THE THEORY AND PRACTICE OF MODERN LIGHTING

THESIS FOR THE DEGREE OF E. E.

Marshall George Houghton

1931

THESIS

Electric lighting

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THE THEORY AND PRACTICE
OF
MODEL LIGHTING

A thesis submitted to
the Faculty of the
MISSISSIPPI STATE COLLEGE
of
Agriculture and Applied Science

by
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for the
Professional Degree
of
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June 1951

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The object of this book is to present the theory of modern illumination and a practical method of design in a clear and simple form with explanations of the theory, processes, and limits of design. The [illegible] and methods employed are those used by the professional designer.

In the preparation of this work the author found it convenient to treat the subject in the following manner. First, a discussion of the fundamental concepts, units of measurement and their application; second, the principles of light control and their bearing on the final results; third, the requirements of modern industrial and commercial interiors, and the design to fill these needs; fourth, floodlighting and exterior illumination, its design and application. Blueprints are included that illustrate the various fundamentals and their practical applications.

There are a great many pictures published from time to time which show the practical as well as the exceptional beautiful effects that may be obtained by painting with light. The reader, in travelling around, will see many lighting installations which he will wish to analyze; also new lighting problems to develop. These may be readily done by following the methods outlined in this book.

The author found it impossible to secure original photographs of installations in sufficient number to illustrate all that has been done, so a great many commercial pictures have been incorporated in the appendix. The

appendix also contains cuts of many floodlight projectors and other lighting fixtures referred to in the design problems. This is not a complete reference book on units but each is representative of the group under which it has been chosen.

The author has to acknowledge [illegible] to the following [illegible] and [illegible], Underwriters' Laboratories and [illegible] for [illegible]; [illegible] the Crouse-Hinds Company, General Electric Company, Mitchell Manufacturing Company, American Gas Accumulator Company, (A.G.A., Spencer Turbine Company, Electric Service Supply Company and Detroit Edison Company.

Marshall G. Nolan

Detroit, Michigan
May 1, 1931

The Theory and Practice of Modern Lighting

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This contains many tables, graphs and charts.

Also Blueprints of present "Model Installations".

"Light is the essential condition for Vision."

Webster's Dictionary

Changing the amount of illumination on a rotating disc or wheel apparently changes its speed of rotation. Under low illumination the disc appears to rotate rapidly; the geometrical designs on its face are blurred and indistinct. When the illumination is increased there is apparently a pronounced slowing down of the disc, the patterns becoming distinct. The truth illustrated here is fundamental: namely, that it takes less time to see under high illumination than under low-- that there is a time factor in the process of seeing, just as there is a time factor in taking a photograph.

Saving time, crowding extra seconds into every minute, is the common objective of efficiency effort. We do it by substituting machinery for hands, and orderliness for lack of system; but wherever human eyes are used, if the light is inadequate, the hour is not long enough for the work to be accomplished. The eye in its camera action is forced to take time exposures instead of snapshots. These exposures are taken thousands and thousands of times a day, and the extra fraction of a second for each exposure spells an accumulated loss of half an hour or so during the period. Ample diffused illumination on the work saves this time

and with less, rather than more, effort on the part of the operator.

Good artificial illumination is a development of comparatively recent years, and although it is quite generally conceded to be desirable, there are few who entirely comprehend how the accompanying benefits are derived. Many curves have been drawn by various authorities and research men that present basic facts which provide a direct link between light and time - between better illumination and the increased production and decreased accidents which have invariably resulted. Several of these curves and a complete discussion of the results are included later as an aid to choosing the correct value or amount of light needed for a given kind of work.

In addition, good lighting has numerous other advantages that cannot be expressed numerically, but which are none the less real and important. The marked improvement made in the general appearance of a room, the cozy comfortable atmosphere created in the home, the stimulating enlivening influence exerted in the store, the office and the shop - these are valuable by-products of proper illumination.

It is readily seen that the subject of illumination has a direct bearing on the health, wealth, and happiness of practically every living person. It follows that great benefits can be derived from the use of the knowledge we have in this line, that those individuals who have

the most information at hand will be best fitted to benefit mankind.

For some time the need has been felt for a more comprehensive work to cover the several phases of illumination, at least in a general way, and give examples of actual installations. Much of this information is now in print but can only be found in the catalogs of the various companies who either make installations or sell the equipment. Much of this data has been published in current magazines or pamphlets at the time of the first showing. In order to get a cross-index or reference library at the present time one must have all these catalogs, pamphlets, and leaflets, as well as current magazines and trade literature on hand. It is evident to even the casual reader that to efficiently use such a mass of information one must have a very thorough knowledge of the products of the various manufacturers and their methods of using the same in order to turn with any degree of certainty to a catalog and get engineering data and methods on any one type of installation without wasting a great deal of time searching through irrelevant material.

It would be a very ambitious text, indeed, which attempted to completely cover the subject of illumination or even one phase of it, giving due allowance to the special cases which arise; so this thesis has been limited to a statement of the fundamentals in the various fields,

explanations of these factors, and one or two representative layouts as examples. This, it is hoped, will be of value to the student who is primarily interested in how things are done and to the design engineer for use as a basis to make new and varied layouts in fields which may not be wholly familiar to him. The writer has referred freely to the most recent commercial information on the subject and assembled sufficient data to make workable the formulae and graphs given under the separate titles. Additional data may be had from many of the companies mentioned in the bibliography.

As the trend goes from low to high and constantly higher levels of illumination the architect and designer are called upon to justify the increased operating expense and increased first cost. A large number of tests have been run in industrial plants to determine the relation between illumination and production, other factors being kept constant. In every case, increased illumination has increased the production far beyond the added lighting cost.

One such investigation was completed not long ago in the Inspection Department of the Timkin Roller Bearing Company at Columbus Ohio. The number of bearings inspected per operator per hour was found, first under the old lighting system (providing an average of about five foot-candles on the work) and then under well designed systems providing 6,13, and 20 foot-candles.

Unusual care was taken to prevent any factors other than illumination from influencing the results. During the ten weeks of the test the humidity and the interior temperature were kept practically constant, and the employees did not know their production was being investigated.

The results of the test furnished proof that for the class of work carried on in the Inspection Department investigated, the production was materially affected by the illumination supplied. Without exception, the production increased when the illumination was raised and decreased when it was lowered.

Under the old glaring lights, which gave only about 5 foot-candles on the work, the number of pieces inspected per operator per hour was 408. Under a well designed system providing 6 foot-candles, with a minimum of glare and specular reflection, the number of pieces inspected per operator per hour was 424, representing a 4% production increase over that obtained under the former faulty illumination of about the same foot-candles. Likewise, increasing the illumination from 6 to 13 foot-candles, with a well designed system, resulted in an output of 440 pieces per operator per hour, which was an additional 4% increase, and when the illumination was raised to 20 foot-candles, the production increased to 458 pieces per operator per hour, representing a further 4.5% increase in production. Thus comparing the 20 foot-candle system with the one originally in use a 12.5% increase in production is found.

Granting that this has occurred we must now turn to the economics of the situation. The cost figures for the Timkin installation are:-

Cost of Lighting (Current, lamp renewals, fixed charges, etc.) new 20 foot-candle installation	$0.32	per hr.
Cost of Lighting, old 5 foot-candle installation	.04	" "
Added cost of better lighting	.28	" "
Hourly total wages of 44 Inspectors	13.20	" "
Hourly saving to company through a 12.5% production increase	1.47	" "

Thus the saving to the Company is over five times the added cost of better lighting, and proves that the money spent on this improvement was a very good investment.

It is interesting to investigate this case from another angle to see what the increases in production were, compared to the added lighting cost in percent of pay-roll.

After this correction is made, and using the old lighting of 5 foot-candles as a standard, we find that with 6 foot-candles of new design lighting an increase of 0.5% in light cost provided a 4% increase in production; with 13 foot-candles a cost increase of 1.3% -

an 8% production increase; and with 20 foot-candles the lighting cost increased the pay roll 2.1% but provided a 12.5% increase in production. This easily proves that the lighting changes will pay for themselves many times over.

In addition to assisting the work, good lighting has highly beneficial influences in other phases of everyday life. In the commercial field, the attracting power of the brightly lighted show window has been demonstrated repeatedly, and within the store good illumination not only assists the customers in selecting the merchandise wanted, but its cheerful atmosphere builds a good will and stimulates the desire to buy.

Insufficient illumination is the direct cause of over 17% of the night traffic accidents. Adequate street lighting avoids this loss, besides decreasing crime, facilitating traffic movement, and generally arousing civic pride.

To assist the 30% of the school children who have defective vision, and to prevent eyestrain when studying, the school and the home should have ample light.

In addition, the home may be greatly beautified by the use of light for decorative effect.

These are only a few of the many reasons why illumination has come so rapidly to the front during the past few years; the reader can furnish many others.

Now comes the startling statement from Mr. Symmonds of the Symmonds Saw Co., announcing construction plans for the coming year to include one large building with ground floor area of over 6 acres (2 city blocks) to be built without windows, and illuminated entirely by electric lights "because electric lights are so much more satisfactory, cheaper in the long run, and furnish even illumination far superior to the ever changing value of sunlight obtained through windows that are always getting dirty and frequently breaking", to quote Mr. Symmonds. A percentage of ultra violet light will be added to make the working conditions more healthful and forced ventilation will furnish the men with washed air of the proper moisture content. Truly this is a wonderful age, and the trend toward "manufactured ideal conditions" continues on all sides.

Fundamentals of Illumination.

Without light, the most important of the senses which bring information from the outside world, that is the sight sense, is useless, for without light even a perfect eye is blind. On the other hand, the use of light determines what kind of service we can get from

our eyes, because it is a well known fact that through bad lighting the eyes become impaired and defective. If one shuts his eyes, he can easily realize how much of his knowledge of what is going on in the world depends on light, and conversely, if he looks at the sun for an instant, he realizes how annoying and harmful a glaring light can be.

The process of seeing is not fully understood by everyone, and a short statement of the facts will give a basis upon which future work depends. Suppose the sun is shining on a building; - because of the light rays one can see its size, shape, and the color of the walls, window sills, etc.

The sun pours upon it a great many energy waves, including light waves, and instead of stopping or absorbing all the rays, each individual part of the building reflects and scatters a portion of the rays falling upon it, and absorbs the rest. As a result of this scattering, some light from all parts of the building in the field of view falls upon the eye; furthermore, the parts of the building appear in their characteristic colors. For example, the bricks appear yellow because in general they absorb relatively few of the rays of wave lengths which are capable of giving the impression yellow. The eye in turn conveys the message to the brain that the bricks are yellow. In the same way, the brown mortar absorbs most rays except a particular combination of waves which make

up the color brown, and when these are reflected to the eye, they convey the impression that the mortar is brown. If there are any parts of the building which absorb practically all of the sun's light that falls on them, with the result that no visual impression is made, those parts are called black. The white portions of the building reflect nearly all of the light that falls upon them equally for all wave-lengths, and it is for this reason that the pillars appear white. The shape and form of the building and its parts are made evident by the varying amounts of light falling on the different surfaces and the percentages of this light which they reflect toward the eye. The pillars appear round only because the eye has become accustomed to recognize certain gradations of light and shade as being characteristic of round objects.

Again the amount of light available has much to do with how much we see and how readily we see it. When called upon to examine the inner workings of a watch, one almost always moves over to the window to get maximum illumination. Also in playing tennis in the late afternoon, we remember that the ball was clearly seen in our opponent's hand, but after it was served and in motion, it disappeared entirely, or seemingly so, until it bounced at our feet. This shows that the illumination was inadequate for moving objects of this size.

These factors must be made use of in floodlighting of buildings, especially if color is used, in lighting of airports, tennis courts, or baseball diamonds, as well as interior work. In this highly complicated process of seeing which the eyes are performing constantly, it is well to remember that for both natural and artificial illumination an object is not seen as a result of the light which travels direct from the light source to the eye, but only as a result of the light which travels first from the source to the object looked at and from thence to the eye.

Units of Measurement -

THE CANDLE: -

Some time 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, which was familiar to all. The first comparisons were made by setting the two lights up in the field of view and gauging the difference by looking from one to the other, the most natural direction in which to look at the sources being the horizontal. While there are any number of directions one may look at a source, the light giving power in a horizontal direction was made the basis of comparison, 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 lights as they came out, were rated according to their strength in this same direction and were stated to give so many candles, a 20 candle lamp being 20 times as strong (or having an intensity 20 times as great) in a horizontal direction. This rating of a lamp is now made by a device known as a photometer, a description of which is included later.

One very essential point to remember in this connection is that the candle power of a lamp represents its intensity in one direction only. 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. Late commercial information shows, however, that with modern filament design and inside frosted bulbs the dead spot has been reduced so far that it is no longer necessary in practice to rotate the source while measuring its intensity.

One important conclusion must be drawn, however, and that is that the candle power of a source does not necessarily give an indication of the total quantity of light emitted by the source. For example, an automobile headlamp may produce a beam with a maximum candle power of 100,000, the source being a 21 c-p bulb. The reader is familiar, however, with the very efficient reflectors developed during the past two to three years which concentrate practically all of the emitted light into a narrow beam, running the beam candlepower quite high while the source c-p remains low.

THE LUMEN

Assume that a source is giving one candle in every direction, and that this source is placed at the center of a sphere painted black on the inside and having a radius of one foot. If now an opening is cut in the sphere some of the light will escape. The quantity of light allowed to escape may be varied by varying the size of the opening, with the candlepower of the source and the radius of the sphere remaining fixed. It follows that if some definite size opening is assumed, a definite quantity of light which may be used as a unit for measuring quantity will result. The simplest area or unit to assume is 1 square foot, and it has been established that the amount of light escaping shall be considered the unit of quantity, and is called a lumen. Thus a permanent unit for the measurement of the quantity of light has been established. If the area of the opening is doubled, the light escaping will be 2 lumens; if the area of the opening is 1/2 a square foot the light escaping will be 1/2 a lumen. Now, since the total surface of the sphere having a radius of 1 foot is 12.57 square feet, removing the sphere entirely there would be equivalent of 12.57 openings 1 foot square and the total light emitted would be 12.57 lumens. A value of 12.5 is sufficiently accurate for most practical purposes, and is a convenient figure; dividing the mean spherical candlepower by 8 and multiplying by 100, the lumen output is obtained directly.

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.

THE FOOT-CANDLE

Light is a cause and illumination the effect or result. Both the lumen and 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 amount of illumination on a desk, book, newspaper, or other working plane, there is a unit called a foot-candle. A foot-candle represents an amount of illumination equal to that produced at a point on a plane 1 foot distant from a source of 1 candle and perpendicular to the light rays at that point. Now if the surface is not perpendicular to the incoming beam of light it is evident that the light is spread over a larger area hence the intensity can not be as great. It is easily shown that if the intensity on a plane perpendicular to the beam is I, and the new plane makes an angle A with the plane perpendicular to the beam, that the intensity on the new plane is I x cos A.

The level of illumination measured in foot-candles is the measurement most intimately associated with everyday use of light, and it is a measurement which the eye either consciously or unconsciously is making whenever the faculty of vision is being employed, because the number of foot-candles there are on a working plane, all other things being equal, determines directly whether or not there is sufficient light. Some time if you would like to get a working knowledge of what a foot-candle of illumination is, just hold a newspaper approximately one foot away from a candle and read it for ten minutes. There is a definite reason for adding the time limit. At first the illumination may seem adequate but very soon you will wish for more light.

Inasmuch as the source of illumination is very seldom as small as one candle-power and the distances are greater than one foot, with much larger areas, an equation must be set up to express the change in one with respect to another.

The first law considered will be the relation between the change in the candle-power of the source with a fixed distance and area. It may be stated as follows: - The amount of illumination on a given area located at a fixed distance from the source varies directly as the intensity of the source. The proof of this truth is very simple. Suppose an area is illuminated to an intensity of 1 foot-candle by a five candle power light source. If now the five candle power source is removed and replaced by a 10 candlepower light, the intensity on the area will be 2 foot candles, or twice as much as before. The 10 candle power light will emit twice as many lumens as the 5 c-p unit, hence twice as many lumens will be intercepted by the given area at the same distance as in the first case, and the intensity will be twice as great. In like manner, if a 25 c-p source is used, the intensity will increase five fold.

The second relation is commonly known as the inverse square law. The inverse square law is the most widely known of all optical laws and is treated in all elementary physics books. Briefly stated it is,: - The amount of illumination received on an object varies inversely as the square of the distance between the object and the

source. The explanation of this basic truth is as simple as the first one. With a source of 1 candle, the intensity on a plane 1 foot distant is one foot-candle. Let this area of one square foot determine the limits of a beam from the light source. Now move the plane 2 feet distant from the source and the same beam will cover four square feet. Inasmuch as the same number of lumens are in the beam as before and they are spread over 4 square feet instead of 1 square foot, the intensity must be ¼ as much as before or ¼ foot-candle. If now the plane be moved 3 feet away from the source, the same beam will cover an area of 9 square feet and the intensity will be 1/9th foot-candle. At 5 feet the intensity will be 1/25th foot-candle, etc.

In spite of the fact that this law is the most widely known of the optical laws, its misapplication has led to many poor lighting installations. In these the principal error has been in mounting the lighting unit too low with the idea of getting more foot candles on the working plane. Mounting a local lighting unit close to the work is the proper thing to do if the area to be lighted is small, such as the tool point of a drill press or lathe, or the needle of a sewing machine, but in no case should the units of a general lighting system be lowered to accommodate the apparent need for more light over a particular point.

The distribution curve of a lighting unit for general lighting will usually show that the unit has

been designed to give a reasonably high concentration of light directly beneath it, but that also a great portion is spread out in zones and at such angles that light is provided in areas at some distance from a point directly beneath the unit. Therefore, for general overhead lighting the units should be mounted as high as is practical with their distribution so that every point in the room will be lighted from several directions. This will reduce sharp shadows as well as give more head room, and the room will be more uniformly illuminated. Local lighting where necessary should be used to supplement the general illumination.

Reference to the second law, first case, in which the surface was illuminated to an intensity of 1 foot-candle; by definition this is one lumen. This gives the important relation that if one lumen is so utilized that all of the light is spread over a surface of 1 square foot, the surface will be lighted to an average 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 foot-candles 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 400 square feet to an average of 10 foot-candles, 4,000 lumens must be projected on the surface. This method of calculation is called the "Lumen Method" and has many advantages over the older

"point by point" system as will be seen later when the complete process is outlined.

REFLECTION FACTORS.

The amount of illumination on a surface in foot-candles should not be confused with the brightness of the surface. A buff or gray surface lighted to an average of five foot-candles does not appear as bright as a white one, because such a large percentage of the light that falls on the surface is absorbed and lost. A full statement of the situation will read, "The brightness of an object depends both upon the intensity of illumination on it and the percentage of light that it reflects." The ratio between the foot-candles reflected from a surface and the foot-candles directed on it is called the reflection factor of the surface. The following short table shows the reflection factor of a number of painted surfaces: -

Reflection factors.

White - - - - -	80%	Sky Blue - - -	35%
Ivory - - - - -	70%	Olive Green- -	20%
Buff - - - - -	65%	Cardinal Red -	20%
Sage green - -	40%	Black- - - - -	5%

Since the ease with which objects can be seen depends directly upon the amount of light they reflect, it is seen that very high levels of illumination must be provided where the materials worked on are dark in color.

It also follows that the colors painted on the ceiling and walls of a room will have a direct bearing upon the kilowatts of installed lights necessary to bring the room up to a given level of illumination. The installation of more lights means greater first cost, greater upkeep and greater operating expense.

PHOTOMETRY.

Photometry is a very specialized branch of the science of illumination and must be made the object of a great deal of study in order to cover all phases of it. Any reader who wishes to make a study of this subject is referred to specialized physics texts or other books on light and its measurement. For the purpose of this text it is sufficient to know that: - Photometry is the science of measuring accurately the intensity of a lighting source and its distribution around the source.

The simplest type of photometer that can be made may be described as follows: - A vertical paper screen in the center of which is a grease spot is placed between the lamps to be compared. By sliding the screen back and forth a position can be found where the outlines of the spot will vanish and the spot itself will disappear. When this condition occurs, the illumination on both sides of the screen is the same and the intensity of the unknown unit can be found by calculation from the relation; the intensity of the unknown is to the intensity of the known unit as the inverse square of the distances between the respective units and the screen. For accurate photome-

try the grease spot is no longer used, but modern comparison photometers are the same in principle. In this case when the illumination on one side of the screen is greater than that on the other, the spot will appear darker on this side and lighter on the other side, than the surrounding paper. The reason for this is still evident.

