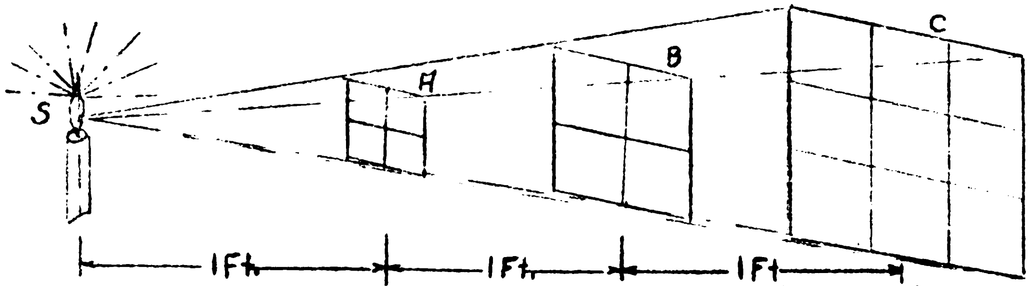


Fig. 6--The Illumination on a Surface Varies Inversely as the Square of the Distance from the Source to the Surface.

this same beam of light would have to cover four times the area of A; and, inasmuch as we cannot get something for nothing, we would find that the average intensity on B, 2 feet away, would be one-fourth as high as that on A, 1 foot away, or one-fourth of a foot-candle.. In the same way, if B also is removed and the same beam allowed to fall upon plane C, 3 feet away from the source, it will be spread over an area nine times as great as A, and so on; at a distance of 5 feet we would have only one-twenty-fifth of a foot-candle. From this we deduce that the intensity of illumination falls off not in proportion to the distance, but in proportion to the square of the distance. This relation is commonly known as the inverse square Law.

Important Relation Between Foot-Candle and Lumen.

If we refer back to Fig. 3B we see that the surface OPQR is illuminated every point to an intensity of 1 foot-candle. We also know by definition that the quantity of light falling on the plane OPQR is 1 lumen. This gives us the important law that if 1 lumen is so utilized that all of the light is spread over a surface of 1 square foot, that surface will be lighted to an average intensity of 1 foot-candle. This relation greatly simplifies the designing of a lighting installation, for once the number of square feet to be lighted and the intensity of illumination which it is desired to provide are known, it is a simple matter to find how many lumens must fall on the working plane. If, for example, it is desired to illuminate a surface of 100 square feet to an average intensity of 5 foot-candles, 500 lumens must be utilized. The designing of a lighting installation is taken up more in detail in succeeding pages.

Foot-Candles Meter.

An instrument called the foot-candle meter has recently been designed to measure foot-candle intensities quickly and with a fair degree of accuracy. It is very simple in operation, so light that it can be easily carried about, and so small that readings can be taken in very restricted spaces. The instrument is shown in Fig. 7. In operation, it is placed upon or adjacent to the surface on which a measurement of the foot-candle intensity is desired. A lamp within the box illuminates the under side of the screen to a much higher intensity at one end than at the other. The illumination which it is desired to measure, is, of course, practically uniform over the entire scale. Closely spaced translucent dots, which serve the same purpose as the grease spot in the simple bar photometer, line the scale from end to end. If the illumination on the scale from the outside falls within the measuring limits of the meter (0.05--25 foot-candles) the spots will appear brighter at one end of the scale than at the other, and at the point where the spots are neither brighter nor darker than the white paper scale the illuminations from within and from without are equal. The scale is accurately calibrated with the lamp within the box burning at a certain definite voltage. A voltmeter and rheostat permit the operator to adjust the lamp voltage to that at which the instrument was originally calibrated. The endrgy is supplied from small dry cells.

This instrument is proving very serviceable for "checking up" installations to insure, for example, that the illumination is ample when the lighting equipment is in first-class shape and to see that it is not allowed to fall below a desirable vaue due to improper care and attention being given to the lighting system.

THE STORY OF ARTIFICIAL ILLUMINATION

CHAPTER I

Early Artificial Light

The first source of artificial light was the burning log. The natural development was the pine wood torch and the brazier to hold a small fire for the purpose of lighting.

Next came the rope link saturated with animal or vegetable fat, pitch or bitumen and the vessel that held it was the first lamp. Shortly after this, hard fats were used and formed into candles.

The early lamps were in the form of covered basins or jars with a hole for filling and one or more holes for the wick. These lamps were made of both pottery and metal by Greeks and Romans and many were of very beautiful design.

More attention seems to have been paid in the past to the artistic features of the lamp than to the lamp itself, for it was a long time before anything was developed better than the lamp with a loose wick that burned with a flickering and smoky light.

From candles and lamps of this type using animal and vegetable fats and natural oils, no further progress in the art of illumination was made until the introduction of the Argand lamp, patented by M. Argand in 1787. This lamp had a tubular wick fed upwards between two metal tubes, admitting air to both the exterior and interior of the flame.

T

The most successful ȁil lamps of the present day are constructed on the Argand principle.

No marked improvements in the substances burned in these lamps were made until the "burning fluids" were brought out in the middle of the nȁneteenth century. These fluids gave off a steady and brilliant flame, but were dangerous to use. They soon went out of use after the discovery of petroleum.

The use of petroleum products as illuminants began about 1860 when petroleum fields in both America and Russia began to be developed.

Shortly after the introduction of the Argand burner, an entirely new illuminant, gas, was demonstrated. In the year 1792, Mr. William Murdock of Cornwall, England, exhibited to a few friends a sheep's gladder, apparently filled with air. He pricked it wiȁh a knife and applied a lighted candle to the hole and a bluish yellow flame shot out---the first gas light. Mr. Murdock later piped the gas from his colliery and used it to illuminate his house.

When the Amiens Treaty of Peace was signed by England and France in 1802, Mr. Murdock erected an enormous arch of gas pipe surmounting the word "Peace" near his colliery in Birmingham. The pipes were pierced with numerous little openings. Gas was turned into the pipes and the arch lighted. The entire populationof Birmingham turned out to see the wonderful sight, and the result was a great demand for the new illuminant.

In America illuminating gas was first used by Mr. David Melville of Newport, Rhode Island, In the year 1806.

Gas was first burned in an open flame and this method is still in use to a certain extent. The common practice now, however, is to use an incandescent mantle either singly, or in a group called an arc.

Natural Gas

Natural gas, where available, is used extensively as an illuminant in preference to the artificial gas on account of its low cost. It has long been used in western China and elsewhere. It was first utilized in New York in 1821, but did not become commercially important till 1847, when found in great abundance in western Pennsylvania and adjoining states.

Acetylene

A recent addition to the list of flame illuminants is acetylene, known for many years, but not until recently produced on a commercial basis. It is made from calcium carbide (prepared by subjecting a mixture of powdered lime and coke to the heat of an electric furnace) and by treating it with water.

It is used chiefly for lighting country residences and in isolated places where the community is not supplied with illuminating gas or electricity. Its cost of production and distribution does not render it commercially attractive under ordinary conditions.

The Electric Arc Lamp

Illumination by means of an electric current was first accomplished through the medium of an electri c arc.

Its principle of operation is based on the fact that when an electric curcuit is broken at any point, the current doesnot immediately cease to flow but jumps across the intervening gap (if the distance is not too great) and continues the circuit with the production of intense heat and bright light.

Great brilliancy is thus obtained by the passage of current through two carbon rods - the tips of which grow white hot when separated.

The light derives its name from the path taken by the current flowing between the carbons which is in the form of an arch or arc of a circle.

The first arc light was exhibited in 1802 by Sir Humphrey Davy at the Royal Institute, London. The current was supplied by a small battery. In 1810 it was again exhibited by Davy and brought to general attention through the use of a huge battery of 2000 cells.

These experiments, however, bore no immediate fruit, and a period of almost forty years elapsed before improvements in carbons and mechanism renewed interest in the arc lamp.

In 1844 Faucault, following Dayy's principle, but using hard carbons and improved mechanism and batteries, succeeded in producing a continuous and brilliant light which was publicly exhibited in Paris. The use of the arc lamp on a commercial scâle, however, was not possible on account of the prohibitive expense and inconvenience of the battery, which at that time was the only source of currmnt supply.

The Alliance magneto machine originated by Nollet in 1849 was improved by Holmes, Masson and others, and in 1863 was used for lighting the light houses of the French coast by electricity. This was probably the first important practical use of electric light.

The lighting of city streets was not undertaken until 1 1878, at which date the electric generator had been developed. In that year, the Avenue de L'Opera andother portions of Paris were ligh'ed by means of the so-cal led Jablochkoff candle, an improved form of arc lamp, named after its inventor a Russian military officer. This system required a new candle to be switched on every two hours and this limitation prevented it from becoming a pesmanent success commercially.

The Brush system intented by Charles F. Brush of Cleveland, Ohio, was brought out in 1878 and proved a commercial success. Another successful system was later brought out by Thompson and Houston, and still another by Weston.

A system of lighting by means of alternating current transformers was intented by Gaulard and Gibbs, in 1882 and later developed by other inventors. It was successfully intorduced into the United States in 1887 through the efforts of Westinghouse, Stanley and others. On account of the saving in the amount of copper wire required for carrying the current, it was rapidly and widely adopted.

The Enclosed Arc Lamp.

The enclosed arc was introduced by L. B. Marks in 1893. The principle of this lamp is very simple. The enclosed feature merely consists of fitting around the carbons a small globe of refractory glass provided with a metallic cap thru which the upper carbon is fed. The result is that the oxygen is quickly consumed and rapid oxidation ceases since the heated gas within checks the access of fresh air to the carbons. Consequently the carbons burn away approximately at the rate of one-eight inch per hour. The lamp, therefore, requires trimming only about once in a hundred hours' burning, whereas the open arc requires trimming about once every twelve hours' burning.

The successful working of this lamp requires an arc about twice as long as required by the open type of lamp. this increased length of arc gives a better distribution of light than is obtained from the open arc, but the temperature is very much lower and the intrinsic efficiency is accordingly lower.

The Flame Arc Lamp.

Another type of are lamp that has come into use recently is the flaming arc, which employs electrodes impregnated with metallic salts which vaporize and give intense light. The efficiency of the light does not depend upon absolute temperature, but upon the character of the vapor. As a result, it is possible to obtain a very high efficiency. Various substances are used for mineralizing the electrodes, the principal one being calcium fluoride. Various colors are obtained by the introduction of different salts.

The Luminous Arc Lamp.

Still another lamp now in use is the luminous arc, charged with compounds of iron, titanium, chromium, etc. This lamp gives a white light of high efficiency, but requires very active ventilation. These lamps are also known as magnatite of metallic flame arcs, so-called from the source of the light and its nature.

They cannot be used on alternating current and if it is the only supply a vailable, it must be rectified before entering the lamp.

A similar lamp designed for alternating current known as the titanium-carbide arc has been brought out, but on account of the difficulties encountered in the use of this metal, its develâpment has been retarded.

The Cooper Hewitt Lamp.

The Cooper Hewitt lamp is radically different from the ordinary type of arc lamp in that the arc stream is produced in a sealed tube and the light given out from a luminous gas. It was invented by Peter Cooper Hewitt of New York in 1901.

This lamp consists of a glass tube one inch in diameter and from 20 to 50 inches long, having one end enlarged into a bulb for holding mercury and the iron cap serve as electrodes, or carriers of electric current, which is supplied to them through wires hermetically sealed into the glass. The air is exhausted from the tube. When the electric current is caused to pass from one electrode to the other, it vaproizes a small quantity of mercury which fills the tube and is rendered luminous by the passage of current.

The light produced by the glowing vapor differs radically from that produced by other means. It contains practically no red rays, most of the light being yellow with a fair addition of green and blue, thus giving a peculiar bluish-gr green color.

Moore Tubes

The Moore tube was invented by D. McFarlan Moore in 1894. This lamp consists of a long tube filled with some permanent rarefied gas made incandescent by the passage of electric current through it. The tube is generally 1 1/2 to 1 3/4 inches in diameter and many feet long---sometimes several hundred feet. The tube forms a closed loop running about the area to be illuminated. It is fed by an individual high tension transformer coupled directly to the tube so that no high tansion wire is exposed.

Ordinary air mr any convenient gas may be used. Ordinary air gives a pinkish light. Nitrogen, which gives a high efficiency and is more commonly used, gives a more yellowish tint. Carbon dioxide gives a pretty close approximation to white. The efficiency varies with the gas. Nitrogen shows an efficiency of 2.4 watts per mean hemispherical candle power, while carbon dioxide used to some extent in short tubes, has an efficiency of from 6 to 8 watts per candle.

The Nernst Lamp.

The Nernst lamp, invented by Dr. Walter Nernst, a German scientist, in 1899, was introduced into America by Mr. Westinghouse and was the first high efficiency incandescent lamp to appear.

It differs from other incandescent lamps in that the light-giving body is a non-conductor when cold, and is operated in the open air instead of in a vacuum.

Its fundamental prlcniple is the use of a glower made of rare earths, artificially heated at the start to render it a conductor and which then continues to glow under the passage of current.

The light is of pleasing color and the distribution is good. Before the introduction of the other high efficiency lamps, Nernst lamps were extensively used but the preference to day is for the Mazda incandescent lamp--on account of its simplicity of construction, economy and satisfactory performance.

The Electric Incandescent Lamp.

The first strictly incandescent lamp was invented in 1841 by Frederick de Molyens of Cheltenham, England, who made use of platinum wire for the filament. In 1849 Petrie employed iridium for the same purpose, also alloys of iridium and platinum and iridium and carbon.

The principle of the lamp is the use of a filament of high electrical resistance which can be brought to incandescence by the passage of electric current. The development of this lamp parallels that of the arc lamp and many well-known inventors worked at the solution of the problems which it presented, notably Edison, Swan, Sawyer, Maxim, Man and Weston.

Among the first to make incandescent lighting a practical success were Thomas A. Edison and Sawyer and Man, the latter eventually becoming associated with George Westinghouse.

The first patent for incandescent lamps in the United States of which any records exist was granted to J. W. Starr of Cincinnati in 1845, who used carbon for filament. About the same time Wm. R. Grove published an account of a similar piece of apparatus which was said to have been used in 1840.

For a period of about 20 years no new feature occurred in the development of the incandescent lamp.

At Newport, R. I., in 1875, Moses G. Farmer, of the United States Naval Station, lighted a private residence by means of 42 el ctric lamps in which platinum wires were used for the filament. For limited applications, this style of lamp gave satisfactory results, but for general purposes it was not feasible on account of the excessive cost of platinum wire and the large amount of current required to bring the wire to incandescence.

In June, 1877, the same month that the Jablochkorr candle was publicly exhibited, William Sawyer, of New Hampshire, filed his first application for an "Improvement in electric engineering and lighting apparatus and system." This claim was granted by the United States Patent Office the following August.

In November of the same year, Mr. Sawyer patented his plan of running lines in parallel or branch circuits, his specifications embodying the identical arrangement of lamps, with respect to the generator that is now in universal use.

In 1878, Mr. Albon Man, of Brooklyn, became associated with Mr. Sawyer in electrical work and subsequent patents were issued to the two men as joint inventors. One of the patents describes "a lamp in which a small piece of carbon is heated to incandescence in an atmosphere with w ich it will not combine."

The substitution of carbon for platinum as the filament material was probably the most important step in the entire history of the incandescent lamp.

By the summer of 1878 Sawyer and Man had produced incandescent lamps that would burn for several days. In fact one lamp burned for many weeks and then was broken by accident. The popular press of the time contained many accounts of the inventions; the illustrations of the papers showed these lamps used as lighting for interior and as small portable searchlights.

It soon became evident that the art could produce a more durable carbon filament than nature had provided, and further experiments were directed to the production of a filament of this sort.

Edison, after a great deal of experimenting, produced a successful filament of carbonized paper and the first commercial incandescent lamp was introduced by him in 1879.

On Jan. 9, 1880, Sawyer and Man applied for a patent covering the use of a filament of structural carbon to which had been given the form of an arc or horse shoe.

This application led to a protracted interference case between the inventors and a rival claimant. Five years afterwards, many appeals having been taken dicision was given in favor of Sawyer and Man.

The efficiency at which the first commercial carbon lamp operated was 7 watts per candle. The adoption of carbonized bamboo increased this efficiency to 5.8 watts per candle. Further improvements in 1881 increased the efficiency to 4.8 watts per candle.

The introdubtion of the cellulose filament which is still in use increased the efficiency to approximately 3.1 watts per candle.

The Metallized Filament Lamp

The next important step was the development of the metallized filament lamp produced by heating theordinary treated carbon in an electric furnace to a very high temperature. This gave a filament that could be operated at a considerably higher temperature than the ordinary carbon filament and increased the efficiency to 2.5 watts per candle.

The Osmium Lamp

Shortly before the metallized filament lamp was brought out, osmium as a filament material was introduced and gave an efficiency of 1.5 watts per candle. Osmium, however, is such a rare metal that the earth's entire supply would not be sufficient to fill the requirements of incandescent lamps for more than a few weeks. No attempt was therefore made to introduce this lamp on a commercial scale.

The Tantalum Lamp

The tantalum lamp was developed and placed on the market in 1906. It produced an efficiency of 2 watts per candle, but soon gave way to the more efficient Mazda lamp.

The Mazda Lamp

The discovery that tungsten could be used for incandescent lamp filaments was made in 1906. The first tungsten lamp manufactured in America was made in 1907. The filaments in the first tungsten lamp were composed of two or three short pieces of wire. The Westinghouse Lamp Co., in 1910, manufactured the first lamp with a contunuous tungsten filament which increased the strength of the lamp wonderfully. This pioneer lamp in continuous filament construction was known as the Westinghouse Wire Type.

MAZDA is a trademark affixed to the product of those American lamp manufacturers who receive benefit of the research work and selective skill of that corps of scientists which specialize in the field of incandescent lamp illumination under the name of Mazda Service.

The Mazda C(gas-filled) incandescent lamp has greatly broadened the field of incandescent lighting. In every kind of lighting service this lamp, the latest development in the art of lamp manufacture, is successfully replacing other less efficient types of illuminants.

In view of the rapid progress which has been made and because the Mazda C lamp is a new development, it is not surprizing that but few people are familiar with its history and its characteristics.

The facts set forth relative to manufacture and application are based on methods in use at this writing, such methods are liable to change at any time since improvements in lamp manufacture are frequent occurrences.

History and Development.

The origin and history of incandescent lamps containing inert gases of various forms is difficult to trace, but it is known that as early as 1880 incandescent lamps containing inert gases were manufactured. These lamps, however, did not prove successful and were abandoned in favor of the vacuum lamp.

The research and developmental work in America, which immediately preceded the present successful Mazda C lamp, must be accredited to Dr. Irving Langmuir, of Schenectady, N. Y. Dr. Langmuir's original investigation was calculated to discover the effect of residual gases in ordinary vacuum tungsten lamps. The results of this work indicated that certain gases were extremely harmful in their effects on the operation of the lamp while other gases apparently had no decided effect, but with certain filament construction might be made beneficial.

For a period of at least a year, experimental work was conducted to determine the value of the use of inert gas in incandescent lamps and to explain the physical theory of its functions.

Tungsten filament lamps deteriorate during the hours of burning, this deterioration being caused by the evaporation or disintegration of the filament itself. As the filament disintegrates, particles of it are deposited on the bulb, which results in the bulb becoming blackened. At the same time th through this evaporation the diameter of the filament becomes smaller and eventually grows so thin that it burns out. The life of tungsten filament lamps, therefore, is shortened th through two causes, both of which originate from the same source; first, the loss of light, due to its absorption by the black coating on the bulb, and second, by the reduction of the filament due to the evaporation of the metal.

Dr. Langmuir's research work proved that by surrounding the filament with an inert gas at the proper pressure, the rate of filament evaporation could be decreased. It is obvious that if a metallic filament can be prevented from evaporating as rapidly, still operating the lamp at the same temperature as the vacuum lamp, the result will be a superior lamp, at least as far as its life is concerned. On the other hand, by raising the operating temperature of the filament so that the rate of evaporation in the inert gas is approximately the same as in the vacuum, as much more efficient lamp from the standpoint of ratio of light to current consumed can be produced with a life equal to that of the vacuum lamp.

There were incident problems involved in this theory, one of the most important being the loss of heat by convection, which is present only in small amounts when the vacuum lamps are considered. It was found that by using gases with a low heat conductivity value the losses by convection were low enough to be more than offset by the increased operating efficiency, resulting from burning the filament at higher temperature. The mechanical construction of the lamp was designed to emphasize those features which would aid in reducing the loss of heat by convection. It was demonstrated to be of advantage to closely coil the filament and to make the bulbs as small as possible. The idea in these features was to keep down to the minimum the area of the radiating surface of both filament and bulb.

Manufacture

In the early days of the commercial manufacture of Mazda C lamps onlylamps of large current capacity were utilized. The loss of heat with small diameter filaments promised to be so great as to somewhat offset the advantages of surrounding these with inert gases. It is possible, however, to manufacture lamps in smaller sized, and lamps with a filament consuming approximately 1 ampere or 100 watts at 100 volts are being manufactured.

Lamps using current in excess of 1 ampere are most efficient, the efficiency increasing with the amount of current consumed. Lamps consuming 15 amperes or more operate at efficiencies as high as 1/2 watt per mean horizontal candle.

The first Mazda C lamps for commercial circuits were of street series type closely followed by the 750 and 1,000 watt sizes for the 105 to 125 volt range.

Rapid progress in the perfection of mechanical design and in the search and utilization of gases of lower heat conductivity, such as nitrogen or argon, have made possible the production of lamps as small as 100 watts for the 105 to 125 volt range and 200 watts for the 200 to 250 volt range. The commercial manufacture of lamps smaller than 100 watts, with an efficiency equal to or higher than similar sizes of vacuum lamps, is a question for the future.

During the developmental stages of the Mazda C lamp many experiments were made with bulbs of various shapes and sizes until finally the pear-shaped bulb with a long neck closed in with a mica disc was adopted as being the most satisfactory.

In this bulb the inert gases, becoming heated, flow upward into the neck (the lamp being operated in its proper position tip downward) and come in contact with the mica disc and cooler sides of the bulb, which starts the downward flow again, thus making a complete circulating movement. The heated gases on the way upward carry with them the evaporated particles of filament and deposit them on the cooler surface of the neck of the bulb, in this way confiming the blackened area to the upper part of the lamp, where it does not interfere with the light source. The mica disc which partially closes up the neck is designed to keep as much heat as possible away from the upper part of the glass and the brass base. It does not entirely enclose the neck, and interferes only slightly with the circulation of the gases.

The essential processes in the manufacture of Mazda C lamps are similar to those in the making of older forms of Mazda lamps. The points of difference are the coiled filament, which is supported somewhat differently and the presence of the inert gas.

The introduction of inert gas in the bulb is accomplished only after the lamp has been very carefully evacuated. In fact all of the regular processes in the exhaustion of the vacuum lamps is carried through to completion before the inert gas is introduced.

Application

The advent of the Madda C lamp brought about a wonderful extension in the field of incandescent lighting. It completed the line of incandescent lamps for every conceivable kind of lighting service by extending the range of sizes to the large units which are successfully replacing older forms of carbon arc lamps for street lighting and for the illumination of large interiors and exteriors.

The Mazda C lamp has four distinct points of advantage. First and perhaps most important is economy and efficiency in operation; second, better color of light; third, a concentrated light cource; and fourth, ruggedness not exceeded by other forms of incandescent lamps.

The efficiencies of the gas-filled lamps range from .45 watts per mean horizontal candle to .3 W.P.M.H.C.P., depending on the size of lamp, the larger sizes being more efficient. When the simplicity and reliability of the incandescent system is considered, it is evident from the standpoint of operating and maintenance cost the Mazda C lamps are the most efficient lighting units available.

The color of light produced by the Mazda C lamp is very much whiter than that radiated by the older vacuum lamp. The whiter color is brought about by the higher operating temperature of the filament, which naturally results in a higher incandescence and more nearly white light.

The Mazda C lamps naturally do not produce the same character of illumination as daylight but with the exception of some of the high-powered ard lamps, which are unsuitable for many classes of installation, they produce a light which more closely approximates daylight than any other illuminant which has yet appeared on the market.

The coiled filament has at least two points of superiority over the more straight type. The light is concentrated in a comparatively small area in the center of the bulb, which is of particular advantage when used in connection with reflectors, since it is possible with properly designed reflectors to control very accurately the redirection of light. The concentrated filament also makes possible the use of lamps of this character for stereopticon service where a light source of small area is absolutely essential.

The other advantage of the coiled filament is in its strength, the filament being tightly wound and being mounted on supports of short lengths.

The multiple lamps in sizes from 100 to 1,000 watts for 105 to 125 and 200 to 1,000 watts for 220 to 250 volts have been adopted for almost every kind of lighting. The larger sizes, 750 to 1,000 watts, are being used for exterior lighting installation on concourse, in railroad yards, in parks, on tennis courts, in front of stores and theaters and for the lighting of very large interiors in railroad stations, shops, industrial plants and big stores. The smaller sizes, 100 to 500 watts, have been used for exterior and interior lighting of all kinds. The 200, 300, 400, and 500 watt lamps are extensively employed in semi-indirect and indirect lighting installations. The 100 watt lamp is especially recommended for the lighting of desplay windows and is used in certain direct lighting installations.

There are several principles in the use of Mazda C lamps which should always be considered.

As manufactured at present this type of lamp should always be burned tip downward. If operated in an inverted position, satisfactory results cannot be obtained unless when the lamps are ordered from the manufacturer it is stated that lamps are to be burned tip upward. Lamps of pmoper design can

be provided be provided on such orders which will satisfactorily operate in the desired position.

Great care must be exercised in the selection if fixtures for Mazda C lamps in order that such fixtures may be of proper design and provide sufficient ventilation for the lamps. The high temperature at which the filament operates, and the small bulb area as compared with the older vacuum lamps, requires that the heat be dissipated, otherwise the lamps will become excessively hot and its life shortened thereby.

It is desirable with the larger sizes of incandescent lamps, whether Mazda C or the older vacuum lamps, to operate them in enclosing globes or reflectors of some form, unless the light units are placed well out of the line of vision. Wherever Mazda C lamps are burned within the line of vision it is essential from the standpoint of good illumination as well as appearance, that they be used with enclosing globes or else bowl frosted, in order that the flare from the lamp be reduced.

In conclusion it may be said that the most important effect of the marketing of the Mazda C lamp has been to greatly widen the field for incandescent lighting, and as further improvements and developments in the manufacture are made, the field will continue to broaden out. Each new lamp means a new application for light, a new channel along which sales and advertising efforts may be directed to augment the use of electricity and lamps.

The outstanding characteristic of this lamp is the pleasing softness of its light. The large volume of light which the small filament emits is diffused to the point where the bulb itself appears luminous, The brightness of the bulb is about 13 candles per square inch over the brighëest square inch of area, whichis, of course, far below that of the filament of a Mazda B lamp. The white Mazda lamp is made in the 50-watt size, and, notwithstanding the low brightness of the bulb, supplies more light than the 50-watt Mazda B lamp.

It has been pointed out that glare (which, however defined, is ultimately light which hurts the eye) is to a considerable extent a matter of brightness contrast. The familiar illustration of automobile headlights, which glare at night but which are scarcely noticeable during the day, will be recalled. Because of the softness of its light, the white Mazda lamp can be used satisfactorily in locations where any other incandescent lamp unless frosted would be objectionably bright. Frosting the bulb has always proved an effective means of reducing the brightness of small incandescent lamps, but the practice has not been widely followed, largely because the frosted bulb collects dust and dirt mo e quickly than a clear bulb and is more difficult to clean. The bulb of the white Mazda lamp is smooth, and is as readily cleaned as a clear-glas bulb.