FOOT-CANDLE MEASUREMENTS.

It will be noted that in measuring the candlepower of light sources as previously discussed, the illumination on opposite sides of the screen is balanced. Generally, however, the interest is in the amount of illumination itself, or the foot candle intensity which is being supplied to a given working plane, and not in the candle power of the sources which supply this information. Devices called foot-candle meters have been developed to read these values direct, their main difference from photometers being in construction and calibration. In most all cases they are small and easily portable, their value being to check existing installations for redesign, or verify a new building on an acceptance test. The principle of operation is simple. A small incandescent lamp is concealed in the box at one end of the screen. This illuminates translucent spots on the screen to a high intensity at the lamp and low at the other. The illumination to be measured is assumed to be uniform over the entire scale. At the point where the spots appear neither brighter nor darker than the surrounding scale, it is evident that the

illumination from within is equal to that on the outside and the intensity can be read directly. The scale is calibrated with the lamp within burning at a certain specified voltage and a rheostat and voltmeter are provided so that these standard conditions can be duplicated each time a reading is wanted.

THE CANDLE POWER DISTRIBUTION CURVE.

The candle power distribution curve of a lamp or lighting unit is a graphical chart showing the intensity of illumination or light distribution from the unit. The unit is assumed to be the center or hub of a wheel and intensities are measured in all directions around the unit at an angle, compared to the spokes of a wheel. These values, when plotted on a circular chart all lines of which radiate from the center, show exactly how much light leaves in any one direction from theunit. These distribution curves were widely used at one time in calculating the illumination at certain distances from the source, but the lumen method of computing illumination was shown to be so much more accurate and simple that the "point-by-point method has fallen into disuse. Distribution curves are now used principally for design information and for comparing reflectors for a given service from the standpoint of light distribution and light absorption.

PRINCIPLES OF LIGHT CONTROL.

It is now a common fact that the light from a bare incandescent lamp is distributed in such a manner that it cannot be used under most conditions without a reflector or enclosing glassware. A reflector of suitable design will redirect the light into such angles that it can more efficiently be used. Some times the enclosing glassware also serves this purpose but its chief advantage is in modifying the brilliancy of the light source, diffusing the light to produce a soft and pleasing illumination.

The three systems of lighting most commonly employed are the direct, indirect, and semi-indirect. In the direct lighting system, the units distribute the light downward into the room or onto the working plane: in the indirect system all of the light is thrown upon the ceiling and reflected from there to the working plane; in the semi-indirect system the majority of the light is thrown upon the ceiling and reflected downward, as in the indirect system, the remainder of the light is diffused directly through the fixture to the working plane. The choice between these three is made on the basis of the use of the room, class of service, and available funds - both first cost and operating expense being taken into account. More will be said about this later.

Reflectors and enclosing glassware are made from

three classes of substances: - transparent, translucent, and opaque. Transparent substances transmit a large portion of the light striking them without scattering it, hence objects may be seen clearly through transparent plates. Window glass and gold fish bowls are transparent. Some lights, especially for outdoor use, are surrounded by a clear glass bowl to protect them against the elements and the light bulb can be clearly seen through them. Translucent substances transmit light but scatter it so that the outlines of objects cannot be clearly seen through them. A good example of this is the milk white or milky bowls and units that are commonly used for direct illumination. The opaque substances do not transmit any light but reflect and absorb it. Steel reflectors, either polished, enamelled or painted, are good examples of this type of light control. All three types of substances absorb a certain portion of the light rays which strike them, and the radiant energy so absorbed tends to raise the temperature of the unit.

Light may be controlled by four methods; absorption, refraction, reflection, and diffusion. By the use of these methods it is possible to make the light from any source perform practically as desired. To explain these four methods of control one must go back to the fundamental statement which says that a ray of light will travel along a straight line indefinitely until modified or redirected by some outside body or agency. Such modifi-

cation might be by absorption and will vary from a small percent to complete extinction of the beam. It is noticed when a beam of light passes through a piece of dense glass or a cloud of smoke or steam.

The second form of modification is termed refraction, and applies to that peculiar property evidenced where light rays pass from one transparent medium to another of different density and appear to be bent at the point of junction of the two mediums. Refraction makes a fish line appear to bend at the point it enters the water. We know the line does not bend, but the light waves coming from that part of the line under the water are refracted when they come into the air, thus creating the illusion. The third and best known method is reflection. The redirection or throwing back of light from a surface is best illustrated by a mirror or an automobile headlamp or searchlight "reflector". The fourth form is diffusion, which is the breaking up of the beam and spreading its rays in all directions either by passing through a medium or falling upon a surface.

The next item to consider is the various reflecting surfaces in use at the present time and their effectiveness. The simplest form of reflection is that which takes place when a ray of light strikes a polished metal surface. The angle of incidence is equal to the angle of reflection in this case and is called regular reflection. It is easily seen that it is possible to redirect light traveling in any given direction into any other direction by

means of a surface properly placed. While all polished metal surfaces reflect light in the manner described, they do not reflect it in like amounts. For instance, a polished silver surface will reflect 90% of the light that is thrown on it, an aluminum surface reflects 60%, and a chromium plated reflector will return approximately 66% of the beam which impinges on it - the balance being absorbed and lost. Polished metal reflectors are used most extensively in equipment where they can be tightly covered to keep out the dust, dirt, and fumes in the air which will tarnish them and decrease their efficiency. Automobile and railroad headlights, and small floodlights for airport and advertising illumination are the best examples in this class of equipment.

Mirrored glass is similar in its reflection characteristics to polished metal surfaces, but the commercial type of mirror has silver backing; thus the light is forced to pass through the glass twice, once approaching and then leaving the silver surface, and the loss in the glass depends on its quality. This brings the efficiency down to about 85% and makes the mirrored glass less desirable for laboratory uses, even though its deterioration is less than polished metal. Mirrored reflectors have the disadvantage that they usually throw brilliant images of the filament on the surfaces illuminated. Practically these images are often eliminated by fluting the reflector or frosting the lamp. Both of these methods, however, cause a loss in control

of the light and decrease its efficiency.

Much use is made of mirrored glass for reflecting surfaces in the totally indirect type of lighting fixtures, in motion picture machines, floodlights, and show window reflectors.

Dull finished metal reflecting surfaces are favored for certain types of fixtures due to their light weight and low cost, the more common materials are spun aluminum and aluminum finish metal. Desk lamps, small spots and floodlights are daily examples familiar to everyone. The chief disadvantage of this surface is its ability to quickly acquire a layer of dust and dirt which seemingly cannot be wiped, washed, or scrubbed clean. The low first cost offsets this disadvantage to a great degree.

The next reflecting surface is also used for diffusing light and finds a great deal of use at the present time commercially. It is white or milk-glass, sometimes called opal glass. Its operating properties can easily be explained if we consider it as plain glass with fine white particles held in suspension. As a beam of light strikes this glass, 10 to 15 percent is immediately reflected from the polished outer surface, the remainder continues on until it strikes all of the fine particles where it is dispersed in all directions. In the enclosing globe type of fixture where where diffusion is the main objective, the glass should have a maximum transmission without revealing the outlines of the filament or light

bulb; the glass is then said to be completely translucent. When this condition exists there is not even one percent of the light which passes through unchanged. The transmitted light will be between 30 and 60% but cross reflection may bring the efficiency of the unit up to 60 or 65% .

Two piece glass units are used a great deal in which the glass in the upper unit is much denser than that in the lower bowl and reflects a large percentage of the light itself downward to give a higher intensity of direct illumination. A small amount of light escapes upward and helps up the intensity on the ceiling. Similar fixtures as these are often inverted and used for indirect illumination, the majority of the light being sent to the ceiling first, where it reflects downward to the working plane.

The shape of the white glass units is not nearly as important as the design of mirrored glass reflectors, and depends entirely on the appearance that is desired. The only care necessary in the choice of this class of equipment is to be sure that a dense enough glass is obtained to reduce the brightness of the light source to a point that a sharp contrast can not be noticed between the unit and its surroundings.

White glass is used for totally enclosed units, open reflectors and semi-indirect units for offices, school rooms, some types of industrial units, and general commercial work. The two chief advantages of this reflector

material are in its smooth surface which limits the collection of dust and is easily cleaned, and its property of transmitting a portion of the light which gives a luminous reflector and enhances the appearance of the unit.

Porcelain enamel steel reflectors are well known to the commercial and manufacturing trade as being the basis for industrial lighting units where efficiency can be sacrificed a little to give a more rugged and permanent reflecting surface. Porcelain enamels vary a great deal in efficienty. But in spite of this fact, the units are widely used, the majority being manufactured under the trade name of R.L.M. domes.

Some types of enclosing glassware for the smaller sizes of bulbs are made from frosted glass. The glass surface is either etched with acid or sand blasted and unless a very fine job is done, the surface compares favorably with spun aluminum and collects dirt readily. It is also very hard to clean.

Wherever it is desired to produce a very broad distribution of light and have a high degree of efficiency, the illuminating engineer turns to a set of refracting prisms. They are the basis of the Fresnel lenses used for light house service, street lighting units, railway and traffic signals, and many semi-indirect and direct type of units for public buildings, offices, and schools. This is a more expensive method of light control, but the results justify the expense incurred.

Effect of Maintenance and Color of Surroundings on Resultant Illumination.

Until recently, it was generally thought that after a lighting installation was made it could be completely ignored until a bulb burned out and then a new one would grudgingly be installed. This attitude has changed a great deal, but there is still much good work to be done by the electrical contractor, as well as all others connected with the industry, in advising the customers as to the necessity of frequent and regular cleaning. The housewife believes her home would soon become a very poor place to live unless she cleaned it periodically; offices and stores have their scrub people; factories and industrial plants have regularly employed sweepers and cleaners, but there are still those who do not give the lighting equipment the attention it deserves. The sad part about the whole situation is that just as soon as the intensity drops so low that the men can not see clearly to do their work well, the lighting engineer gets the blame. His good judgment is questioned because of the oversight by those whose duty it is to see that the lighting units are cleaned regularly. It becomes, then, the engineer's duty to embody within his design a suitable cleaning schedule to be followed by the customer in order to maintain the standard of excellence which the new building exhibits on its opening night.

It is interesting at this point to review the

results of tests which have been made to determine the actual amount of depreciation that can be expected in normal installations. The intensity in several offices was measured just after being cleaned and an accurate record kept for a period of six months. By that time 40% of the original intensity was being absorbed by the dirt. A great deal of this depreciation occurred during the first few weeks, so for a period of several months the desks had been receiving only 60% of the light which had been intended for them, and which could have been obtained at practically no extra cost if a little attention had been paid to cleanliness. Why, then, should lighting equipment be allowed to become so inefficient and place a big handicap on the large percentage of workers who are unlucky enough to be located between the lights where the depreciation is the highest, when a very small amount spent in cleaning will keep the average efficiency close to 95% - at least above 90%? It has been pointed out previously that the increased efficiency more than justifies the cost and effort.

There are two big divisions in the causes of falling off of illumination as the time passes; they might be called acquired and inherent depreciation. The first is by far the most serious - dust, soot, flying particles of oil and all other sorts of foreign matter collect on the bulbs and lamp surfaces. These form a coating which because of its black and dirty nature

absorbs a large percentage of light which must penetrate it before reaching the work.

To subdivide acquired depreciation in three general classes would give Location - first, Type second, and Design of equipment - third place. It is quite obvious that an installation located in a small or suburban town will have a much lower depreciation than one in a down-town office where soft coal is used as fuel in adjacent buildings. The store will not have anywhere near as much dirt in the air as a machine shop, hence the cleaning ratio will point to the machine shop as the one needing the most attention. In the extreme case shown here the ratio may be as high as 10 to 1. A careful selection of lighting units and paint will help considerably, however.

Under the heading, "Type of Unit" it is shown that a steel direct lighting reflector will not depreciate as fast as an indirect unit. The dust does not readily gather on the inner reflector surface, and the reflector is strong and substantial and will stand abuse. A semi-indirect or totally indirect unit will be affected most by dust settling on the upper surfaces and cutting the light rays off short. Naturally, then, these should not be selected for an exceedingly dusty location but will be very satisfactory in the cleaner building.

Since the question of proper maintenance is such a vital factor in good lighting practice, it is most

desirable to examine the fixture with great care and see that the choice is one which will be the best for the location in question. Is it of a shape that will be difficult to clean? Will a reasonable accumulation of dirt materially reduce its light output? Are there a great many parts to remove in order to clean the glassware properly and replace the lamps? Does the unit assemble easily or are there too many small screws, clips, etc., so that the time of assembling will be materially increased over what it should be? Is the cleaner apt to drop and break the light while trying to assemble it because of the awkward catches, etc.? By carefully answering a series of questions like the foregoing the engineer will be aided in his choice of lighting fixtures, and a more satisfactory layout will result.

There are several methods of cleaning which are in use at the present time and it is well to indicate some methods are much better than others. It is commonly thought that for dry dust a good wiping with a dry cloth cleans the glassware sufficiently. This is not true however, as tests show that this only removes about 50% of the dirt that a damp or wet rag will. When it is considered that the time involved is about the same for both methods, the difference in results will justify using the water. Soap and water should be used if grease or other wet accumulations are prevalent. It is well to take extra care and get the glassware

completely dry before putting it back, as damp glass collects dirt very rapidly and much of the benefit of the washing is quickly lost. Where the units are mounted high a great deal of time can be saved, as well as an extra trip up the ladder, if an extra unit is procured and cleaned. This is carried up the ladder on the first trip and put in the place of the dirty one which is removed and brought back down to the floor where it can easily be cleaned. It is then exchanged for the next unit in line and so on.

Industrial installations present a more difficult problem, as the fixtures are often up in high bays above moving cranes, etc. In such a case it is well to utilize the small fixtures manufactured and sold by a leading electrical catering company which permits of disconnecting the entire unit, support and all, and removing it for inspection and cleaning. In some buildings the units can be placed just above the crane beam and this can be utilized as a foot walk for relamping and cleaning. As a rule, once a month is sufficient to clean units in such places; however, the most efficient way is to keep track of the intensity with a foot-candle meter and determine the necessary frequency of cleaning by limiting the depreciation to a reasonable percent. Over all efficiency will improve as the guess-work is eliminated.

Many people do not understand the economics of proper painting, and again it is the duty of the engineer

to impress the fact on all who buy paints that the first cost is not always the complete cost. When specifying paint, he should be careful not to get a paint with a high depreciation. This is especially true of the ceiling paint which is most important from the standpoint of light reflection. As a guide it is recommended that a plaster ceiling be treated as follows:-

First coat ----- good impervious primer.

Second and third coats ----- high grade lithopone paint (not less than 75% lithopone.)

Fourth coat ----- high grade eggshell enamel.

Extensive tests have been run and it is not out of place to mention the names of some typical high grade paints for the last coat. These are arranged alphabetically by companies and the omission of any prominent manufacturer should not cast reflections on the quality of his product; the ones named proved satisfactoryon the test.-

Tecmilite- - - - - - - - - Dean and Barry Co.

Moore's White Mill - - - - Benjamin Moore Co.

Savakota - - - - - - - - - Chas. M. Childs & Co.

Degraco- - - - - - - - - - Detroit Graphite Co.

B.P.S. Inside White- - - - Patterson - Sargent Co.

S.W. Eggshell Mill White - Sherwin Williams Co.

Rice's Mill White- - - - - U. S. Gutta Percha Co.

From an illumination standpoint, the walls of a room are not as important as the ceiling, and a less expensive coating will serve. However the same economies

can be affected on the walls by choosing a high grade paint with a good initial reflection factor as well as a low rate of depreciation. First coat - good impervious primer mixed with an equal part of zinc lithopone paint. Second and third coats - high grade zinc lithopone paint of which the last should be tinted to the desired color.

There is no doubt but that it costs appreciably more to paint an interior correctly than to apply calcimine or some other paint which depreciates rapidly or has a low reflecting factor, but careful analysis reveals the expenditure is well warranted.

To further illustrate the effect which the reflection factor has upon resultant illumination; if all surfaces of a room were painted black and had no reflecting factor, the illumination on any surface would be only that received directly from the lamps. If all surfaces had a reflection factor of 50%, the illumination would be practically doubled. If the walls and ceiling were painted eggshell or white and the reflection factor raised to better than 90 percent, the illumination would be increased approximately ten times.

Desirable Finishes for Industrial Plants

Of late years the industries have been informed concerning the value of paint and lighting by the extensive national advertising campaign put on by the

the paint manufacturing companies. The amount of natural lighting is greatly increased if the interior surfaces are painted light in color; then any light which comes in contact with the walls and floor will be reflected again, around the room, raising the level of illumination appreciably. The change may be as much as from 85 per cent to 10 per cent, depending on whether the surface is a clean white or dark brown and smoke covered.

Surprisingly high utilization constants can be obtained in rooms which are properly painted. With a white ceiling and side walls, and light wood floors (bare), the cross reflections were so numerous that a utilization constant of 1.00 was obtained. The photometer actually measures the same energy more than once. Of course this cannot be expected in practice, but is illustrates how important the colors of the surroundings are in enabling the illuminating engineer to have the maximum amount of light on the working plane for any given current expenditure.

Another important point to note from the readings obtained is that the color of the floor cannot be ignored if much exposed. Light which strikes the floor will be reflected to the ceiling and back again, providing the surface is such that it doesn't absorb all the impinging rays. All of the floor not covered with machinery should be painted as light as is consistent with the nature of

work being carried on. In buildings where the aisle is subjected to heavy or persistent traffic and a real light surface cannot be maintained, it is recommended that these aisle-ways be made as narrow as possible and have distinctly defined borders so the truck drivers will keep within the prescribed limits; the remainder of the floor area can then be painted a more efficient light gray. A good color for this type of work is the well known battleship gray which is furnished in several shades.

The painting of machines themselves in the factory should receive attention. (It is well understood that a coat of paint will materially lengthen the life of a piece of apparatus.) If this paint is of suitable color, it will serve to increase the illumination. Such a paint should be hard in order that it may not be marred easily; smooth, but not glossy, in order that it may be easily cleaned, collect the minimum dirt, and not give any annoying reflections, light in color that it may increase the useful light in the room. It is desirable that it be impervious to the actions of oils and compounds used as lubricant for drill points and milling machine cutters.

Many colors have been tried to find the one best suited for machinery and for most uses a light gray seems to answer the purpose. It reflects approximately 35% of the light which strikes it and yet is dark enough so that finger prints and stains do not show up too much.

Light orange has received considerable favorable comment and can be recommended where the darker colors are not preferred by the plant owners or operators. It should be kept in mind that proper painting of machinery will also make for safer operation, the shadows which generally prevail around slotters, milling machines, and punch presses are eliminated, and the moving parts made visible.

Ceilings should be made white where possible. A high grade oil paint is desirable, but where white-wash is absolutely necessary, frequent cleanings will speed production and keep the lighting bills at a minimum. The sidewalls also should follow the same color scheme as the ceiling. The lower part of the sidewall is of less importance in reflecting light, and for purposes of appearance it is often desirable to have a shade of dark green, gray, or some other neutral color, as finger marks and other disfigurements are not quite so noticeable. The dado is of advantage in another respect also in that it reduces the brightness of the background in the field of view.

A clean bright interior has a decided effect in improving the morale of the workman and it increases the production materially.

Suitable Finishes for Offices, Schools, and Stores

On account of the widespread use of indirect and semi-indirect lighting systems it is always desirable that the ceilings be light in color. A color should be chosen such that its reflection factor is above 50% and much better results are obtained when a 70% or higher factor is installed. The exact tint is determined by the use to which the room is to be put, allowing for proper color harmony.

For the walls it is not desirable to have one color throughout unless the contract between north and south rooms will not be noticed. A slight bluish cast is preferable in a north room and is obtained in combination with pale olive green to give the desired results. A south room will respond best when the olive green is given a yellow cast. Light buff or cream are very good colors for walls and come next in line. There are cases however, where a greenish tint will give a soft and restful atmosphere which is much to be desired and answers the color question for these rooms. The co-efficient of reflection should not exceed 60 to 65%.

It should be borne in mind, however, that a light colored room is much more cheerful than one finished in dark colors and in many cases dark surroundings will give the impression of bad lighting while in reality there is a high enough intensity on the working plane. In many places it is well to sacrifice lighting economy

ior artistic effect, but due recognition should be given to the psychological effect produced on the individuals. A dark, gloomy interior will always be oppressive and weigh down on one's feelings so if bright and cheerful pupils, customers and clerks are desired, the tendency should be toward the brighter shades.