There will,perhaps, be a tendency to use the white Mazda lamp without reflecting equipment because of the softness of its light. However, for most locations the bulb is still too bright to be used alone; moreover, it must be remembered that reducing glare is only one of the functions of a reflector. From the standpoint of effective distribution of the light generated, it is just as important that a good reflector be used with a white Mazda lamp as with a Mazda C lamp.

White Mazda
50-Watt Lamp
(Approx. 1/2 size)

Broadly , the field for the white Mazda lamp lies in the replacement of the smaller sizes of Mazda B lamps in existing reflector equipment. The effect produced by using white Mazda lamps in semi-indirect fixtures is particularly pleasing, for distinct shadows of the bowl edge and the bowl suspension, and all striations on the ceiling, are eliminated because of the large area from which the light comes. For the same reason white Mazda lamps are also particularly desirable for portable lamps, where their use will eliminate the formation of grotesque, and frequently annowing, shadows upon the walls or upon the pages of a book; fringe shadows, which are often very disagreeable, are eliminated.

In Table 1 are given the results of tests made to determine the effect of the diffusing bulb upon the output of lighting units. It will be noted that there is little dif-

ference in the absorption of any of the units tested when equipped respectively with Mazda B and with white Mazda lamps.

Table No. 1 -- Data on Light Output

Type of Unit	Output in percent of Bare Lamp Output	
	Mazda B.	White Mazda
Glass Bowl, 6-inch Diameter...	85.4	87.6
Glass Bowl, 7-inch Diameter-,,	84.8	86.1
Enclosing Unit................	77.5	76.4
Enameled-Steel Bowl...........	60.5	61.3

CHAPTER II

COLOR

The Langhage of Color*

From a study of human organism it has been found that there are certain physiólogical effects of a few fundamental colors. Color is a medium capable of creating pleasure and this should be sufficient stimulus to bhe lighting specialist to inspire him to atbempt to use its power in lighting.

A great difficulty is encountered in the use of color in lighting, which is equally true to many other acitivities: namely in recognizing the boundry between fact and fancy or between the psycho-physiologicaleffects upon manking as a whole and that which we call taste.

It would be impossible in this paper to completely treat the subject of color, but a few of the most conspicuous colors will be tseated. In many applications of colored light the decorative scheme must be controlled and even called upon to aid in carrying out the desired effect.

RED, is usually considered to be stimulating or exciting and this has been proven by experiment. The nerves are in a certain excited state, and it has been shown that the amount of certain kinds of work which can be done in a limited amount of time is augmented under red light. Its effect is similar to stimulants in this respect and its continued use would be as readily condemmed. In the lighter tints it becomes mildly stimulating and in the rose which is a tint of a reddish-purple, is delightfully stimulating in a mild manner. For this reason light of a barely perceptible rose tint-more felt than seen- is appropriate for living rooms and in ballrooms and restaurants, etc. Light tints of red and even red combined with white have been used symbolically to suggest blooming youth, health and happiness.

YELLOW, in its warmer hues and orange poscess the same stimulating effect as red altho in a milder degree. It is interesting in this respect to note that shades and tints of yellow are used predominantly in decorating interiors. Perhaps this has arisen from the phychological effect of this color which imparts warmth to an interior and logically is one of the aims of housing to provide a cheerful, inviting, and protective environment. Of further interest in lighting is the warm yellowish tint of nearly all the early illuminants which thru thepersistance of habit have added their influence in creating a desire for illuminants of a warm color in interiors. These may be obtained by the use of tinted lamos, screens and glassware in rooms whose walls and ceilings are of yellowish hue. The finer color sensibility manifests itself in an aversion toward amber - a greenish-yellow which is sometimes considered by the uninitiated to be a substitute for warm yellow.

Yellow is a luminous color and is often associated with sunlight altho strictly the latter is not yellow except during sunrise and sunset. However, it appears yellowish by contrast with blue skylight. Being warm, luminous and associated with the sun, yellow has been symbolic of fire.

The attribute of abundance has been bestowed on yellow doubtless thru the association with nature a bountiful harvest because this is a common color of ripened crops.

This color has been widely used by poets to symbolize jealousy but usually a greenish-yellow described or implied. It has also been used to symbolize inconstancy and deceit tho in this office an impure or soiled yellow is usually implied. For example, the garb of Judas is often described as yellow and the custom has been in vogue the last centuries of using yellow on the doors of the abodes of fellons.

It has been quite generally used to symbolize sickness; hence it is the flag of quarantine and has been used to indicate field hospitals in war.

GREEN, is most characteristically described as being a natural color. Perhaps its abundance in nature has gradually subdued any striking influence it might have had on the human organism and doubtless continued adaptation to this color in natural environments had rendered it neutral. There is no doubt about this characteristic and hence shades of green are proper colors for certain interiors. The applications of green light however, appear to be extremely limited altho scientific investigation may indicate certain desirable psycho-physiological effects which may be utilized in the future. It has a place in lighting as a vital or contrasting spark in certain in certain attempts whichmay be made to "paint" with light. It is used to symbolize perpetuity as "evergreen memory" and the practice of placing green foliage on the graves of the dead is one of fine sentiment. Doubtless due to the fact that green is the conspicuous color of springtime, this color is used to symbolize youth, immature judgment, vigor, freshness and hope.

BLUE, is a cold color, the degree depending upon the exact hue and purity. When it inclines toward violet it looses this attribute and becomes restful. Blue is of low lumánosity and being cold is somewhat depressing when used with lighting. However, it may be used to advantage sometimes when it inclines in hue towards green. For example a theater in summer appears to be much more comforáable when lighted by blue or glue-green light. $_T$t is thus seen that an attribute of color which may seem unpopular can be used to advantage in a proper place. Many such applications of colored light fall within the lighting specialists province.

Certain tints of blu appear to possess the attribute of serenity, at least this has been bestowed on them. This may arise thru the restfulness of these colors but it is interesting to note that the finer sensibilities have recognized the serenity of the blue sky and of Natures solitudes. In the latter case the illumination is often chiefly due to the blue skylight. Owing to the dominance of the blue sky in natural scenes this color has been looked on as possessing a harmonizing because in Nature it is a color which is nearly always present in any scene.

Perhaps owing to the fact that it is the color of the heavens - the abode of the gods - mythology has also bestowed on it the attribu'e of intelligence. Many interesting speculations arise in the study of the language and symbolism of the color. For example blue eyes are very common and the eyes are very closely associated with the intellect and the personality. From these reasons the attribute of intelligence may have partly arisen or Minerva may have been considered the "blue eyed" progeny of Jove for similar reasons.

As blue inclines toward violet or a deep shade it has been characterized as restful, quiet, dejected and even dismal. It is easy to account for these attributes partially thru our experience with Nature.

PURPLE, has scanty application in lighting tho it appears to be characterized by certain attributed and symbolic uses. It has been chiefly characterized as being dignified, stately sedate, solemn, and pompous and has long been the garb of royalty. The latter is another example of the influence of usage for doubtless it became the color of royal robes for in the early centuries of civilization it was a rare and costly color. For this reason it became the mark of royalty and wealth. It is sometimes used in mythology and poetry as a color of the blood which is a more correct usage than red for the same purpose.

WHITE, naturally assumed the attributes of chastity, virginity, purity, innocence, fidelity, peace and friendship, and mythology and poetry aboudd with examples of such usage. It also marks weakness perhaps thru association with feminimity and was the mark of untried manhood. Consistently therefore, it is the flag of surrender and truce.

BLACK, quite naturally is quite the opposite of white, being characterized as dismal, deadly, desolate, malignant, threatening, evil, chaotic, and loathsome. It is evident why it is so universally used in mournings and other like ways. It has its place in lighting effects for low intensity of illumination or the absence of lighting the proper places in an interior is a potent factor in proper lighting.

Many other colors and combinations of colors appear to have symbolic uses or attributes seemingly appropriate. For example gray which lies between white and black partakes of the attributes of both and by this mixture assumes a role lying conspicuously between them.

Much information gathered from studying these color effects may only be applied indirectly but it is valuable to the lighting specialist because it deals with color and therefore light. Lights of all colors have at least decorative value and must be applied in this respect according to the principles of harmony.

There are no laws of harmony which can be stated in a few words because such a statement resolves itself into a statement of a single harmony. However, it may be noted that in dealing with colors there is the principle of harmony of

sequence and that of contrast. According to the former the hues of the colors are closely associated in a spectrum or sequence of approximately the same hue is arranged in respect to tint or shade. According to the principle of harmony of contrast, the colors are contrasting or far apart in hue.

Summary

Red-Warm, exciting, passionate

Orange-warm, exciting, suffocating, glowing,lively.

Yellow - warm, exciting, joyous, gay, merry.

Yellow-green - cheerful.

Green - Neutral, tranquil, peaceful, soothing.

Blue-green - sober, sedate.

Blue - cold grave, tranquil, serene.

Violet - solemn, melancholy, neutral, depressing.

Purple - neutral, solemn, stately, pompous, impressive.

EFFECT OF COLOR OF WALLS AND CEILINGS ON RESULTANT ILLUMINATION

CHAPTER II

General Considerations

No matter how carefully designed a lighting system may be as to type and size of lamps, type and make of reflector, spacing, height, etc., if the surroundings are not adapted to reflecting such light as strikes them, then an ineffícient system may result. The question of proper painting of walls and ceilings is therefore of great importance.

The ceiling and wall surface in a room are secondary sources of light---receiving and reflecting light from the lamps---and merely increasing the reflection coefficient of the ceiling a slight amount may greatly increase the effective illumination.

It is therefore very important to see that the ceilings are as light in color as possible. Pure white is usually to be preferred, although if a tint is artistically demanded it should be of a slight cream order rather than gray or similar tone. Not only is the color of the ceiling important, but the actual finish muct also be considered.A glossy surface reflects images of the lamp filament and glare is introduced, causing eye strain. A flat or matt finish is therefore essential. A thin coating of white paint through which a dark surface may be seen has the same effect as a thin coating of enamel on a reflector. In other words, the light gets through the surface and becomes absorbed unless this surface is thick.

It is safe to say that differences between well painted white ceilings and ordinary light buff or similar colored ceilings give increase of between 20 and 30 per cent in illumination where semi-indirect or similar lighting systems are in use. This is really a conservative figure.

Industrial Plants.

As a result of a campaign of educationon the part of certain paint manufacturers the industries now realize that natural light is greatly aided if the interior surfaces are light in color. Any light striking these parts of the room is reflected in a degree depending upon the color. If dark brown or smoke covered possibly only 5 per cent will be reflected. If pure white the reflection coefficient may be as high as 70 per cent.

Efficiency of utilization of light is highly important in the industrial plant, and pillars, walls and ceilings should be pure white. Even the floor should be kept as light as possible for a portion of the flux which strikes this is reflected to the ceiling and then back to the work.

A recent test in a new factory building with white ceiling light wood floor and light colored side walls showed more units of light reaching the working planes than were generated by the lamps themselves. This apparent paradox is explained by a consideration of the multiple reflections whereby the same energy was received on the test plane more than once.

The lower part of the sidewalls is of less importance in reflecting light, and for purposes of appearance it is often desirable to have a dado of dark green or some neutral color, as fingermarks and other disfigurements are not so n otice-able. This treatment of the walls also reduces the brightness of the background in the field of view.

In many instances painting certain parts of a machine white or a light color will greatly improve working conditions. For example, on a large vertical slotter the surface which faces the table, or on a lathe the area surrounding the work, finished in white will materially help in softening shadows.

High grade oil painting, as discussed later, is most desirable, but where whitewash is absolutely necessary frequent cleanings will speed production and keep the lighting bills at a minimum. A clean, bright shop has a decided effect on improving the morale of the workmen.

Offices.

On account of the justly widespread use of the indirect lighting systems and the likelihood of these being installed at any time, the ceilings should always be light in color.

For the walls a soft pale olive green with a slight blue cast is recommended in north rooms and with a yellow case in south rooms to give the best results. The matter of tint of the wall surfaces, however, is largely a matter of personal preference. Some individuals prefer a greenish tint which is soft and restful, others for artistic reasons prefer a light buff or cream. It is recognized that it is often worth while to sacrifice lighting economy for artistic effect.

With most systems of lighting a considerable portion of the flux strikes the upper part of the walâs, so these also should be of a light tint. The lower area can well be of a darker neutral color to provide space on which the eye can rest in comfort.

A light-colored room is much more cheerful than one finished in dark paint. In many cases dark surroundings have given the impressionof bad lighting, while in reality there was a high enough intensity on the desks. The psychological effect of gloomy interiors is wèll known, and it is, of course, desirable to keep clerks bouyant and cheerful.

Light surroundings, in general, reduce the conditions of glare, An artificial light source viewed against a gright ceiling is less annoying than in other positions. Light-colored walls diffuse the light back toward the side of the room with windows, which lessens the contrast between the bright sky and adjacent walls.

As has been pointed out before, glossy wall surfaces should not be used, and even the furniture and trim should not be highly varnished. In this connection close cooperation between the builder and lighting engineer is essential.

Light buff window shades are desirable, and if these are drawn at night they materially assist in reflecting the light rather than allowing it to escape to the street. If these shades are slightly translucent they are very useful in the daytime in cutting down the direct sunlight which passes through them, and preventing a sharp line of shadow demarkation which may result if opaque shades are used.

Stores

A pure white finish throughout is most universally applicable to stores, not only for its effect on the amount of light utilized and general bright appearance desired, but for the color result secured.

White light striking a colored surface will have some of its rays absorbed and be reflected as colored rather than white light. (This property is what makes the surface colored.) Hence, if an approximation to daylight is used as a light source and all of the reflected light tinted, the final effect will be of a different color than that given out by the lamp. A practical illustration of this lack of understanding is to be seen where Daylight Mazda lamps are used in semi-indirect units in a room with a yellow ceiling. White surroundings do not modify the color of the reflected light as colored surroundings do.

Permanency of Various Wall Finishes

The freshly scraped surface of a block of magnesium carbonate reflects more light than any other object--88 per cent of the light falling on it is sent back. We cannot expect as good results from ordinary painted surfaces for the usual mediums including even zinc white are quite gray as compared with magnesium carbonate. A paint made with magnesium carbonate. A paint made with magnesium carbonate as a pigment more nearly approac es this value and is desirable from the standpoint of light reflection. As comparative average values for properly prepared and freshly mixed samples, the following figures apply:

Paint	Coefficient of Reflection New	After aging one year.
White lead and oil.............	0.75	0.67
Lithopone......................	0.77	0.72
Calcimine type.................	0.74	0.67
Flat enamel (magnesia bearing)	0.76	0.73
Gloss enamel...................	0.75	0.75

There is comparatively little choice between any good white paints when fresh. The story is different, however, after they have been exposed to normal daylight conditions.

It is seen from this table that the enamels have held their own very well. The lithopone paint has fallen off by 6 per cent of its initial value. Calcimine and white lead have fallen off about 10 per cent. The falling off of calcimine is due largely to its porous nature which permits it to absorb dirt readily. The falling off in white lead and calcimine is progressive and does not decrease in rate. Numerous observations on lead and oil paint in use for two years indicate a falling off of about 20 per cent. The slight falling off of f flat enamel occurred in the first month, no further decrease being observed. The coefficient of reflection of the gloss enamel was constant throughout the test.

These tests were all made under constant laboratory conditions and must serve only as a guide for judgment. They form a starting point for observation and pracitce.

Method of Applying Paint

Now as to the actual painting itself, what conclusions do we draw from the data above presented? It is obvious that a gloss enamel will not fulfill one of our initial conditions, due to its high value of specular or image reflection. We are, therefore, forced back on some type of what we have called flat enamel. This paint must contain no lead and probably no linseed oil. It must be composed of chemically inert white substances ground exceedingly fine (to produce density) and mixed in an inert vehicle which is impervious and non-porous when dry. It must dry flat and be washable.

The most permanent and highest practical coefficient of reflection and diffusion can be obtained with plaster surfaces treated as follows:

First coat -- Good impervious surfacer.

Second coat -- Straight lithopone paint

Third coat -- Gloss enamel and lithopone mixed equal parts.

Fourth coat -- flat enamel (magnesium bearing) flowed on.

For metal surfaces, after the usual preparation, apply first coat of red lead thinned with raw linseed oil drier and turps to give an eggshell finish. Over this a coat of lithopone paint mixed one gallon to one quart of good varnish; then the second, third and fourth coats as applied to plaster.

From an illuminating standpoint the walls of a room are not as important as the ceilings and they should be less bright. A simple painting formula will apply. It is, in brief: First coat---good impervious surfacer mixed with equal part lithopone paint. Second and third coats--straight lighopone paint, the last tinted with japan tint, thinned with turps.

If it is necessary for any purpose to use a gray tint it should never be obtained by mixing lamp black in the paint. This is the substance having the lowest known coefficient of reflection. To obtain the gray it is desirable to mix vermillion a d emerald green to get black and then thin out with white. This produces what is known as a warm gray and has a reasonably high coefficient of reflection.

In any painting the surface on which it is applied should be properly prepared and non-porous so that it will not absorb any of the vehicle of the final coat. It must also be chemically inert with respect to this final coat.

A number of paint manufacturers have investigated the subject of "painting for light" and have produced pigments which give results comparable with those specified above. Any of these concerns will gladly furnish detailed information on their product upon request.

Economics of Situation.

It is true that it is somewhat more expensive to paint the surroundings correctly than to apply calcimine, mill white, or some other paint which depreciated quite rapidly; yet the economics of the situation well warrant this expenditure. For example, the following calculation applies:

If we consider a room in which the ceiling is painted with white lead and oil as described in the test quoted above, we may expect at the end of two years the illumination efficiency will have decreased not less than 15 to 20 percent due alone to the reduction in coefficient of reflection of the ceiling, other conditions being constant. But in actual work other conditions are not constant---for one thing the coefficient of reflection of the paint on the wall also undergoes a decrease. It is probably safe to say that the use of lead and oil (or calcimine) as an interior paint entails a progressive loss of light amounting to 15 per cent of the light measured at the beginning of the year. Thus a room so painted, of 400 sq. ft. floor area, initially lighted by four 100-watt lamp at the end of two years to bring the illumination back to what it was in the beginning---an increase of 25 per cent in energy consumed and lamp renewals. Surely this figure is striking enough to warrant the necessary expenditure.)The writer is indebted to an article by Mr. Bassett Jones, Consulting Engineer, on "The Characteristics of Interior Building Finishes as Affecting Illumination," for many of the figures presented in connection with painting)

*Green on the lower part of the walls is particularly good practise. A light green is particularly advisable for wall tints where there is a large window exposure to the north and east light. It is a well known fact that the strong rays of light existing at certain seasons of theyear are very irritating and injurious to the human eye, if they are allowed to enter through a large window surface and strike the eye directly or indirectly from polished surfaces at certain angles. If light tinted walls extended down to the floor line, employees, when looking up from their work, would be confronted with a

*T. I. E. S. Vol IX No. 2,1914.

bright wall surface which would to a certain extent, reflect too high an intensity of light and thus affect the visual acuity or seeing efficiency of their eyes. With light green walls, the strong daylight rays are absorbed, diffused and reduced in intensity, so that far more hygienic conditions are furnished the office worker. The same principle holds true with artificial illumination coming from overhead general illumination. From a utilitarian standpoint, it is self apparent that a light green painted wall surface is easier to keep clean than one of a lighter color, when either a painted or calcimined finish is employed. Painted walls and ceilings, in preference to calcimined surfaces, are coming into use quite generally, because they are conceded to be preferable from both a sanitary and a utilitarian standpoint.

Measurement of Reflected Factor.

There are a number of laboratory methods of obtaining this value, some of which employ elaborate apparatus, and which take into account with a high degree of accuracy the direction of the incident light, color of incident light, and similar features. A complete description of these methods will be found in the technical press, references to which are gimen in the bibliography which follows.

The practical determination of the coefficient of reflection of a diffuse reflecting wall or ceiling is quite simple indeed and can be made by anyone familiar with the operation of a portable photometer employing a detached test plate. The standard on which reflection factors are bases is of a freshly wall is to the coefficientof reflection of wall.

If the surface to be tested is polished or has a considerable element of specular reflection, then the determination of the coefficient is more complex, and several readings at different angles should be taken to insure the obtaining of a fair average value.

The Method of Determining the Coefficient of Reflection of a Wall Surface with Macbeth Portable Photometer. At left, Secondary standard in place; at right, reading of wall.

No difficult mathematical equations are involved in this determination. Simple readings of the photometer and a porportion is all that is necessary. Example, calibration, magnesium carbonate block apparent foot-candles 10.5, white blotting paper apparent foot-candles 9.1. 10.5 is to 0.88 as 9.1 is to x. Coefficient of reflection of blotting paper is 75 per cent. Test of wall surface, apparent foot-candles white blotting paper in place, 3.7. Apparent foot-candles of wall blotting paper ~~in place~~ removed, 2.6. 3.7 is to 0.76 as 2.6 is to x.

REFLECTION FACTORS OF COLORED SURFACES

The proportions of light reflected by walls and ceilings of various colors, i.e., their reflection factors, have an important bearing on both the natural and the artificial lighting. The figures here given show what proportion of the light of mazda lamps these painted surfaces reflect. Reflection Factors are of especial usefulness in determining the coefficient of utilization (ratio of light delivered at the work to total light of lamps) applicable to an interior. The reflection factor of any surface may be found by comparing it with these samples.

81% White paper

73% Gray

67% Gray

51% Gray

46% Gray

39% French Gray

28% Gray

18% Gray

76% Ivory White

72% Caen Stone

72% Ivory

58% Ivory Tan

67% Primrose

70% Lichen Gray

70% Pearl Gray

50% Silver Gray

44% Buff Stone

59% Buff

51% Buff Stone

37% Tan

22% Cocoanut Brown

67% Satin Green

47% Bright Sage

43% Bright Sage

21% Forest Green

14% Olive Green

53% Pale Azure and White

36% Pale Azure

31% Sky Blue

57% Shell Pink

51% Pink

27% Cardinal Red

scraped block of pure magnesium carbonate. One of these standards can be secured at any drug store, a block approximately 4 inches square and 2 inches thick can be purchased for a few cents. The first step in the determination is to scrape the surface of this and place the block in any convenient position relative to an artificial light source. The photometer is then pointed at the block from some angle not too far from the normal and a reading taken and recorded. A secondary standard of working standard such as a sheet of blotting paper is next calibrated. This is substituted for the magnesium block, and with the same illumination indident on it as when the previous reading was taken a second reading is taken and recorded. We then have the following proportion applying: Reading "A" is to 88 per cent as reading "B" is to the coefficient of reflection of the blotting paper.

Taking care that the blotting paper or secondary standard does not become dirty it is removed to the room in which the test is desired, placed at a convenient position on the wall or ceiling the reflection factor of which is desired, and with the portable photometer a reading taken of the brightness of the blotting paper with the normal illumination received on the wall incident on the paper. The paper is now removed and a reading taken of the wall surface. We have already determined the coefficient of reflection of the blotting paper and the following proportion applies: Reading on blotting paper is to the coefficient of reflection of blotting paper as reading on

Coefficient of reflection of wall, therefore, 53 per cent.

Artificial Daylight.

Artificial daylight is now available from different types of lighting units amd is a commerdial illuminant it is rapidly growing factor in lighting practice. A few years ago when discussions of artificial daylight were centered about theoretical impractical units, the supposed fields for such units was limited to stores and to textile industires. Owing to the expansion and to the continued recession of the horizon of artificial daylight it appears that there is no definable limit to which the artificial light may be used. The construction of daylight entrances is more expensive then ordinary roofing and blank walls, in crowded cities the space sacrificed for light courts and windows reduces the possible rental from the ordinary price of ground. Furthermore the increase in cost of heating buildings with considerable window space is no small matter. With the decreasing cost of artificial light it is possible that the future may witness a keener competition between artificial and natural lighting.

The Influence of the Illuminant on the Appearance of Colors.

Colored media.	Blue skylight	Noon sunlight	Mazda lamp
Ultramarine	Blue	Greenish blue	Darker ruddy blue
Chrome yellow	Lemon yellow	Golden yellow	Orange yellow
Vermillion	Yellowish red	Brick red	Red
Chrome green	green	Yellowish-green	Yellow green
Cobalt blue	Light blue	Light blue	
Purple			Violet
Pink	Pink	Redder pink	Light red
Dark blue	Blue	Blue	Bluish black

CHAPTER III

GOOD LIGHTING PRACTICE

The purpose of this summary is to present facts in regard to lighting which may be capitalized by the man who realizes that in improvéd lighting he may find a means for increasing his income, adding to his pleasures, increasing his own safety and the safety of the men who work for him. The material is prepared in the form of a digest of current authoritative literature, the findings of competent committees, and the opinions of practicing illuminating engineers.

While the necessity of good light is so evident that a list of its effects may seem commonplace, these same effects are of the greatest importance in their relation to factory and mill management. The effect of good light, both natural and artificial, and of bright and cheerful interior surroundings includes the following:

1. Reduction of accidents.
2. Greater accuracy in workmanship.
3. Decreased spoilage of product.
4. Increased sales and output for the same labor cost.
5. Less eye strain.
6. Better working and living conditions.
7. Greater contentment of office help.
8. Better order, cleanliness and neatness in the office.
9. Easier supervision of the help.

In regard to offices, stores, and commercial buildings in general, it is hardly necessary to do more than point out that here, just as truly as in the industries, good lighting is economy. Ward Harrison, Illuminating Engineer of the National Lamp Works, in speaking before the Illuminating Engineering Society said:

To-day there is no reason for other than the best illumination in new offices. Equally good lighting should also be provided in the older buildings, although here the result is obtained at a somewhat greater expenditure for in the majority of cases some change in the location of outlets will be necessary. In general, however, the required alterations in wiring will be found profitable even where considerable expende is involved for there are no locations where the consequences of poor lighting are more serious or more keenly felt than in offices and drafting rooms.

No store can hope to acquire a reputation for quality furnishin s without paying particular attention to lighting. In fact, a visit to a number of better-class stores will convince anyone that for the most part intensities higher than those actually required for good vision are employed; the extra light is an advertisement which the progressive manager cannot do without.

The layman is likely to believe that to obtain good lighting it is only necessary to experiment with lamps of various sizes unt l sufficient light is supplied to permit close discrimination of the objects lighted. If he has difficulty in reading comfortably at home, he endeavors to correct the trouble by using a lamp of higher wattage; in some cases this may solve his problem, but the chances are the real trouble involves not only the size of the lamp but the type of reflector equipment and location of the lighting source as well. Good lighting practice calls for the fulfillment of three requirements:

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

Of these three requirements, the first two must be discussed somewhat generally at present for the reason that sufficient data are as yet not available to permit definite conclusions to be drawn. As regards light intensity, values which are known to represent good practice can be readily tabulated to serve as a basis for individual requirements.

Light Quality.

Any discussion of the quality of light leads invariably to a consideration of glare and color.

Glare

Glare has been rather loosely defined as light out of place. It has been more fully 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 faults most commonly found in all lighting installations.

A glance at the sun proves that an extwemely bright light source within the field of vision is capable of producing acute discomfort. Light sources of far less birlliancy than the sun such for example as the filament of an incandescent electric lamp or the mantle of a gas lamp, are also quite capable of producing discomfort by direct glare, but the annoying effect is not usually so marked. From our present knowledge, it appears that there are at least two distinct brightnesses which are of particular interest in connection with illumination problems. The more definite of these two is the brightness at which a given source looks just uncomfortably bright when viewed casually against a background. The second, and mush lower value, is the brightness at which a source proves tiring and causes fatigue when continually within the fisld of vision for a considerable period of time. The latter value is much more difficult to determine and it apparently varies through wider limits for different individuals. What these values represent may perhaps be more clearly understood by considering the analogous case of looking out of a window which by day is a source of light for a room. Unless the room is very dark or the landscape very brilliant, the effect of looking out of the windwo for a moment will not be at all unpleasant, but to sit all day facing the window would prove extremely tiring, even if one were sitting at a desk or table and not paying particular attention to the window. This is exactly comparable to the case of a light source which is not bright enough to cause an immediate sensation of glare but too bright to be viewed continually. The problem of determining definite values for these two conditions of glare is rendered extremely difficult because of the fact that the extent to which glare is objectionable is particically dependent upon the contrast in brightness between the light source and the background. This is illustrated by the fact that although automobile headlights as seen at night against a dark background are likely to be so glaring as to be temporarily blinding, the same lights would in the daytime hardly be noticed. The permissible brightness of alight source is greater when the general illumination is of high intensity than when it is of low intensity. That is, for a room which has dark walls and furnishings, a unit of lower brightness should be used than would be permissible in a well illuminated room in which the decorations are light in color. The permissible ratio between source brightness and background brightness is not, however, constant; the ratio must be smaller at high values of intensity than at low ones.

The glare from street lights is often scarcely noticed as one walks along the street, but if one sits on a porch facing a unit, the glare is likely to cause acute discomfort. Such data as are now available indicate that ordinarily the brightness of a lighting unit which is in the central portion of the visual field should not exceed from 2 to 3 candles per square inch of apparent area, if that unit is not to give

rise immediately to a sensation of glare, and the brightness should be reduced to 1/2 candle per square inch of apparent area if it is not to fatigue the eyes when viewed continually. In this connection it is interesting to note that the brightness of the sky rarely exceeds 3 candles per square inch. A 200-watt Mazda C lamp in a 10-inch opal ball of medium-density glass will emit light at an intensity of about 180 candles (the opal ball so diffuses the light that the candlepower in all directions from the unit is approximately the same). The apparent area of a ball 10 inches in diameter is about 80 square inches, for as we look at such a ball from a distance we see a circular area of 80 square inches, which is acting as a source of 180 candles. In other words, the opal ball is a source emitting 2 1/4 candles per square inch of apparent area. Such a unit would be too bright for an office, but would be satisfactory for hallways, store rooms, and similar places which are used intermittently and for a large proportion of stores and industrial plants where those using the illumination frequently move about and are not called on to face the lighting units for long periods. If a 60 watt lamp were substituted for the 200-watt in the 10-inch ball referred to, the brightness would be reduced to slightly over 1/2 candle per square inch, and this would usually be the largest lamp that could be used in a medium-density opal ball of this size if all danger of glare were to be avoided with the unit placed in an office or similar location.

It is sometimes possible to improve poor lighting conditions where the direct litht from sources in the field of vision causes glare by changing the position of the sources. Little interference with vision is evident where light sources are 25 to 30 degrees away from the normal line of sight; but even then so located they are quite capable of producing eye fatigue if continually within the range of vision.

A form of glare which is often less obvious than that which comes direct from the source to the eye, but which is frequently more harmful because of its insidious nature, is that which comes to the eye as glint or a reflection of the source in some polished surface. This form of glare, known as specular reflection or veiling glare, is frequently encountered where the work is with glossy paper, polished metal or furniture, or other shiny surfaces and is particularly harmful because of the fact that the eye is often held to such surfaces for long periods of time, and while the glare may not be sufficiently annoying to be recognized as of a serious nature, it may nevertheless in time produce eye fatigue or even permanent injury. Since the brightness of the reflected image is dependent upon the brightness of the light source, it follows that the harmful effects of specular reflections can be minimized by reducing the brightness of the light source. Frequently specular reflections can be prevented from striking the eye by locating the light source in such a position with respect to the work that specularly reflected light will be thrown away from, rather than toward, the operator. The use of lighting units of large area and a diffusing medium to prevent any direct rays from the lamp striking the surfaces illuminated will aid in avoiding bad specular reflection, but on the other hand, if the source is very large, as, for example, a ceiling lighted by indirect units, a certain amount of specular reflection cannot be avoided. For a machine shop, a more highly diffusing light source will be required than for a wood-working shop because the reflected images from metal are much more distinct than those from wood.

The Appendix to the Proposed Code of Industrial Lighting for the State of Ohio speaks of glare as follows:

While addquate illumination must be provided, it is equally important that the light be supplied in such a way as will not cause discomfort or injury to the eye. Thus, among the more frequent and serious causes of bad lighting, are those due to glare in various forms.

Glare may result from one or more of the following cond ditions:

A. The source of light may lie too far within the field of vision, that is, the angle between the line of sight and the line to the light source is too small.

B. The light source may be too bright, that is, too much light flux from a small area.

C. There may be too great contrast between the bright light source and a dark background or adjacent surfaces.

D. The total quantity of light entering the eye may be excessive. The harmful effects of glare are much affected by:

A. Distance from a light source in the field of vision.

B. Time of exposure to the light source.

The most common and troublesome cases of glare are those which are due to unshaded or inadequately shaded lamps located within ghe field of vision.

To reduce such glare, lamps located as follows should be shaded:

A. All lamps hung 6 1/2 feet or less above the floor.

B. Lamps whose suspension height above the eye level is less than lne-fourth the distanse to the lamp in fromt of any worker and which are less than 20 feet from the floor. The above is not so necessary for lamps of 200 candlepower or less whose height above the floor is 15 feet or more.

Lamps hung at 6 1/2 feet or less should not expose to the eye of any worker any square inch of luminous surface giving a higher candlepower than 5 and lower values are to be preferred. No shaded lamps under 20 feet should expose a square inch of luminous surface giving more than 75 candlepower to an eye located as in Section B above.

The above provisions will not eliminate all glare but will correct the most serious cases. In many situations more complete shading is to be recommended.

Glare resulting from contrast will of course be much more serious in the case of dark walls and ceilings than where these are painted a light color.

Serious glare may result from specular reflection from polished and other materials upon which work is being performed. It is sometimes practical to avoid such glare by a change in the relative location of the light source and the work, but usually it ca be obviated successfully only by decreasing the brightness of the light source at all angles below the horizontal.

Glare re sults in decreasing ability to see, it may cause temporary discomfort, and if the condition is long continued may result in permanent injury to the eyesight. This de-c creased ability to see results in a lower quality and decreased quantity of output; consequently aside from the discomfort and danger to the eyes, glare is economically bad.

Since the bad effects from glare are dependent upon time of exposure to the same, glare due to temporary or emergency lighting is to be considered from the point of view of danger of accidents rather than of discomfort.

Glare Elimination.

The necessity of the elimination of glare depends largely on the purpose to which the room is to be put. In a living room or a general office or an audience room where persons sit for long periods in one position it is of first importance to avoid glare in the eyes of the occupant. On the other hand if the eye is not to be exposed to the glare for long periods, some temporary glare is permissible in many cases to keep down the cost of construction and operation.

Glare may be kept from the eyes of the occupants of a room by limiting the brightness contrast ratios to which the eye is subjected. In the case of artificial light this is done by inserting opaque reflectors or a diffusing medium between the lamp and the possible positions from which it can be seen.

Practically all sources of artificial light now in common use are too bright for continuous exposure to the eye with the background illuminated no better than is common practice to-day.

In eliminating glare by the insertion of diffusing glass or other material between the light source and the eye three general methods have been used. An opaque reflector or one of dense translucent glass, cloths or paper can be placed over the lamp far enough to protect the eyes of occupants of the room and yet allow direct light from the lamp and reflector to fall on objects under and near the lamp. Another method is to reverse this process, putting opaque or dense translucent reflectors under the lamp to reflect the light to a light colored ceiling or wall and so obtain a diffused light from the ceiling or wall. As the light is spread out on the ceiling its brightness is comparatively low and the brightness contrast ratios are cut down to bring them within the limit of tolerance of the eye. A third method is to put around the lamp an enclosing globe that will diffuse the light going in all directions. While this is a very common method it is an incomplete solution of the problem of the most modern illuminants because a diffusing globe which will cut the brightness down to a proper figure is either so large as to be prohibitively expensive or so dense as to cause a prohibitive loss of light.

The second method, that of using indirect lighting, or semi-direct lighting with bowls of very low brightness, is the only reasonably economical and practical method which conforms fully to the hygienic requirements in most cases where low brightness of the units is required. Evenif the ceiling is dark in color it may be more feasible to light the room indirectly from a dark-colored ceiling than to put in enough outlets to supply general illumination from the enclosing globes.

A method whichpartially eliminates glare, adopted in many cases in which indirect lighting would be considered too expensive on account of the poor reflecting qualities of the ceiling, involves the use over the lamps of reflectors of various types of opal and with opaque reflectors of white anamel steel, aluminum-finished metal and mirrored glass. This method is necessarily an incomplete solution of the problem of eliminating glare because it is possible to see the lamp filaments, mantles or frosted tips of the lamp and the interior surfaces of the reflectors, any of which is bright enough to cause contrast glare. It is however much more efficient and less glaring than the use of bare lamps or flat reflectors.

CHAPTER 4

CALCULATION OF THE LIGHTING INSTALLATION *

Introduction

There are two basic methods of predetermin ing the illumination produced by a given lighting installation.

The first is based on certain mathematical calculations depending upon the distribution and candle-power values of a lamp with its reflector equipment, and the distance of the source from the point where the illumination is to be deretmined. While this method is especially useful for determining the amount of light upon specified points, it necessitates many tedious calculations and does not take into consideration the light reflected from the walls and ceiling.

The second method is more convenient and is an absolutely reliable means of calculating an illumination problem, as it is based on the law of conservation. According to this law all of the light flux (lumens) produced by a source or sources of illumination in an enclosure, such as a room, is absorbed by the illuminated surfaces in the enclosure. Calculations based upon this law, which is fundamental, must be accurate when the assumption is to absorption etc. are correct.

A certain portion of the light is reflected back from the objects upon which it falls, such as the walls and ceilings, the remainder being absorbed by these surfaces. The percentage of the light which is reflected to the amount

*Edison Lamp Wks. of G. E. Bul L.D. 117

of 1 foot radius. This light would illuminate the inner surface with an intensity of 1 foot-candle, and the illuminated area would be 4 pi = 12.57 square feet, since the surface of the sphere is found by multiplying the square of the radius by the constant 4 pi. If the same light quantity of light originally distributed over the area of 4 pi square were placed in the center of spherical shell of two foot radius, the feet would now be distributed over an area of four times 4 pi, 50.28 square feet. It is readily seen that the illumination on the largest surface would be 1/4 of a foot-candle, since the total amount of light is the same in both cases, and the larger surface is four times the smaller. A lamp of 16 spherical candle-power at the center of the smaller sphere would give an illumination of 16 foot-candles on the inner surface. If placed at the center of the larger sphere, the illumination on the inner surface would be 4 foot-candles. If placed at the center of a hollow sphere of 4 foot radius the illumination on the inner surface would be 1 foot-candle.

If a light source is located at the center of a spherical surface all the light rays emanating therefrom will meet this surface normally, hence normal illumination in foot-candles is found by dividing the candle-power of the source by the square of its distance from the surface illuminated. Therefore normal illumination equals candle-power (cp), divided by distance squared (d^2). This rule, known as the law of inverse squares, does not apply in this state to conditions falling upon the surface is known as the reflectéon coefficient of the surface. This reflected light may again be reflected, and so on.

The useful light may be considered as that reaching an arbitrary working plane (say 30 inches above the floor), and knowing the light flux produced and the reflections of the walls and ceiling, etc., it is possible to determine the total lumens usable.

This would necessitate many measurements and mathematical computations to obtain the various reflection coefficients. Therefore, typical cases have been tested and tables derived from them, which are found to be very convenient for designing an illumination layout.

In order to facilitate thw work of laying out the proposed installation, which is rather cumbersome by some of the methods, a system of tables, has been developed, later on called Method No. 3. The principles involved in the first two methods have all been taken into consideration in the new method, leaving only a substitution of values from the curves necessary for the one who is planning the lighting layout.

Candle-Power Relations

Before going into the methods, leading up to this latest one, there are a few facts regarding the relation of foot-candles, candle-power and the distance of the light source from the surface, which are well to consider.

Considerx a light of 1 candle-power intensity in all directions placed in the center of a small spherical shell where the light falls obliquely on the surface under consideration, nor where the ratio of the size of the light source, to the distance from the source to the plane, is not small enough for the source to be considered as a point neither does it apply to a line source nor a plane source such as a diffusing ceiling.

Point by Point Method (method No. 1.)

A fundamental principle for laying out illumination depends upon the calculation of horizontal illumination by the point by point method.

In practical illumination most of the rays do not meet the surface normally. In Fig. 1, the rays from the lamp shown at "S" are assumed to be normal to the plane "AB". As has been shown, the illumination or normal foot-candles on this plane is

$$In = \frac{CP}{d^2} \quad . \quad . \quad . \quad . \quad . (1)$$

"CP" equals cp. of the lamp at S in direction SA, d equals distance SA, In equals normal illumination."

Byt in reality, the light that would have been intercepted by "AB" will be distributed over the larger plane, "AC". From the triangle ABC

$$\frac{AB}{AC} = \text{Cos a.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . (2)$$

$$AC = \frac{AB}{\text{Cos a}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

that is, the square feet in plane AC is found by dividing the square feet in AB by the cos. a. To illustrate, if "a" had such a value as to make its cos equal to .5, area of the plane A.C. would be found by dividing that of AB by .5, that is, area AC would be twice as great as AB and the intensity of illumination would, therefore, be onehalf that of AB.

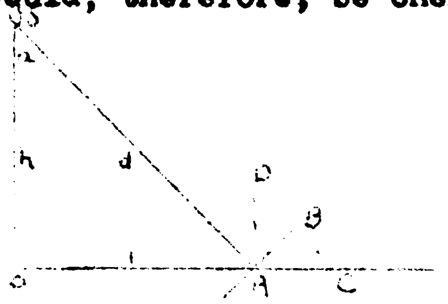


Fig. 1. Diagrammatic representation of the relation of normal and horizontal illumination.

Hence, the general rule, that since the area of the oblique plane AC is obtained by dividing that of the normal plane AB by cos a, the illumination of AC is that of AB multiplied by cos a, or for oblique illumination,

$$In = \frac{CP}{d^2} \cos a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

But from the triangle OSA

$$\frac{h}{d} = \frac{So}{SA} = \cos a \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5) \text{ or}$$

$$d = \frac{h}{\cos a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Squaring, $d^2 = \frac{h^2}{\cos^2 a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$

Substituting for d^2 in equation (4)

$$In = \frac{CP}{h^2} \cos^3 a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where In is the intensity in foot-candles on the horizontal plane.

Equation (8) is known as Lambert's law, and is very useful in the calculation of illumination. In the rest of the bulletin on page 22 will be found values of $\cos^3$ a for different values of "a" from 1 deg. to 90 dig. To facilitate the use of the above formula there are given in Table No. 1 values of illumination on horizontal planes at different heights and at different horizontal distances of a light source of 1 candle-power and also the corresponding angles made by the light rays with the perpendicular to the plane, or angle "a".

Method of Using Table

Obtain the distribution curve of the lamp and reflector in use or to be used. Take from Table No. 1 the value (in foot-candles) of illumination which a 1 candle-power light source would produce at the point selected. Also note the angle corresponding to this point. From the distribution curve of the lamp, take the candle-power at the corresponding angle. Multiply this value by the illumination value found in the table, and the result will be the illumination, in foot-candles at the point selected, of the lamp under consideration.

For example: Required the illumination produced by a 200-watt bowl enameled Mazda C lamp with RLM standard dome reflector at a point 12 ft. below thelamp, and 12 ft. to one side.

From Table No. 1, the value corresponding to these distances is 0.0025, and the correspondign angle is 45 deg. From the distribution curve of the 200-watt bowl enameled Mazda C lamp with RLM standard dome reflector the candle-power at 45 deg. is approximately 475, then 0.025 x 475 equals 1.1875, which is the illumination in foot-candles at the specified point. The illumination on a certain spot where there is more than one lamp in the firld of vision may be obtained in a similar manner, using the respective distances, from the point directly beneath the lamps to the spot and the vertical height of the lamps above the plane. Obtain values from Table No. 1 and proceed as above. The sum of the values thus obtained will be the total amount of light on that specific point.

Illumination of Vertical Surfaces.

For formulae for the calculation of illumination on vertical surfaces and surfaces at other angles than the normal or horizontal, see a paper by Mr. F. A. Benford , Jr., entitled "The Theory and Calculation of Illuminating Curves," Transactions of Illumination Engineering Society, Volume 7, 1912.

Flux of Light Method (method No. 2)

While the "point by point" method is fundamental and must be used in calculations involving equipment whose characteristics are not fully determined, it will be found too cumbersome for general use and a more convenient formula would ob necessity be essential.

A lumen is a quantity of light which will illuminate 1 square foot of area to an intensity of 1 foot-candle. A table is here giving intensities in foot-candles recommended for the various classes of lighting service. The floor area of any given room is readily ascertainable, and this multiplied by the desired foot-candle intensity gives at once the lumens which should be effective on the working plane.

From an inspection of the distribution curve of any lamp or of a lamp and reflector combination, it is apparent that all of the light flux (emitted lumens) from the lamp does not reach the working plane; for in the case of a bare lamp approximately one half of the total light is emitted upward, and to reach the working plane must strike the ceiling s and side walls and then be reflected. Since there is no perfect reflecting surface, any reflection is accompanied by absorption and loss of light. This is true even in cases where reflectors are used, for a reflector, no matter what its reflecting surface may be, has a certainportion of the light absorbed by it. This may be shown by comparing the light emitted by a bare lamp and the same lamp equipped with a reflector.

An obvious method of determining this loss of light is to set up in an average size room with certain colored walls and ceilings, an installation of one type of reflector; then to actually measure the illumination on a horizontal working plane, and also determine the total light supplied, or generated lumens. Many such investigations have been made with various types of units from the direct steel refledtors to totally indirect units, and utilization factors thus determined may be found in Table No. 2. The values in this table represent the percentage of the total lumens emitted

by lamps that reaches an assumed working plane. WHILE THE values of the constants given in this table may appear to be a little low, theyrepresent average conditions of service

Table No. 2.

Utilization Constants - Per Cent Lumens Effective
Allowing a 25 Per Cent Service Depreciation.

Ceiling................	Light			Medium			Dark	
Walls..............	Lt.	Med.	Dark	Lt.	Med.	Dark	Med.	Dark
Reflector								
R.L.M. Standard Dome, Clear	.49	.47	.45	.48	.46	.44	.45	.44
RLM Standard dome Bowl enameled........	.42	.41	.39	.41	.40	.38	.39	.38
Deep bowl, steel Clear*...............	.41	.39	.37	.39	.38	.37	.38	.37
Reflecto Cap Diffuser Clear................	.35	.34	.32	.34	.33	.31	.32	.31
Deep bowl, Glass Bowl enameled........	.40	.38	.36	.37	.35	.33	.32	.31
Diffusing, enc. globe Clear.............	.37	.34	.32	.35	.33	.31	.31	.30
Light opal, semi-ind. Clear........	.34	.31.	,28	.29	.26	.23	.21	.19
Dense opal, semi-ind. Clear	.29	.27	.25	.22	.20	.19	.26	.14
Totally indirect Clear.............	.27	.25	.23	.20	.18	.16	.12	.10

*Bowl enameled lamp, not generally recommended with the deep bowl opaque reflectors on account of the pocketing of light and resultant low utilization.

with surroundings and equipments as indicated, taking into consideration a depreciation in lamp and reflector equipment of 25 per cent due to normal dirt and dust collection. The results obtained from such testing, supplemented by calculations, may be made use of in two ways.

There are times when it is desirable to know the illumination from an existing system and a portable photometer is not available. By the use of Table No. 2, the average foot-candles may be obtained in the following manner. The total lumens generated by the lamps may be obtained from Table No. 6. Knowing the type of fixtures and color of the walls and ceilings, a utilization factor, applicable to the special case, may be found from Table No. 2. The total generated lumens, multiplied by this factor, will give the total lumens effective on the working plane. Again, the total effective lumens divided by the area of the floor in square feet will give the average foot candles. In this way, the flux of light method is applicable for use with existing installations.

On the other hand, it is also possible to determine the size of lamp necessary in a proposed installation where it is desired to obtain a certain foot-candle intensity on the work. In this case, the area of the floor is multiplied by the foot-candles desired, which will give the total effective lumens necessary. Dividing this fugure by the utilization factor adaptable for the proposed installation, found in Table No. 2, will give a total emitted or generated lumens which must be furnished by all of the lamps. The lumens per lamp may then be found by dividing the total by the number of outlets, and then referring to Table No. 6, giving the total lumens for any standard lamp, the necessary size of lamp may be selected. It is always advisable to use a larger rather than a smaller lamp, if there is a small difference in choice as a safety factor.

The spacing and hanging heights of the units will be discussed at length in the following method.

Modified Flux of Light Method (method No. 3)

In order to facilitate thw work of laying out an installation by eliminating as many calculations as possible, a system of tables based upon the above discussion, has been drawn up to show the relation of the watts per square foot of floor area to the foot-candles of illumination, for different reflector equipments and grades of colors of walls and ceilings.

Accordingly the following is a short and yet reasonably accurate method of designing a general lighting installation.

Before attemtping to lay out a lighting installation, there are a few facts concerning the building or room which are essential.

These are:

Character of work to be carried on.

Floor dimensions.

Ceiling height (maximum hanging height)

Distance between columns (if any)

Color of walls and ceilings.

In order to facilitate thw work, the first step should be to make a sketch to scale of the room under consideration.

Having the information, before proceeding further, it is necessary to determine the type of reflector which is to be used. Having determined the proper reflector for the special class of building, proceed to Case 1 for direct lighting units, and to Case 2 for semi-indirect and totally indirect units.

Case 1. For Direct Lighting Units.

When an even illumination is desired over the entire working area, there is a fixed relation between hanging height and spacing for the several types of direct lighting fixtures. It is always advisable to hang the units as high as possible due first of all, to the fact that there will be more cross light and thus less dense shadows, and again, by increasing the height, the spacing is increased and a less number of outlets with the more efficient larger sizes of lamps may be used.

The ceiling height cannot be taken as the maximum hanging height, however, as some space is taken up by reflector and fittings. Where it is possible to hang the units close to the ceiling, 1 foot clearance should be allowed. In other words, a ceiling 15 feet high would have a maximum hanging height of 14 feet. Again, if there is considerable overhead horizontal belting which would cast objectionable shadows from lamps hung above it, the maximum hanging height is the height of the lowest horizontal belting.

To determine hanging height and spacing of units for the case under consideration proceed as folows:

From table 10 showing the relation of the hanging height of a unit to its spacing, determine the maximum distance between units.

Divide the widty of the room by the maximum spacing obtained above to determine the number of fows of outlets in the room. If this spacing does not divide into the width evenly, take the next larger whole number, which will be the number of rows of outlets.

In case the room is divided into bays by columns, as is usual in mill construction, consider each bay as a small separate room.

Divide this number into the width of the room, finding the new spacing, and thus determine the new hanging height from Table 10.

The distance between outlets in each row should be approximately the same as the distance between rows, and still have the length of the room evenly divided.

Divide the length of the roomby the spacing between rows determined above, and if this does not come out as a whole number, take the next larger whole number, which will be the number of outlets per row.

Now locate the outlets on sketch so that the distance from wall to first lamps will be one half the distance between outlets (see Fig 2). We have now determined the spacing and hanging height of the units. It remains to decide upon the size of the lamps to be used.

Multiply distance between rows by distance between outlets in rows to find the square feet area to be covered by each lamp.

Refer to Intensity Table No. 13 for foot candles required for the partãcular class of work to be carried on.

Find the equivalent watts per square foot from Talbes Nos. 14-18 for theparticular type of reflector to be used, and multiply this fugure by the area per outlet. The result will be the watts necessary per outlet.

Select the nearest size of Mazda lamp, preferably the s size larger.

Case 2. For Semi-indirect and Totally Indirect Units.

A method of procedure similar to Case 1 may be followed for these types of fixtures, using the values given in Tables 10 and 12. for spacing and hanging height instead of those of Curve No. 1.

Determine maximum speáing for a given céiling height from table No.10 and determine suspension length of fixture for final spacing from Talbäe 12. The size of lamp to be used is found in a manner similar to Case 1. Using the values of watts per square foot for the desired foot-candles, found in tables 14 to 18.

Revising a Present Installation.

Many times it is advisable or necessary to use the present out-lets in a building which is already wired for lighting, but where the new high intensity has not been in use. In such cases, it is first necessary to determine the floor area of the building in square feet.

Divide the area by the numberof outlets to obtain the average area to be taken care of by each lamp.

Multiply this by the watts per square foot found in table 14 to 18. for the particular work and surrounding conditions.

Select the nearest size of lamp, preferably the one larger, which will be the necessary size to use.

To determine the hanging height, knowing distance between outlets use table 12. If this value is much greater than the maximum permissible, due to a low ceiling, even illumination will not be obtained, and more outlets will be necessary. The room should be rewired and calculations made as outlined in Cases 1 and 2.

CHAPTER V

TESTS IN VARIOUS TYPES OF UNITS

This chapter deals with various arrangements and types of reflecting units installed in offices of the same size and finish, where the conditions for careful testing are especially faovrable. The results of illumination tests are shown for the various systems on a basis of equal quantity of light flux generated and also in terms of the wattage which would bw required to give an average intensity of 5 foot-candles. The character of the walls and ceiling surface is fully described and the results of surface brightness tests are tabulated so as to indicate the contrasts which exist with various systems, and are given on a basis relative to white blotting paper and also in absolute values. Corridor lighting, loss of light due to dust collection and effect of room size on utilization factor are touched upon.

The lamps used for tests were selected so as to give their rated candle-power when operated at the test voltage. The voltage for the test circuits was regulated by hand, thereby doing away with the necessity for voltage-candle-power corrections. In the tests which will be directly compared, the same lamps were used except where one test required clear lamps and the other bowl-frosted. The bowl-frosted lamps were rated before being frosted and the "clear' values used in computations.

With the thought in mind that contrasts on the walls and ceiling are important factors in an illumination design, surface brightness readings were taken at what appeared to be the brightest and dimmest spots. These are given in terms of equivalent foot-candles on white blotting paper, for the reason that it is a very simple and convenient method and also because the values so given furnish, it is believed, a better conception of the magnitudes than such units as candle-power per unit of area.

The data would be incomplete without including values showing the reflecting ability of the walls and ceiling. These reflection characteristics are given relative to white blotting paper, that is the ratio of brightness of the surface in question to that of white blotting paper in the same position and under constant and diffused light conditions.

The various systems employed in these standard offices are:

(A) pour direct, opal glass units fitted with bowl-frosted tungsten-filament lamps.

(B) Same as A except that reflectors are inverted and clear lamps used.