Glare, one of the evils which must be watched in many lighting installations, will be materially reduced if the artificial lighting unit is viewed against a bright ceiling. Light walls and ceiling tend to spread the daylight around the room and reduce contrasts during the daylight hours. Great care should be taken in specifying glossy walls or ceilings because glare and specular reflections are much more pronounced with this type of surface than with any other.

Desirable Finishes for Residences

Lighting efficiency in the home is not at all important, but the color of the walls and ceilings has a big effect on the pleasing appearance of the rooms.

If the chosen colors do not reflect light satisfactorily, the room will never appear bright and cheerful, no matter how much light is supplied. Dark green is a noticeably poor color and lighting units contract so brightly that they are annoying. There is one way to get around a painting scheme using dark colors, and that is to furnish desk and floor lamps in addition to

the central fixture. These bring up the intensity where it is desired and allow the rest of the room to remain dimly lit.

Of course, the most desirable finishes are light colored wall paper or paint. Ivory, white, ivory tan, silver gray, cream, pale azure and combinations of these colors are usually considered best for ceilings. The walls follow along with the darker shades of the above mentioned colors. Lately the use of buffs, tans, and light browns both clear and stipple has come to the fore as a favorite interior finish. Paint directly on a plaster wall will have a higher diffusion but a slightly lower co-efficient of reflection. Use should be made of this fact when choosing lamp sizes.

The Essentials of Modern Indoor Illumination.

Up to this point, the fundamental concepts of the measurement of light and the means by which it can be controlled have been stated and discussed at some length. These factors are basic, and a thorough knowledge of them is absolutely necessary to design a satisfactory lighting layout.

Quality and quantity are two distinct divisions that must receive special consideration in indoor work, so the discussion continues, taking up these and other necessary features from the design engineer's standpoint.

The quality of illumination has to do with the distribution, diffusion, and color value of the light; while the quantity is the amount of light, either necessary or already available, on the working plane. There are several divisions under quality, and the first of these is glare.

GLARE.

Glare may be defined as any brightness within the field of view that interferes with vision, causes eye fatigue, annoyance, or discomfort. It is light out of place, and may be direct or reflected, that is, it may come directly from the lighting unit to the eye, or may be reflected from the wall, polished desk surface, nickled machine surfaces, or glazed paper. Glare should always

be guarded against in making a layout and if it becomes evident later should be removed.

Direct glare from a light source is the most common and generally the easiest avoided. Direct glare from a bare lamp is one of the greatest hazards to vision. On this account all lamps of 60 watt size or larger should not be installed without a shade.

The extent to which glare is objectionable is dependent upon the contrast in brightness between the light source and the background. When meeting an automobile on a dark road, the headlights may be so bright and glaring as to be blinding to the eye, while the lights of the same automobile on a brightly illuminated street in the city would hardly be noticeable.

Locating a unit within the field of view will also increase the glare. Take two examples, one from each extreme. In the rug department of a large store, the rugs will be hung high on racks and the units should be placed back out of the natural line of vision with the rays directed forward to the vertical surfaces of the rugs. A directed type unit such as is used in store windows answers this purpose. An alternate solution is a totally indirect or semi-indirect system with a very dense milk glass unit, which will give the necessary illumination without glare. The second example could well be a shoe store where the brightness of the units is less of a problem, and a uniformly high level of illumination over

the entire floor area is desirable. He knows that the people move about considerably, and their attention is not repeatedly drawn upward, as it would be while inspecting rugs, in such a manner as to include a lighting unit in the direct field of view.

There are two distinct glare points to watch for in artificial lighting. The one is a source of light that feels uncomfortably bright as soon as it enters the field of view. This type or source should never be used for interior lighting. The second, and a much lower glare point, is one which, while not bright enough to cause immediate discomfort, will fatigue the eyes when it remains within the field of view for a period of time. This lower glare point is much more difficult to determine because it varies for different individuals. A good figure to follow is to never let the brightness of a unit which is to be continually in the field of view exceed ½ candle per square inch of apparent area. A unit which is not to be in the field of view continually may have its brightness increased, the limit being 2 to 3 candles per square inch of apparent area, depending on the color of the background.

Reflected glare is all its name implies, and comes to the eyes as a shine or glint of the lighting unit on some polished surface. It is much harder to deal with because it usually comes from some location below the horizontal, and the eye cannot be protected from it easily. Specular reflection, as it is sometimes called,

is most frequently encountered by the reader while looking at the highly polished or glossy surfaces of a magazine, the print in certain sections seeming to fade away into a bright shiny spot or larger area. Local specular reflection may be relieved and generally removed by changing the lighting source to such a position with respect to the work that the specularly reflected light will be thrown away from the eyes.

The brightness of a reflected image is dependent upon the brightness of the source. Either change the unit for one which possesses thicker milk glass, thus diffusing the light to a higher degree, or else change the color of the background so that it has a higher coefficient of reflection, reducing the point brilliance to a degree where it ceases to bother.

SHADOWS.

Almost as important a question as glare, shadows deserve consideration when making any lighting layout. In general, shadows are undesirable and should be eliminated. Their most frequent causes are spacing the lighting units too far apart or not using large enough bulbs. Having given large enough bulbs and units properly spaced, shadows may creep in due to an increasingly thick layer of dirt on the fixtures.

In lounge rooms, dens, and some lobbies, soft shadows are restful and pleasing. It is the sharp, black, well defined shadows which should be guarded against.

they are the ones which hide projections on the floor or moving parts of machinery and tend to impair depth vision. Large area lighting units tend to eliminate deep shadows, and if two or more units shed light on an area it is almost impossible to have deep shadows.

No attempt is made here to cover the special shadow illumination required in photograph studios or in art museums where statuary and monuments are displayed.

UNIFORMITY OF ILLUMINATION.

In years past the owners of buildings, in their desire to keep the initial costs low, saw fit to allow lighting installations to be made in which proper spacing was not established. Instances are on record where workmen situated between lighting units had only one quarter the illumination their neighbors had, who were located under the lights. R.L.M. domes with 200 watt lamps were mounted 10 feet above the floor, and seven feet above the working plane. These units were spaced 20 feet apart. This gave an intensity on the working plane of 12.5 foot-candles directly under the units, while at points 10 feet away, located between the units, an intensity of 3 foot-candles was obtained. By changing the spacing of these units to 10 feet the intensity under the units was increased to 14 foot-candles while that between units was 12 foot-candles, a permissible variation.

From many tests the following general rule can be stated, viz, in general, the spacing between units shall not be more than one and one-half times the height of the light sources above the working plane. Closer spacing will be necessary to maintain extra high levels of illumination, but the maximum limit stated should not be exceeded, except in special cases, and then with the knowledge that an uneven level will result.

ILLUMINATION ON VERTICAL SURFACES.

There are many places, such as drafting rooms, school rooms, and newspaper composing rooms, where light is required principally on horizontal planes as desk and table tops. It has been the custom to calculate the necessary illumination on the assumption that if the horizontal surfaces received enough the vertical and sloping surfaces would also. Inasmuch as vertical illumination from ordinary units is only about half that of the horizontal, it is readily seen that at times this may be inadequate. For general illumination, the units should have a good distribution in the 50 - 60 - 70 degree zones as well as downward; this will give sufficient illumination on the vertical surfaces.

In art museums, poster boards, show windows and in some industrial applications, such as automobile body painting, etc., where illumination on the vertical plane is desired above that on the horizontal, angle reflectors should be used to supplement general overhead lighting.

COLOR QUALITY OF LIGHT.

For centuries the human eye has been developing, and it has adapted itself to function best in natural light. Natural light varies considerably in quality throughout the day, but should be the standard of reference with artificial units, the same as daylight levels of illumination represent the standards for industrial plants.

The ability to see objects in their true colors is important when one is matching colors of materials or trying to get a true conception of an original work at an art exhibit. Colors help a great deal in distinguishing one object from another, such as a brass bushing on a polished steel plate. A black and white picture will not always show these objects one against the other. Since in a great many applications it is difference in color which renders objects readily recognizable to the eye, color discrimination is important from a utilitarian standpoint. Another factor to consider is the unfavorable impression created by unnaturally-colored light; this must be guarded against also.

The development of the modern Mazda bulb has been carried on with the color results always in mind until now all of the colors of daylight are present, though not quite in the same proportions as in daylight. The changes in the colors of objects when viewed in this light are not serious. For some operations, however, it is especially desirable to approximate natural light as closely as possible. The Mazda daylight lamp, with a

blue glass bulb produces a light of afternoon sunlight in quality. This entails an absorption of about 35% of the emitted light. Using the same bulb with special blue glass enclosing globes, the light approximates noon sunlight: 60% of the emitted light is absorbed. The third combination, a projector type unit using a daylight bulb and special enclosing glassware, gives a north sky quality and is used for color matching alone and requires a large expenditure for power as 85% of the light is absorbed. For show windows, clothing, fur, and rug stores, or wherever color is an element in the display of merchandise, the daylight bulb should be used. In industries where the requirements are more strict, such as chemical and textile factories, lithographing and other paper work, and the areas to be lighted are medium in size. The projector is for very exact work where the areas to be illuminated are very small, such as color matching units on store counters - - hosiery and jewelry counters, and clothes shops. The exact north sky units will satisfy even the most exacting individuals and are the best that science has developed for this work (- - except for the mechanical, electrical matching machines which eliminate the human element).

QUANTITY OF ILLUMINATION

The eye is capable of adapting itself to see under illuminations which range from a high level of 6 to 10 thousand foot-candles down to a fraction of a foot-candle. Through this wide range good vision is possible. On a clear, bright day the illumination in sunlight will vary from 6 to 10 thousand foot-candles, and in the shade will drop to approximately 1,000 foot-candles. The other extreme will be found on a clear moonlight night when the illumination varies from 1/2 foot-candle down. An illumination of approximately 100 foot-candles will be obtained indoors by a north window on a clear day. It is readily seen that it will be difficult indeed to provide too much light for the eye as long as it is well diffused and there are no extreme brightness contracts between the surface to be looked at and its surroundings. The problem is to properly control the light.

At the present time the highest recommended illuminations are for operating rooms in hospitals and for show windows in brightly lighted districts; these values are from 100 to 200 foot-candles. The next bracket of from 50 to 100 foot-candles will find many and varied uses such as jewelry and watch making, extra fine bench and machine work, extra fine inspection, linotype, monotype and engraving, the ring of the boxing arena, automobile paint shops and dark leather sorting, cutting and sewing. Excellent lighting for industrial plants is from 20 to 30 foot-candles according to present accepted

standard. To the uninitiated this sounds like a great deal of light and this illumination does look very bright when first installed. "To make a room bright as day" means an illumination above 100 foot-candles. Considerations of economy usually limit the level of artificial lighting to the lower values, and many factors must be taken into account because of the low limit imposed on the designer.

A word at this point about the function of the eyes will explain the necessity for maintaining high levels of illumination. The eyes are always on duty during the waking hours, shifting around and changing focus, the muscles and nerve centers using a large amount of energy during the day's work. It becomes important that the lighting shall be such as to make possible an effective impression upon the retina with the least strain. When the illumination is of a low order, these impressions will be inadequate, the eye muscles have extra work thrown on them and they become rapidly exhausted. The speed with which the work is done has to be greatly decreased and mistakes are frequent.

Tests of several thousand employees in factories and commercial establishments show that more than 50% of the employees have uncorrected faulty vision. Additional tests also show that an astigmatic eye or subnormal eye is helped more by improvements in illumination than the normal eye. It follows that as the

illumination is increased a point is quickly reached where the men with subnormal eyes will be able to see almost as well as those with normal eyes. This is the desirable situation because it improves the 50% of the men having faulty vision.

Mr. P. W. Cobb of the Edison Lamp Works ran a great many tests on the time and light required for perception of a small test object under various levels of illumination, the results of which are shown on the accompanying graph. This shows that it takes 3-1/2 times as long for the normal eye to perceive the test object under 2 foot-candles as it does under 100 foot-candles, twice as long under 6 foot-candles, 1.7 times as long under 100 foot-candles, 1.5 at 16-foot-candles, 1.4 at 20, 1.3 at 30, 1.2 at 40, 1.15 at 50 and 1.1 times as long at 60 foot-candles as it does under 100 foot-candles. This is an average curve for normal eyes and shows that good illumination has an optimum value between 10 and 20 foot-candles, at the knee of the curve.

Data taken by Mr. Farre and Mr. Rand on the time and illumination required for discrimination, plotting the normal eye against the astigmatic eye, shows the pronounced improvement registered by astigmatic eyes over a given increase in illumination. Taking a normal eye as 1, or unity, at 12 foot-candles, it takes 4-1/2 times as long to discriminate under 1 foot-candle and twice as long at 6 foot-candles, relatively speaking.

An astigmatic eye requires 15 times as much time at 1 foot-candle as the normal eye needs at 12 foot-candles, or 3-1/2 times as much as the normal eye under 1 foot-candle (the same illumination). The astigmatic eye needs 4-1/2 foot-candles to see as fast as the normal eye does under 1 foot-candle, and 12 foot-candles to see as fast as the normal eye at 6 foot-candles. A continuation of the curve will show that the astigmatic eye needs 20 foot-candles or more to see as fast as the normal eye at 12 foot-candles.

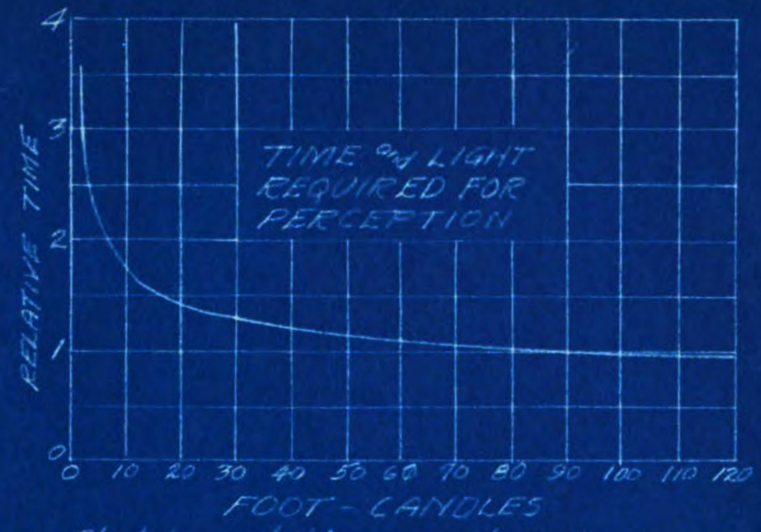
Information collected by messrs. Luckiesh, Taylor and Linden, of the General Electric Research staff shows that the speed of reading with a black and white contrast in an illumination of 16 to 24 foot-candles is 20% faster than the speed in 3 foot-candles of illumination. With a gray background, the increase was not so great, and taking into account the fact that commercially we seldom, if ever, have a white background with black objects, facts again show the necessity for higher illumination such as 20 to 30 foot-candles for commercial establishments.

Better visual conditions will increase production, decrease spoilage, reduce the number of accidents, bring up the morale of the personell and pay for themselves after a limited time.

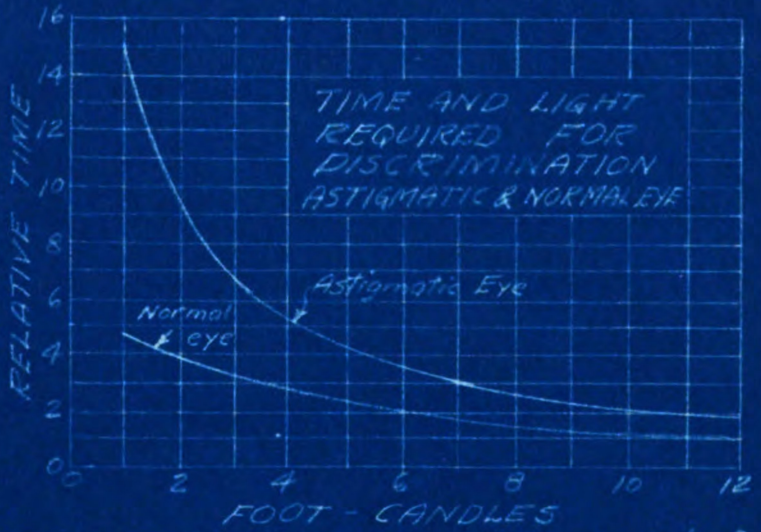
Complete tables of recommended standards of illumination have been established by experience and are issued by various authorities and are given as a guide for different classes of work. By keeping in mind the character

of the work and the fineness of detail to be observed, one is able to select from the values given in the table a suitable level of illumination. A very complete table is included with this work as an aid to those wishing to make new designs. This table is one which is made available to the trade by a reliable manufacturer of lighting equipment and can be used freely except for one reservation, viz., the "minimum values" given are too low and should not be used. The column headed "good practice" gives, as a whole, fairly accurate values to use in the formula for finding the necessary lamp size. Where the value obtained is slightly over a given lamp size, the next size larger should be chosen. It should be kept in mind that there is a marked tendency toward higher levels of illumination.

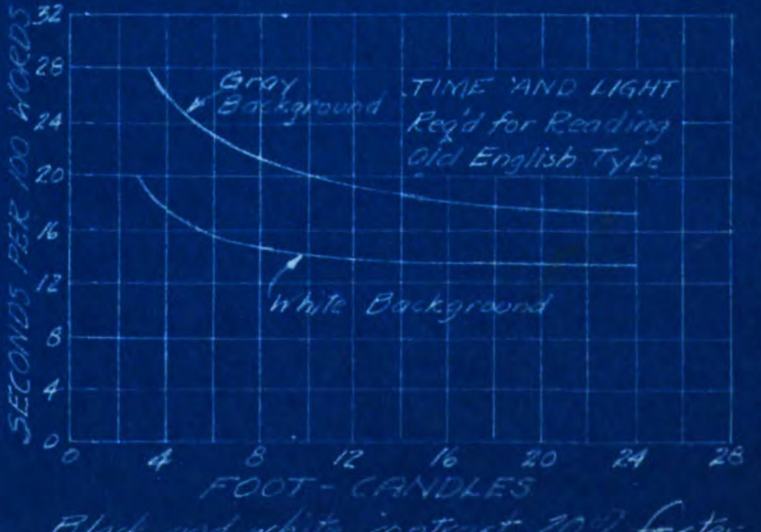
TIME AND LIGHT



It takes $3\frac{1}{2}$ times as long to see a small test object under 2 f.c. as it does under 100 f.c.



An astigmatic eye must have $4\frac{1}{2}$ f.c. to see as fast as a normal eye at 1 f.c.



Black and white contrast 20% faster.

M.G.H.

CHOICE OF A LIGHTING SYSTEM

As has been previously discussed, there are three general systems of illumination classified according to the manner in which the light is distributed:

A - Direct Lighting

B - Indirect lighting

C - Semi-indirect lighting

The fundamentals of these three systems will be discussed, as will the general requirements, and a guide given to assist in the proper choice of a system.

The individual characteristics of a room to be lighted are important factors in the selection of a lighting system. Cost and efficiency are factors which limit the choice, although the present tendency, particularly in the more specialized branches, is to make good lighting the first consideration. Attention is again called to the fact that a suitable choice of colors and frequent painting or cleaning are important.

Where a decorative lighting unit is essential the primary purpose of the lighting unit is to provide light of sufficient quantity and quality to establish and maintain the required intensity on the working plane. No matter how beautiful or artistic a unit is, it should not be accepted unless the lighting requirements are satisfied. Units can be designed to be highly artistic and still function as efficient

lighting devices.

DIRECT LIGHTING.

Direct lighting systems employ lighting units which send the greater portion of light directly to the surfaces being illuminated.

Direct lighting is recommended for industrial or commercial interiors such as machine shops, assembly rooms, factories, foundries, etc. This system has the greatest overall efficiency from a power input standpoint and the least depreciation with the passage of time. The presence of large quantities of dust and dirt in the atmosphere, and the dark tone of the walls and ceilings are most effectively overcome by a direct lighting system. Line shafts near the ceiling of machine shops preclude the use of a semi-indirect system. For high bays and mounting above crane runways a searchlight or projector type of direct lighting unit is the only kind which will provide satisfactory illumination on the working plane with a reasonable expenditure of power.

At first, open reflectors of metal or glass were the most common type of units used, but with the arrival of more efficient bulbs and a constantly increasing lumen output, the use of the open type glass reflectors has been largely discontinued. Open type metal reflectors, especially those of porcelain enamel interior surface, are being used very successfully

in the industrial lighting field. Porcelain enamel reflectors are commonly classified by shape, as a dome or bowl. The dome is preferable because it gives a better illumination on vertical surfaces and higher efficiency.