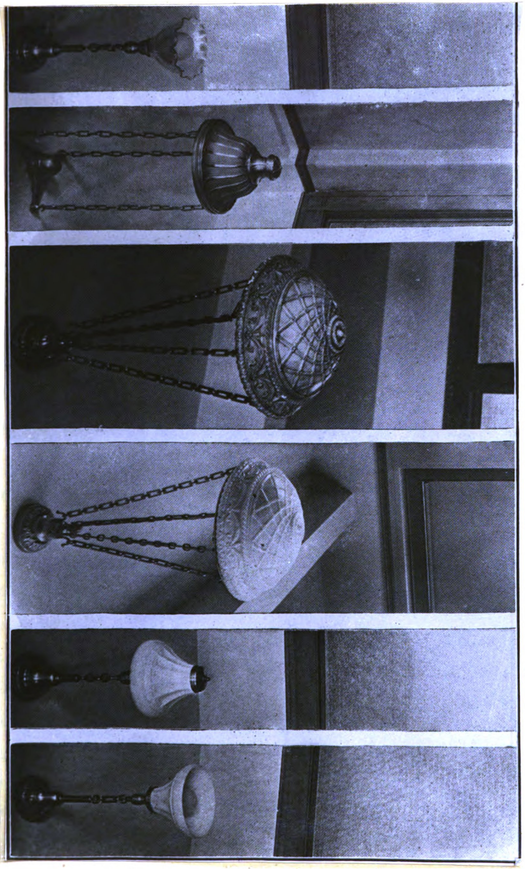
(C) One semi-indirect bowl with clear lamps in central outlet.

(D) One indirect plaster bowl with clear lamps in central outlet.

(E) Four mirrored glass indirect units with clear lamps.

(F) pour direct prismatic glass, intensive, with bowl-frosted lamps.

A single unit of each system is shown in Fig. 7.



A B C D E F

System A is the one generally adopted throughout the offices. The others are used in places where the requirements are special or where special consideration was givne to the individual tastes of the occupant.

In the tests A-F lamps of equal luminous output were used so that comparisons show the results obtainable with the different systems with the same amount of light generated at the lamps. It is hardly necessary to state that the same wattage is not to be recommended; however, it was thought best for purposes of comparison to make tests on this basis. Reflectors in all cases were of the correct size for the wattage of lamps used, except that in the mirrored glass reflectors it was necessary touse an extension in order to insure the proper lamp position.

A summary of the results of tests A-F, as outlined above, is given in Table s 1 and 2.

Before comparing these systems with one another and with the efficiency figures in other installations, the exact conditions as regards spacing of outlets and character of walls and ceiling surface should be borne in mind. The walls are finished with a greenish-grey paint which reflects 53 per cent as much tungsten filament light as does white blotting paper used in all these tests showed on measurement by the Nutting* reflectometer method, a coefficient of reflection of 77 per cent. The walls, therefore, absorb 59 per cent. The

*Illuminating Engineering society Transactions, Oct. 1912.

ceilings refl ct 76 per cent. as compared with the blotting paper, and, therefore, absorb 41 percent. of the light falling upon them.

Table I. - Intensity Distribution.

Description	Test	Illumination Foot-candles on 30" plane Average	Maximum	Minimum	Efficiency Lumens per watt	Per Cent Utilization efficiency
Direct, 4 units opal glass, bowl frosted lamps	A	4.58	5.54	3.89	2.95	32.5
Semi-indirect, 4 units, opal glass clear lamps	B	2.69	3.01	2.32	1.73	19.0
Semi-indirect, 1 unit, diffusing bowl, clear lamps	C	3.19	5.63	1.75	2.05	22.6
Indirect, 1 unit plaster bowl, clear lamp.....	D	2.39	3.66	1.42	1.54	17.0
Indirect, 4 units, mirrored glass clear lamps	E	2.65	3.04	2.20	1770	18.7
Direct, 4 units prismatic, bowl-frosted lamps	F	5.00	5.78	4.33	3.22	35.5

Room area--257.5 square feet and 4--100-watt lamps used in each test.
Ceiling height, 11 ft. 10 in. Height of unit above floor, Tests A, B and F, 10 ft., 6 in.; Tests C and D, 9 ft 5 in. Test E, 9 ft. 9 in.

Table 2. - Surface Brightness Distribution.

Description	Test	Surface brightness foot-candles equivalent to white blotting paper. Ceilings Maximum	Ceilings Minimum	Walls Maximum	Walls Minimum
Direct, 4 units opal glass bowl-frosted lamps	A	5.23	0.663	6.03e	0.846f
Semi-indirect, 4 units opal glass, clear lamps	B	1.95a	0.561b	2.13e	0.477f
Semi-indirect, 1 unit, diffusing bowl, clear lamps.	C	60.3a	0.768d	1.83e	0.593f
Indirect, 1 unit plaster bowl, clear lamps	D	65.1c	0.280d	1.32e	0.263f
Indirect, 4 units, mirrored glass, clear lamps	E	60.2a	1.040b	2.52e	0.461f
Direct, 4 units, prismatic, bowl-frosted lamps	F	3.59a	0.995b	2.67e	0.782f

Table 3.

Surface	Reflection coefficient, per cent: Relative to white blotting paper as obtained by brightness readings.	Absolute
White blotting paper	100	77
Walls in standard offices	53	41
Ceilings in standard offices	76	59
New factory white paint, worst	90	69
New factory white paing, best	110	85
New white finish plaster	120	92

It is possible with the best white paint to obtain a coefficient of reflection as high as 85 per cent. Measurements on new white finished plaster surfaces showed coefficient of reflection as high as 92 per cent. Therefore, with the very best possible conditions, as regards ceiling, the illumination of the indirect systems could be raised more than 50 per cent. The semi-indirect systems could, of course, be made to shew nearly as great an increase if the best possible ceiling surfaces were used.

Table 3 is a summary of reflection data for all tests.

The lighting of rooms of a character similar to those tested involves not only the illumination of the working plane, but many other considerations such as the lighting of the walls, the elimination of dense shadows on the desks, etc. Utilization efficiencies given apply strictly only to this one size room with the same character of walls and ceiling. They are not representative of what may be obtained with larger spaces, an example of which appears later in the paper. However the size of the room and the finish of walls and ceiling represent a fair average of office buildings in general.

From Table 1 it may be seen that the four 100-watt direct prismatic units gave an average illumination of 5 foot candles, which is higher than for any ofhthe others. Since the wattage in each test was the same, the prismatic units gave also a higher efficiency. Table 4 shows the wattage which would have to be used to obtain the same quantity of light on the 30-inch plane.

The differences in the direct, semi-direct and indirect systems of lighting would, of course, be decreased if the ceiling were of a high coefficient of reflection. Even though the coefficient of reflection of the ceiling is only 50 per cent., it has been termed a good white ceiling by many observers, and so perhaps does not differ greatly from the average ceiling used in semi-indirect and indirect systems.

Table 4

Description.	Test.	Wattage necessary to produce an intensity of 5 foot-candles.
Direct, 4 units, opal glass, bowl frosted lamps.	A	109
Semi-indirect, 4 units, opal glass, clear lamps.	B	186
Semi-indirect, 1 unit, diffusing bowl, clear lamps	C	157
Indirect, 1 unit, plaster bowl, clear lamps.	D	209
Indirect, 4 units, mirrored glass, clear lamps	E	189
Direct, 4 units, prismatic bowl-frosted lamps	F	100

A **Metal Housing**--Made of steel. White porcelain enameled.

B **Yoke**--Made of heavy spring steel. It supports the metal holder and the deflector. The latter deflects the heat of the lamp from the lamp base and socket.

C **Metal Holder**--Supported by the yoke. Outlets provided in its upper rim for the exit of superheated air.

D **Reflecting Dome**--Made of opal glass. Gathers the upward rays of light, softens and distributes them. Permits just the right amount of light to filter upward to the ceiling, preventing shadows, black rings and bright spots.

E **Air Intake**--Plenty of cool air enters this small opening and drives all super-heated air through the outlets in the holder.

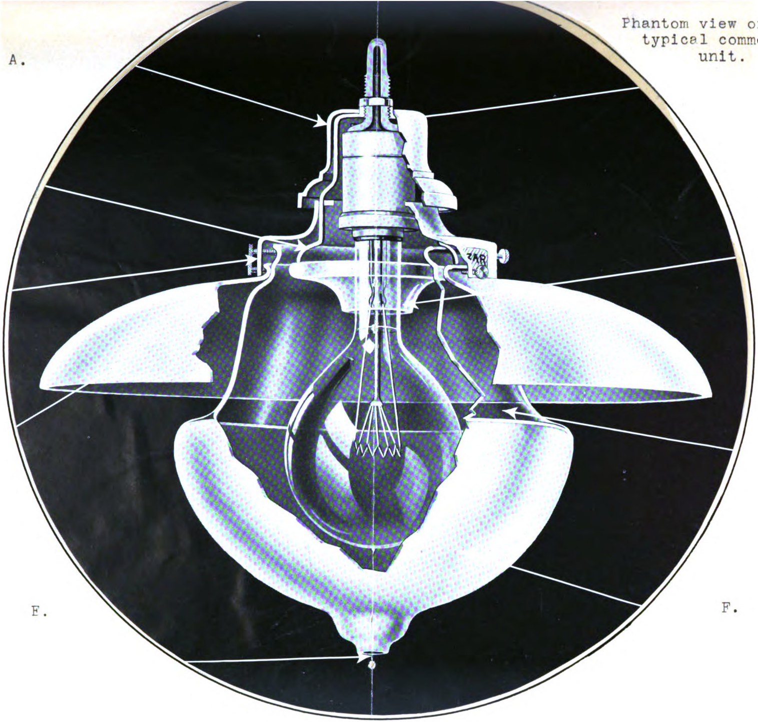
F **Adjustable Hanger**--Allows the easy adjustment of the lamp to the proper position without removing the glass ware or any part of the unit.

G **Deflector**--Made of steel. White porcelain enameled. Checks all wasteful light. Catches the upward rays and redirects them toward the working plane.

H **Upper Part of Bowl**--Permits all the upward rays from the lamp and the reflected rays from bowl, to reach the reflecting dome in full strength. Prevents accumulation of dust and dirt.

I **Lower Part of Bowl**--Conceals the lamp filament from the direct line of vision and eliminates glare of the lamp.

Phantom view of
typical commercial
unit.



SEMI-ENCLOSING UNITS are justly popular for the lighting of nearly all classes of interiors. They present a good appearance and are in general very efficient. They also provide a good diffusion of light; but are not, however, as satisfactory for the lighting of offices and drafting rooms as the totally indirect or dense semi-indirect units, which should always be employed in these locations when the ceiling conditions permit. These units are nearly always preferable to light density semi-indirect fixtures in an office.

Some of the latest developments in semi-enclosing fixtures have been in the direction of one-piece construction for the bowl and the reflector, the unit being blown from clear glass, and having the upper and lower portions enameled white with a clear section between. To be most satisfactory, fixtures of this type should have a fairly large bowl of considerable density so that the brightness may not be excessive. Those units with the greatest number of vital surfaces exposed to dust accumulation will, of course, show the most rapid depreciation in service.

THE ENCLOSING GLOBE and the light density SEMI-INDIRECT units function to produce a general effect of brightness over the entire area to be lighted, including the side walls and the ceiling, rather than to concentrate the light on some specified "working plane". These units find their principal application, therefore, in the lighting of main floors of stores, hotel lobbies and similar locations.

SEMI-INDIRECT units of dense glass and TOTALLY INDIRECT units are applicable to the locations mentioned above, and in addition are the best units available for the lighting of offices, drafting rooms, reading rooms, auditoriums and all similar locations where a well diffused and non-glaring light is required. A ceiling of high reflecting power, that is, white or nearly so, should always be provided where this form of lighting is to be used, as its efficiency is entirely dependent upon the proportion of light which the ceiling reflects.

DUPLEXALITE units are applicable to many different conditions and requirements and may be used wherever indirect or semi-indirect lighting is appropriate, including drafting rooms. Duplexalites should only be used, however, where there is a light ceiling, as most of the light is deflected upward. Duplexalites present a very pleasing appearance when used either alone or with shades or other fabrics. R.C.Kinney.

CHAPTER VI

THE LIGHTING OF OFFICE BUILDINGS

(Illustrated by Example)

Introduction

There is no doubt that a fruitful field for imporvement exists with this class of service. Recent tests have proven beyond a shadow of doubt a condition that engineers have recognized for a long while: that proper high intensity lighting increases production.

In the industrial plant with high intensity illumination, the workman has an increased quickness of perception, He sees all parts of the machines with ease, he does not lost time hunting about in shadows for the next piece of work or tool, he is not fatigued through eye strain and he has the confidence which always comes with clear visual conditions.

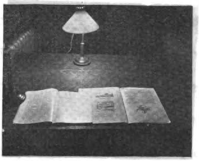


Fig. 1. Illustrating the effect of specular reflection from a polished surface. The book at the right has matt paper, the one at the left glossy. The camera is placed at the position of the eye. It is impossible to see the printing on the glossy paper.

The same general conditions prevail in the office, altho they are not as universally recognized. 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 eypewriter or ledger, eye strain is introduced. These effects are partidularly 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 text books and handbooks shows the average values set down as desirable to be between three and four foot-candles.

You can,of course see to read or typewrite with less than one half a foot-candle, but severe eye strain is intrduced, 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.

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 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 position of the lamps by tying the wire to some stationary object, a practice which is objectionable from the standpoint of safety and forbidden by the wiring codes.

Local lighting is objectionable as there is a great liabilit 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 r est 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 wall out of the ordinary angle of view, equipping them 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, t at general illumination is a real economy, all things considered, in comparison with local lighting.

Good office lighting provides a high intensity of light. Lamps are so arranged and equipped that annoying shadows are avoided. There must be no objects of hight brightness in the field of view to distract the attention and fatigue at the eye. Undue contrast between light sources and the background against which they are seen or between any adjacent surfaces in the field of view is objectionable.

The Mazda C lamp on account of its high efficiency, low maintenance cost, convenience of control, steadiness, pleasing color of light and wide range of sizeds available, is practically the standard illuminant for office lighting.

The types of auxiliary glassware or reflectors now standard are many varying from the efficient prismatic and mirrored glass types to the purely decorative light density opalescent enclosing units which have practically no reflective properties. A reflector is required for two purposes: in the first place, all commercial light sources are far too bright to be looked at for any length of time, hence the light rays must be broken up or diffuese, or ase the eyes protected entirely from direct light. The other propertyof the reflector is to send the light in a certain direction, making the lighting system as efficient as possible by directing the light where most needed.

The question of the proper color of walls and ceiling is of such importance that it was deemed advisable to treat it rather completely in a spearate chapter II.

Comparison of Systems of Lighting.

There are now three methods generally accepted of supplying the light, known as direct, semi-indirect and totally indirect. With direct lighting a reflector is placed above the lamp, or an enclosing globe around it, sending the larger part of the light at once to the desk level.

A semi-indirect unit consists of a translucent dish, bowl or reflector placed below the lamp, sending most of the light to the ceiling, from which it is reflected downward, but allowing part of the light to be duffused through the glass.

A totally indirect unit consists of an opaque reflector below the lamp, sending all of the light to the ceiling.

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 improperly 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 stand point of aglaring installation. The light is usually 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.

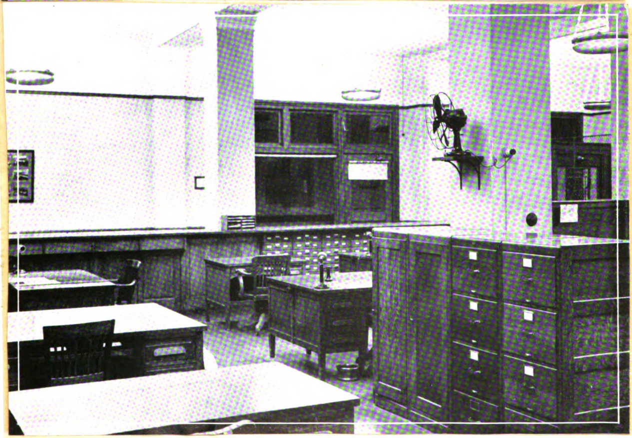
Semi-indirect lighting is an intermediate practice; it is more efficient than totally indirect and much better for the eye than the average direct-lighting system. Semi-indirect lighting is not glaring if the proper unit is chosen it ca be made very decorative, the light is quite evenly distributed and 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 protion 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 manner 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 farily narrow angle resulting in a ring or circle of very bright illumination on the ceiling directly above the unit with the spaces between units 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 c cream, to secure the maximum efficiency or reflection.

The following table gives the approximate percentage of light, generated by the lamps, which may be expected to reach the desks under different conditions in rooms of average size, say, above 20 by 20 ft. These values are called utilization constants. The method of applying them to a specific problem will be found in Bulletin Index 13.

Ceiling	Light		Medium	
Walls	Light	Medium	Light	Medium
Prismatic glass direct	0.60	0.53	0.52	0.48
Opalescent glass direct	0.50	0045	0.44	0.42
Totally indirect	0.32	0.30	0.23	0.20
Semi-indirect	0.38	0.34	0.28	0.24

Spacing of Outlets

Many rules will be found in textbooks and handbooks as to the spacing of outlets equipped with different types of reflectors. The ratios given between hanging height and distance apart take into consideration the securing of uniform illumination. Uniform illumination, however, is not the only factor which must be gimen consideration. For example, with extensive reflectors, the statement is made that they can be spaced twice as far apart as their distance above the working plane. In other words, with a 10-ft. ceiling, a maximum spacing of approximately 14 ft. would be permissible. Direct lighting units on 14-ft. centers in a room with a 10-ft. ceiling would not provide satisfactory office lighting. The shadow iffects would be too great. For satisfactory illumination, it is desirable to have the illumination on a given desk or table received from several sources. This introduces what might be termed "cross lighting" and tends to eliminate shadows.

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 n necessitate the dividing of the larger 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 ofopening the ceiling for rewiring.

In cases where an unsymmetrical arrangement of outlets is necessary, they should be located relatively nearer the windows, than the outside 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 windows.

It is very rare 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.

Modern practice for large clerical offices supplies the following approximate wattage per square foot:

Direct lighting with efficient dense opal or prismatic reflectors and bowl frosted or bowl enameled Mazda C lamps, 1.25 to 1.75 watts per square foot.

Direct lighting with semi-enclosing units such as the Ivanhoe Ace, the Brascolite, the Denzar, the pour-in-one unit, etc., with clear Mazda C lamps, 1.5 to 2.0 watts per square foot.

Semi-indirect, dense,opal or mirrored glass totally indirect units with clear Mazda C lamps, 1.5 to 3 watts per square foot.

Where work is likely to be done with faint figures requiring close scrutiny, the higher values apply. Light ceilings and walls will give the maximum illumination with a given expenditure of power.

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

For provate 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 offices where glass tops are used on the desks, particular attention must be paid to the type of lighting fixtures to avoid reflections.

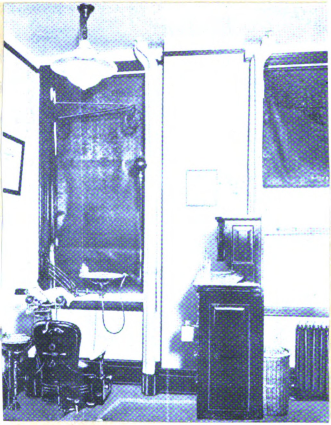
Lighting of Corridors.

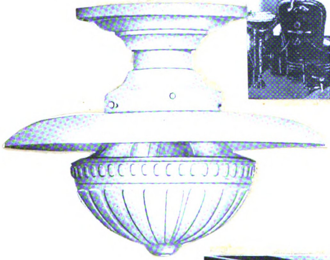
The primary function of corridor illumination is to rpovide enough intensity for anyone to pass along without danger of stumbling or interfering with another pzerson. This, of course, can be accomplished with low candle-power lamps spaced quite widely and equipped with diffusing glassware or reflectors, giving a wide spread of the light, as uniform illumination is not necessarily essential. This arrangement, while satisfactory for an industrial plant or basement, however, does not fulfill the conditions as they ordinarily exist in the large office buildings.

The important feature of corridor, entrance and lobby lighting is its advertising value. If the prospective tenant gets a favorable opinion of a buildigg on entering its attractive lobby, the desirability of renting in that building is impressed upon his mind. The lighting fixture is one of the vital parts of this equipment. Brightly lighted lobbies and entrances, through which everyone must pass several times a day, are not only desirable but from this view point essential. The lighting should supplement the architectural decorat ons and not appear merely as a makeshift.

Not only is the drawing power of good illumination a factor, but a fair intensity of light is really needed, for it is necessary to dëstinguish the mumbers of the rooms and read the names of the occupants. For this reason lighting units should be located in fromt of the doors which will made the maximum spacing not over 20 feet.

Most buildings are so constructed that the partitions along the corridors are o translucent or ribbed glass. The lamps placed in the hallways assist in the office lighting and are particularly valuable in building up the illumina-





tion in the darkest part of the room, namely, opposite the windows.

A row of outlets, symmetrically spaced along the center line of the ceiling, is generally to be preferred and any of the three systems, direct, semi-indirect or totally indirect, will prove satisfactory. Which one is used will depend largely on the office lighting itself, for it is advisable to have the building harmonious throughout.

Often the building is so laid out as to make ceiling outlets inadvisable. In this case bracket or wall fixtures must be employed.

Chairs for the reception of salesmen or other visitors are often located in the corridors. One usually attempts to read while awaiting an appointment and if adequate lighting is not provided this is difficult, and time drags heavily with resultant irritation.

Miscellaneous Uses of Light.

The uses of light in and about an office building are many, and it is impractical togo into detail on all of these.

Electric signs on the exterior of the building cause it to become well known , and the value of the sign has been demonstrated before now. A number of the prominent office buildings have their names outlined in glowing lines of flame visible for miles. The electric sign is also most useful in the building itself, designating the direction of offices, exits, elevators and the like. The subject of sign lighting is discussed at length in a separate Bulletin Index 92.

Floodlighting has come to the foreground very rapidly in the last few years, although many important installations were made some time ago. For example, the Singer Tower strikingly illuminated by arc projectors, is recognized as one of the beauties of Greater New York. Properly designed Flood lighting illuminates the entire exteriof of the building to the proper intensity, causing it to stand out against the dark background formed by the sky. Recent developments in incandescent lamps have made flood-lighting with incandescent lamps very practical and some of the most prominent buildings in the country are so illuminated. For example, the Woolworth Building on Broadway, New York City. This field of lighting, also, is treated in another publication, Index 93.

Safety demands that the stairways be well lighted. It is advisable to provide an outlet at each landing. Medium sized lamps are adequate and should be equipped with diffusing glass ware of a decorative nature.

Elevators should, of course, receive attention, for unless the floor and edge of the car is clearly visible there is danger of stumbling, for the general illumination of the car itself, it is customary to provide a diffusing glass hemisphere at the center of the roof of the car, equipped with two small lamps; then, if one should fail the other will still be in service. There are a number of methods in use in the most recent buildings of illuminating the edge of the car. One of these consists in having aperforated plate with glass insets and lamps below the floor shining up through this plate; another scheme is arranged so that when the car is stopped a small lamp, enclosed in a reflecting device at the side of the door, is turned on, sending a beam of light across the floor.

The operating departments presnet problems akin to the machine shop, wood working plant and the like, which subjects are fullyi discussed in Bulletins Index 62 and 63.

It is not practical to go into details of wiring or to specify methods of providing auxiliary outlets, but it should be borne in mind that the uses of electricity are diversified; convenient side wall and baseboard receptacles are necessary for the attachment of e ectric fans, portable lamps, small motor devices, vacuum cleaners and similar apparatus.

Electric incandescent lamps are used in many places for signaling devices as demonstrated in the elevators, and it is often advisable in the busy office to install communicating systems where miniature lamps light up when the person is called, thus doing away with the annoyance attendant on the ringing of a bell or buzzer.

Example No. 2.

It is desired to replace the present lighting system with up-to-date lamps and fixtures in a high class confectionery store where a particularly soft well diffused illumination is desired. The dimensions are as follows: Length, 100' width, 20'; height, 15'. This store has light walls and ceiling, and one row of outlets down the center, spaced 20' apart.

The solution of the problem is as follows:

a. The Duplexalite equipped with ornamental shade is chosen as a suitable unit for this store.

e. Area of floor is 100 x 20 or 2000 square feet.

f. Number of square feet to be illuminated by each unit is 2000 ÷ 5 or 400

g. The Classification Table,#13 indicates that the lowest intensity desirable in a store of this kine is 4 foot-candles.

h. Referring to the Table #17 or Watts per Square foot for Duplexalites we find that a room with light walls and ceiling, having one row of units, for an intensity of 4 foot-candles, requires 1.25 watts per square foot.

400 x 1.25 = 500. This figure indicates the wattage of lamps to be used. Therefore, five 500-watt Mazda C lamps in the proper size of Duplexalite are specified.

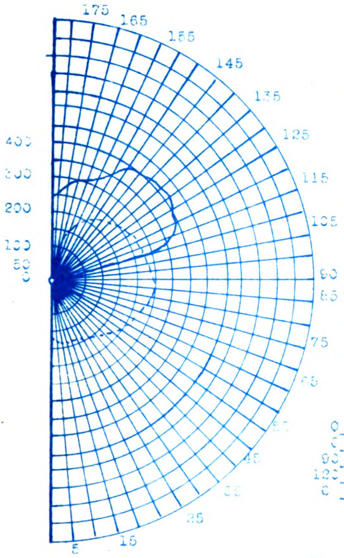
i. The width of the store and the spacing distance between outlets are both 20 feet, therefore referring to the Spacing-

Ceiling Height Table for Indirect, Semi-Indirect, and Duplex-alite units #12, we find that the ceiling height should be at least 16 feet.

In this case the ceiling heightis only 15 feet, and the spacing ratio is slightly exceeded, therefore, the illumination will not be uniform but will be satisfactory for this kind of a store.

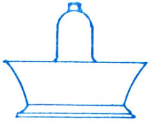
Duplexalite
Lamp - Mazda C
Rotating unit
Test distance 10ft.

POLAR GRAPH OF DUPLEXALITE UNIT



Angle	Candle-Power	Zone	Lumens
0	133		
5	147	0_10	14
15	141	0_20	54
25	134	0_30	116
35	119	0_40	191
45	94	0_50	264
55	71	0_60	328
65	47	0_70	375
75	27	0_80	404
85	19	0_90	425
90	9		
95	21	0_100	450
105	310	0_110	737
115	399	0_120	1128
125	420	0_130	1503
135	411	0_140	1821
145	393	0_150	2068
155	316	0_160	2214
165	302	0_170	2300
175	259	0_180	2325

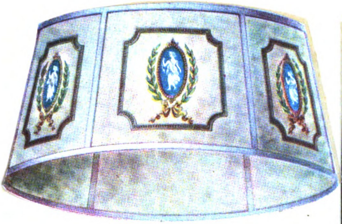
Zone	Lumens	%Total Clear Lamp	Mean C.P.
0_60	328	10.6	104
0_90	425	13.7	68
90_180	1900	61.3	303
120_180	1137	38.6	381
0_180	2325	75.0	185.

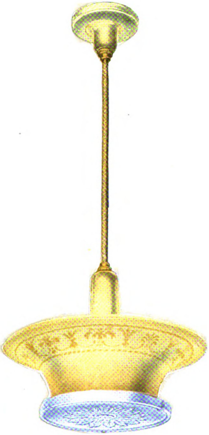


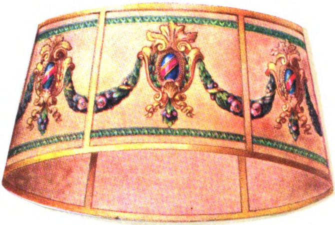
Outline of type of unit used for test.

(The above data was taken from the Duplexalite Cat.).

R.C.Kinney







Example

It is desired to design the lighting system for the main floor of a department store which measures 150' long by 100 feet side, ceiling 16' above floor, finished in white, four beams running lengthwise of the store and six running crosswise divide the seiling into 35 bays, each measuring approximately 20 ty 21 1/2 feet. The store is located in the main business district of a large city and the management is favorably impressed with the appearance of a semi- indirect lighting unit of medium-density glass, which, in addition to providing well diffused illumination, will give to the store a bright and attractive appearance.

By reference to Table 13 it is seen that from 6 to 10 foot-candles is the desirable range of intensities for the main floor of a department store. Since t is store is located in the principal business district, the latter figure will be selected.

Multiplying the length of the store by the width, the area is found to be 15,000 square feet. Multiplying this result by 10, the foot-candle intensity desired, it is found that 150,000 lumens will be required on the working level. The fraction of the total light from the lamps which is effective when medium-density semi-indirect units are used in a department store with ceiling and walls of the usual tones, is found from table 2 to be 0.45. Dividing the number of lumens required on the working level, 150,000, by this fraction, the number of lumens which the lmaps must give is found to be slightly in excess of 333,000. In order to compensate for the decrease inlight from initial to average output of the lamps, this value is increased, by 10 per cent, to 366,300. A further allowance of 10 per cent is made for decrease in light due to the accumulation of dust, so that the bare lamps required for the installation should initially provide 403,000 lumens.

The fact that the ceiling of this store is divided into rectangular bays, makes it desirable to provide a symmetrical arrangement of units with respect to each bay. The simplest and probably the most attractive method is to install one unit per bay, provided that sufficient uniformity of lighting will be obtained. If one unit is to be used to each of the 35 bays, each lamp must supply 11,500 lumens. Upon referring to Table 6 it is found that the 750-watt Mazda C lamps, giving 12,800 lumens, comes the nearest to fulfilling the requirements, and this lamp is selected.

As previously explained, the ceiling acts as the light source in indirect lighting and the maximum spacing permissible between units depends upon the ceiling height. In the problem at hand, the ceiling height is 16 feet, and the height above the working plane is 13 1/2feet. By reference to Table 10, it is seen that for this height the spacing between semi-indirect units should not exceed 21' 6" if uniform illumination is to be obtained. Since the maximum distance between units if one is placed in the center of each bay is 21 1/2 feet, the requirements for uniformity are sufficiently well fulfilled.

How far the units would be suspended from the ceiling would be determined largely by considerations of appearance; this would involve not only the appearance of the unit with respect to the store as a whole, but the appearance of the ceiling with the units lighted. Shadows of chains and of the bowl upon the ceiling if pronounced could be eliminated by etching the lamps.

Example Case 2.

Character of work---general office

Floor dimensions--30 ft x 45 ft.

Ceiling height--13 ft.

Columns--15 ft. centers.

Color of walls and ceiling--light

Type of reflector equipment selected--deep dish, dense opal, semi-indirect fixture.

Considering a bay as a room, the dimensions are 15 ft. by 15ft. From Table 10 the maximum spacing for a 13-ft. ceiling is 16 ft. and so one outlet per bay may be employed. From Table 12, the minimum suspension below the ceiling for the units should be 28"

To determine size of lamp:

15 ft. x 15 ft. = 225 sq. ft. - area for each lamp.

Foot candles desirable for this class of work from Table 13 equals 10. From table No. 14 for more than one row of outlets and light surroundings, it will be found that 2.2 watts per sq. ft. will produce 10 foot-candles with this equipment.

225 x 2.2 = 495 watts per lamp.

The lamp to be seledted is, therefore, the 500-watt clear Mazda C lamp.

Chapter VII

STORE LIGHTING

Utilization of Light

Satisfactory store lighting depends primarily, upon a correct utilization of light. There must be sufficient light and it must be efficiently utilized. This requires a study of the lighting requirements of each store before deciding upon any special system of illumination and its application. It is important to illuminate every store so that the general effect is one of brightness. No merchant can afford to economize to such an extent that the interior of his establishment appears gloomy and uninviting. There is no justification for such unsatisfactory lighting and in most cases it will be found that the store is dark because half the light is wasted.

The Quantity of Light Required.

Conditions are frequently encountered where satisfactory lighting cannot possibly be obtained without increasing the number or size of lamps. A very good general rule to follow is to allow one watt for each square foot in an interior of average size with a light ceiling. In this way an interior representing 500 square feet would require as an absolute minimum 500 watts, and this wattage would be distributed in accordance with the architectural and structural conditions of the intetor or according to the location of the outlets, if these had been previously located. In some interiors of this area, one 500-watt lamp would suffice. Again, two

250-watt lamps or five 100-watts lamps might be properly used, according to the ceiling height and system of illumination employed.

Cause or Effect

Effective store lighting, independent of any particular system, depends largely upon the elimination of glare, and this necessitates the modification of the brightness of the source itself before it ispossible for the eye to see distinctly. The lower the ceiling the greater necessity for glare elimination. No installation with exposed lamps can be termed efficient or effective in the slightest degree, since the influence of lighting on the eye is the most vital issue involved. This desiredmodification of xxxxxxxx source brilliancy is accomplished by enclosing the lamp with glassware which has diffusive and redirective effect, according to the manner in which it is employed in the various systems of lighting known as direct, indirect, and semi-indirect.

Direct Lighting.

Many stores are equipped with fixtures composed of stems terminating in cross-arms to which pendent or upright sockets are attached. Such installations are quite prevalent and the glassware which is usually a part of fixtures of this type is quite invariably "ground" or etched, possessing practically no glare-eliminating or light-redirecting properties and is neigher useful ororamental. These fixtures, however, can be modified to give satisfactory illumination by substituting good diffusing glassware of opal in various forms.

Changing from spheres of ground glass to spheres of opal glass will effect a marked improvement, when fixtures are hung so low that the lamps are directly in the visual field, and with higher fixtures the use of the shades of opal glass redirect the light downward and upward. These opal shades may be obtained in various densities. The dense opal shades may be obtained in various densities. The dense opal allows verylittle light to pass through towards the ceiling (reflecting or diffusing more downwards from the inner surface) and is appropriate for interiors with ceilings which are not in the best of condition, or those having wiring in mouldings or inactice outlets. The tendency of such shades is to concentrate the light beneath the shade, so they are not suitabble for interiors wit very low ceilings. They may be obtained in shapes which give a wide eistribution of light, but the flaring mouth of these shades exposes the filament of the lamp and unless the installation is made with the utmost care it is diffĭcult to avoid glare.

Under no curcumstances should lamps project so far below the shade as to expose the filament to view, resulting in glare and non-utilization of light. If it is not possible to obtain an up-to-date fixture, it is always possible to use glassware which possesses some character. A very ordinary fixture can be improved by globes of simple design which look equally well lighted or unlighted. The better rypes of these globes have designs in bas-relief which stand ou' sharply when the globe is lighted, owing to the varying thickness of the glass.

It is not expensive to have special designs or trade-marks rendered on such globes, and if a few dozen are ordered the cost per globe is only a few cents extra. Designs are sometimes painted on the surface of opal glassware, but they are not permanent and will not stand washing.

Lanterns can be made of wood or metal with glass plates and hung from chains or placed on side brackets or pedestals. Direct lighting application s of this sort are made possible and practical only through the recent developments in the manufacture of Mazda C lamps.

In stores where the interior cabinet work is carefully planned, the designers can include such lanterns in their scheme and make them harmonize with the surroundings most effectively. Glass plates of opal glass should be set in frames (exactly like window glass) and the Mazda lamp centrally placed within. Under no conditions use clusters of small lamps for such applications. The single unit is more efficient and effective. The entire success of any direct lighting application, like any other application, lies in creating something distinctive and different. For this reasonit is absolutely impossible to select any certain type of figures suitable for all stores.

In some instances in very large interiors, direct lighting fixtures consisting of frames, forming globes, or other figures, are a pleasing departure from the conventional, providing the lamps are applied in an effective way.

The usual custom, in vogue fifteen years ago, of "studding" such fixtures with bare bulbs is to be avoided. It makes the fixture look like an electric sign with its rows of lights spaced at close intervals. A better way is to use larger lamps, at less frequent intervals, incased in globes of decided character. Still a better way is to utilize panels of glass in combination with the metal frame, placing lamps behind the panels so as to illuminate them evenly.

Semi-Indirect Lighting.

The novelty is beginning to wear off from semi-indirect lighting, and now that the market is flooded with such equipment discriminating buyers demand fixtures which are distinctive and not commonplace. There is really no justification for installung commonplace equipment, since the best fixture manufacturers have provided a great variety of distinctive desggns which are decorative without being ornate or tawdry, and effective through their simplicity and beauty.

Fixtures for store lighting should be in sympathy with their environment. The elaborate fixture is out of place in plain surroundings but, on the contrary, the simple fixture is o ten quite appropriate for the over-decorated establishment. In either case the fixture should never be predominant unless intended to be featured as an advertisement.

With semi-indirect or indirect bowls or dishes, fixtures which eliminate thechain support, afford a contrast to the commonplace. The glassware can be obtained in any vafiety of design to meet any requirement. The best designers are discarding the bowls of glass for fixutres formed of glass and metal, the glass being bent to conform with the fixture lines. In this way it is possible to insure individuality and distinctiveness.

Lamp Usage.

When bowls ar dishes are used, the best results are obtained from single Mazda lamps in larger sizes rather than clusters of smaller lamps, except in very shallow or very large bowls designed to illuminate large interiors. The wasyed light between lamps and inadequate redistribution are the principal objections to the "cluster".

Redirection of Light.

In semi-indirect or indirect applications reflectors, within bowls or dishes, are necessary to obtain efficient utilization. These may be formed of metal with reflecting surfaces o aluminum or white enamel. The unbreakable kind are naturally the most desirable. Their use eliminates waste of light and prevents excessive luminosity or brightness of the bowl's surface, which very often causes such obliteration that an expensive piece of glassware resembles anordinary bowl of "spotty" ground glass.

In some cases translucent reflectors can be used advantageously within bowls to bring out the design and at the same time direct the light upwards. These reflectors give best results when shaped to concentrate light on the ceiling, directly above the fixture.

Over-bright spots on the ceiling can be eliminated by proper hanging, but with verylow ceilings, it becomes necessary to employ reflectors giving a wider distribution in order to eliminate the spotty effect.

Indirect Lighting.

The indirect system of illumination possesses many advantages, but it should not be regarded as the best solution for every lighting problem. Diamonds, for example, and other classes of merchandise, require direct rays of light or their sparkâà and appealis lost.

The conventiànal mode of indirect lighting consists of opaque bowls (deep or shallow) suspended from chains secured to ceiling canopies.

Many objections have been raised to the unnatural appearance of a dark,non-lumonous fixture body contrasted against a bright ceiling. This objection, however, is spacious only when applied to installations which have not been carefully designed. As previously stated, the floor, like the ceiling, reflects more or less light according to its color.

If the color of the opaque fixture bowl is dark and the floor beââw it is also dark (in color), very little light will be diffused upwards by the floor and the detail or design on the exterior of the opaque fixture bowl will be lost in a mass of shadow andis neither useful nor ornamental. The correction lies in the substitution of any good diffusing glass (such as opal), effecting a marked improvement in the way of distribution and diffusion, not to mention glare elimination.

Lighting Glassware.

The shape of such glassware has a great deal to dowith the utilization of light. If spheres are used, the light transmitted through the upper and lower hemispheres is about equal, but the downward light illuminates the merchandise directly, whereas the light transmitted upwards through the upper hemisphere of the sphere strikes the ceiling and is then partially sedirected downward, with considerable loss due to the absorptionof the glass and the ceiling. This loss is greater than in the sase of semi-indirect lighting where only the lower hemisphere in the form of a bowl or dish is used, allowing thelight from the lamp or lamps (within) to pass directly to the ceiling.

Totally Enclosing Globes.

When globes are used which entirely enclose the lamp, better results can be obtained by employing larger Mazda lamps in large opal globes instead of groups of smaller lamps in individual globes. Direct lighting is by no means obsolete, and one of the largest new buildings in New York City, the Equitable, has adopted that system in preference to the ~~individual globes~~. indirect or semi-indirect. Furthermore, the improvements in lamp manufacture are constantly increasing the efficiency of Mazda lamps, even in the smaller sizes, to such an extent that quite satisfactory results can be obtained by applying them to fixtures such as previously described, providing good duffusing glassware is used.

The Ceiling Outlets.

Generally the ceiling outlets have been assigned, and it remains to make the best of them. With any system of lighting necessitating the suspension of fixture from ceilings, too frequent spacing of outlets must be avoided, owing to the utter monotony which results in congestion and confusion. Less frequent spacing with larger lamps is preferable, and the ceiling then becomes less of a distraction factor and vastly less conspicuous, making an interior seem bigger and brighter.

Ceiling Treatment.

More or less light always reaches a ceiling. Unless the flooring is very dark it will redirect a considerable percentage of light upward, and so will the merchandise and fittings. Many ceilings are not good tolook at in a revealing light.

It has been determined that the intensity of light on side walls need not exceed one-fifth to one-third of the intensity on the working plane (an imaginary plane surface generally two feet six inches above and parallel to the plane of the floor). Unless a ceiling possesses good ornamentation, which should be accentuated for decorative reasons, the intensity thereon with direct lighting should be sufficient to dispel gloom, but not high enough to expose a mass or unornamental piping, wiring, fire nozzles, and similar ugly contraptions. These defects become undesirably prominent with indirect or semi-indirect lighting, and the correction lies in eliminating the offensive contrasts by painting or tinting all projections the same color as the ceiling, thereby rendering them quite unnoticeable.

Very often an otherwise attractive interior is marred by such a ceiling. To avoid this obliteration, light-colored fixture bowls should be used over dark-colored floors. On the contrary, the design of a very dark opaque bowl will be very clearly expressed if the bowl is suspended over a light-coloredfloor, owing to the greater quantity of light reflected upwards by the floor. Like indirect lighting or semi-indirect lighting of conventional design, too frequent spacing of outlets gives an aspect of monotony. Similarly, it is best to avoid groups of small lamps, using in preference, as single units sizes ranging from 100-,150- and 250-watt Mazda B lamps to the larger sizes of the Mazda C lamps. A great variety of fixtures may be obtained to conform with all sizes of Mazda lamps.

Light and Advertisement

The greatest value of indirect lighting lies in its advertising value, as a means of illuminating any store where light-colored ceilings prevail. Mazda lamps and their reflectors may be concealed within urns, behind recesses in side walls, in pilasters or on torches above show cases and clothing racks, in vases, indeed there is no limit to their adaptability. The absence of the conventional hanging fixtures is so marked that the unique effect invariably results

Illuminated by the Eye Comfort Lighting System

CAPITOL SAVINGS BANK
Chicago, Ill.

National X-Ray Reflector Co., Chicago and New York in great advertising value.

One very great advantage which indirect lighting possesses over direct is its utilization, quantities of light being diffused broadcast by the ceiling over areas which are quite remote from the source itself. In this way wiring expense is saved and continual changes in the arrangement of display counters or desks do not involve the expensive alterations demanded by localized lighting under such conditions.

Individuality may also be expressed in connection with ceiling outlets by designing special fixtures in accordance with the character of the extablishment, denotéd by the exterior treatment of the fixture. In many instances trademarks can be made a feature of these designs, and thereby impressed forcibly upon the minds of the buying public through the medium of artificial light.

For consideration of their lighting requirements, stores may be divided into four classes:

1. Department stores, and the large specialt stores of our principal cities.
2. Medium-sized stores, including the large stores of the smaller cities.
3. Small select stores and shops.
4. Small stores of the usual type.

In stores of the first named class the lighting requirements are very similar, although the location of stores, their size, and the individual preferences of their owners

will, of course, cause considerable variation in the design of lighting installations. Such stores are usually imposing establishments and the lighting equipment shoudld assist in furthering the impression created by the store as a whole. On the main floor, especially, a high intensity of light and a pleasing appearance of equipment are necessary.

For stores of medium size, in which class it will be noted are included the large stores of the smaller cities, the system provided should possess distinctive and decorative features, but these shoudd be obtained with due regard to the efficient utilization of the light. In the select small store or shop, great freedomis usually permissible in the selection of a lighting system; good appearance and a pleasing effect are the important considerations.

For the usual small store, elaborate lighting is not required; rather, the system should supplyplenty of light efficiently.

No matter what your lighting problem may be, it resolves itself into this one question:

Whatare you really buying? is it fixtures--or illumination?

If illumination is what you want, ?-Ind. Lighting will be your choice.

Managers and officials have long sought for the following results, all of which are secured by the use of the Indirect Lighting system:

1. Increased efficiency of those who work under artificial light.

2. Absence of glare and eye strain.

3. Preservation of the health and retention of the services of valuable employees.

4. Elimination of the cluttered desk lights.

5. A spacious and cheerful appearance of the office room.

6. Absence of dark, dirty-looking corners.

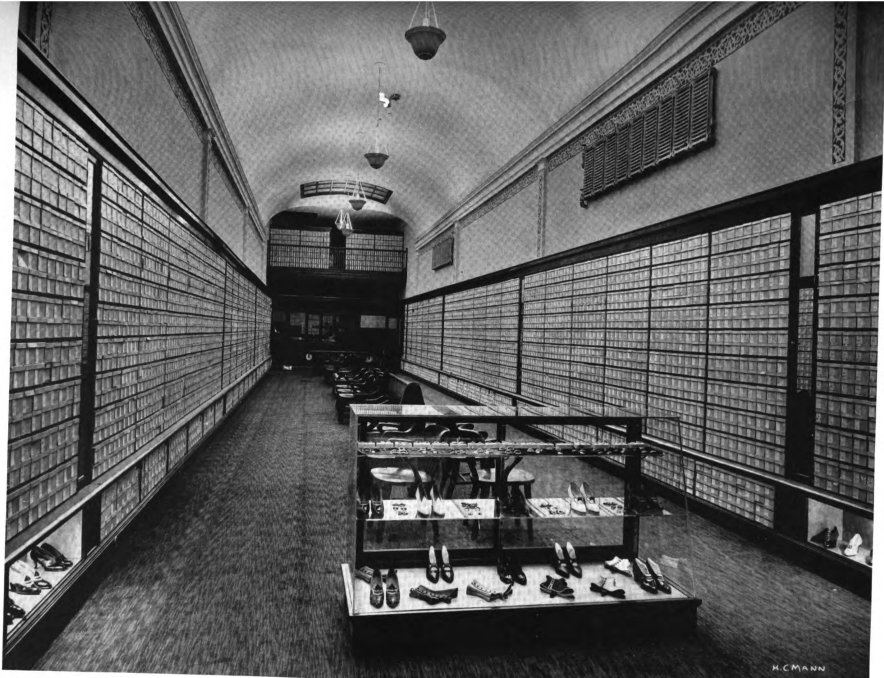
7. Utilization of every square foot of floor space, with arrangement of desks and files independent of the lighting system.

Department and Large Specialty Stores.

For the main floor of a department or large specialty store, a system of enclosing units or of some form of semi-indirect or totally indirect units is preferable to a system employing open reflectors. With the exception of the prismatic type, totally enclosing units do not provide a high degree of light control, and the maximum candle-power is usually in a direction near the horizontal. In order to avoid undue glare, the units should be of large area and highly diffusive. A portion of the light from these units is transmitted directly to the objects beneath, and another portion reaches them by reflection from the ceiling, but the efficiency of an opal enclosing unit system will not be materially higher than that of a good totally indirect system, except where the ceiling is finished in an unusually dark color; for with the opal units a large percentage of the light flux is emitted at angles near the horizontal and never reaches the counters.

Light emitted near the horizontal does, however, serve a very useful purpose in that it illuminates vertical or inclined surfaces, such as shelves, racks, etc., which if lighted only from directly above would be inadequately illuminated. Enclosing units are obtainable in a wide variety of shapes and sizes ranging from very inexpensive to very costly and exclusive designs, which features have led to their common use in all classes of stores. Prismatic-glass enclosing units ppoduce much the same lighting effect as open reflectors, with which they compare favorably in efficiency; they possess however, the advantages of being more decorative and of properly screening the filament of the lampf rom view.

From the standpoint of comfortable vision, indirect and semi-indirect units are more desirable for the main floors of department stores than are enclosing units. With strictly indirect systems, where the ceiling acts as the light source and there is a pronounced downward direction to the light, the uniformity and diffuison of the illumination are excellent glare from the light source is absent, and reflections from plate glass and polished fixtures are avoided; however, shadows, which, if of the proper density, are a great aid in judging the shape and proportions of an object, may be too greatly reduced. The direction of the light, moreover, tends to make vertical surfaces appear poorly lighted. Since the illumination of the room is entirely dependent upon reflected light from the ceiling, the efficiency of the system will be highest if the ceiling is finished in white. However,



Illuminated by the Eye Comfort Lighting System

S. J. THOMAS & COMPANY
Norfolk, Virginia

National X-Ray Reflector Co., Chicago

with the present low cost of light, a tinted ceiling is justified where essential to the decorative scheme of the room or where lighting of a certain color tone is desired.

The luminous-bowl type of indirect unit produces the same gen ral character of illumination as that produced by strictly indirect units, but the auxiliary bowl, being luminous, give s a direct component which assists slightly in illuminating vertical surfaces, and, in the opinion of many, adds to the decorative value of the installation.

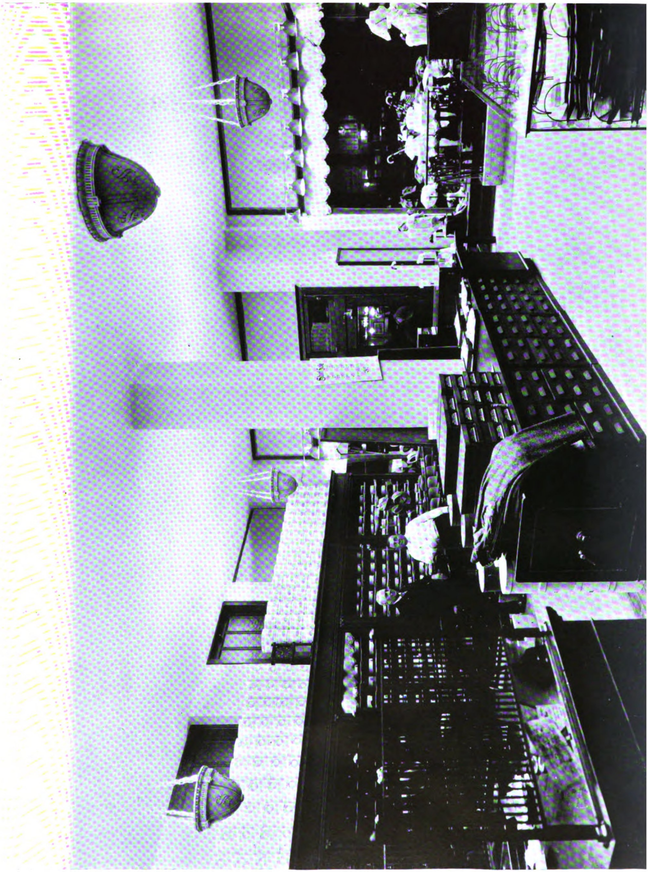
Semi-indirect units of dense or toned glass give an effect very similar to that given by luminous-bowl indirect units, but they transmit a higher percentage of the light, and are, under usual condition, slightly more efficient. With bowls of light density, the results approach more nearly those obtained from opal-glass enclosing units; contrary to what might be expected, however, the semi-indirect system is often more efficient due to the fact that less light is absorbed by the bowl, less light is emitted in angles near the horizontal, and more light is directed to and diffused from the ceiling at effective angles.

It is possible to obtain either indirect or semi-indirect bowls in exclusive designs harmonizing with the decorations and conforming to the tastes of the user; regardless of the design of the exterior, however, it is of the utmost importance that the interior be a hard, smooth reflecting surface in order that good efficiency may be maintained. In an installation which runs into any considerable e xepnditure, it is well worth while to secure the opinion of a competent architect or decorator before determining upon a definite exteriof design.

Lighting units of the same general type as are used on the main floor are suitable for the upper floors of large stores; often a smaller size of the same design may be chosen. In some cases, a well designed direct-lighting system may meet the requirements satisfactorily. With open reflectors, bowl-frosted lamps should always be installed and the units should be suspended at such a height that they will be, as nearly as possible, outside the range of ordinary vision. As previously stated, Mazda lamps of larger than 200 watts should not be used in open reflectors. Semi-enclosing units are available, however, which operate on much the same principle as an open reflector but which are provided with a diffusing glass bowl below the reflector which screens the lamp from view. With such units, any size of lamp may be used. Their efficiency compares favorably with that of the prismatic t pe of enclosing unit. Onall floors, the fixtures should be located symmetrically with respect to the divisions or bays usually formed in the ceiling by the constructional features of the building, unless it is desired to arrange the lighting to enhance some architectural effect in light and shade, or color, in accordance with a skillful designer's well considered plan.

Stores of Medium Size

The lighting requirements of stores of medium size are



the same as those cited for large stores, except that a location amid less impressive surroundings may decrease the nedd for purely decorative features. In this class of store a semi-indirect system employing some form of inexpensive medium-density bowl will often fully meet the requirements of a distinctive and economical installation. A well designed direct-lighting system, such as might be used in the upper floors of large stores, is very frequently deemed entirely satisfactory,--especially where a semi-enclosing unit, of which No. 1, Fig. 1, is a type, is used.

Exclusive Stores.

Exclusive small stores or shops, found principally in the larger cities, lend themselves to an artistic treatment which is impossible in larger areas. In many cases, the use of colored lamps to provide lighting of a distinctive tone is highly desirable, while uniformity of illumination is to be avoided rather than sought. The fixtures may well be of special design but care should be taken to avoid the very common error of allowing too brilliant light sources within the range of vision. Modifications of semi-indirect, indirect, and enclosing fixtures are used almost entirely. A prismatic glass semi-indirect unit has been recently developed which consists of two glass bowls between which may be placed flowered silk, cretonne, or other decorative fabric of any pattern desired. The prisms, which line theouter surface of the inner bowl where they are protected from dust, insure an efficient distribution of the light; the decorative fabric may be changed at will.

Small Stores in General.

Efficiency is the first requirement of a lighting system for the usual small store. A high intensity is necessary for the convenience of customers and for advertising purposes, but the fixtures may be of very simple design. Consequently, direct lighting with open reflectors of the prismatic or dense-opal type, or with a good type of semi-enclosing unit, is, as a rule, most applicable although often the installation of an inexpensive semi-indirect or enclosing unit is preferable.

Semi-enclosing units possess and advantage over open reflect ors in t at they diffuse the light from the filament over a comparatively large area; hence they may be used with any size of lamp, and in locations where open reflectors would cause annoying glare. They possess an advantage over opalenclosing units in that they distribute light in much the same yay as a dense opal open reflector and are therefore less dependent for their efficiency upon the finish of the walls and ceiling.

A common mistake in small store lighting is the installation of a single row of direct-lighting reflectors along the center of the store, where at least two rows of small units should be used to prevent the customer's shadow from interfering with his examination of the wares, and to illuminate the shelving or high cases along the sidewalls. A

single row of semi-indirect or enclosing units is, however, usually satisfactory. An exception to the use of bowl-frosted lamps with open reflectors may be made in the case of small jewelry stores where brilliant reflections in gems and cut glass may be desirable; the units should, however, be placed well above the usual line of vision to avoid glare.

Illumination Intensities.