The highest grade of industrial units manufactured for this purpose are called the "R. L. M." domes. (R. L. M. stands for Reflector and Lamp Manufacturers Standard Dome.) These must be built to standard specifications of contour and quality of the reflecting surface. This insures a durable and highly efficient unit, a contour of reflectorwhich will insure an effective light distribution, and a depth which will shield the filament from view sufficiently to minimize glare.

A still higher development of the dome is known as the Glasstell Diffuser. It is a combination of the dome reflector and a white glass globe. The milk glass globe completely encloses the bulb and diffuses the downward light. The reflector fits over the globe and concentrates the rays downward except for a few slots around the top which allow a small portion of the light to be emitted upward, thus illuminating the ceiling and improving the appearance of the lighted room. The reflector also reduces glare by hiding a large part of the bright area of the globe. These units

should be recommended where a very high quality of illumination is desired in an industrial plant.

INDIRECT LIGHTING.

In illumination by the indirect method all of the light is first thrown to the ceiling and upper sidewalls where it is redirected and diffused to all parts of the room. Glare from the unit is eliminated since the ceiling acts as the light source and a maximum of distribution is directly downward. A very even distribution of light is obtained, with soft shadows and without reflections from surfaces at the working plane. A somewhat smaller percentage of illumination is thrown on vertical surfaces than with the other two methods.

This system is the least efficient from a power input standpoint as all light which is received at the working plane must first be reflected from the ceiling or sidewalls. To help raise the level of illumination for a given power input the most efficient units employ a mirrored glass reflector within the bowl to direct the light to the ceiling.

The quality of illumination obtained by indirect lighting is counted to be the very best. This somewhat offsets the increase in cost, but in spite of this fact, the present tendency is to employ a semi-indirect system almost exclusively where formerly an indirect layout would have been specified.

SEMI-INDIRECT LIGHTING.

Semi-indirect lighting furnishes a means of combining the features of direct and indirect systems. With a correctly designed bowl of white glass, brightness of this unit is low enough so that eye fatigue is avoided, and sufficiently direct light is emitted so that the proper degree of vertical illumination, and soft or graded shadows are produced. As has been previously noted, a light density of white glass may be used in certain locations where the units are hung high and the nature of the work is such that the units are not in the usual range of vision. There is no marked difference in lighting effect between a very light density semi-indirect unit and the usual enclosing unit for direct lighting, but the general rule says that any unit which directs more than 60% of the light upward is classed as semi-indirect. The better class of these units usually is of sufficient density so that only 20 - 25% of the light is transmitted through the bowl. This type of illumination has a higher overall efficiency from the power standpoint than the indirect system, gives a higher grade of lighting than the direct method, as well as eliminating some of the bad features.

The semi-indirect method best adapts itself to residence, office, and public building lighting, where the system must be of good appearance and in harmonious relations with the decorative or architectural features of the surroundings. Since this system best fulfills these

requirements, it has come to be used more than either of the other two.

INDUSTRIAL AND COMMERCIAL INTERIORS

MAKING A SUITABLE LAYOUT.

For an engineer or anyone who is installing a system or estimating its cost, or who is responsible for the results, the location of outlets, wire size and choise of units are of utmost importance. Even with the proper unit, an incorrect spacing will spoil the lighting effect. Given the right unit with proper spacing, inadequate illumination will result if the wire size is not large enough to furnish the lamps with full operating voltage. It becomes imperative, then, that the units be properly spaced and adequately wired. If this is done, a change can be made in the type of reflector or bulb size at a later date without overloading thus improving the flexibility as well as insuring proper operating conditions. Special attention is called to these facts here because of their great importance to successful lighting. Choice of units and proper spacing is covered in this book. For information on computation of wire size, the reader is referred to any good handbook or elementary text books of direct and alternating currents.

SPACING OF LIGHTING UNITS.

The spacing between units in relation to their height determines the degree of uniformity of illumination and also influences the degree of shadow which results

this has been discussed somewhat previously but the various facts will be summed up now for ready reference.

In most cases the construction of a building divides it into a number of bays, and for the sake of appearance the units should usually be placed symmetrically in these bays. This contributes to uniformity of illumination. Panel designs, or beams, on the ceiling, and other decorative or outstanding features, also call for a symmetrical spacing, but it must always fall within the limits of maximum permissible spacing with regard to the height of the units above the working plane, if uniformity is desired. When there are no natural divisions in the room, and the outlets are not already placed, the room should be divided into a number of areas approximately square, and the units placed at the center of each, the maximum distance between units not exceeding 1-1/2 times their height above the plane of work, which in most cases corresponds to a spacing about equal to the mounting height above the floor. With such a system, the distance from the nearest row of outlets to the wall is one-half the spacing distance; the distance from the walls may necessarily be made less than half the spacing distance in order to avoid shadows and to maintain a high level of illumination on benches or desks close to the walls. It will be found necessary to install more than this minimum number of units in order to create and maintain a level above 30 foot-candles.

Another case where the above minimum does not hold

is for a high bay mounting in a turbine room, or machine shop up above a traveling crane. A special type unit has been developed called a high high bay unit which is, essentially a small angle spread floodlight, much like an automobile headlight with a clear lens, and will require a reasonably close spacing to furnish even distribution at the working plane. The light from a unit of ordinary characteristics would be almost completely dissipated before it reached the floor from a high bay mounting, so we must resort to the deep reflector to increase the efficiency of the system. When installing lighting units above a crane way, it is a good policy to use the triangular or diamond spacing so that a complete row of units can never be covered by the walking beam at any one position of the crane. This eliminates shadows on the floor.

A group of sample or model installations are shown on the accompanying blueprints and an explanation of each is included. These are readily followed, always keeping in mind the maximum unit spacing is 1½ times the height above the working plane.

FACTORS INFLUENCING SIZE OF LAMP REQUIRED.

The lumen method of calculation is the simplest and quickest that has been developed, so it is the one most used at the present time. Having decided upon the desired number of foot-candles, the total number of lumens which must be supplied at the working plane is

equal to the foot-candles desired multiplied by the area of the space in square feet to be illuminated. It is evident that the lamps must emit a greater number of lumens than this, because not all of the light generated reaches the plane of work; some of it is absorbed in the reflector or enclosing glassware; part of it strikes the walls and ceilings and of this, part is absorbed and only a portion reflected to the work. The amount lost depends upon the characteristics of the lighting unit, the finish and color of the walls and ceiling, and the proportions of the room.

ROOM INDEX.

The technical term which covers the proportions of the room is called the room index, and in order to better understand the effect of room proportions and the mounting height of units on resultant illumination, consider a room 40 ft. by 40 ft. with dark walls equipped with two systems of lighting which are identical except that in one the units are 10 ft. above the floor and the other 14 ft. It is easily seen that a higher level of illumination will result in the case of a lower mounting height because with the same amount of light starting downward, there is less light in proportion which strikes the walls and a higher proportion striking the working plane.

The fact that in one case the units are further from the working plane in itself has no influence upon

the percentage of light utilized. It is the proportions of the room, not the actual dimensions that count. A mounting height of 10 ft. in a room 40 ft. x 40 ft. is exactly the same as far as efficiency is concerned as a room 80 ft. x 80 ft. with a mounting height of 14 ft.

The shape and size of the room, for a fixed mounting height, is likewise important with reference to the proportion of the light which strikes the downward, materially affecting the foot-candles on the horizontal working plane. For example, take a room 60 ft. x 20 ft. with the same ceiling height as the 40 ft. x 40 ft. room previously considered. The floor area in both rooms is the same but the proportion of wall area is much greater in the 60 ft. x 20 ft. room than the 40 ft. x 40 ft., thus giving a smaller room index. This shows that there is a comparatively higher utilization of light in large rooms for equal mounting height.

It does not follow that it is desirable to keep all light off the walls and ceilings. A certain amount of it is necessary to reduce brightness contrasts, to prevent a tunnel-like appearance of the room, and to give it a more cheerful, pleasing atmosphere.

It is not necessary to calculate the room index for each individual room as it is needed. Inasmuch as the room index does not vary with the installation, tables of these values have been compiled both for indirect and semi-indirect systems as well as for direct illumination. A set of these is included and it is only

necessary to look up the proper room size and mounting height, to select the room index.

COEFFICIENTS OF UTILIZATION.

As its name implies, the coefficient of utilization is the percentage or proportion of light generated by the lamps which finally reaches the working plane. It is dependent upon the type of diffusing and reflecting equipment, the color of the walls and ceiling, and also upon the proportions of the room.

Due to the contour and quality of materials, certain types of reflectors will direct light more efficiently to the work than will other types. With open type enamelled-steel reflectors (R.L.M. Domes) the influence of the color of walls and ceiling is quite minimum. The effect of this factor becomes of increasing importance with open glass reflectors, enclosing light-directing, and simple diffusing units. It is of major importance in semi-indirect and indirect types of lighting where the majority or all of the light must be reflected from the ceiling or walls before reaching the plane of work.

Since the coefficient of utilization varies with the unit, color of ceiling and walls, and room index, it would be very difficult for the uninitiated to assign a proper value to it. Here again the engineer-scientist has come to our rescue and made exhaustive tests on all representative types of units and incorporated his findings in a table. This table is

included and the exact method to apply it will be explained in detail.

Take the chart of reflection factors of colored surfaces and compare with the painting schedule on a new layout, or with the actual colors of the room on a redesign installation, and find the actual reflection factors of the ceiling and of the walls. Record these values. Next pick out the unit which is to be used, or one with a distribution curve as close to the new one as possible, and refer to the opposite page of calculation data. Next make use of the reflection factors obtained at first. If the ceiling reflection factor is 70% or better, use the first three columns as indicated; 50% to 70%, the middle three columns; less than 50%, the last three columns. In like manner an individual column choice is made by reference to the wall reflection data. Now follow this column down to the zone applying to the chosen unit and the proper coefficient of utilization will be found opposite the room index, previously determined on another chart. This appears quite complicated but the method is really simple and after several coefficients have been determined, it works itself down to a system and no trouble will be experienced. An example will be added later.

DEPRECIATION ALLOWANCE

In addition to increasing the total lumens provided by the lamps to compensate for the losses in utilization allowance must be made initially for the inherent depreciation in lumen output of the lamps and in reflecting efficiency of the reflector, walls, and ceiling due to deterioration and to the collection of dust and dirt. The average depreciation will vary from 15% to 50% depending upon the type of reflector and local conditions of smoke and dust. The length of time between cleanings is also a very big factor.

The probable average illumination in percent of initial illumination will vary, due to all the factors mentioned above. To obtain uniform results, the following depreciation factors may be used as a guide: .75 - .80 for clear or clean locations, .70 for average rooms, and .65 for dirty locations or places which are infrequently cleaned.

CALCULATION OF LAMP SIZE

Only one more factor must be taken into account, and that is the necessary bulb size. It readily follows that the necessary lamp lumens can be found from the formula as given, and by reference to a table which shows the lumens emitted by bulbs of different size a suitable one can be chosen.

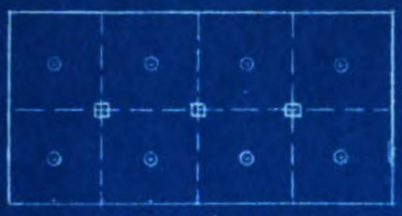
$$\text{Lamp Lumens Required Per Outlet} = \frac{\text{Floor Area (Sq. ft.)} \times \text{Desired Foot-Candles}}{(\text{Number of Outlets}) \times (\text{Coefficient of utilization}) \times (\text{Depreciation factor})}$$

The explanation of the formula is as follows:- From the definition, one foot-candle over an area of one square foot equals one lumen, therefore, to find the total lumens necessary for the room, multiply the total floor area in square feet by the desired foot-candle intensity. Now divide the total number of lumens needed by the number of units, thus finding how many each unit will have to emit (assuming 100% efficienty). This figure must be increased by the amount of light absorbed by the unit - ceilings and walls - so it is necessary to divide by the coefficient of utilization, previously determined in the table for the room and unit in question. The last step is to make an allowance for the natural accumulation of dirt; this is accomplished by dividing by the depreciation factor. All mathematical steps having been properly performed, the result obtained is the lamp lumens required per outlet. Reference is now made to a table which gives the lumens emitted by bulbs of each size, and it will be noted that the figure obtained lies between two bulb sizes - so the larger one is chosen.

A study of the many layouts included will give the application of this method to commerical problems. The accuracy and ease with which it works is easily

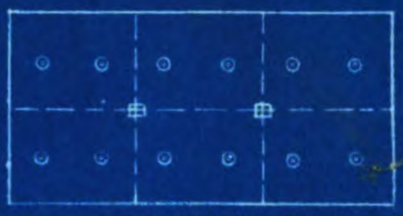
apparent, and satisfaction can be guaranteed by the lighting engineer to even the post particular customer.

SUGGESTED LAYOUTS - SYMMETRICAL SPACING



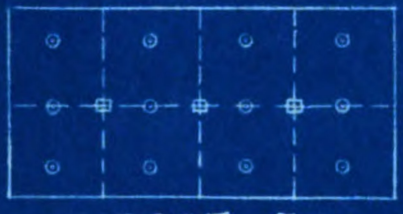
CASE 1

A common practice. Useful when bay size is no greater than maximum permissable spacing.



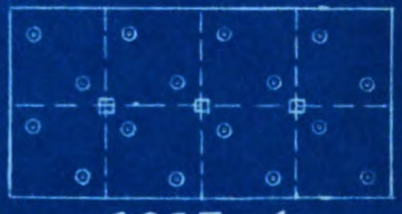
CASE 2

Useful in narrow bays where width is less than two thirds the length.



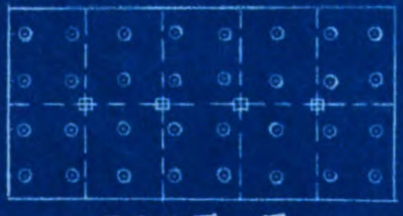
CASE 3

Used in rectangular bays which are too large for Case 1. Note units prevent addition of partitions.



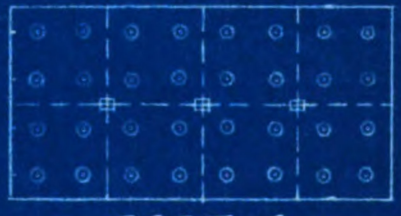
CASE 4

Used in bays which are too large for Case 2 and too small for Case 6.



CASE 5

Equivalent to three units per bay. Used in bay sizes between Case 4 and Case 6.



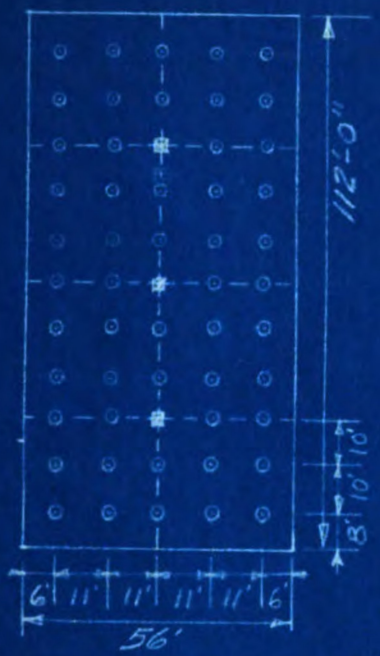
CASE 6

Most common case with modern bay sizes.

Exterior room dimensions, ceiling height, and column spacings will determine which case will apply for the new layouts.

M.G.H.

COMMERCIAL APPLICATIONS

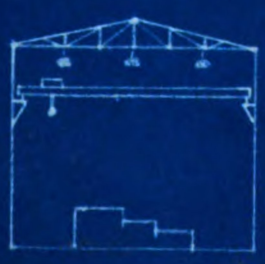


PRINTING - LINOTYPE - ENGRAVING.
Room 56'×112' - 14' ceiling.
Caen stone ceiling, Irory tan walls.

Room Index - Table 6 = 3.00
Mounting height - 12 ft.
Use 52 units - #9 in table 7
Coefficient of Utilization = .58 Table 7
Depreciation factor = .80
Intensity - 50 foot candles

$$\text{Lamp lumens per unit} = \frac{(56' \times 112') \times 50}{52 \times .58 \times .80} = 13{,}000$$

Use 750 watt bulb - Table 9 - which gives 14,800 lumens - enough to provide 57 foot-candles.



TURBINE ROOM - POWER HOUSE
Room 50'×100' - 42' to roof truss.
35' clearance to top of crane hairy.
White ceiling - white tile sidewalls.

Room Index - Table 6 - = 1.2
Mounting height = 36' to clear crane.
Use 18 high bay units - #5 in table 7.
Coefficient of Utilization = .58 (")
Intensity = 15 foot candles - Table 5.

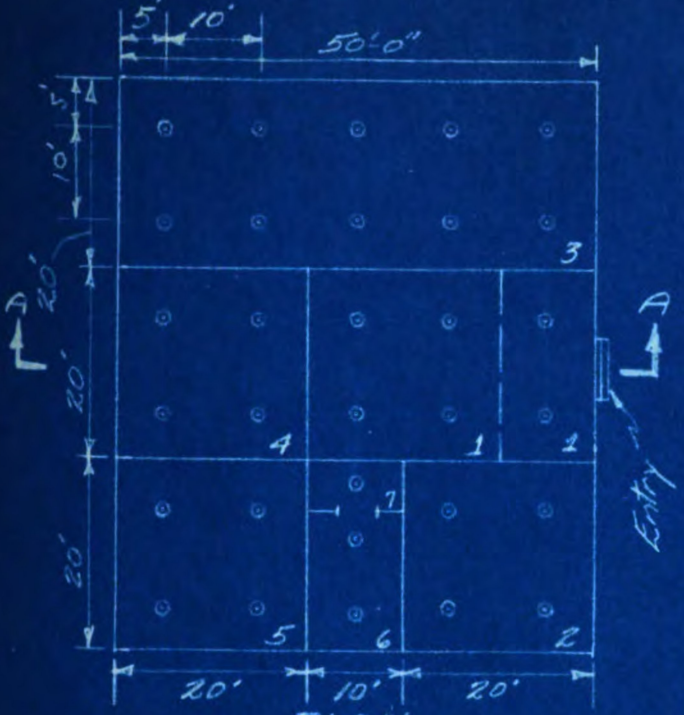
$$\text{Lamp Lumens per unit} = \frac{(50 \times 10) \times 15}{18 \times .58 \times .80} = 8{,}980$$

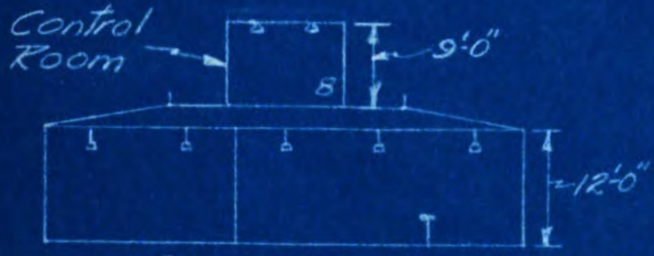
Use 500 watt bulb - Table 9 - which emits 9,500 lumens - This bulb will give 15.9 foot candles.

[Turbine room open to public - hence high values for intensity - 15 f.c. - and low depreciation - .50 % —]

M.G.H.

AIRPORT ADMINISTRATION AND CONTROL BUILDING





SECTION A-A

This building offers terminal facilities for passenger and mail routes, airport executive offices, pilots quarters, and a master control room with all necessary switching and observation equipment

PAINTING SCHEDULE

ROOM NO.	USE OF ROOM	COLOR	
		CEILING	WALLS
1	ENTRY-OFFICE	IVORY	BUFF
2	MAIN OFFICE	IVORY WHITE	IVORY TAN
3	WAITING ROOM	CREAM STONE	BUFF
4	MAIL	#2-GRAY	#5-GRAY
5	PILOTS LOUNGE	IVORY TAN	BUFF STONE
6	WASH	WHITE ENAMEL	WHITE-TILE
7	SHOWER	WHITE ENAMEL	TILE
8	CONTROLS SWITCHES	IVORY	BUFF-(WINDOWS)

ILLUMINATION DATA.