A lighting installation serves a double purpose: first, it permits the merchandise to be examined with comfort; second, it advertises the store. Light is recognized as one of the least expensive and most effective advertising mediums and hence intensities higher than absolutely necessary for comfortable vision are almost universally demanded. The three factors which govern the selection of an intensity for any particular case are: the nature of the merchandise---for dark goods require a higher intensity than light goods to appear equally well illuminated; the illumination standard of the immediate neighborhood; and, the amount which the owner feels is expedient to apportion for the advertising value of a high intensity. The lower values of any table of intensities should, therefore, be used cautiously and full weight given to local conditions. However, values applying to average conditions are useful as a basis upon which to estimate desirable intensities, and such values are given in Table 1.

Coefficients of Utilization

Intensities of illumination are commonly expressed in foot-candles and are not in themselves measures of the total quantity of light. To determine the quantity of light required to provide a given average intensity, it is only necessary to multiply the area in square feet of the surface to be illuminated by the desired intensity in foot-candles; the result will be the quantity of light flux, or lumens, which must be supplied to the area to produce the desired foot-candles intensity. Obviously, if just sufficient wattage is installed to supply the number of lumens so calculated the illumination will fall far short of the desired value because of the light flux which will be absorbed by the reflector equipment and by the ceiling and vertical surfaces. The proportion of the light flux generated by the lamps which is effective in illuminating the "working plane", that is, an imaginary surface parallel to the floor and at a height of 2 1/2 to 3 feet above it depending upon the height of counters, cases, goods etc., depends upon the type of fixture selected, the color of the ceiling and walls, and the size of the room. Ceilings in stores are usually fairly light in color and the walls are, in most cases, lined with shelves; hence, it is possible to give values for the proportion of light which is effective in illuminating the working plane for various reflector equipments for the different classes of stores. These values, which are called coefficients of utilization, are given, as fractions of the total light of the bare lamps, in Table 2.

Calculation of the Required Wattage

In calculating the wattage required for a certain store the first step is to decide, at least tentatively, upon the type of fixture, in accordance with the general principles discussed above. The second step is to decide upon the intensity in foot-candles which will be needed on thwe working plane; Table 13 will be found helpful in determining this intensity. The third step is to determine the lumens required to produce this intensity; this is calculated by multiplying the area of the room in square feet by the intensity in foot-candles. The fourth step is to divide the calculated number of lumens by the coefficient of utilization, expressed as a fraction; this fraction may be obtained from Table 2. The result obtained will be the number of lumens which thek lamp must furnish to give the desired intensity. In order to take care of the decrease from initial to average light output of the lamps, the number of lumens so calculated should be increased by 10 per cent. A further number should be added to allow for depreciation due to the collection of dust upon the lamps, reflectors, ceiling, and walls. It is fo great importance that a schedule providing for regular and frequent cleaning be adopted, but even where units are cleaned thoroughly once a month, 10 per cent additional lumens should be allowed for dust depreciation. The final value, then, represents the lumens which the vare lamps should provide initially.

The lumens initially given by the Mazda lamps commonly used in store lighting are given in Table 6. With the total lumens known, the required number of lamps of any given wattage may be readily approximated by reference to Table 3.

Size of Lamp, Hanging Height, and Spacing Distance.

Of the lamps which will supply the required quantity of light, the size to be chosen depends upon the ceiling height and upon the type of fixture, i.e., whether the fixture distributes the light over a large or a small area. Enclosing units and open reflectors should, as a rule, be suspended as high above the floor as is consistent with good appearance in order that the light sources may be as far removed as possible from the range of vision. This allowable hanging height determines the permissible spacing of units of any given type for reasonable uniformity of illumination. The maximum ratios of the spacing distance to the height of the unit above the working plane (not above the floor), which may be used with fair uniformity of illumination with the various types of units discussed in this bulletin, are given in Table 10. If greater spacing distances than those determined by these ratios seem desirable, it should be remembered that as the spacing is increased the degree of uniformity decreases rapidly. The greater the permissible spacing distance, the larger the lamps which may be used and the fewer the number required. The fewer the units of a given type, the less the installation and operating expense, but the greater the area affected by the failure of a lamp and the denser the shadows.

However, if the ratios given in Table 10 are not exceeded, no trouble from this source need be anticipated. It should be noted that conditions governing the hanging height and spacing distance for indirect and semi-indirect units are somewhat different since in installations of this type, the ceiling acts as the light source. The hanging height may, in such installations, be chosen from considerations of convenience and appearance but it should be borne in mind that if units are hung close to the ceiling, the areas directly above the units will be brightly lighted in contrast to intermediate areas; this effect may be considered desirable or it may be considered undesirable, depending upon the effect which it is desired to produce. Shadows cast by the bowl of the unit and by the suspension rods or chains may, if considered objectionable, be eliminated by dipping the lamps in an etching solution. The spacing distance is determined by the height of the ceiling since the ceiling acts as the light source.

As previously mentioned, it may be desirable to obtain special light and shade effects in certain instances; where this is the case, the rules given above do not, of course, apply.

Amount of Light Required.

The first step in planning an installation is to determine how much light will be required. The illumination to be supplies in any given case will, of course, depend upon the purpose for which the light is used. An office where people are working continuously requires relatively much more light than an auditorium. A store displaying dark colored merchandise requires a greater illumination than one displaying light colored goods, for dark goods reflect to the eye only a very small proportion of the light that falls upon them. Again, because of the nature of their business, some stores require higher intensities of illumination than others of different character. A jeweler should have brighter lighting than a hardware merchant. Then, too, the location of the store influences the degree to which it should be lighted. In the brightly lighted downtown retail section, more light is demanded than in an outlying or side-street business district.

The fundamental requirements of satisfactory store lighting installations are:

1. Sufficient illumination of uniform intensity over the entire area.

2. Freedom from glare, glaring reflections, extreme contrasts in brightness, and troublesome shadows.

3. A system of good appearance which is simple, reliable, easy to maintain, and reasonable in operating cost.

Two Classes of Installations

In plannigg a commercial lighting installation, one of the two following conditions is presented:

1. Where the building has not been wired previously, or where, if wired, the customer is willing to rearrange outlets, if necessary, to secure adequate illumination. Here the

greatest freedom is allowed in plannigg the installation, which latitude permits thoroughly satisfactory lighting results.

2. Where no change or addition is to be made in existing outlets. In this case one has but to decide upon the proper type and size of unit to replace the present fixtures. The advantage to be gained by changing over is then dependent entirely upon the greater efficiency and diffusion of light furnished by the newer units in comparisen with less modern equipment.

The Planning of Illuminating for New Buildings of for Old Buildings Where Existing Outlets Need Not be Utilized.

a. Choose the type of lighting unit best adapted to the location, with due regard to the several suggestions given in tables.

b. Measure the ceiling height of the room and decide upon the greatest practical mounting height of the lighting units above the floor consistent with the satisfactory appearance.

For Enclosing and Semi-Enclosing Units.

In case the mounting may be close to the ceiling approximately one foot must be allowed as the minimum mountable distance between the ceiling and the center of the lamp filament, as shown.

For Indirect Units.

The ceiling is the principal light source, hence the total distance from floor to ceiling should be considered the mounting height.

c. Refer to the Spacing-Mounting Height Table, or the Spacing-Ceiling Height Table corresponding to the unit selected, and find what the average distance between units should be that will correspond to the mounting height determined upon.

The proper drop from the ceiling for Indirect and Semi-Indirect Fixtures is also shown in the table.

d. Make a diagram to scale of the floor area of the room to be lighted and lay out on it the position of lamp outlets. If the width of the room is not much greater (fr m 2 to 5 feet) than the spacing value just found, one row of outlets down the center will probably be sufficient, unless much work is performed near the walls. Otherwise, the outlets should be laid out in two or more rows in the form of squares, or approximately so (see fig. 2) The distance between units being approximately the spacing distance found in c.

(see blue print at end of chapter)

Fig. 2. Showing how lighting outlets should be laid out to provide a practical degree of uniformity in light distribution. Here each lighting unit is given a definite area to illuminate,i.e., all the space falling within 7 feet from a point directly beneath the lighting unit.

The distance between the outside row of units and walls should not be greater than one-half the spacing distance (see fig.2). For office spaces it should be approximately one-third the spacing distance. (The exception to this is in the case of general offices and other locations where it is essential to have a very good lighting clear out to the walls. Here two or more rows of units are almost always necessary.)

e. Compute the total floor area of the room by multiplying its length in feet by its width in feet (making due allowance for irregularities in contour).

f. Divide the area thus found by the number of outlets. This will give the average number of square feet which each unit must illuminate.

g. Find from the Classification Table, the class to which the lighting installation belongs.

h. From the Table showing Watts per Square Foot corresponding to the type of fixture under consideration, select the column which most nearly describes the interior to be lighted. In this column find the figure (watts per square foot) which applies to the Classification determined in g. multiply this value of watts per square foot by the area to be illuminated by each lamp. The result will indicate the size in watts of lamps to be used.

i. The mounting height of units may be finally corrected for the actual spacing chosen under d. in accordance with Table. In other words, it is not necessary that totally and semi-enclosing units be placed right against the ceiling if the spacing permits a lower mounting height. Also, in the case of units in the indirect class the drop from the ceiling should be corrected according to the spacing-Ceiling Height for the actual spacing distance chosen.

Thus the problem is solved, as size of lamps type of fixture, mounting height and spacing have been determined.

For offices, stores, and other business places, a general system of illumination consisting of regularly spaced outlets and units of uniform size is in almost every case desirable. However, in auditoriums, churches, etc., sometimes more pleasing and decorative effects can be obtained otherwise, although more often a uniform lighting system is used in such locations also.

Case II--Planning an Installation Where Existing Outlets Must be Utilized.

Here, in addition to choosing the type of fixture to be employed it is only necessary to decide upon the size of lamp and the mounting height of the units. Items b,c and d, as determined in Case I, need not here be cauculated.

e. Compute the total floor area of the room to be lighted by multiplying the length in feet by the breadth in feet (making due allowance for irregularities in contour)

f. Divide the area in square feet thus found by the number of outlets. This will give the average number of square feet which each unit must illuminate.

g. Find from classification Table No. 10 the class to which the lighting installation belongs.

h. From the Table showing Watts per Square Foot corresponding to the type of fixtures under consideration, select the column which most nearly desmribes the interior to be lighted. In this column find the figure (watts per square foot), which applies to the classification (g). Multiply this value of watts per square foot by the area to be illuminated by each lamp. The result will indicate the s size in watts of lamps to be used.

i. It now only remains to determine the proper mounting height of the units. For enclosing and semi-enclosing units, when there is only one row of units, take the distance (A) between two units, See Fig. 3, of the width (B) of the room, if this value is larger than (A), find the best mounting height above floor for this spacing.

Enclosing and Semi-Enclosing Units.

If there is more than one row of units, determine the best mounting height, using the larger of the two spacing values, A or A' (see fig. 3). If, as is sometimes the case, the ceiling is not quite high enough tp permit this mounting height, place the units as close to the ceiling as possible. But when the discrepancy between the mounting height indicated by the Table , and the greatest height which the ceiling permits, is large, the number of outlets in the room is not sufficient to make possible a lighting installation which will give uniform and satisfactory light with any kind of lighting fixture. The customer should be urged to re-wire.

For Indirect Units.

For fixtures of the indirect class a check should be made from the Spacing-Ceiling Height Table II, to see if the ceiling is high enough to give approximately uniform illumination with the distance which exists between outlets and also to obtain the proper drop from these units from the ceiling. If the spacing is found to be much too wide for the ceiling height the customer should be urged to re-wire. In case the customer re-wires the lighting layout must be recalculated on the basis of figuring outlined under the Planning of Illumination for New Buildings or in Old Buildings where Existing Outlets Need Not be Utilized,

Comments.

Frequently it may be hard to decide between specifying one or two rows of lighting units,or the installation may so figure out that one is undecided as to whether, for example, 100 or 150-watt lamps whould be used. In such cases one must depend upon his best judgment and experience in arriving at the correct solution.

In this connection it is well to keep in mind that in a store, absolutely uniform illumination is not necessary, and so the spacing ratios may be stretched a little where there is a considerable advantage to be gained by so doing. On the other hand, in an office, uniform illumination is a prime requirement, and when there is any doubt as to whether one row of units or two should be used always install two.

Likewise, in deciding between two sizes of lamps, if it is felt that the location is one in which especially good lighting will not be appreciated, one may be justified in choosing the smaller of the two. In the end, however, the customer will usually be better satisfied with an ample intensity of light even though the first cost of installation and the current consumption may be a little higher.

Recommendations should in nearly all cases be based on the highest lighting intensity classification as shown in Classification Tables. The better illumination which results is easily worth the slight increase in initial cost and upkeep.

Example No. 1.

Lay out a lighting system for a newly built shoe store in the downtown district, requiring very good illumination. Assume dark wallsand ceilings and dimensions as follows: Length, 55'; width, 40'; height, 16'

a. The Ivanhoe Ace, a one-piece semi-enclosing unit, is chosen for this store. This unit is particularly suitable where the questionof maintenance is of considerable importance.

b. Since the ceiling height is 16' the greatest height at which the center of the fixture could be above the floor will be approximately 15'. However, in a room of these proportions a fixture suspended by 1 to 4 feet of chain would present a much better appearance. We shall, therefore, set 13' as a tentative mounting height.

c. Referring to the Spacing-Mounting Height Table, 10. we find that for a mounting height of 13' the units should be 16'6" apart.

d. Fig. 4 shows how to diagram the room to scale and locate the outlets. It is evident that by dividing thelength of the room by the spacing distance (16'6") we get the required number of units lengthwise and approximately 3 1/2. Obviously we should specify 4. Dividing the width of the store by the same spacing gives us approximately 2 1/2 units. So we will have to put in three units across--12 units in all. This will mean a lengthwise spacing lf 14' with 6'6" between end units and end walls, and a crosswise spacing of 14' with 6' between the two outer rows of units and the side walls.

e. Area of floor is 40x55x2200 sq. ft.

f. Average number of sq. ft. each unit must illuminate is 2200 ÷ 12 or 183.

g. Turning to the Classification Table #13 we find that for very good lighting this shoe store requires an illumination of 6 foot-candles; that is, it falls in Class 6.

h. Referring to Table 14, Watts per Square Foot for Semi-enclosing Units, it is found that a room with dark walls and ceiling having more than one row of units in class 6, requires 1.15 watts per square foot. 1.15 x 183 = 210, which figure represents the wattage of the lamps to be used.

Since Mazda C lamps are not made in the 210-watt size 200-watt lamps should be specified.

Thus the problem is solved, and twelve 200-watt mazda C lamps in Ivanhoe Ace units should be installed, located as in Fig. 4.

i. With our exact spacing (14 feet) determined we refer again to our Spacing-Mounting Height Table 10, and find that this spacing corresponds to a height of 11'6" above the floor. A length of chain which will bring the units approximately in this position will insure a good appearance and best illumination results.

Should the owner desire to economize on the number of outlets to the greatest possible extent it would of course be possible to place the units very close to the ceiling, thus securing a mounting height of 15'. From the Spacing-Mounting

Height Table it will be seen that this height corresponds to a spacing of 20', and under these condtions two rows of three units--six units in all--would satisfy the requirements. A study of the problem will show that 400-watt lamps should be used in this case.

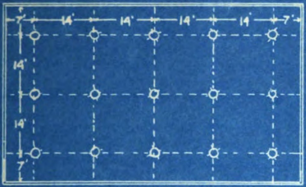


Fig 2 - Showing how lighting outlets should be laid out to provide a practical degree of uniformity in light distribution. Here each lighting unit is given a definite area to illuminate, i.e.,all the space falling within 7 feet from a point directly beneath the lighting unit.

Fig. 2.

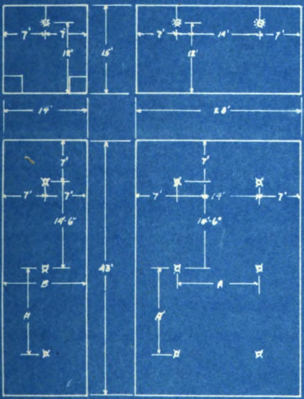
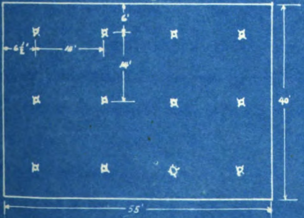


Fig 3 - To the left is shown the ground plan and an end elevation of a long narrow store, while lower down we have a store of the same length and height but of twice the width. In long narrow stores when one row of outlets is sufficient, the width of the store should be taken as the spacing figure if it is greater than the actual distance between the outlets. When there are two or more rows of outlets the ideal arrangement is that of squares though rectangles are satisfactory if the difference between the length and breadth of the rectangle is not too marked.

Fig. 3.



Arrangement of outlets for example number 1.

Fig. 4.

R.C.Kinney

CHAPTER VIII

HOW TO PLAN WINDOW LIGHTING

The information contained in this thesis is the same simple and complete ever compiled onshow window lighting. There is no superfluous technical data. The engineering of this important matter is boiled down and simplified so that merchants can quickly determine what is best for their particular windows.

THE SHOW WINDOWS OF A MERCANTILE ESTABLISHMENT CAN BE MADE AS EFFECTIVE BY NIGHT AS BY DAY BY PROPER CONSIDERATION OF THE PRINCIPLES OF GOOD ILLUMINATION --- NEW EFFECTS POSSIBLE BY SPECIAL CONTROL OF LIGHT DIRECTION AND COLOR

The show window is an adjunct of recognized value in merchandising and should receive treatment in keeping with its commercial importance. A well dressed window is a work of art, and the window dresser who arranged it an artist. He employs color and material harmoniously arranged and depends on light to make the resulting picture effective. In the daytime the appearance of the window is limited to that which may be obtained under natural light, in which the color and direction are not controllable. At night the flexibility of artificial illumination permits unlimited variations in light direction, color and intensity, and provides the window dresser with means of using material and color to produce a variety of beautiful effects.

In show-window lighting the fundamentals of good illumination apply as well as in any other branchof illumination. Not infrequently show windows are lighted by m ans of bare lamps

suspended directly over the displayed goods and in the line of vision of the observer. While t his was bad practice in the days when carbon and other vacuum lamps were in general use, now that Mazda C lamps with their intensely bright filaments are being used almost entirely for this class of service, this practice is all the worse and should not be tolerated.

The obvious and simplest method of avoiding glare is to conceal the lamps. This is most easily and satisfactorily done by locating the lamps, properly equipped with reflectors, along the top front edge of the window. If the window glass extends to the ceiling the units may be visible from the street. In this case a valence draped from the top of the glass may serve the double purpose of beautifying the window and condealing the light sources.

The first principle of good window lighting is to conceal the lamp completely. Therefore, if your window has no background, or a low one, or one of glass, the reflector must cover the lamp so that it will not glare into the store. If the background is of mirror the same precaution must be used or the glare will be feflected into the eyes of people looking at the displays.

The second principle is a to flood the display with uniform light without wasting any on the ceiling or ends of the window or on the sidewalk. This requires the right reflector, used with the lamp and holder for which it was designed. This is covered fully on the following pages.

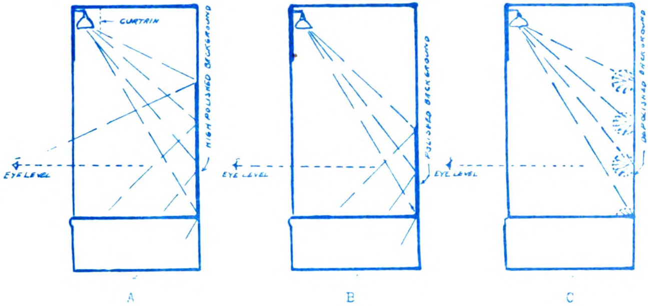
The third principle is to secure just the right intensity in the window, for, even if the glaring lamps are hidden, it is possible to make a window so bright as to be unattractive. The amount of light which will properly illuminate a display of furniture of dark color, in a window with oak or mahogany background, will be altogether too bright for a display of white goods.

Comparison of Illuminants.

There are so many types of lamps in general use, and of such varied effieiencies, that it would be a difficult matter to make comparisons on paper which would hold under the extreme variations of practical usage in various localities. Aside from t is, there is only one "best" way of convincing a layman regarding the superiority of oneilluminant over another, and that is by acutal comparison, the placing of one unit against another under exactly similar conditions, so that the question of superemacy can be determined at a glance. After such a demonstration the question of economy, or how much saving will be effecred by the use of number of the units, is very much simplified. This applies with equal force to all lighting applications where the substitution of one illuminant for another is an issue.

Brightness of Show Windows.

The brightness of a display window depends fundamentally on whether the light of the lamp is utilized or not. One window may have three times the number of lamps and appear less



The above sketches show the effect of polished backgrounds.
(A) Poor example. (B) Satisfactory. (C) Very good.

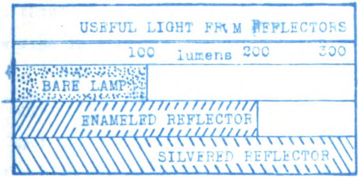
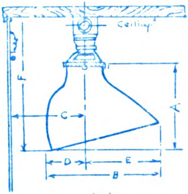


Chart (A)



(B)

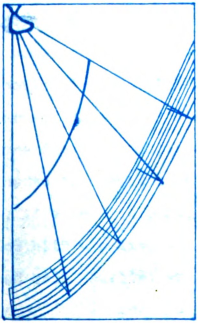


Chart (A) shows the relation between amount of light reflected by three different fixtures. Sketch (B) is a typical example of a silvered reflector.

Sketch on the left shows the proper form which the curve of (candle power) graph of window reflector should assume to give uniform light on the background shown.

(The above illustrations were taken from the National X-Ray Catalogue).

R. C. KINLEY

bright and distinct than a window having a correct utilization of light. The term "utilization" means "using light where it is needed", and not wasting it in direction where it is not needed. Consequently, in lighting display windows, it is necessary to confine theillumination to the lower portion of the window where the display is located, there being nothing on the ceiling of a window requiring light. In fact, bright ceilings not only waste light, but distract attention from the display below, which is boviously undesirable. The ideal effect should be a bright square of light wit in which the merchandise is very prominently defined without too great a blank or waste space above or on each side. From the above it is apparent that the brightness of a display window depends upon the utilization of light and, in turn, this utilization is accomplished by refl ctors which redirect the light of the lamp where it is needed.

Importance ofConsidering Background.

A point often overlooked in show-window lighting is the proper consideration of adapting the window background to the illumination system. The background should be made so that specular reflection is either avoided or properly controlled; for glare due to specula r reflection is often as annoying as that due to the presence of the light source itself. For instance, if a lamp is placed (as shown in Sketch A, Fig. 2) in a window with a polished background, such as a mirror or a polished wood paneling which extends from the floor of the window almost to the ceiling, the image of the source will be reflected into the eye of the observer as shown by the broken lines. If the background does not extend up so high (as in Sketch B, Fig. 2), little reflected light will strike the eye at tis ordinary height. The same result can be secured by dropping a curtain between the light sources and a high background, as indicated in Sketch A, Fig. 2; or, if a high background is a necessary part of the display, it may be mat-finished so that the reflections instead of forming brilliant images will be diffused in all directions, as shown in Sketch C, Fig. 2. When light is reflected from mat surfaces in all directions the surface appears uniformly illuminated and no excessively brilliant image is formed to dazzle the eye.

Control of Light Direction

In the present practice of window lighting it is too often the purpose to secure merely uniform illumination of the display without considering whether or not the presence of some shadow would make the display appear to better advantage. A certain degree of shadow is necessary in order that each part of an object may appear in its proper relation to every other part. Obviously the detree of shadow is controlled by the direction of the light. The location of the outlets should be such that light can be obtained from several directions.

Reflectors and Their Use.

Too much emphasis cannot be placed on the importance of selecting the right type of reflector:

1st. The reflector which will conceal the brilliant light filament from the view of either the passerby or persons inside the store, and which will illuminate the window evenly. 2nd. One that will direct all the light, even that usually wasted on the ceiling and top background of the window and sidewalk, onto the display.

There are three general t pes of reflectors which will solve the utilization requirements of any display window. These reflectors are cut at various angles and apply as follows: For high windows of medium or shallow depth, reflectofs cut at an angle of 15° cut the light from the lamp so that it is directÂd sharply downward, illuminating the foreground of the display close to the window glass, without wasting any valuable light on the sidewalk. The background is also illuminated high enough to meet the requirem nts of "trim" of average height. This same type of reflector is suitable for low windows which are not deep, for obviously this reflector is not intended to direct light very far back into a window. For high or low windows of considerable depth a 30° reflector is the proper thing, and these may be obtained in various forms so that the brightness of the background can be "shaded" or cut off at any desired point above the line of trim. The third type of reflector is cut atan angle of 45° and is appropriate for very deep windows, throwing the light far back and considerably high up on the background. In windows of unusual height and depth, where it is necessary to increase the bright-

C. W. KLEMM, Inc.
Bloomington, Ill.

X-RAY Lighting
from Concealed Sources

National X-Ray Reflector Co.
Chicago, New York and San Francisco
Serial No. 285, Description-Over

Z. L. WHITE COMPANY
Columbus, Ohio

X-Ray Lighting
from Concealed Sources

National X-Ray Reflector Co.
Chicago, New York and San Francisco
Serial No. 201, Description-Over

ness of the display near the window glass, this result can be obtained by combining the 15° reflector with the 30° and 45° reflectors in a ratio of 3 to 1.

X-Ray Reflectors

Every window presents a distinct problem in lighting, and is treated as such with X-RAY reflectors. Those shown herein are the results of years of constant perfecting, experimental work and study, so that now we can confidently present a reflector that meets any problem of window lighting.

Classification of Reflectors.

For large windows use the Jove or Jupiter with 100 Watt Mazda C lamps.

For average windows use the Scoop or Hood with 75 Watt Mazda C lamps.

For very small windows use the Scoopette or Hoodette with 15 watt Mazda B lamps.

Classification of Background Conditions.

If the background permits people inside the store to see the window lighting equipment use only Jupiter, Hood or Hoodette. If the equipment is not visible any of the reflectors may be used, fitting the proper style to the window under consideration.

Size Classification.

For shallow windows use Jupiter, Hood or Hoodette, For average or deep windows use Jove, Scoop or Scoopette,

These classifications will some time interfere. It is then necessary to decide which of the wrong conditions will


STEVENS, MALON
STATIONERS ... PRINTERS ... ENG
X-Ray.
BACKGROUND
GLASS FRONT


STEVENS, MALON
STATIONERS ... PRINTERS ... ENG
X-Ray.
BACKGROUND
GLASS FRONT

least interfere with the production of perfect lighting, and sacrifice that one.

Make note of the size, background conditions and depth of your windows, check these against the above classifications and you will have no trouble in determining the proper reflector. To secure perfect results you must use the lamp for which the reflector was designed and also the proper reflector holder.

Spacing.

In average installations the spacing, or distance from center to center for these reflectors, is about as follows:

Jupiter-- 100-Watt Mazda C lamp..........24 in.

Jove -- 100-Watt Mazda C lamp..........24 in.

Scoop -- 75-Watt Mazda C lamp..........18 in.

Hood -- 75-Watt Mazda C lamp..........18 in.

Possibilities in Color Effects*

Color is, of course, one of the show-window dresser's most effective tools, yet full advantage is seldom taken of the possibilities of artificial lighting in the renditionof colors. The color contrast in a display depends, among other things, upon the color quality of the light which is used. A favric is said to be red in daylight because it absorbs practically all the other colors in the spectrum and reflects mainly the red. Under a green or a blue light, in which red rays are absent, the same faborc would appear almost black. Mazda lamps give all the colors of the spectrum, but their light contains relatively more of red and yellow rays than does day-

*See chapter on color.

light. Hence, these lamps emphasize the reds, yellows and browns, and likewise fail to bring out the blues and violets in their proper weight. By the careful sel ction of color screens,(see figure 1.) however, any color may be given emphasis.

Thus for instance, if it is desirable to emphasize the whiteness of goods, on display or to bring out the blues in dressgoods a color screen should be used which will absorb a part of the excess red and yellow rays while freely permitting the others to pass. Blue-green glass of the proper sele ction will do this, but if correct color value of the light and a high efficiency are to be obtained a thorough knowledge of color must be used in the sel ction. Lamps designated as Mazda C-2 lamps have been developed,which, through the effect of special coloring elemdnts mixed with the ingredients of the glass from which the bulbs are blown, give a light of afternoon sunlight quality at about the efficiency of the Mazda B lamp. The lamp manufacoutrer has placed the proper [illegible] color in the bulb instead of depending on auxiliary equipment, since other glass having the same appearence as that used in Mazda C-2 lamps might, bo the user's disadvantage, transmit light of very different color value.

Color variation is, perhaps, the most effective means of holding attention. A florist's window, for example, can be made to change wonderfully by simpley changing the color quality of the light which illuminates it. It it is lighted entirely by a white light, such as is obtained with Mazda C-2 lamps the whites, blues, greens and violets will appear to stand out because the reds, yellows and browns with which they are contrasted will be depressed. If the color quality of the light is made to change by adding to the white light, brown and yellow light from amber-colored bulbs, the colors that first appeared prominent will appear to fade and the yellows and browns will be given prominence. Again, if red light is added to the white light, the effect will be to make the con- trasts between red and the other colors more marked.

Such effects, as mentioned, may be readily secured by having available in the window the colored lamps necessary. The changes from one color to another may be made by a suit- able flashing device and may be sudden and contrasting, or they mat be gradual and harmonious. The colors in rugs, dressgoods, wallpaper, pictures, paintings, etc., are suscept- ible to the same treatment. A window dresser who will make a study of the possibilities of colored light as well as the possibilities of light direction will be able to produce beautiful and unusual effects.

The Intensity Necessary for Effective Lighting.

The intensity required for show-window lighting depends largely on the brightness of the surroundings. Show windows located on "white ways" will require a greater intensity than those located on a dark side street. However, as light is one of the most inexpensive and effective means of advertising, an intensity higher than is absolutely necessaryfor suitable lighting can usually be employed to advantage. Another factor

which must be considered in determining the intensity is the color of the display. An object is seen by the light which it reflects, and, therefore, dark-colored displays require more light than do those of lighter colors. Since the display of a show window is frequently changed both in material and color, the flexible arrangement of lamp sockets suggested for securing directional lighting effects offers a method of varying the intens ity at will. In general the intensities for window lighting range from 10 to 50 food-candles.

The advantage of using reflecting equipment in show-window lighting should be generally understood. When lamps are used without reflectors a greater part of the light falls on the walls, background and ceiling before it reaches the display. Usually window backgrounds and ceilings are poor reflectors and much of the light, which by the use of reflectors could be utilized, is lost. The mo t satisfacotyr reflectors for window lighting are the prismatic and the morrored glass. These reflectors afford good control of the light with a high efficiency.

In lighting a show window the first question is usually one of how much light is needed. The statement that so many foot-candles are required is only of value when the equivalent is given in wattage. Many times the amount of light required is expressed in watts per square foot of the window floor. While this designation is satisfacotry for windows in which the display covers only the floor surface, it fails to do justice to to those many windows where the displays cover a considerable portion of the background as well as the floor. In other words, the floor space of a window is not the only consideration which enters into the determination of thw wattage necessary to light a window properly.

Simple Method of Calculating the Lamp Equipment.

The following is a simple method of finding theintensity suitable for any show window regardless of the display arrangement. This method is based on the efficiency of Mazda C lamps and of prismatic or mirrored-glass reflectors. For the purpose of calculation show windows may be divided into ten classes on the basis of intensity of illumination desired. Class 1 includes those windows in which the lowest standard of illumination will be permissible--an intensity, in fact, which would not be adequate in most cases. Class 2 includes the average country store, where a low intensity is sufficient. Classes 3 to 6 cover the average store; Classes 7 to 8 the department stores of most cities. The finest windows of the largest stores and exclusive shops located on brightly lighted streets fall in Class 9 or 10, representing the highest intensities which can be used to direct advantage.

The first step in the calculation is to place the specified window in one of the ten classes. The next step is to add the depth of the window, in feet, to the height of the lamps above the window floor, in feet, and multiply this sum by the class number of the window. The result will give the required watts per running foot of window frontage, assuming that 100-watt

Mazda C lamps are to be used. To get the number of lamps necessary the number of watts per running foot of window frontage should, of course, be multiplied by the window frontage in feet, and this result divided by 100. Should the window be other than rectangular in shape the length of the window f frontage whould be taken as the average of the length of the actual window front and the length of the window background.

This met od of calculation as described applies only where windows are to be lighted by a dirdct system using well designed mirrored glass or prismatic reflectors placed at the top of the window. Where Mazda C-2 lamps are to be used, since the 150-watt C-2 lamp gives approximately the same intensity as that of the 100-watt Mazda C lamp, due to the absorption of light by the colored bulb, the number of units to be used is the same in either case.

Location of Spacing of Reflectors.

The spacing of reflectors varies from distances of 12 inches between centers (minimum) to 24 inches between centers (maximum). It would be absurd to define any set rules regarding the number of reflectors per window, since every merchant has decided ideas regarding the brightness of his own window and insists upon carrying them out. Reflectors should be placed as close to the front of the window as possible to give best results.

If a window is open on two sides, and it is necessary to illuminate the rear of a display, this can be accomplished by a second line of lights carried around tb the side and equipped with reflectors of the proper type.

In certain lines of business the color of the display varies greatly, being either white or very dark. The dark display requires much more light to bring out the quality of the merchandise. For t is reason it is desirable to have two separate circuits, one for displays which are light in color and both for dark displays. Suggestions for this sort are greatly appreciated by users of electric light.

Concealment of Illuminants.

In order to give a finished appearance to a window, the illuminants should be concealed behind a strip of valance which may be formed of silk, paper, or paint upon the back of the window glass. The exposure of lights in a display window distracts the attention of the observer from the display and is therefore undesirable. Another objection is the glare caused by exposed lamps which make it impossible for anyone to see the display clearly. The concealing strip can be placed directly below the transom bar in windows of medium height and, if the ceiling extends above this, the units can be placed upon a rack attached to the bar which is also concealed by the valance. By lowering the lights in this way and bringing them nearer to the display additional brightness is obtained. Moreover, in any high windows, the blank space above the merchandise is of no advertising value and, if brightly lighted, distracts attention from the trim. Such concealment of lighting, when well done, gives decided character to a display window.

Sign Transparencies.

Translucent signs, painted on the back of the window glass at the top of display windows, require illumination, but it is wasteful and extravagant to employ translucent reflectors for this purpose. While the light which they emit in an upward direction accomplishes the effect, a considerable quantity is wasted in illuminating the ceiling. Such transparencies can be illuminated in a far more economical and attractive manner by placing behind them boxes containing small 15 watt Mazda lamps in aluminum reflectors, arranged so that their light is directed against the white inner surface (back) of the enclosing box, which diffuses the light, thereby illuminating the sign perfectly without the characteristic "spotty" effect resulting from placing lamps directly behind sign letters.

Incident Considerations.

Whenever possible the polished surface of cabinet work within a window should be depolished, since it acts as a mirror in reflecting the images of the lamps and reflectors, causing a streak of light which detracts from the finished effect of a window and distracts attention from the display.

To facilitate comparisons in window lighting a temporary strip of moulding, wired and fitted with lamps, sockets, and reflectors, can be prepared and installed in any window without disturbing the display. In this way one window may be compared with another and it is possible to immediately see any improvement which exists. This method is very effective in demonstrating the superiority of Mazda lamps over gas lamps and incandescent lamps of the carbon filament type. It also serves to show the greater efficiency and better light of the 100-watt Mazda C lamp compared with the 100-watt Mazda B lamp. Actual comparisons are always most convincing and "seeing is believing."

CHAPTER IX

MAINTENANCE OF THE LIGHTING SYSTEM *

The proper maintenance of the lighting equipment is a very important factor in illumination. The housewife, for example, realizes that the home would soon become a very poor place in which to dwell unless she made periodic house cleanings and attended to the household duties in this respect from day to day. The industrial plant, or office, would soon become unsanitary unless scrub people were employed. On the other hand, lighting equipment is often neglected from the time it is installed until it becomes obsolete. Persons seem to believe that after once hanging a fixture and screwing a lamp into a socket no further attention needs to be given to this part of the home or office. A widespread campaign of educating the public in this respect is most essential and it is up to everyone interested in lighting to preach the gospel of proper maintenance. The electrical contractor, when he has finished an installation of lighting, should not leave the job without advising the customer as to the necessity of cleaning. To quote a prominent official of the Department of Labor of an important industrial state, when addressing the annual convention of electric contractors, and dealers:

" If you sell a man a motor, you usually give him an instruction card telling him how to oil the motor, adjust the brushes, and the like. If you did ~~not do~~ this and he did not

*Bul. L. D. #101 G. E. Co.

attend to the matter through his own appreciation of the subject, the motor would soon stall, burn out, and you would be justly blamed. On the other hand, many a lighting installation is sold with no instructions or suggestions as to its maintenance.

"A lighting system demands careful maintenance. If it does not receive it, the intensity will soon drop so low that the men cannot see to perform their work. You will get the blame. You will be told that the installation you designed and installed is not adequate for the purpose. Your engineering judgment will be criticized."

Depreciation of Lamps.

Inherent: As the Mazda lamp is burned small particles of tungsten are evaporated from the filament and colåect on the lamp bulb in the form of a dark deposit. With the Mazda "C" lamp the gas current carries these particles to the upper part of the bulb, where they have less effect in absorbing light than when deposited directly opposite the filament. Nevertheless, any accumulation on the interior surface of the bulb absorbs light, and blackened lamps should, of course, be replaced. It is comparatively simple to figure out the most economic point at which to remove lamps from the sokket, taking into account the price of lamps and the cost of current. For average conditions, when the candle-power has depreciated to between 75 and 80 per cent of initial rating the lamp should be discarded. Of course, a photometric test might be desired to determine exactly the percentage of depreciation, but observation and experience will soon indicate to the Maintenance Department when a lamp has depreciated to approximately this value. The Mazda lamp is designed to maintain its candle-power above the limits mentioned above for an average life of 1000 hours' burning, and at the end of this period should be removed and discarded if the most economic conditions are to prevail.

Acquired: Not only does a black deposit occur on the inside of the lamp bulb, but dust collects on the outer surface; flying particles of oil, or similar materials, are also deposited here. This accumulation cuts down the light from the lamp and should be removed at the time reflectors are cleaned. This is often more serious than realized.

A s a concrete case, we might quote a test on some lamps which were installed in a grinding room, where the air was moist, and laden with steel dust particles. Half of the lamps installed for the test were removed at the end of a week and thr remainder at the end of three weeks. The lamps were taken to the photometric laboratory and tested. Those with a week's accumulation of dirt showed an average absorption of 16 per cent. Those removed at the end of three weeks had an average absorption of 23 per cent. This does not take into account the loss of light which would occur due to the grease and dirt on the reflector. Putting this in other words, at the end of a week an increase over 16 per cent in wattage, and at the end of three weeks nearly 23 per cent increase in wattage, would be required in order to obtain the same illumination as secured when the lamps were clean. Of course, many conditions are not as severe as this, and some--for example, the foundry or large shop--are even more severe.

Another important point, in regard to the lamp, is the question of having lamps of the proper voltage in use. While initially the installation may be correct as to voltage, on replacing or ordering additional lamps, an error may be made in specifying the voltage of these lamps. Mazda lamps are designed to operate at the voltage indicated on the label. This voltage rating takes into account renewal and energy costs. If the circuit voltage is appreciably higher than the label voltage, short life of lamps will result. If the voltage at the socket is considerably lower than that indicated on the label of the lamp in use it will not emit the proper quantity of light. To make up for this loss of illumination, it would be necessary to install additional lamps. For instance, seven Mazda lamps operating at rated efficiency will give the equivalent amount of light of eight Mazda lamps operating 4 volts below the rated efficiency of the lamps. Before ordering lamps it is desirable to determine what average voltage is actually attained at the socket. Where the voltage of the system fluctuates during the day, or where it varies in different parts of the installation, it is proper to order lamps as near the average of this variation as possible.

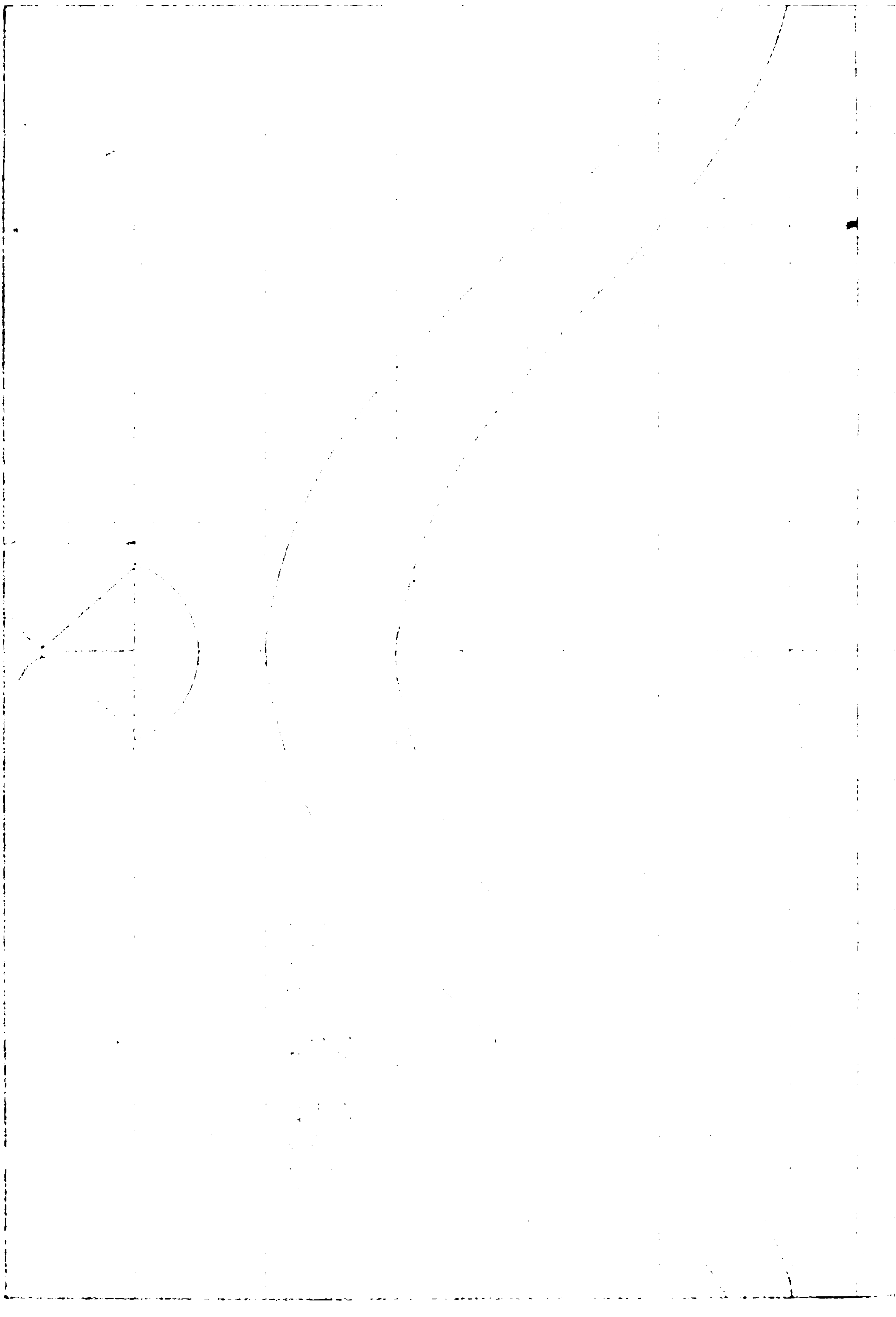
Depreciation of Reflecting Equipment.

All lamps and reflectors should be regularly washed and cleaned. Thex period between cleanings will vary with locality and type of equipment. Obviously, a steel direct lighting reflector will not depreciate as rapidly as an indirect unit. In the case of the former the under surface of the reflector offers very little opportunity for dust to gather, and that on the lamp bulb will be the rpimary cause of loss. In the case of the inverted unit, however, a thin layer of dust soon settles on the entire reflecting surface,as well as on the lamp, which will reduce the light output appreciably in a very short time. Not only is this ture, but the very arrangement of parts makes the accumulation greater. With the direct lighting equipment, the reflector itself shields the lamp from falling particles, while they enter directly into the inverted unit.

Table No. 1.

Approximate Loss in percentage of initial illumination on Working Plane.

Weeks...	4	8	12	16	20
RLM standard dome....	5	8	10	12	14
Dense opal bowl direct lighting..............	7	10	13	16	19
Prismatic bowl direct lighting..............	9	13	16	19	22
Li:ht density opal bowl direct lighting...	12	18	24	28	30
Semi-indirect..........	14	22	29	35	40
Totally indirect.......	20	29	37	44	50



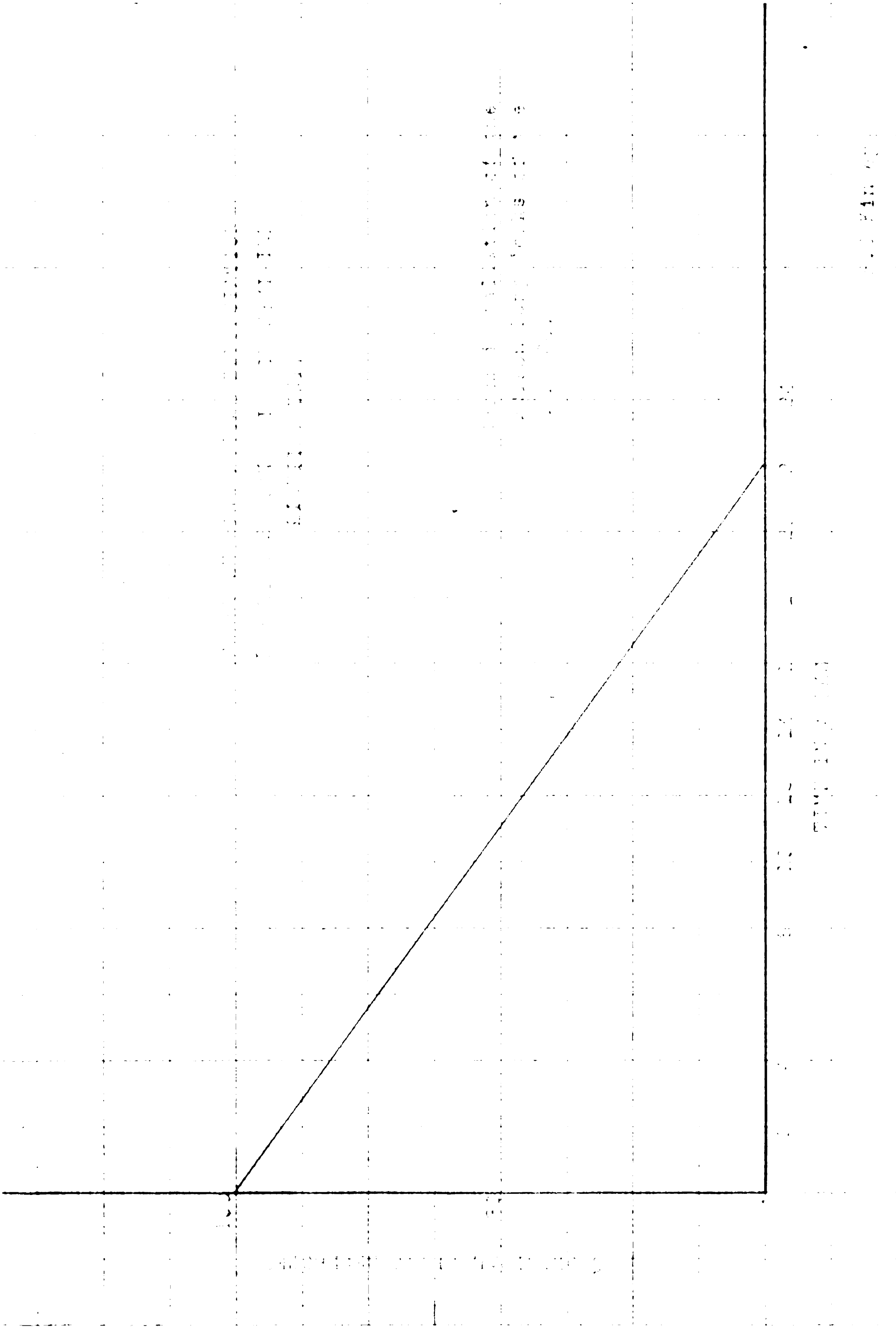


Table No. 1 presents figures on the approximate loss of light for various lighting systems, based on average office conditions in an inudstrial city. For s me other locality other figures will apply. The country town will have less depreciation than the busy city. The figures presented, however, are fairly typical of average conditions. It can be seen that the steel reflector depreciates least, while the opal reflectors for direct lighting vary as to the density of the reflector. This is to be expected, considering that, with a light density unit, more light is transmitted through the glassware, and dirt on the outer surface will have appreicably more effect.

Another feature enters in comparing direct and indirect systems. With direct lighting, the dirt gathers on the exterior surface and is readily visible to the occupants of the room. With the semi-indirect and totally indirect systems, the dirt gathers on the inner or reflecting surfaces and is not noticed until conditions become so aggravated that the illumination drops far below that intensity for which it was designed. Hence, a more careful maintenance of any indirect system is exteemely important.

Depreciation of Surroundings.

As pointed out in another bulletin, the questionof color of walls and ceilings is very important. No matter how carefully painted a room may be, soot, smoke and other agencies soon darken the surfaces of the room and cause it to lose considerable of its reflecting power. Any porous paint, suchas calcimine or whitewash, is particularly susceptible to this effect. In industrial localities it is frequently necessary, if maximum economy of lighting is to be obtained, to paint the ceilings every year and a half and sidewalls every three years. A test, to determine the reflection coefficient of the ceiling and walls at frequent intervals, may save considerable on the lighting bill. In general, paint is far cheaper than electrical energy, and in dirty plants painting or cleaning is especially important.

System of Cleaning.

Haphazard cleaning has not usually been found satisfactory, since the accumulationis so gradual that it is not readily noticed by those responsible. Much better success has been secured by organized cleaning, at stated intervals, under the charge of a maintenance department where one person is absolutely responsible for this. As pointed out before, the periods between cleaning will vary with the locality and with the equipment. Considering average conditions and typical equipment, the fixtures in an office should be wiped out at least once every month, and removed for careful washing once every three or four months. In the foundry it is probably necessary to carefully clean fixtures once each week.

The cost of cleaning again varies with the type of equipment and labor charges. As typical figures for industrial plants with direct lighting reflectors, from 3 to 5 cents for cleaning might be considered as average. Some figures o obtained in a large office building where semi-indirect units of a fairly simple design are inuse, indicate that the cost for cleaning by wiping lamps and reflectors with a damp cloth and then drying is approximately 5 cents per unit. Removing the semi-indirect bowl from the fixture and carefully washing costs approximately 10 cents. The most economic period for cleaning a given installation can be obtained by taking into consideration the cost of power, the burning hours per day, the loss of light due to the accumulation of dirt, and the cost per cleaning. The calculation is not involved, as indicated by the following exampàà.

Using figures of light depreciation as given in Table No. 1, costs of cleaning, as quoted above for semi-indirect units, and a power coat of 5 cents per Kw-hr., average burning hours per day assumed as 6, and 200-watt lamps in use.

For a 12-week peridd, the following calculatøons apply:

total kw-hr. consumed= $\frac{\text{6 hours x 6 days x 12 weeks x 200 wattts}}{1000}$

= 86.4 kw-hr.

Case A. Fixtures wiped every 2 weeks, washed every 12 weeks.

Cost of cleaning, 5 + 5 + 5 + 5 + 5 + 10 = 35¢

Equivalent power loss, 4% (from curve) or 86.4 x .04 = 3.45 kw-hr.

Cost of loss energy, 3.46 x .05 = $.173

Case B. Fixtures wiped every 3 weeks, washed every 12 weeks.

Cost of cleaning, 5 + 5 + 5 + 10 = 25¢

Equivalent power loss, 5.5% o 86.4 x .055 = 4.75 kw-hr.

Cost of energy ~~km~~ 4.75 x .05 = $.24

Case C. Fixtures wiped every 4 weeks, washed every 12 weeks.

Cost of cleaning, 5 + 5 + 10 = 20¢

Equivalent power loss, 7% or 86.4 x .07 = 6.05 kw-hr.

Cost of lost energy, 6.05 x .05 = $.30

Case D. Fixtures wiped every 6 weeks, washed every 12 weeks.

Cost of cleaning, 5 + 10 = 15¢

Equivalent power loss, 9% or 86.4 x .09 = 7.8 kw-hr.

Cost oflost energy, 8.8 x .05 = $.39

Case E. Fixtures washed every 12 weeks.

Cost of cleaning, 10¢

Equivalent power loss, 14 1/2% or 86.2 x .145 = 12.5 kw-hr.

Cost of lost energy, 12.5 x .05 = $.625

Method of cleaning.

For dry dirt, wiping with a dry cloth or brush, then with a damp cloth, and finally drying all surfaces, will prove satisfactory. Greasy or wet accumulations an any type of reflector must be removed by washing. Soap and water are good agents, but care must be taken to remo e the film of soap by rinsing thoroughly as dried soap accumulates dust very rapidly. There are a number of cleaners on the market, but before these are used on a polished surface care should be taken to see that they are so smooth as not to make microscopic scratches on the glass, and should not leave a film of cleaning material. Most of these may be applied with a piece of cotton waste of soft cloth and polished off with dry waste or cloth. Where lamps are hung high, and it is necessary to use a ladder to reach them, it is advisable to have on hand an extra globe, or reflector, which may be put in place of the dirty globe, and the latter carried to the cleaning place. After washing, the clean globe can be substituted for the next dirty one, and so on. This procedure necessitates only one trip up the ladder for each globe or reflector.

Table No. 1.

Showing the Intensity of Illumination in Foot-Candles on Horizontal Plane at various distanced from a Light source of 1 Candle-Power.

Table 6 Lumen Output of Mazda Lamps.

Subject to Change Without Notice

Size of Lamp in Watts	110-125 Volt Standard Lighting Service			220-250 Volt	
	Mazda C	Mazda B	Daylight Mazda	Mazda C	Mazda B
	Lumen Output				
10		75			
15		125			
25		226			191
40		372			
50	450*	480			442
60		575			
75	865		600		
100	1260		875	995	945
150	2040		1400		
200	3100		2000	2520	
300	4840		3360	4100	
500	8750		5600	7850	
750	13900				
1000	19300			17500	

*White Mazda

TABBE 10 *

Spacing-Mounting Height Table for Semi-Enclosing and Total Enclosing Units.