Room No.	Use of Room	Room Size	Unit No. Table 7	Number of Units.	Mounting Height	Room Index	Coefficient Utilization	Depreciation Factor	Desired Foot-candles	Lamp lumens per Unit.	Bulb - Watts Size	Actual foot candles
1	Entry Office	20'x30'	9	6	10'	1.2	.43	.80	15	4360	300	18.2
2	Main Office	20'x20'	14	4	10'	1.2	.29	.80	15	6460	300	12.3
3	Waiting Room	20'x50'	9	10	10'	2.0	.51	.80	12	2940	200	13.0
4	Mail	20'x20'	8	4	10'	1.2	.35	.70	15	6100	300	13.0
5	Pilots Lounge	20'x20'	8	4	10'	1.2	.35	.80	15	5350	300	14.9
6	Wash	10'x15'	8	2	9'	.8	.27	.80	10	3470	200	9.2
7	Shower	5'x10'	Vapor Proof	1	12'	.6	.50	.80	10	1250	100	10.8
8	Control-Switches	12'x12'	12	4	8'-6"	1.0	.25	.80	15	2700	200	17.8

M.G.H.

COVE LIGHTING

That special adaptation of indirect lighting commonly known as cove lighting, not only has all the other advantages of indirect lighting, but has the additional advantage of entirely concealing all lighting fixtures as well as the light sources.

Industrial lighting is primarily for utilitarian purposes, with the possible exception of the higher class general and private offices, whereas window lighting seeks pleasing aesthetic effects even though its most important aspect is purely utilitarian. The point in this case is the sales power of the window, and in this respect window lighting differs from all other types of lighting.

Now, when it comes to such interiors as church and theatre auditoriums, ball rooms, lodge rooms, hotel and club dining rooms, library reading rooms, court rooms, fine store interiors and other similar installations, indirect lighting from cornices and coves offers an excellent solution. The trouble up to the present time has been to get the aesthetic minded architects and interior decorators into agreement with the all too practically and economically minded engineers and owners. A compromise must sometimes be made between the utilitarian and the aesthetic and this can now be done more easily since cove lighting has been developed. Many large interiors would be

ruined architecturally by the installation of a host of lighting fixtures of the ordinary type that would be required for their proper illumination. With cove lighting it is possible to eliminate visible fixtures. The lighting units may be cleverly concealed within cornices and coves in the architectural desing, wall and floor urns and in other ways. In these locations and for the others previously mentioned, cove lighting should be considered.

Cove lighting leaves little to be desired from the standpoint of the utilitarian inasmuch as it has long been recognized as the nearest approach to daylight in its beneficial effects upon the eye. Glare is very nearly, if not entirely, absent due to the low brightness of the illuminated surfaces of the ceiling and walls. Shadows are greatly softened because of the diffuse character of the illumination and hence annoyance and eye fatigue are reduced to a minimum.

Please refer to the blueprint of "A Cove-Lighted Auditorium" attached.

Now to proceed with the design of the actual installation. From the size of the room, width, length, and ceiling height, (average height if the ceiling is curved) a room index is selected from table 6. Width is 40 ft. at the cove, length of the main floor 84 ft., ceiling height at cove is 25 ft. and 30 ft. in the

center, giving an average height of 27-1/2 feet. Inspection of table 6 for large, high rooms gives a room index of 1.5.

Cove lighting uses quite a large number of reflectors. In this case each cove has 82 reflectors installed on 12 inch spacings. The units are spaced close together to keep from having the ceiling streaked as it would be if they were farther apart. Experience shows that these units seldom are installed with spacings greater than 18 inches; more units and smaller bulb sizes give more even illumination on the ceiling: 8, 10, 12 and 15 inches are the most common spacings used for units.

Bulb size is the last thing determined in the ordinary methods of computation, but in this case experience teaches that it is generally quicker and just as satisfactory to arbitrarily put the units in at some given spacing, and choose a bulb size, then figure through and see what intensity would exist at the working plane. If it is too low, try the next size larger bulb. If this, then, is too high, the units may be spaced a little farther apart and fewer of them used. This will bring the intensity near to the desired value.

Should the first computed intensity be much too low, in addition to stepping up to the next size larger bulb, the units should be respaced closer together and the formula changed to allow for the extra bulbs which will be needed at this new spacing. The reverse of this process is also true. This cut and try method may seem altogether too arbitrary to the uninitiated, but it only means changing one or two values in the formula while making the preliminary computations. This is easily and quickly done, and as the designer gains a little experience he will see the wisdom of this method as it gives a workable layout at each step, even though the intensity may not be the desired value. The chosen bulb size in this case was 100 watts, with 1350 lumens emitted.

The painting schedule called for a cafe stone ceiling with a reflection factor of 78%, and an ivory tan wall with woodwork averaging 55 to 65% for reflection factors.

To find the coefficient of utilization, turn to the indirect lighting units in table 27 and select unit #16 as one representative standard for totally indirect illumination. Under "Very Light Ceiling" 70% and "Fairly Light Walls" 50%, opposite a room index of 1.5 the coefficient of utilization is found. It is .26, which is a good average value; generally it varies between .20 and .30.

The depreciation factor for any totally indirect system under clean conditions is .75.

Solving the general equation for intensity in foot-candles:-

$$\text{Intensity} = \frac{\text{Lumens per lamp} \times \text{number of units} \times \text{Coefficient of utilization} \times \text{Depreciation factor}}{\text{floor area in square feet.}}$$

Substituting values previously determined:-

$$\text{Intensity} = \frac{1350 \times 164 \times .26 \times .75}{40 \times 84} = 12.3 \text{ foot-candles.}$$

This is a desirable intensity for auditoriums.

By inspection of the cross-section of the auditorium, it is evident that the intensity under the balcony on each side will be somwhat less than that out on the main floor. To raise this low intensity to normal and keep down the shadows, mount 6 ornamental units, #23 in table 7, 14 feet high and on 14 feet centers under each balcony. Install a 100 watt bulb in each of these units and the shadows will be eliminated. The usual red exit lights should be specified above each door. No attempt is made to design the lighting layout for the stage, as this is very highly specialized and cannot be covered in the scope of this book.

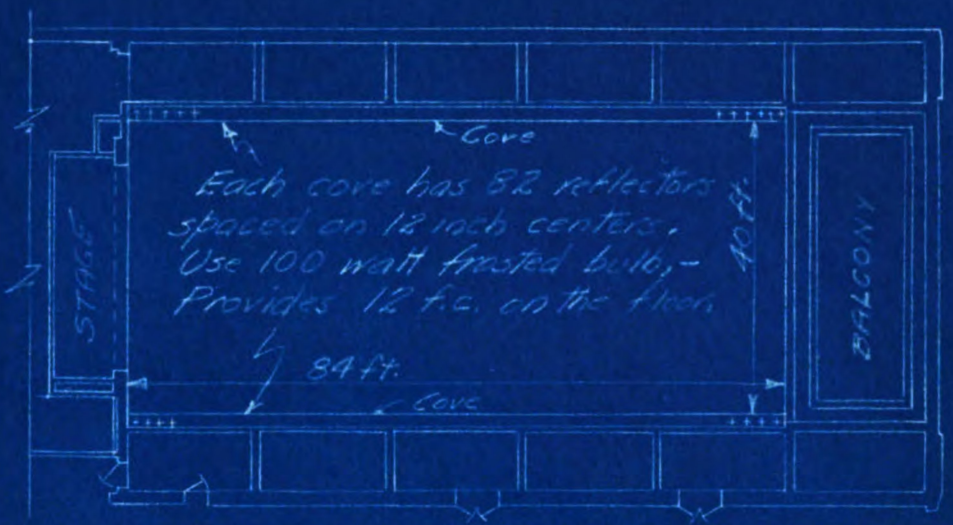
By inspection it is quite evident that the areas under the balcony will be very well illuminated by the "spill light" from the main lighting fixtures due to the complete dispersion from the ceiling. The light from 12 ornamental units with reflectors has been added to bring this up to normal. It should be noticed that

the total floor area was not used; only that which is directly under the coves, and probably the intensity over the whole area may be somewhat less, due to the amount of light which escapes to the area under the balcony. Attention is now called to the fact that the ceiling has a reflection factor of 78% and the walls average 60%. In choosing the coefficient of utilization, a vlue of 70% was used for the ceiling and 50% for the walls in order to use the tables. Actually the ceiling is 8% higher and the walls 10% higher than that allowed, hence the intensity is higher than the first computed figure and will compensate for the losses incurred by the use of the cove projected area on the floor as the actual floor area. This does not occur in ordinary rooms.

If every fourth light is connected on the same circuit and each circuit is put in a series with a dimmer, a variety of lighting effects may be obtained by changing the intensity of each set with respect to the next in line. Other combinations may readily be made by series parallel connections.

To utilize color lighting in conjunction with white lighting of full intensity, it is necessary to bank additional color reflectors both above and below the main installation. This can be more readily done in a shallow cove by placing the color units on the vertical center line between the white units. Theaters and dance halls will be the largest users of the combination systems.

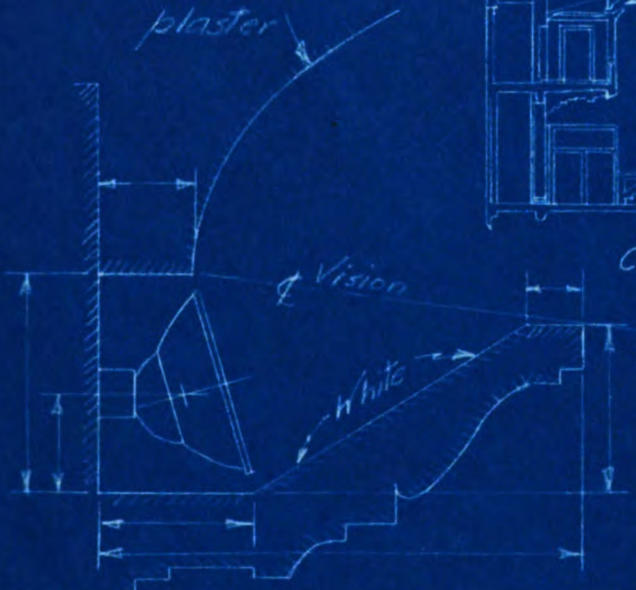
A COVE LIGHTED AUDITORIUM



PLAN - UPPER PART OF AUDITORIUM

For detailed explanation see attached sheets.

CROSS SECTION



DETAIL OF COVE

Marked dimensions vary with height and width of room and line of vision. Architectural details to match building.

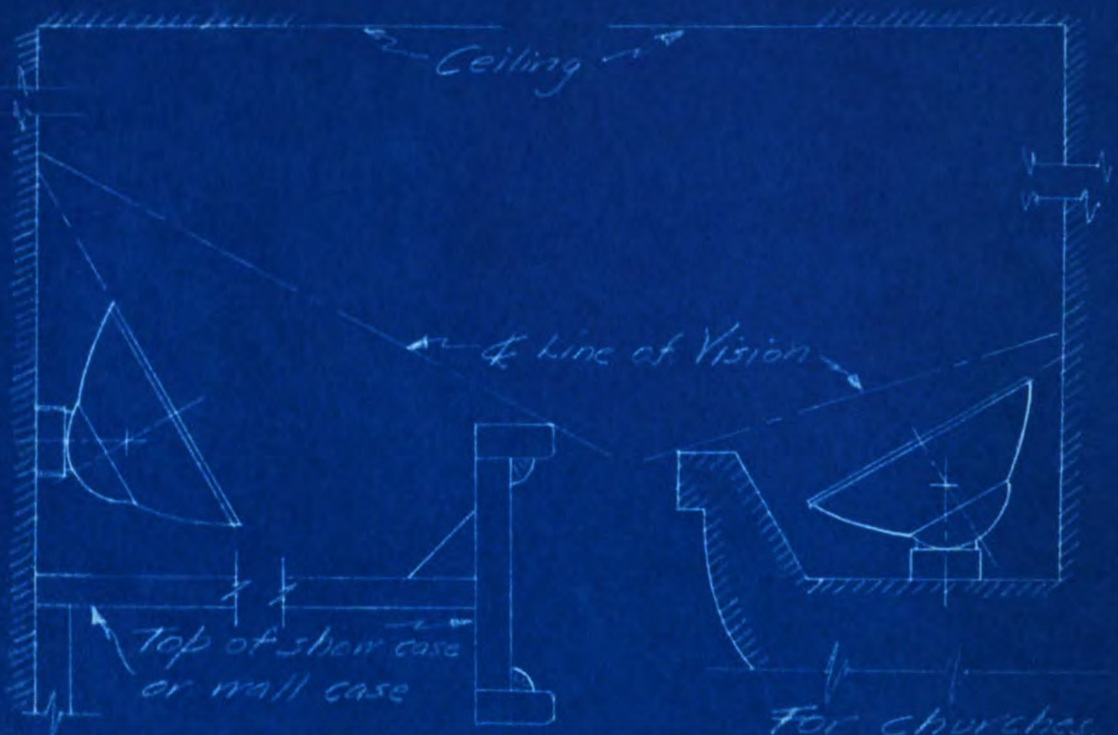
ROOM DATA
Main floor - 57' x 84'
Width at balcony - 40'
Ceiling height - 30'
Cove height - 25'
Height under balcony - 15'
Width side balcony - 8'-6"

Place 6 unit of #23, table #7, on 14 ft. centers under each side balcony. Use one 100 watt bulb in each unit.

Wire every fourth light in the same bank, making a total of four banks. Provide a dimmer for each bank. This arrangement is very flexible and an even intensity of any amount can be maintained; as well as streamers and other varigated designs.

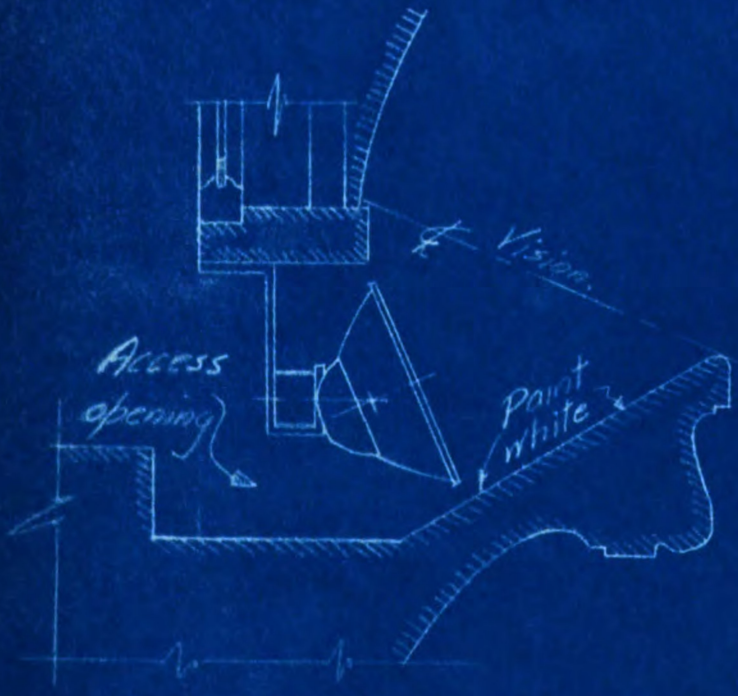
M.G.H.

SUGGESTED COVE ARRANGEMENTS

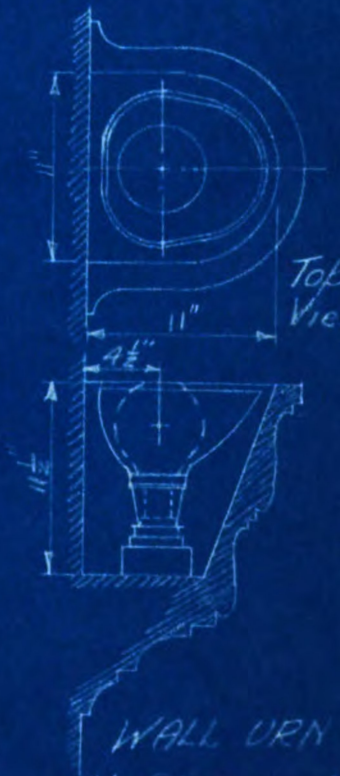


As used in stores.

For churches, Libraries, etc.



Outline for large cove used in theatres and dance halls. This provides a foot walk and access opening "up behind" for relamping and cleaning.



WALL URN

Useful on walls, pilasters, or columns for additional illumination or special lighting effects.

M.G.H.

SHOW WINDOWS.

For years it has been recognized that the show window display, in its essentials, is the same as the theatre stage setting, but until recently the stage manager has outstripped the window display man in the effective use of light. All progressive merchants have redesigned the window lighting, however, until now they can have from 100 to 500 foot-candles of general illumination by turning on additional switches, and even much higher levels up to 1,000 foot-candles by the use of high intensity spotlights which are directed on the central figure of the display.

The amount of illumination necessary in a window varies with the location of the store, those in the brightly lighted districts of a large city requiring the most, and those in the outskirts of the same city or in other less densely populated districts requiring less.

The difference may be great; as much as 500 ft.-candles in the city to 100 foot-candles elsewhere. In choosing an intensity for window display work, there is one good rule to follow:- When in doubt as to whether or not the value chosen is large enough, just step up to the next higher level and make the design for that figure. An additional 100 foot-candles will only cost approximately twenty cents per hour and inasmuch as a window stands out in direct proportion to its brightness, the increased drawing power of the window will easily

boost sales to offset the cost.

"Light on the object but not on the eyes", is a basic fundamental of all lighting problems and is especially true in show window lighting. Modern show windows, when illuminated in accordance with the correct principles, have the light sources located at the top and front of the window, close to the plate glass where they may be readily concealed by valances, painted signs, or curtain drapes. With this arrangement, strong illumination may be directed downward and forward to the trim, giving it the direction which experience has shown produces the most effective results. It has sometimes been found advisable to set the reflectors up into the ceiling until the mouths are flush. The reflector for each window should be carefully selected by studying its distribution curve so that it will direct all of the light to the floor and not lose a percentage of it out of the window. Moreover, reflectors should be closely spaced to insure most effective lighting; this also permits of turning off alternate units leaving sufficient illumination for a white or light colored display.

The necessity for ample provision for window spot and flood lights cannot be overstressed. For instance, if a displace of dark suits is arranged in the window, it will be found that the window will be dark no matter

how much light is poured onto the suits. If, however, a light background is used and the extra illumination is poured onto it, the suits and other dark material will be silhouetted sharply against the light background and the value of the display will be greatly enhanced. These results can only be accomplished by flexible lighting; flood and spot lights provide this medium.

Marvelous effects in imparting atmosphere to window displays may be secured by the judicious use of colored lights. Where careful application of colored light on various merchandise is made, striking window settings may be obtained. General rules to be followed in the application of colored light are very difficult to give, because each window display in itself presents a specific problem requiring special treatment. In general the best results will be obtained if the lighting engineer provides the window decorator with a good, efficient, flexible layout, leaving the details to him. It is to that end that the accompanying layouts are made.

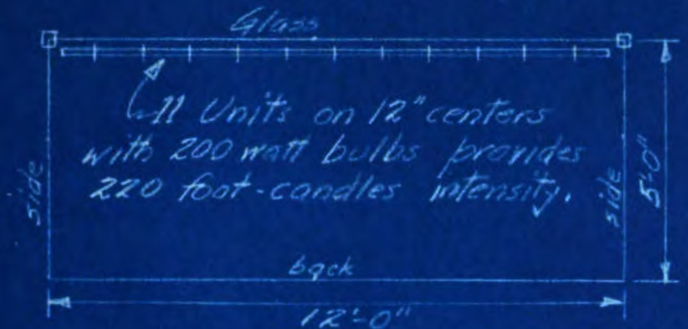
The four fundamental principles which should be observed in designing show window lighting layouts are: To conceal the light source; to locate the light source at the top and front of the window; to control the light by use of the proper reflectors correctly spaced; and to use plenty of light - enough to make the window stand out clearing and attract the passerby. To these might

well be added a fifth, and that is to provide several wall, floor and ceiling plug outlets so that other means of lighting may be easily added as required.

The direct type of illumination as used in show windows is the most efficient in commercial use at the present time. The reflectors emit as high as 85% of the generated light and a good average coefficient of utilization is .65. The usual size of narrow windows will only require one row of units and the spacing will vary from 8 inches to 18 inches depending largely on the required intensity. The quickest way of computing bulb size and checking the installation is to assign units at 12 inch spacing; this gives the number of units; then choose the required intensity, from 100 to 500 foot-candles as outlined, and solve the general formula for the lamp lumens per unit. This gives a choice of the nearest bulb size; if this is too large, fewer units may be used and they may be spaced a little farther apart; or if the reverse is true, several additional units will bring up the intensity to the proper value. These should then be equally spaced all around the window.