Mounting Height of Unit above Floor	Stores: Permissible Distance Between Outlets	Stores: Permissible Distance Between Outlets and Side Walls	Offices: Permissible Distance Between Outlets	Offices: Permissible Distance Between Outlets and Side Walls
9'	10'	5'	10'	3'
9'6"	11'	5'6"	10'6"	3'6"
10'	11'6"	6'	11'	3'6"
10'6"	12'6"	6'6"	12'	4'
11'	13'6"	7'	13'	4'
11'6"	14'	7'	13'6"	4'6"
12'	15'	7'6"	14'	4'6"
13'	16'6"	8'6"	16'	5'
14'	18'6"	9'6"	17'	5'6"
15'	20'	10'	19'	6'
16'	21'6"	11'	20'	6'6"
17'	23'6"	12'	22'	7'
18'	25'	12'6"	23'	7'6"
19'	26'6"	13'6"	25'	8'
20'	28'6"	14'6"	26'	8'6"

* W. E. Bulletin

TABLE 12.

Spacing-Ceiling Height Table For Indirect Semi-Indirect and Duplexalite Units.

	Stores		Offices		
Ceiling Height	Permissible Distance Between Outlets	Permissible Distance Between Outlets and Side walls	Permissible Distance Between Outlets	Permiss-ible Distance Between and Side wall	Drop from ceil-ing to top of Unit
9'	9'6"	5'	9'6"	4'	18"
9'6"	10'6"	5'6"	10'6"	4'6"	19"
10'	11'	5'6"	11'	4'6"	20"
10'6"	12'	6'	12'	5'	21"
11'	12'6"	6'6"	12'6"	5'	22"
11'6"	13'6"	7'	13'6"	5'6"	23"
12'	14'	7'	14'	5'6"	25"
13'	15'6"	8'	15'6"	6'6"	28"
14'	17'	8'6"	17'	7'	30"
15'	18'6"	9'6"	18'6"	7'6"	32"
16'	20'	10'	20'	8'	35"
17'	22'	11'	22'	8'6"	39"
18'	23'	11'6"	23'	9'	43"
19'	25'	12'6"	25'	10'	48"
20'	26'	13'	26'	10'6"	54"

*W. E. Bulletin.

TABLE 13*

Classification Table

Stores and Other Commercial Buildings Classified on the Basis of Lighting Requirements.	Average Lighting Class (foot candles)	Very Good Lighting Class (foot candles)
Department Stores and Large Specialty Stores		
Main Floors and Basement	6	10
Other Floors	4	8
Stores of Medium Size		
Book and Stationery	4	6
Clothing	4	8
Drug	4	8
Dry Goods	4	8
Furniture	4	6
Grocery	4	6
Exclusine Small Stores		
Light Goods	6	10
Dark Goods	8	12
Small Stores in General		
Art	5	8
Bake Shop	4	6
Book	4	6
China	4	6
Cigar	4	6
Clothing	4	8
Confectionery	4	6
Decorator	4	8
Drug	4	6
Dry Goods	4	8
Florist	4	6
Furrier	5	8
Grocery	4	6
Haberdashery	5	8
Hardware	4	6
Hat	4	6
Jewelry	4	6
Leather	4	6
Meat	4	6
Millinery	4	8

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*W. E. Bulletin.

Classification Table (Continued)

Stores and Other Commercial Buildin s Classified on the Basos if Lighting R quirements	Average Lighting Class (Foot Candles)	Very Good Lighting (Foot Candles)
Small Stores in General (con't)		
Music	4	6
Notion	4	6
Piano	4	6
Shoe	4	6
Tailor	4	8
Tobacco	4	6
General		
Auditorium, Church	2	4
Automobile Showroom	4	6
Bank	4	8
Barber Shop	5	8
Dance Hall	2	4
Depot--waiting room	1	4
Drafting Room	10	12
Hotel		
Lobby	2	4
Dining Room	2	4
Library Reading Room	3	6
Lunch Room	2	5
Office	6	10
Restaurant	2	4
School, Class and Study Rooms.	4	8

TABLE 14 *

Table of Watts per Square Foot for Stores, Offices etc., When illuminated with Semi-Enclosing Units and Clear Mazda C Lamps.

*Class of Illumination as Expressed in Foot Candles.	One Row of Units		More than one row of Units	
	Light Walls and Ceiling	Dark Walls and C'ling	Light Walls and Ceiling	Dark Walls and C'ling.
	Watts per Square Foot	Watts per Square foot	Watts per Square foot	Watts per Square foot
1	.29	.33	.21	.25
2	.55	.64	.43	.48
3	.72	.84	.56	.63
4	.94	1.10	.75	.82
5	1.15	1.35	.91	1.00
6	1.35	1.55	1.05	1.15
8	1.75	2.05	1.35	1.50
10	2.15	2.50	1.70	1.85
12	2.50	3.00	1.95	2.20
16	3.30	3.[illegible]0	2.55	2.85

*W. E. Bulletin.

** This table of Watts per Square Foot is based on the illumination requirements as shown in the classifisation Tables, pages 26 and 27. The number of each class is expressed directly in foot-candles.

For the information of the engineer, it may be stated that the watts per square foot as given in this and following tables have been computed on the basis of the average lumens per watt for the most common sizes of Madda C lamps, and the approximate coefficient of utilization for the conditions assumed. An allowance has also been made to cover deprecia-tion in light output due to dust, etc.

TABLE 15*

Table of Watts per Square Foot for Stores, Offices, etc., When Illuminated with Totally Enclosing Units and Clear Mazda C Lamps.

For Mazda Daylight lamps increase these figures 50%

Class of Illumination as Expressed in Foot Candles.	One Row of Units		More than one row of Units.	
	Light Walls and ceiling	Dark Walls and c'ling	Light Walls and ceiling	Dark Walls and c'ling
	Watts per sq. foot	Watts per sq. foot	Watts per sq. foot	Watts per sq. foot.
1	.40	.57	.29	.42
2	.76	1.10	.56	.79
3	1.00	1.40	.73	1.05
4	1.25	1.80	.93	1.30
5	1.60	2.25	1.15	1.65
6	1.85	2.60	1.35	1.90
8	2.45	3.50	1.80	2.55
10	2.95	4.20	2.16	3.05
12	3.50	5.00	2.60	3.65

* W. E. Bulletin.

TABLE 16 *

Table of Watts per Square Foot for Stores, Offices etc.,
When Illuminated with
Indirect Units and Clear Mazda C Lamps.

For Mazda Daylight lamps increase these figures 50%

Class of Illumination as Expressed in Foot-Candles.	One Row of Units Li Light Walls and Ceiling Watts per sq. foot	One Row of Units Dark Walls and C'ling Watts per sq. foot	More than One Row of Units. Light Walls and ceiling Watts per sq. foot	More than One Row of Units. Dark Walls and c'ling Watts per sq. foot.
1	,43		.33	
2	.82		.62	
3	1.10		.82	
4	1.40	Not re-	1.05	Not re-
5	1.70	commend-	1.30	commend-
6	2.00	ed	1.50	ed.
8	2.65		2.00	
10	3.20		2.40	
12	3.80		2.90	

*W. E. Bulletin.

Indirect lighting is especially dependent on the reflecting power of the ceiling and should not be used with dark colored ceilings. On the other hand, the reflecting power of the walls does not make much difference in the illumination, and the values given above can be used with safety under most conditions of walls. If, however, the walls are very dark and there is some question as to size of lamp the larger size should be used.

TABLE 17*

Table of Watts per Square Foot for Stores, Offices, etc., When Illuminated with

Semi-Indirect Units and Clear Mazda C Lamps.

For Mazda Daylight lamps increase these figures 50%

Class of Illumination as Expressed in Foot Candles.	One Row of Units		More than One Row of Units	
	Light Walls and Ceiling	Dark Walls and C'ling	Light Walls and Ceiling	Dark Walls and C'ling.
	Watts per sq. foot	Watts per sq. foot	Watts per sq. foot	Watts per sq. foot.
1	.40		.30	
2	.76		.57	
3	1.00		.75	
4	1.25	Not re-	.96	Not re-
5	1.60	commend-	1020	Commend-
6	1.85	ed	1.40	ed
8	2.45		1.85	
10	2.95		2.20	
12	3.50		2.65	

* W. E. Bulletin.

Indirect lighting is especially dependent on the reflecting power of the ceiling and should not be used with dark colored ceilings. On the other hand, the reflecting power of the walls does not make much difference in the illumination, and the values given above can be used with safety under most conditions of walls. If, however, the walls are very dark and there is some question as to size of lamp the larger size should be used.

TA BLE 18 *

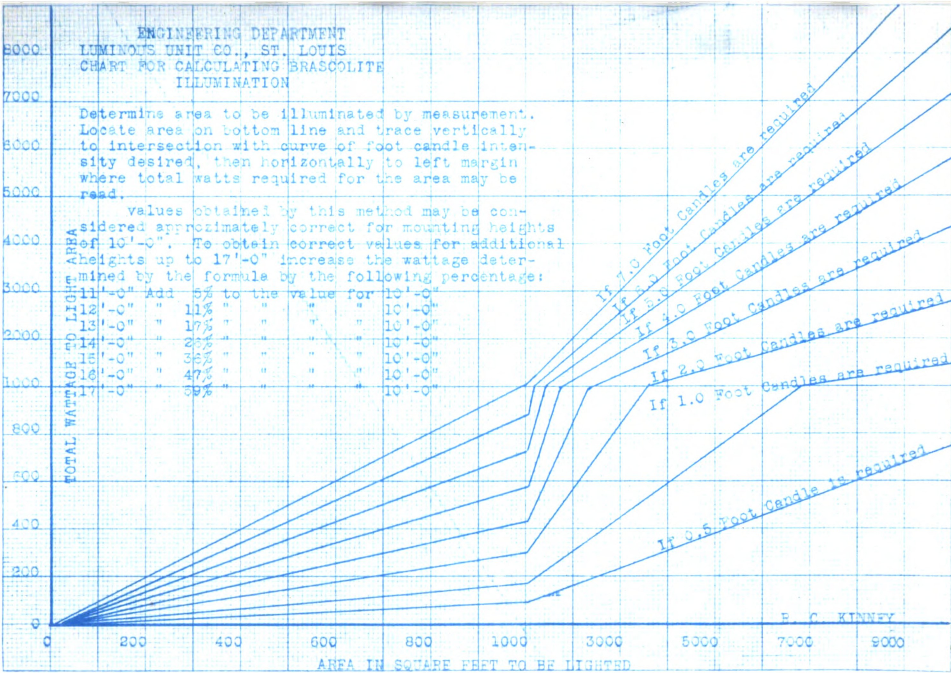
Table of Watts per Square Foot for Stores, Offices, etc., When Illuminated with Duplexalite Units and Clear Mazda C Lamps.

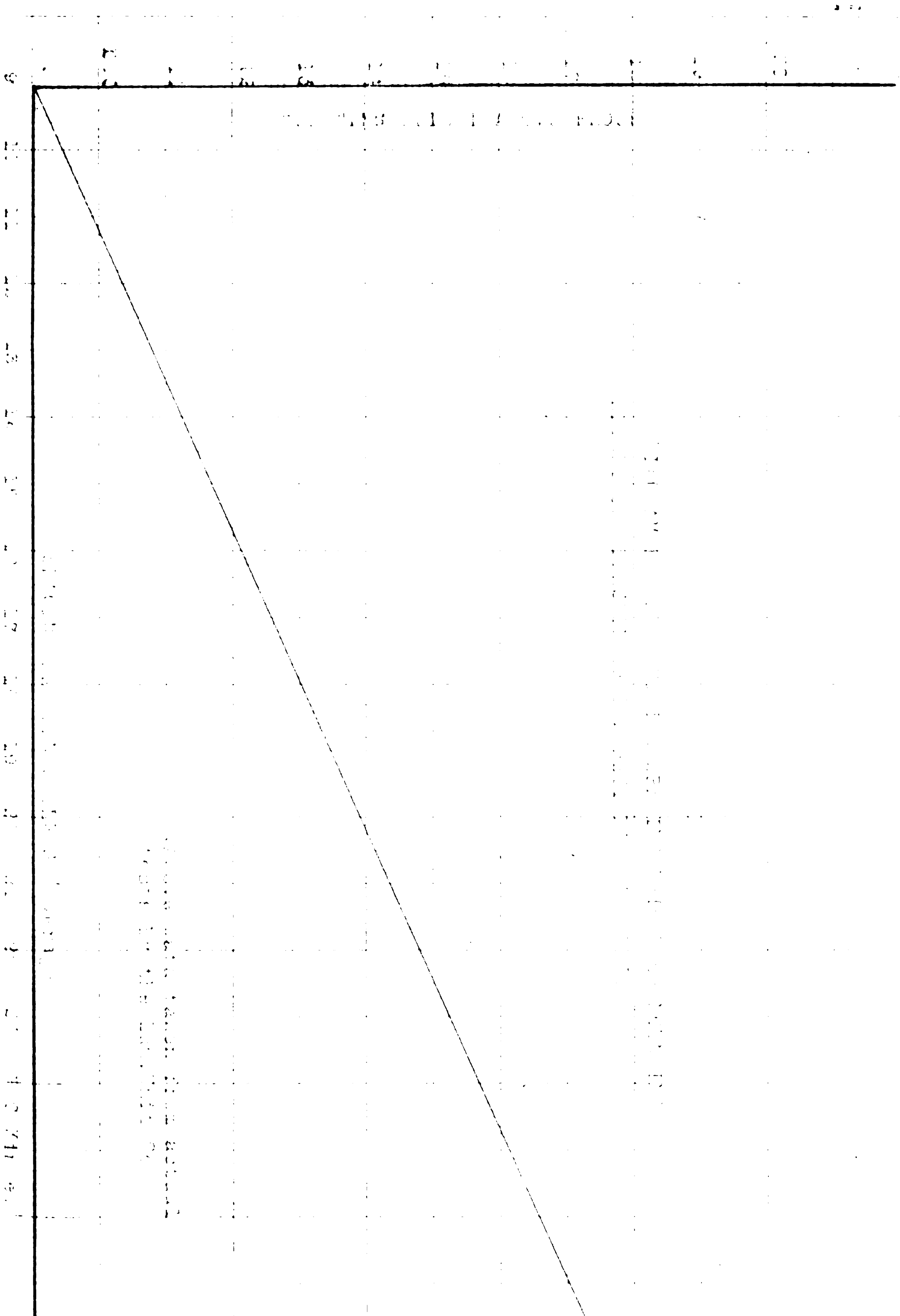
For Mazda Daylight lamps increase these figures 50%

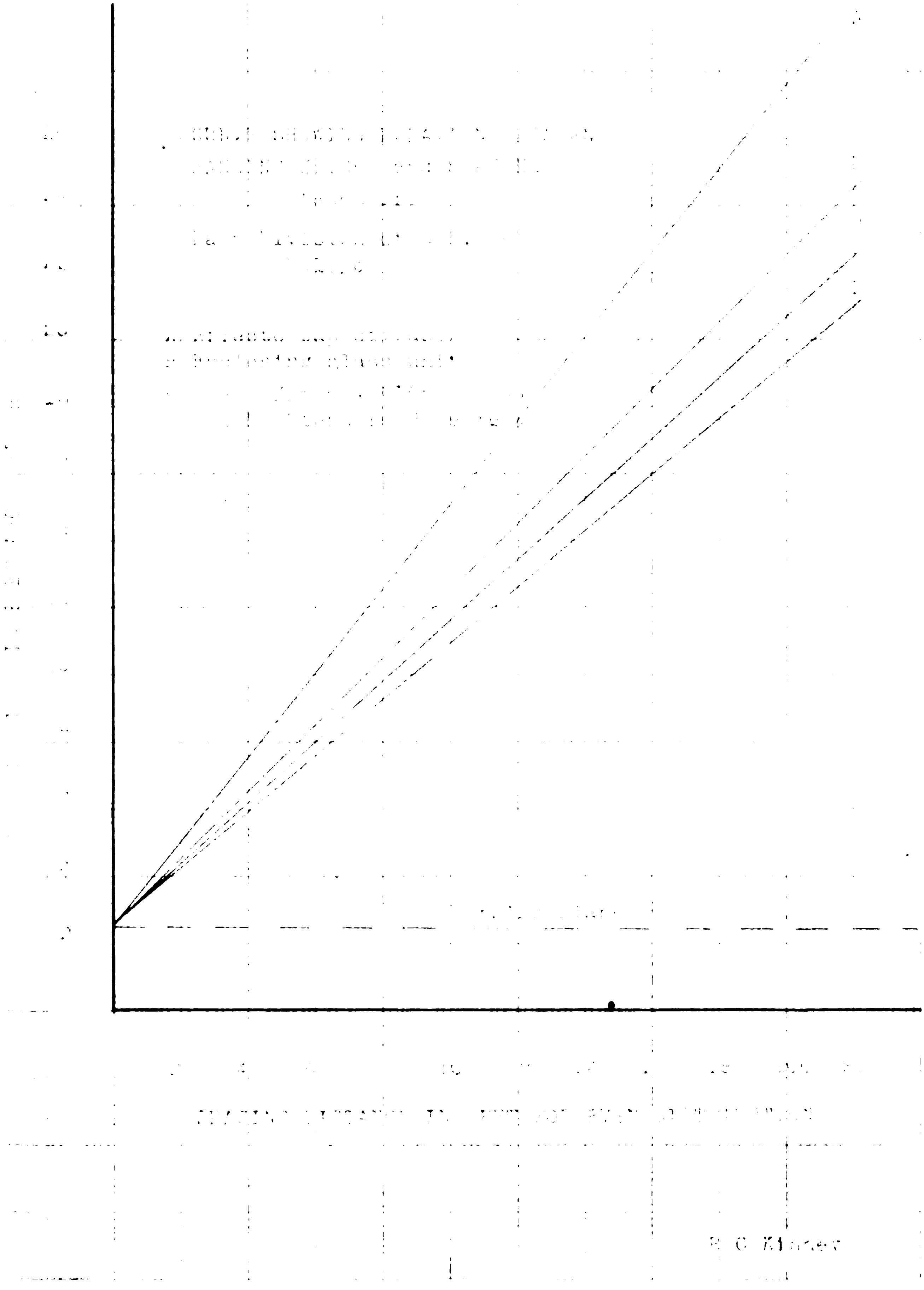
	One Row of Units		More than One Row of Units	
Class of Illumination as Expressed in Foot Candles.	Light Walls and Ceiling Watts per sq. foot	Dark Walls and C'ling Watts per sq foot	Light Walls and Ceiling Watts per Sq. foot	Dark Walls and C'ling Watts per sq. foot.
1	.40		.30	
2	.76		.57	
3	1.00	.75	.75	
4	1.25	Not recommended	.96	Not recommended
5	1.60		1.20	
6	1.85		1.40	
8	2.45		1.85	
10	2.95		2.20	
12	3.50		2.65	

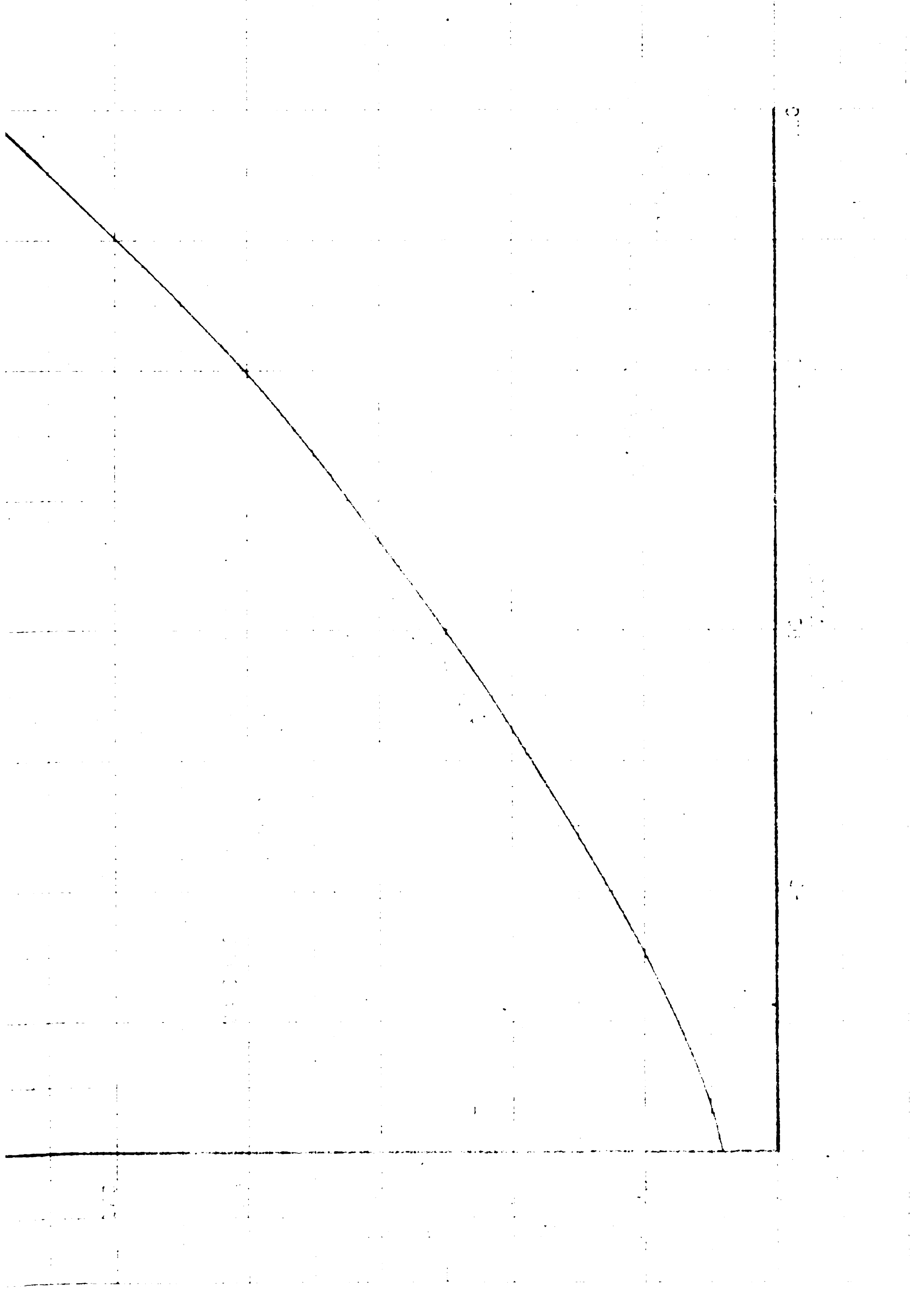
*W. E. Bulletin.

Duplex lighting is especially dependent on the reflecting power of the ceiling and should not be used with dark colored ceilings. On the other hand, the reflecting power of the walls does not make much difference in the illumination and the values given above can be used with safety under most conditions of walls. If, however, the walls are very dark and there is some question as to size of lamp the larger size should be used.

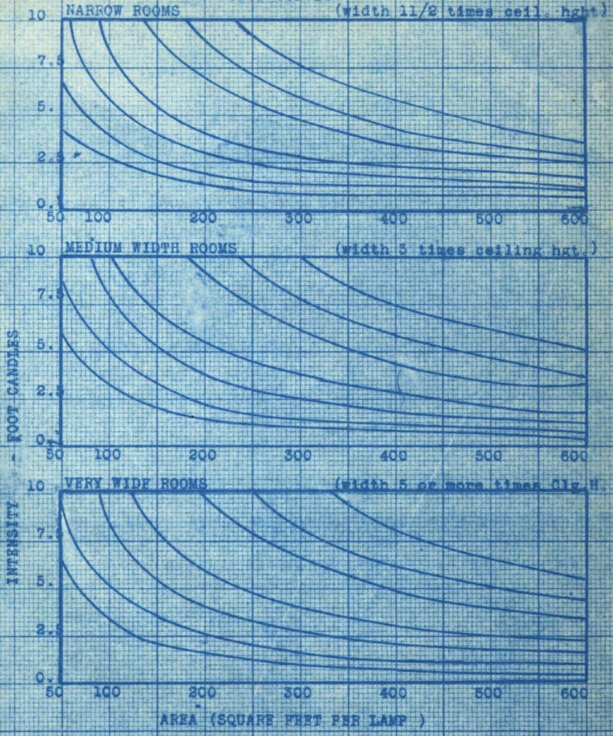

ENGINEERING DEPARTMENT
LUMINOUS UNIT CO., ST. LOUIS
CHART FOR CALCULATING BRASCOLITE
ILLUMINATION
Determine area to be illuminated by measurement. Locate area on bottom line and trace vertically to intersection with curve of foot candle intensity desired, then horizontally to left margin where total watts required for the area may be read.
values obtained by this method may be considered approximately correct for mounting heights of 10'-0". To obtein correct values for additional heights up to 17'-0" increase the wattage determined by the formula by the following percentage:
11'-0" Add 5% to the value for 10'-0"
12'-0" " 11% " " " " 10'-0"
13'-0" " 17% " " " " 10'-0"
14'-0" " 26% " " " " 10'-0"
15'-0" " 36% " " " " 10'-0"
16'-0" " 47% " " " " 10'-0"
17'-0" " 59% " " " " 10'-0"
If 7.0 Foot Candles are required
If 6.0 Foot Candles are required
If 5.0 Foot Candles are required
If 4.0 Foot Candles are required
If 3.0 Foot Candles are required
If 2.0 Foot Candles are required
If 1.0 Foot Candles are required
If 0.5 Foot Candle is required
TOTAL WATTAGE TO LIGHT AREA
8000
7000
6000
5000
4000
3000
2000
1000
800
600
400
200
0
0
200
400
600
800
1000
3000
5000
7000
9000
AREA IN SQUARE FEET TO BE LIGHTED
B. C. KINNEY







INTENSITY CURVES



The above curves are not absolutely accurate but are sufficiently so for all commercial uses, and provide a very easy and quick method of determining the right bulb required for a given job.

(Above data taken from the G.E. Lab. report #[illegible]17)

R.C.Kinney

[illegible]

Ceiling outlet. [illegible] in center indicates [illegible] of standard [illegible] lamps.

Bracket outlets. No. in center indicates No. of [illegible] lamps.

Wall or base. cord receptacle outlet. [illegible] in center indicates no. of [illegible] lamps.

Floor outlet. [illegible] in center indicates [illegible] lamps.

Outlet for [illegible] standard or [illegible], indicates No. of [illegible] lamps.

[illegible] outlet [illegible] [illegible] or [illegible] [illegible]

[illegible] cord outlet.

[illegible] outlet [illegible]

[illegible] outlet. [illegible]

[illegible]

[illegible] outlet [illegible]

[illegible] outlet [illegible]

[illegible] outlet [illegible]

[illegible] outlet....

Electrolier Switch outlet..........

[illegible] outlet.

Distribution panel.

Motor outlet No. in center indicates H.P.

Transformer

Circuit for clock, telephone, bell, or other service [illegible] under floor [illegible] service [illegible] symbol to which line connects

[illegible]

[illegible]

[illegible]

[illegible] line.

[illegible]

[illegible] outlet [illegible]

[illegible] outlet.

[illegible] outlet

[illegible] outlet, [illegible] indicates [illegible] [illegible]

[illegible]

Watchman clock outlet

[illegible] outlet

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] of [illegible] all [illegible]

[illegible] of center of all [illegible] outlets [illegible] floor unless otherwise [illegible]
[illegible] ....
[illegible] .... [illegible]
Corridor.. .... [illegible]

[illegible]