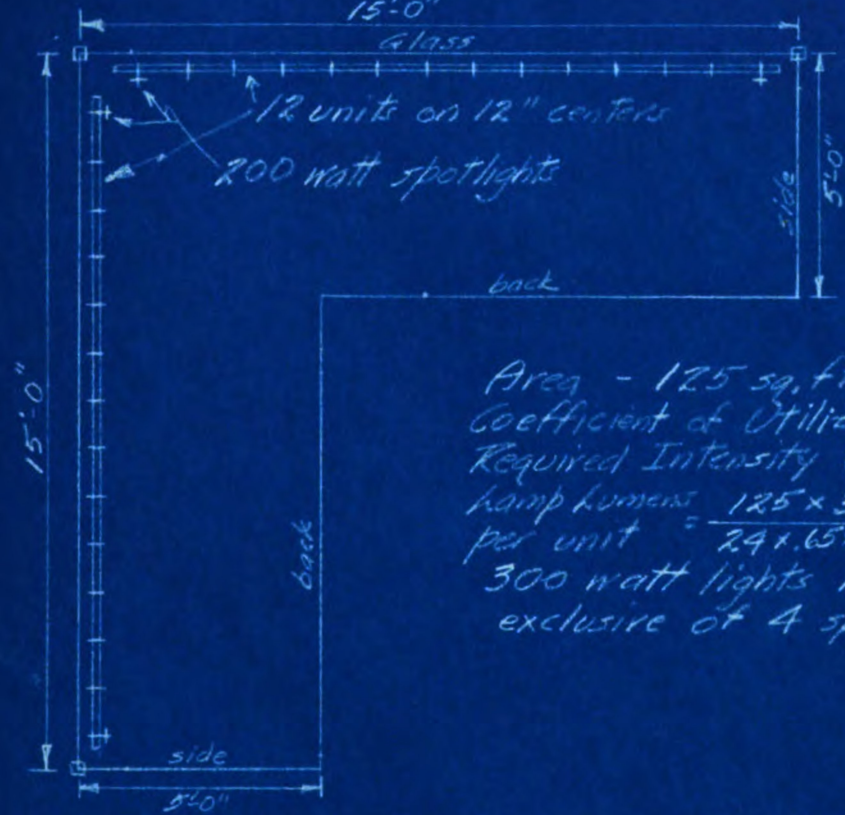
Deep windows and high windows will generally require a double row of reflectors, one of which is tilted to concentrate its output on the back area of the window. An illustration is included to show this method of design.

ILLUMINATED WINDOWS



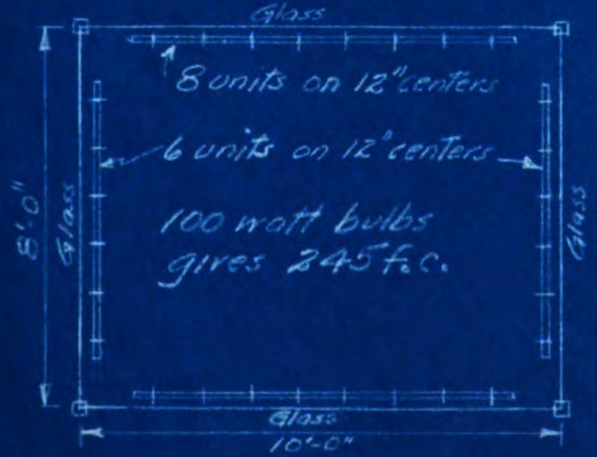
LONG NARROW WINDOW
Units mounted flush in ceiling; which is 10 ft. above the floor.

Conduit troughs shown with cross to mark outlets.-



CORNER WINDOW.

Area - 125 sq. ft.
Coefficient of Utilization = .65 (Average)
Required Intensity (Downtown) = 300 f.c.
lamp lumens per unit $= \frac{125 \times 300}{24 \times .65 \times .80} = 3000$
300 watt lights will give 320 f.c. exclusive of 4 spotlights.

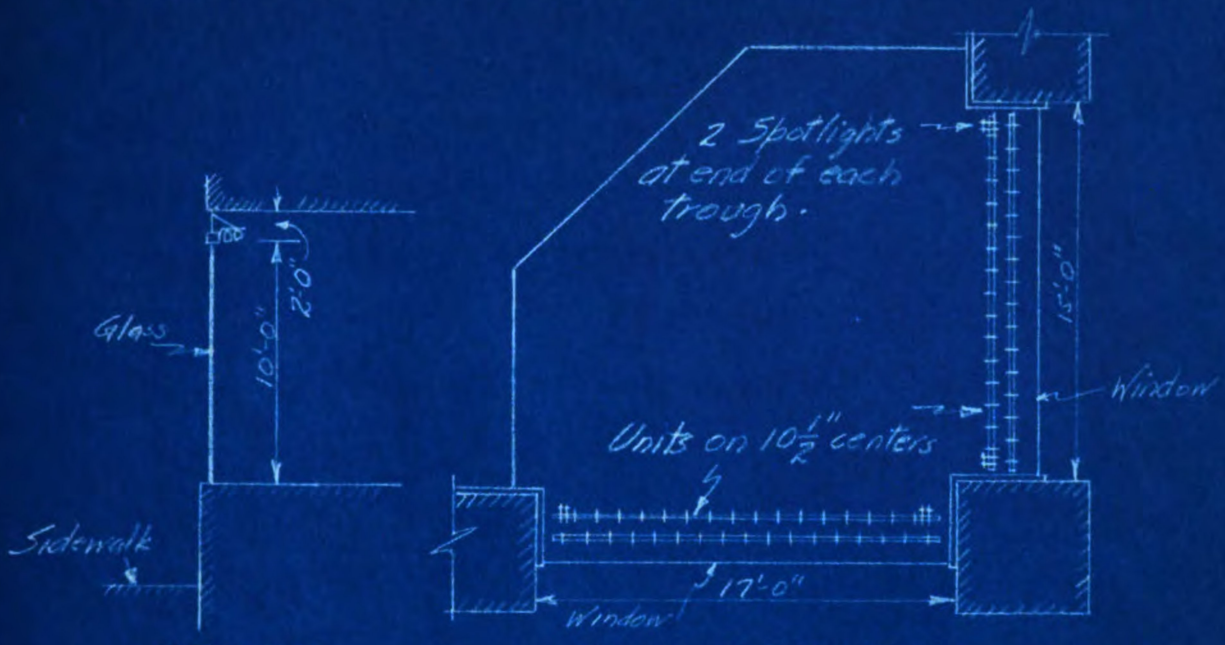


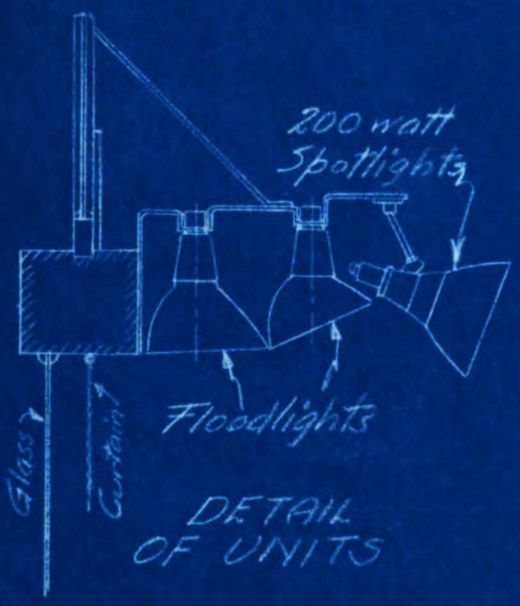
ISLAND WINDOW
Glass on all four sides
Units flush - 10' ceiling.

Connect alternate units on the same circuit - each trough separate.
With alternate lights turned on, the intensity is 125 foot-candles.

M.G.H.

ILLUMINATING A LARGE CORNER WINDOW





Area - 21'x20' - Δ = 360 sq. ft.
Ceiling - 12 ft. high.
Units - 10 ft high.
Room Index - 1.2 (Average)
Coefficient of Utilization - .65
Number of Units - 64.
8 Spotlights extra.
Required Intensity - 300 f.c.

Lamp lumens per unit $= \frac{360 \times 300}{64 \times .65 \times .80} = 3240$

Use 200 watt bulb. (3200 lumens)
Figure exclusive of spotlights.

FOR OTHER DISTRICTS.

All 300 watt bulbs gives 490 f.c.
" 150 " " " 212 f.c.
" 100 " " " 125 f.c.

Connect alternate units in each trough on the same circuit. This gives four levels of illumination in front of each window permitting a choice of the one best suited for the display. Liberal use of the spotlights will serve to bring out high points and lends to the flexability of the scheme.

M.G.H.

FLOODLIGHTING BUILDINGS

The first step in the design of a floodlighting project is to determine the effect desired. In the case of building illumination it should enchance the effect striven for by the architect. Decide what portion, or portions are to be lighted and to what intensity. In area lighting the use to which the area is to be put will determine the quantity of light needed. Another factor which influences the quantity of light is the neighborhood in which the building is located. For buildings located in the central parts or business districts of large cities, the higher intensities must be used in order to get the necessary contrast and make the building stand out as it should. The usual range of intensities for floodlighting buildings is 10 to 20 foot candles; 25 to 30 foot candles are sometimes used in the loop districts downtown or for advertising purposes. These are the favored intensities for billboards and signs.

Having decided upon the lighting effect desired the next step is to determine the available locations for projector equipment. Sometimes, particularly in display lighting, the choice of location is very much restricted and the design is greatly influenced by the availability of locations.

In display lighting the concealment of the equipment is generally of first importance and locations are

selected with this end in view. The lighting of a building with set-backs at various floors offers ideal locations for mounting projectors which will be invisible to observers. They should be mounted inside of and just below the top of the parapet so they will be protected and out of sight. Care should be taken to see that snow, ice, water, and refuse will not accumulate on them.

When locations for mounting the floodlights are not available upon the building itself, it is sometimes possible to mount them on adjacent buildings or ones across the street. A suggested layout for this type of lighting is included and the method followed is very evident from the drawings.

There is another method which is becoming popular for floodlighting buildings. It is used a great deal on low buildings and in locations where no other type of projection can be used. It consists of a lantern bracket type of projector, the external appearance of which duplicates the street lighting units used in the city where the installation is being made. A very novel scheme is used for the internal arrangements. Provision is made in the base for a 200 or 300 watt bulb which illuminates the interior of the unit and casts its rays up and down the street as does any ordinary street light. A 500, 750 or 1000 watt bulb is located in the top of the unit and is equipped with a very efficient reflector, thus directing practically

all the output of the large bulb onto the area to be illuminated. By mounting these units on posts like street lights the direct glare is kept out of the eyes of the passerby.

On the common width of sidewalk, standards for lantern brackets should not be placed closer than 20 feet apart, neither should they be placed directly in front of the doorways. Instead, one should be installed on each side of the entrance. This adds to the appearance of the building and gives the best lighting layout.

In cases where existing street lights are of a certain type it is well to select a lantern bracket of similar design so that all will appear alike.

After choosing a lantern bracket the building and sidewalk layout should be inspected to see how many units can be installed without spoiling the appearance, bearing in mind that they cannot be closer together than 20 feet.

Coverage per unit is the next step. In general, a unit located on the curb of a usual width sidewalk placed 12 to 15 feet from the wall will illuminate an area about 20 feet wide by 50 feet high. This area is not materially different for any bulb size so it follows that for high buildings a double bracket will be necessary, that is two units will be mounted on each standard or post.

The choice of the 500 or 1000 watt lamp depends almost entirely upon the intensity desired and the distance to the surface to be illuminated. The use of 500 watt units for the lower height buildings with "throws" up to approximately 15 feet, gives satisfactory results. For the higher buildings, even with average sidewalks, the 1000 watt units are much more effective. If the highest order of brightness is desired for the building the maximum number of 1000 watt units will be required; this means double brackets every 20 feet. The 750 watt bulb will be useful in obtaining the medium intensities.

Having determined the number of standards and brackets, a bulb size is estimated based on the distance to the building and the desired intensity. This information, with the building size, enables the foot candles to be computed as outlined on the blue prints. If the actual foot candles are materially different from the desired intensity, a change in bulb size or a re-arrangement of units, or both, will accomplish the desired results. Reference to the blue prints will illustrate how this is carried out.

This type of lantern bracket is used extensively in illuminating gas stations and other such areas where they will enhance the beauty of the arrangements as well as efficiently light it. For this service the 500 watt bulb has been found to be most satisfactory. The units should be so located that the majority of the light is

cast across the flow of traffic, thus furnishing illumination with the least possible glare.

It should be remembered in planning a layout for any type of floodlighting that evenness of illumination and complete coverage are most essential. The amount of surface a floodlight projector will cover is a function of the distance from it and the beam spread of the unit. For our purpose we may group floodlights into four general classes:

Narrow beam projectors	-	up to 15° beam spread
Medium beam "	-	16° to 29° " "
Wide beam "	-	30° and over
Special beam "	-	In which the horizontal and vertical beam spreads are not alike.

The exact beam spread required for a specific installation can be easily determined by mathematical calculation or by measurement on a sketch drawn to scale. The closer the bank of projectors to the surface to be illuminated the larger number of units required. Careful reference to the blue print of the floodlighted tower on the office building will bear out this statement. Too much can not be said about making a scale drawing and working up the layout from it. It is fast, accurate, and easily checked. A reasonable allowance should be made for the overlapping of beams at the edges so that a uniform intensity will be maintained.

Attention is called to the fact that there will be a small percentage of "spill" light outside of the published beam spread. Under ordinary circumstances this is perfectly all right and serves to bring up the intensity of the area between the units but should it be desired to eliminate this "spill" light a louvre may be installed just inside of the lens which will eliminate all but the main beam. These can be purchased from the floodlight manufacturers as extra equipment. A visor made of sheet aluminum can also be furnished where it is only desirable to eliminate the upward spill light. This clips on the outside of the front door and is not used in conjunction with a louvre.

Another feature in floodlight construction that is well to mention at this time is in regard to color illumination. Provision is made on practically all units manufactured at the present time to facilitate clipping in a color screen behind the present lens which will impart color to the beam. The screen is made of a special grade of heat resisting glass, designed for the purpose, and it will retain its color qualities for an indefinite period. This screen is used regardless of the type of lens or spread of the beam when color effects are to be obtained.

The action involved in changing a reflector from one beam classification to another is to change either the type of lens, the type of reflector or both. Normal beam classifications of narrow, medium and wide, have approximately the same vertical spread and a horizontal spread according to the following schedule:

Narrow beams - up to 15° beam spread

Vertical beam spreads vary from 5° to 10°

Horizontal beam spreads vary from 7° to 12°

generated by a plain reflector and plain lens. The efficiency of the beam averages 30%, or rall efficiency 66.5%.

Medium beams - 16° to 29° beam spread.

Vertical beam spreads vary from 11° to 15°

Horizontal beam spreads vary from 18° to 22°

generated by a plain reflector and plain lens. Beam efficiency 28%; total efficiency 66.5%

Wide beams - 30° beam spread and greater

Vertical beam spreads vary from 25° to 30°

Horizontal beam spreads vary from 30° to 46°

generated by a prismatic reflecter and plain lens. Beam efficiencies 15% and 28%, total efficiency 66.5%.

Special Beam Classification

Type Reflector	Type Lens	Beam Spread Horizontal	Vertical	Efficiency Beam	Total
Plain	Ranlite	Medium 45°	5°	28%	68%
"	"	" 45°	10°	41%	71%
"	"	" 45°	15°	25%	66.5%

Type Reflector	Type Lens	Beam Spread Horizontal		vertical	Efficiency Beam	total
Prismatic	Ranlite	medium	44°	30°	25%	66.5%
Plain	"	"	70°	6½°	15%	55%
"	"	"	70°	13°	15%	55%
Prismatic	"	"	75°	25°	15	55%
"	"	"	70°	30°	15	55%

The above special beams are representative of what can be secured as they were picked from the catalog data of a responsible manufacturer. Many other combinations are being furnished, a complete list of each will be found in the lighting catalogs.

Various sizes of bulbs are used in the above described units. These range from 200 watts to 1500 watts. With this information and a choice of reflectors practically every condition may be satisfied.

The method of making a floodlighting layout for a building is a more or less "cut and try" proposition at first, but as experience is gained it will be found to be a more exact art. As this discussion progresses, careful reference should be made to the floodlighted tower of the office building and the computation sheet, blue prints of which are enclosed; also the floodlighted theater building.

One thing that always must be kept in mind is uniformity of illumination. It follows that the closer the bank of floodlights to the surface it must illuminate, the larger the number of units necessary to fulfill the

requirement and the smaller the individual bulb sizes. When the units can only be placed two to eight feet back from the surface they are to illuminate, they must be spaced not farther than four feet apart, using 500 or 300 watt bulb depending upon the intensity required. Quite often it is found necessary to space units on two to three foot centers insuring a very complete coverage. Wide or medium wide beams spreads are commonly used for this work. As the bank is moved further away from the surface uniform coverage can be secured with a much smaller number of units, using the same or a smaller beam spread. In order to maintain the same intensity then it becomes necessary to increase the bulb to a 750 or 1000 watt size. Longer distances of projection, such as across a street, or higher than average intensities will generally require the 1500 watt bulb, unless the percentage of units to area illuminated is some what high in which case the 1000 watt bulb will be sufficient.

The calculations for the necessary number of units is carried out as follows: consider the distance of projection and the area to be covered, and choose a bulb size. This gives the emitted lumens per unit and substitution in the general formula with the area to be illuminated, foot candle intensity, 66.5% efficiency and an 80% depreciation, readily solves the number of units of that size which will be necessary to fulfil the requirdments.

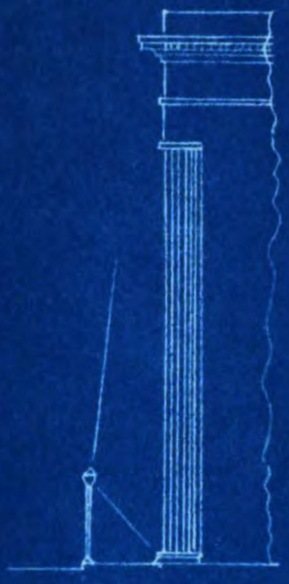
Next, refer to the beam classification chart and select a beam spread which will give acceptably uniform coverage. This may be readily checked by making a scale drawing, placing the units on it and sketching the chosen beam spreads. Some overlapping should be allowed both horizontally and vertically to assure even coverage.

In some cases it may come up in which even coverage can not be obtained with the number of units as computed by the formula. This may be due to the construction of the building, the location at which the projectors must be placed with respect to the surface to be illuminated, or other reasons. It is necessary then to set aside the exact number of units as computed, place them so they will illuminate as much as possible, and add whatever units will be required to eliminate the shadows. No other arrangement will be found satisfactory unless the entire lighting scheme is changed to embody a silhouette effect.

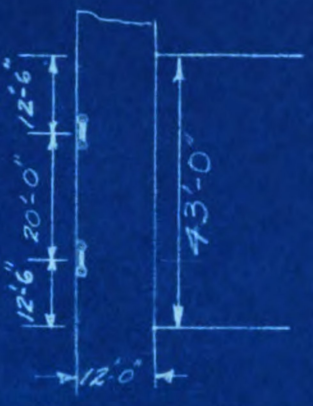
After installation all units should be carefully adjusted so that each one covers its own area, then light and dark spots or streaks will be eliminated and the most desirable effect will be created. This process is just as essential as the original design and must be followed through carefully to get in the best results.

Attention is again called to the blueprints and pictures of floodlight installations in the back of the book.

FLOODLIGHTING SMALL BUILDINGS FROM THE CURB WITH LANTERN TYPE BRACKETS



SIDE ELEVATION

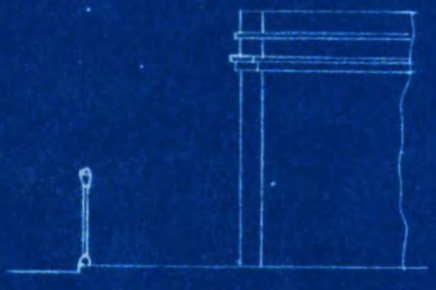


PLAN

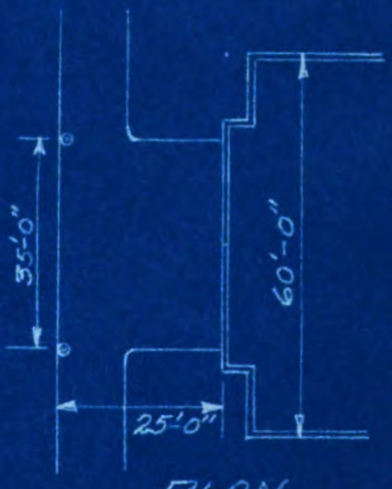
Bank building 77 ft. high 43 ft. wide. Six large pillars of cast stone in the front. Mount two lantern brackets per standard, 14" reflecter, 750 watt bulb.

$$\text{Intensity} = \frac{4 \times 14550 \times .85 \times .80}{43 \times 77} = 12 \text{ foot-candles.}$$

Two units per standard are used to match street lights.



SIDE ELEVATION



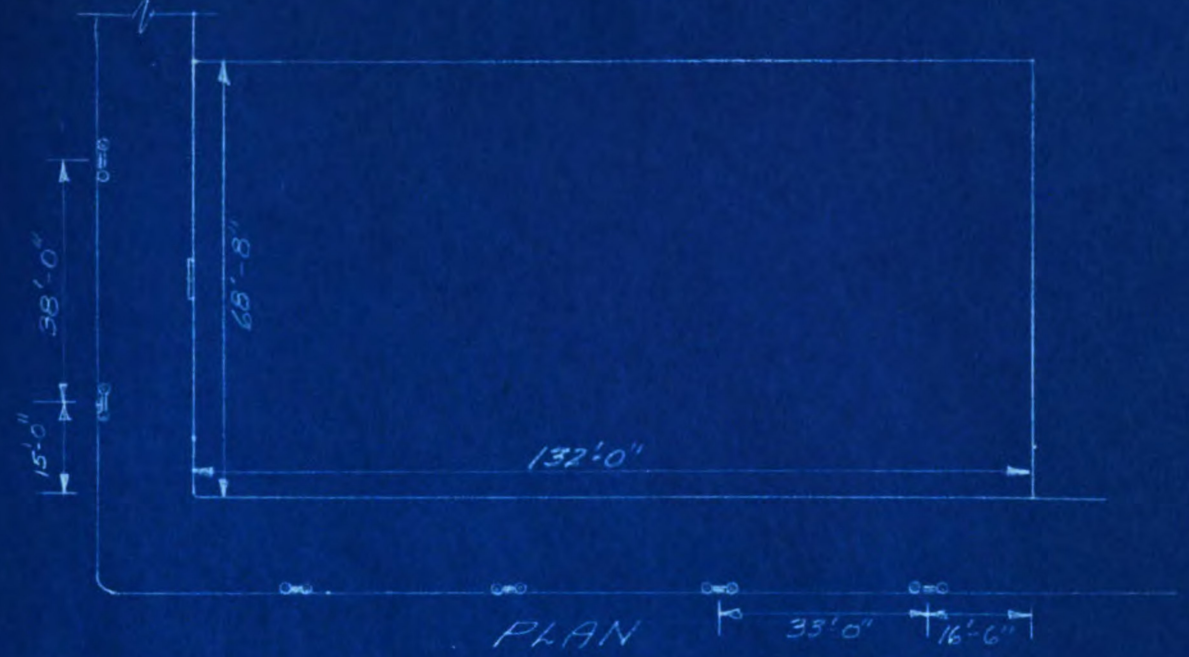
PLAN

Bank building 40 ft. high, 60 ft wide. Use one lantern bracket per standard to match present street lighting. Equipt with 14" reflector and 1000 watt bulbs.

$$\text{Intensity} = \frac{2 \times 20,200 \times .85 \times .80}{40 \times 60} = 11.4 \text{ foot-candles}$$

M.G.H.

FLOODLIGHTING FROM THE CURB.
LANTERN TYPE BRACKETS



PLAN

ELEVATION

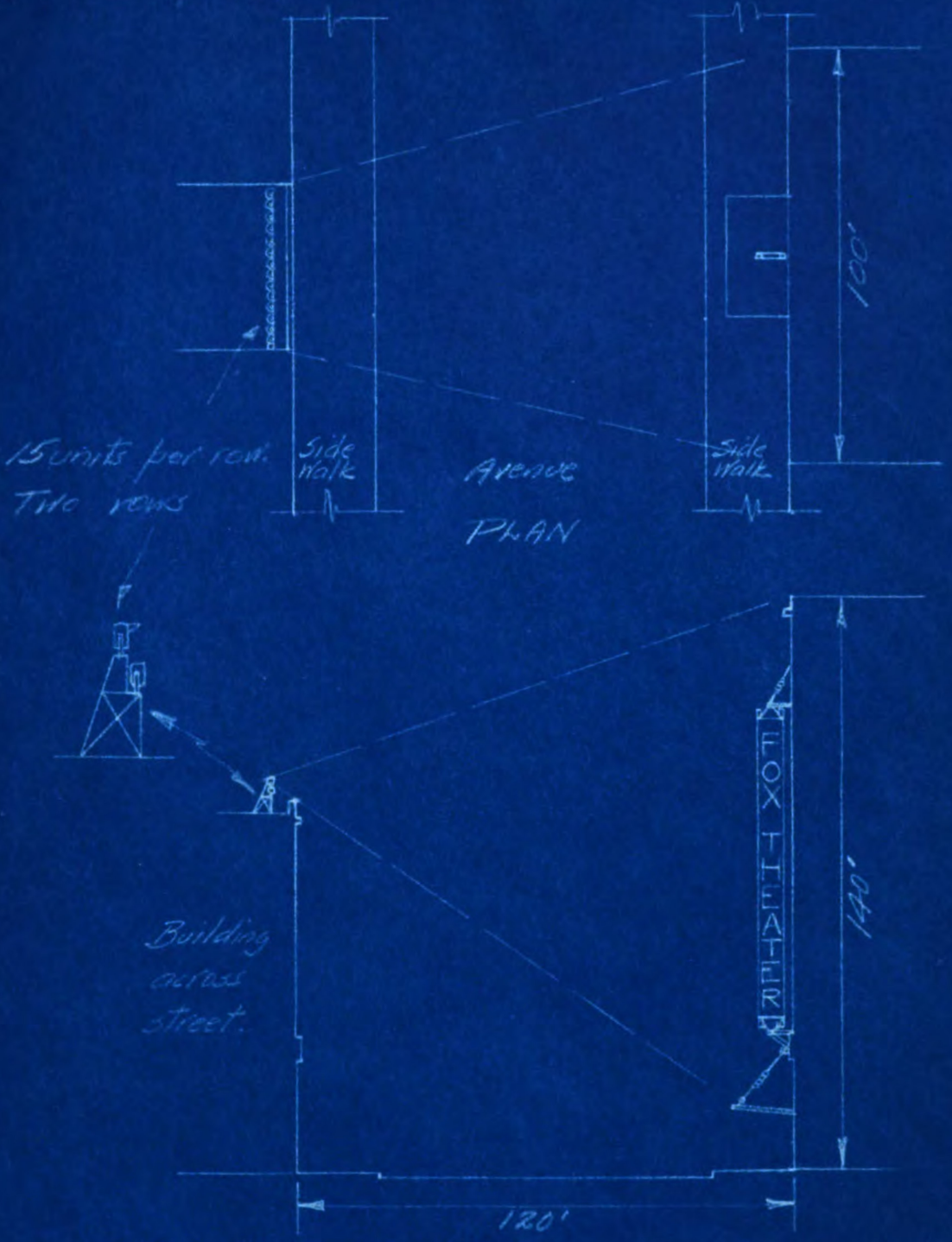
Building as shown - Cast stone - White - 100 feet high.
Use Lantern bracket, 14" reflector, 1000 watt bulb.

Intensity - Front = $\frac{8 \times 20{,}200 \times .85 \times .80}{132 \times 100}$ = 8.3 foot-candles.

" - Side $\frac{4 \times 20{,}200 \times .85 \times .80}{69 \times 100}$ = 8.0 " ".

M.G.H.

FLOODLIGHTING A THEATER BUILDING



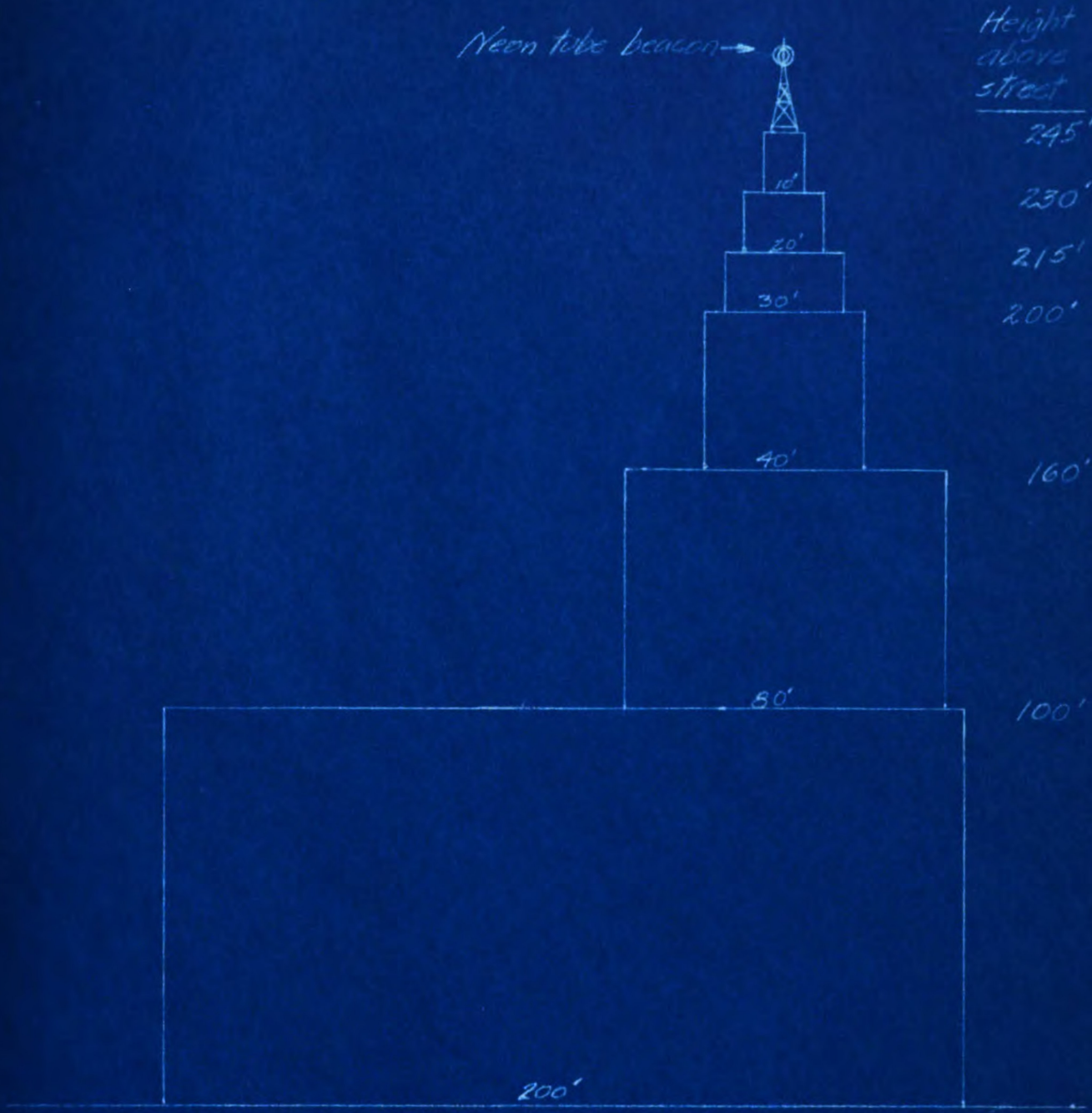
$$\text{No. Units} = \frac{100 \times 140 \times 20}{17{,}800 \times .66 \times .50} = 30 \text{ units}$$

Each of these units equipped with a 1000 watt, G 40 bulb emitting 17,800 lumens in a beam 35° x 30°. [EFF = 66 %] This layout illuminates the white stone front to 20 foot candles. All units mounted on building across the street.

Following the usual custom, the under side of the marquee is covered with 15 watt bulbs. This brings the intensity at the door up to a very high figure.

M.G.H.

ILLUMINATED TOWER ON A LARGE OFFICE BUILDING



ELEVATION
Scale 1" = 40'-0"

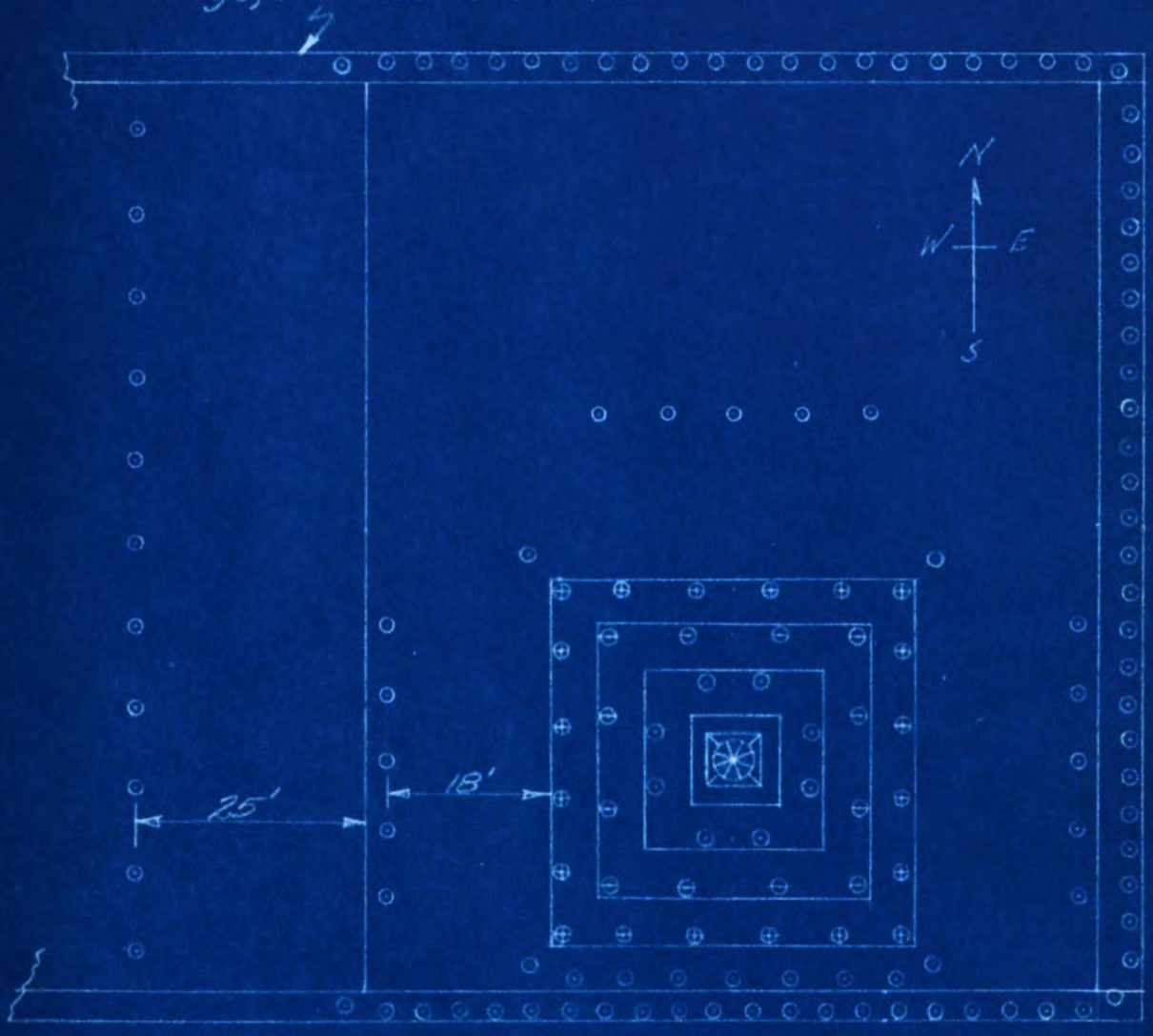
This is the south elevation and fronts on a main boulevard. The east side also faces a main thoroughfare. The building is in the main business district of a large city.

The bottom four sections of the tower are illuminated to 20+ foot candles; the top 10'x15' area to 35 f.c.

The location of all floodlights is shown on an attached drawing.

M.G.H.

FLOODLIGHT LOCATIONS ON OFFICE BUILDING TOWER



PLAN
Scale 1" = 20'-0"

Level	Color	No. Units	Wattage	Spread
100 Ft.	White. ○	11	1000	30° × 30°
	"	68	500	20° × 10°
160 Ft.	White. ○	15	750	40° × 30°
	"	11	500	20° × 10°
200 Ft.	Red. ⊕	20	500	20° × 10°
215 Ft.	Yellow. ⊖	12	500	20° × 10°
230 Ft.	White. ○	8	300	20° × 10°

MGH.

LIGHTING DATA - OFFICE BUILDING TOWER

$$\text{No. units needed} = \frac{\text{Area in square feet} \times \text{Intensity}}{\text{Lamp lumens} \times \text{Unit Efficiency} \times \text{Depreciation}}$$

Level	Side	Watts	Formula	Number of Units	Spread	Color
100 Foot	West	1000	$\frac{60 \times 100 \times 20}{20{,}200 \times .65 \times .8} = 11.4$	11	30°×30°	White
	East	500	$\frac{60 \times 100 \times 20}{9650 \times .65 \times .8} = 24$	24	20°×10°	White
	North, South	500	$\frac{60 \times 80 \times 20}{9650 \times .65 \times .8} = 19.2$	20	20°×10°	White
160 Foot	West, East, North	750	$\frac{40 \times 40 \times 20}{14{,}550 \times .65 \times .8} = 4.2$	5	40°×30°	White
	South	500	$\frac{40 \times 40 \times 20}{9{,}650 \times .65 \times .8} = 6.4$	7	20°×10°	White
200 Foot	W-E N-S	500	$\frac{30 \times 15 \times 20}{9650 \times *.32 \times .8} = 3.6$ *	4	20°×10°	Red
215 Foot	W-E N-S	500	$\frac{20 \times 15 \times 20}{9650 \times *.32 \times .8} = 2.4$ *	2	20°×10°	Yellow
230 Foot	W-E N-S	300	$\frac{10 \times 15 \times 35}{5370 \times .65 \times .8} = 1.88$	2	20°×10°	White

* Note - Colored lights are only 50% as efficient as white. An extra floodlight is installed on each corner to boost the intensity, increase the definition, and prevent any "feather edges". This practice has been found to be very helpful and increases the visability greatly.

TOTAL TO ORDER			
Color	No. Units	Watts	Spread
White	11	1000	30°×30°
	15	750	40°×30°
	79	500	20°×10°
	8	300	20°×10°
Red	20	500	20°×10°
Yellow	12	500	20°×10°

Connected load - 145 units - 81.15 Kw.
Exclusive of neon tube beacon

(M.G.H.

COLOR FLOODLIGHTING

There are two types of color floodlighting - still and mobile. The still color floodlighting installation is the simpler in design, as it consists of but one system and is patterned much the same as the still "white" installation. In fact, a "white" floodlighted building may readily be colored by inserting color filters behind the lens. Colored floodlights are, on the average, about 50% as efficient as the corresponding white light so in order to maintain about the same level of illumination it will be necessary to increase the bulb sizes or install additional units.

The simplest still color application is the floodlighting of a building in one color. More complicated installations may be designed to flood various portions of the building in various colors. Two things must be kept in mind, however - first, that the use of more than one color calls for harmony in the colors used; and second, that the floodlights should be located, if at all possible, so that they are easily accessible for changing the color filters. This last feature will permit variance from time to time of the color effects produced. (One good example of this system in Lansing, Michigan, is the Board of Water and Light Building, on West Ottawa Street. This untilizes colors both from units on the building and from other units in the attic windows of the city hall.) Still color floodlighting

layouts are designed the same as a "white" installation except due allowance must be made for the 50% efficiency of the color units.

Mobile color lighting is the most complicated but it provides the finest, most attractive and spectacular results, and its design should begin with a study of the architecture of the building to be floodlighted. The modern type of skyscraper with numerous set-backs, pilasters and other forms of architectural adornment offer exceptional opportunities to the ingenuity of the designer. These set-backs also provide ideal locations for the installation and concealment of equipment which adds charm, mystery and illusion to the effect when viewed from the ground.

Mobile color lighting has as its limits only the number of colors, the space available for the equipment and the amount of money available for the installation. The installation should be designed to provide sufficient flexibility in effect to prevent monotony. The lighting units should be concealed on the building itself as much as possible. Provision should be made for rapid changes in the arrangement of both color and motion.

The intensity of the illumination and the number of floodlights of each color depend upon the location of the building and the material of which it is constructed, the same as if it were a "white" installation. Each color system is required to fulfill an entire individual part in

the program; this means that there must be a full set of floodlights for each color designed as explained above. These color units will be banked together and with the white units so that as each is individually lighted it will produce the desired effects.

The installation is operated by an all electrical controller which consists of cycle dimmers for the control of the white system and magnetic contractor switches, properly synchronized with the operation of the cycle dimmers, for controlling the colored light. The action may be set to make changes of any duration of time desired. As the "wash" system operates, the white lighting is gradually increased from zero to maximum, at which point its intensity completely washes out the color and the building appears in white. One color may be switched off and another on without perception of any change to the onlooker. Then, as the white system is gradually decreased, the second color gradually comes up to its full intensity. Again, the white light increases, washes out the color, another color takes its place and the white decreases. This action is constant and according to a predetermined schedule.

One of the outstanding examples of this type of art is a large bank on which three complete floodlighting systems are installed: - 1-Red, 2-Blue, 3-White or uncolored. The control equipment is located in the basement and is arranged to give twelve color changes in two minute

intervals. During this time the building changes from white to red, red to white, white to blue, blue to white, white to red and blue (purple), red and blue to white. There are also six periods during which the various tints of red, blue and purple are either increasing or diminished.

Another feature of this system is that various changes can take place on various portions of the building at the same or different times. The delicate shades produced by the increasing and decreasing intensity of the white system, and the combination shades obtained by switching on two or three blending colors at the same time are beautiful. There is a broad field and an unlimited opportunity for this type of illumination. Results are dependent upon the Illuminating Engineer, Architect, and Electrical Contractor who must work together to the common end and develop the sensational combinations possible with this form of lighting. These results will more than justify the increase in cost above the ordinary type of floodlighting.

The University of Detroit Football Stadium

Floodlighting for the University of Detroit stadium was first installed for a few test games in the fall of 1929 and the success of the trial was measured by an increased attendance at the night games over those played in the day time. The installation, during these test games provided approximately 8 foot candles over the field and it was found advisable to use an illuminated ball; i.e. one which was painted white. Due to the success of the scheme it was decided to go into the lighting of the field in a big way and schedule the majority of the games at night for the fall of 1930. Credit for the design and installation of this outstanding step in illumination belongs to two alumni of this school - E. F. Labadie, Electrical Engineer of the Fisher Body Company and Harry Martin of Martin and Gibson Company, both of Detroit.

A decided forward step was made in this installation as it provides an intensity of 50 foot-candles in the stands with "spill" light from the main units. This is many times the intensity usually thought necessary, (8 to 10 foot candles) and is adequate for the players to function as rapidly as by day and without any annoyance from glare. It is not even necessary to use an illuminated ball. The biggest recommendation for the system came from the visiting

teams, some of whom were unused to playing under light.

They experienced no difficulties adjusting themselves to the new conditions.

The economic practicability of this scheme has been evidenced by record crowds at each of the games played last fall. This statement is made to justify the apparent high load, which amounts to 320 K W of electrical energy. The system has a transmission voltage of 460.

One 80 K V A 440/220/110 volt transformer is located at the base of each corner tower to furnish current to the four 110 volt, 10 K W floodlights which are mounted on the top of each tower. This maintains good voltage regulation, as each corner tower requires 348 amperes at 110 volts, and keeps the feeder size down to one # 4/0 cable on the high side and two # 4/0 cables per phase from the transformer up the tower to the units. The center towers also have four units but these are 20 K W each; 20 - 1000 watt, T-20, 105 volt bulbs are mounted as close together as possible within the reflector. These are connected in parallel, the four reflectors are connected in series and operate across the 460 volt supply. This burns the 1000 watt bulbs at 10% over voltage and increases their lumen output.

The entire system operates at an efficiency of 30 lumens per watt. The 10 K W lamps operate at approximately their normal life of 100 hours, and the list price per bulb has been recently reduced from $185.00 to $125.00 each, decreasing both the initial and maintenance cost

considerably. The 1000 watt 105 volt T-20 bulb is burned 10% above its rated voltage which increased its lumen output to 30 lumens per watt, or 30,000 lumens per bulb, but decreases its maximum life to approximately 125 hours. This sytem facilitates maintenance as it limits the useful life of all units to approximately 100 hours, and theoretically all bulbs will need to be replaced at the same time. Another feature of the design is that all units are mounted on trunnion bases and can be easily swung around for servicing without danger to the maintenance man. A set of guides permit their return to the original location without any further adjustments.

Each of the towers if 105 feet high, approximately 3-1/2 feet square, and is anchored with a concrete foundation, sunk approximately five feet in the ground. The towers are so designed that they are capable of withstanding a 100 mile gale. Steel ladders run up the inside of each tower to a platform located directly beneath the units which facilitates maintenance.

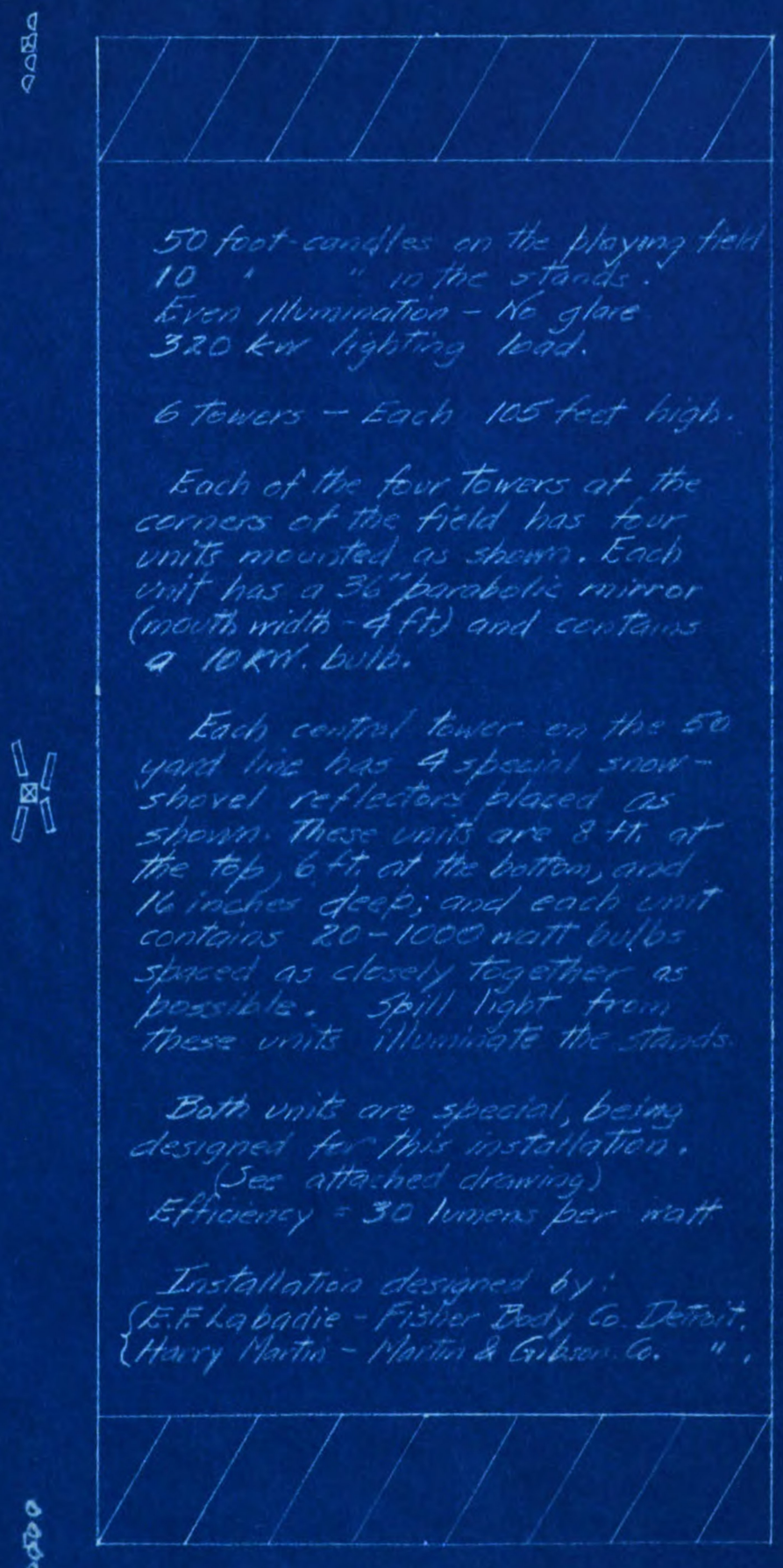
A complete layout of this important development is included as it indicates the modern trend for foot-ball field illumination.

Another interesting feature introduced here is that 2 - 20 inch R.L.M. domes containing 1000 watt bulbs are mounted on each tower and pointed toward the stands. These lights are independent of the regular system and

when the main lights go out, the stands will still be illuminated to a moderate intensity by the six 1000 watt domes on each side.

The lighting units for this installation are all special and as yet are not on the market commercially. It will be found relatively easy to make duplicates, however, as the dimensions are given on the attached drawings.

THE UNIVERSITY OF DETROIT STADIUM
BEST ILLUMINATED FIELD IN U.S.A. - 1930



50 foot-candles on the playing field
10 " " to the stands.
Even illumination - No glare
320 kw lighting load.

6 Towers - Each 105 feet high.

Each of the four towers at the corners of the field has four units mounted as shown. Each unit has a 36" parabolic mirror (mouth width - 4 ft) and contains a 10 KW. bulb.

Each central tower on the 50 yard line has 4 special snow-shovel reflectors placed as shown. These units are 8 ft. at the top, 6 ft. at the bottom, and 16 inches deep; and each unit contains 20 - 1000 watt bulbs spaced as closely together as possible. Spill light from these units illuminate the stands.

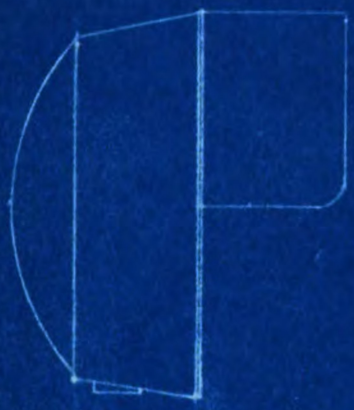
Both units are special, being designed for this installation.
(See attached drawing)
Efficiency = 30 lumens per watt

Installation designed by:
{E.F. Labadie - Fisher Body Co. Detroit.
{Harry Martin - Martin & Gibson Co. " .

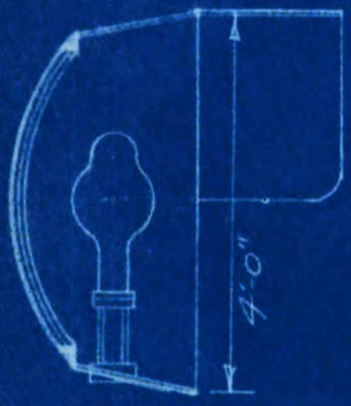
M.G.H.

UNIVERSITY OF DETROIT
SPECIAL LIGHTING UNITS FOR FOOTBALL STADIUM

10 KW UNIT - ON END TOWERS



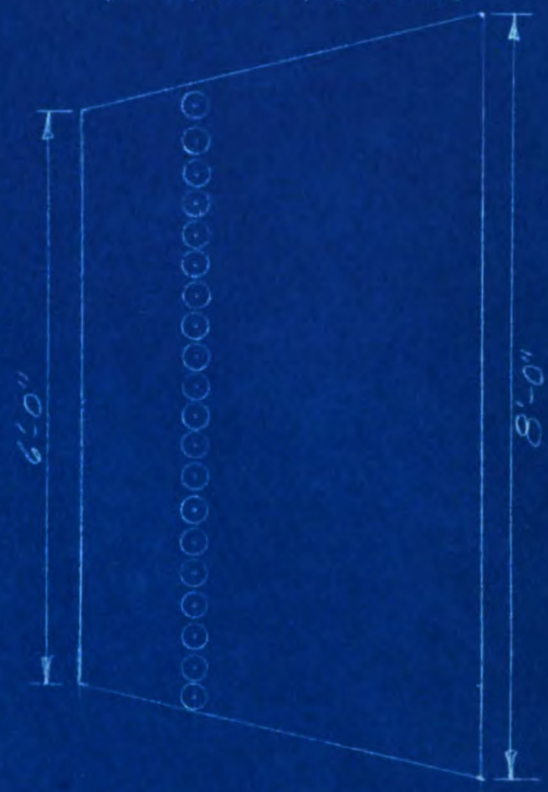
SIDE VIEW



SECTION

This shows the location of the 36" parabolic mirror and the 10 KW. bulb. The reflecting surface of the surrounding housing is of oxodized aluminum. The unit is built of sheet aluminum welded to a steel framework

20 KW UNIT - ON CENTER TOWERS



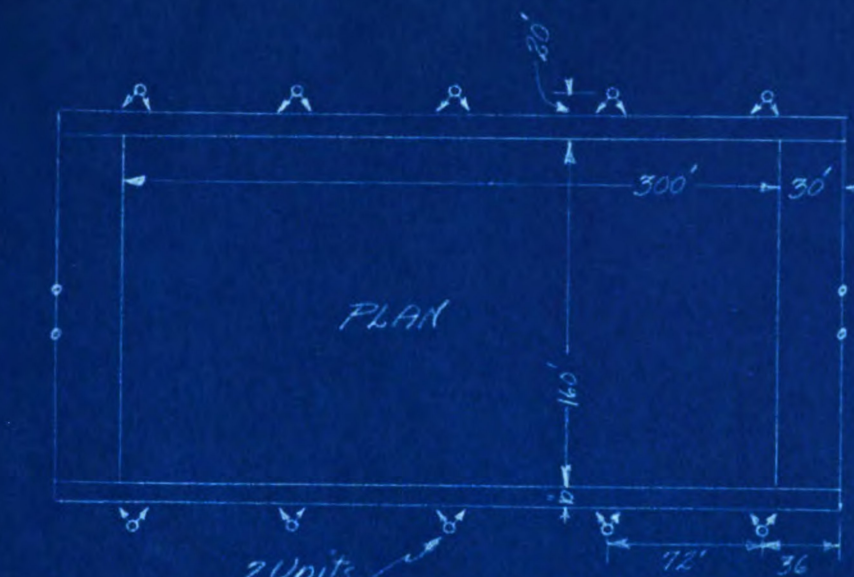
TOP VIEW

SECTION

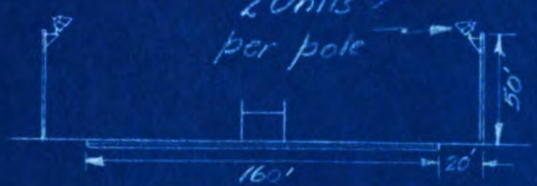
This unit is also built up with aluminum on a steel framework. The reflecting surface is a chromium plated spun copper mirror and directs the light very efficiently to the field. 20 - 1000 watt bulbs placed close together as shown furnish the light.

M.G.H.

TYPICAL LIGHTING LAYOUTS FOR FOOTBALL FIELDS. —



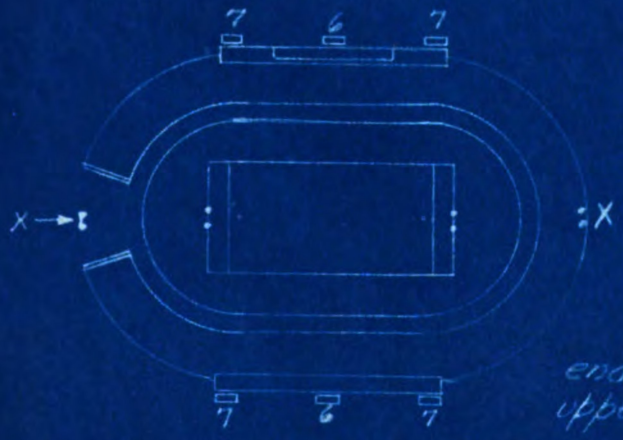
An economical serviceable layout. Use short range wide angle unit. Two per pole. Each with one PS 52, 2500 watt 50,000 lumen bulb. Coeff. of Util. = .70 Depreciation and weather factor = .75



SECTION

$$\text{Intensity} = \frac{50{,}000 \times 20 \times .7 \times .75}{180 \times 360}$$

$$= 8.1 \text{ foot-candles.}$$



STADIUM LAYOUT

Mount 6 units on each center tower and 7 on each end tower. 40° spread lens and louvers. Use 1500 watt bulbs – PS 52 if dimension D is less than 125 ft. and G 40 if D is more. Construct dimension "H" = "D"

X = Locate two units at each end with bottom louvers to light upper air for high punts.

TOWER TOPS

$$\text{Intensity} = \frac{31{,}050 \times 40 \times .7 \times .75}{200 \times 400}$$

$$= 8.1 \text{ foot-candles}$$

M.G.H.

AREA LIGHTING

In this type of lighting it may be said, as a general rule, that the elimination of glare is of the utmost importance. One effective way of reducing annoying glare is to mount the projectors a sufficient height above the surface illuminated. Practically all of the manufacturers' catalogs state the beam candle power of their units but if they do not it will be supplied on request. Beam candle powers and mounting heights are shown in the following table:

Maximum Beam Candlepower	Minimum Mounting Height - Feet
10,000	15
20,000	20
50,000	30
100,000	50
200,000	70
300,000	90

In the lighting of parking spaces, gas stations, driveways, etc., locating equipment so that it faces the flow of traffic, either in or out, is not recommended. As a general rule the larger portion of light should be directed at right angles or as nearly so as possible, to the direction of traffic.

When lighting an area for sports, locations should be chosen so that a minimum number of spectators face the projectors and the area is illuminated evenly over the playing field. Several examples will be cited.

For playing tennis at night a very high intensity and even distribution of illumination are required. Glare and shadows must be eliminated. A large, open type, short range, wide angle floodlight should be chosen for this work. To illuminate a single court properly, six units must be used. These are mounted on the tops of poles 30 to 50 feet high located approximately 10 feet from the edge of the playing court, one at each corner of the court and one opposite the net on each side. These are directed sharply downward and play can continue without any discomfort to the players. In case there are double courts the poles between must support two units. 1000 watt P.S-52 bulbs will be found quite satisfactory as they provide 34 foot candles. Use of 1500 watt units will raise the intensity to 53 foot candles; this is even more desirable due to the smallness of the ball and the speed with which it moves.

Miniature golf courses have recently come to the fore and require consideration to that of the tennis courts except a much lower intensity is required. The balls do not move at high rates of speed. Eight floodlights of the short range, open, wide angle variety will also do fine work here. For square ares one unit is put at each corner and one in the middle of each side. Courses not larger than 120 feet square can be lighted with

1000 watt

lamps to an intensity of 7.5 foot candles or better, while those of 150 feet on a side require 1500 watt bulbs for the same intensity. Rectangular areas should be treated in a similar manner by locating poles down the long sides every 60 to 90 feet with two units per pole. These units should be mounted a minimum of 25 feet above the ground. A much better figure is 30 to 40 feet as it gives much better distribution of light. Short range floodlights may also be used for this type of lighting, best results being obtained when a lamlike or spreading lens is used.

Golf driving ranges are best illuminated by medium and long range floodlights. After many tests a certain floodlight company recommends the following layout. For each 80 feet of width of the driving range install one pole 25 feet high with four units on it. Two units have a 1000 watt P.S.-52 bulb and spread lens, the other two have a 1000 watt G-40 bulb and a clear lens. The spread lens units illuminate the immediate foreground and air while light from the directed type units continue on and to cover the last half of the course, from 150 to 300 yards. Driving ranges are generally about 300 yards deep. If the tees are uncovered the poles should be placed about 25 feet back as this allows spill light from the same units to illuminate the tees, otherwise separate lighting must be provided for this purpose. With covered tees the units may be located immediately back of the shelter.

Aviation Field Lighting

For this type of lighting, the fundaments can again be stated in terms of lumens of light or foot candles delivered per square foot of area. Certain illumination values have been fixed by the United States Government as minima which must be met before a field can receive its license. Before one attempts to design a layout for an airport he should familiarize himself with the regulations as outlined in the bulletin "Airport Rating Regulations". A copy of this bulletin may be obtained by writing the Aeronautics Branch of the Department of Commerce in Washington.

The important lighting equipment for an airport may be grouped into three general divisions: beacons, marker lights and landing field floodlights.

Beacon lighting is an application of the principles of marine lighting with a thought to the additional distribution of light into the vertical plane, on account of airplanes travelling in three dimensions. Each airport must be supplied with a rotating beacon which rotates in a counter clock-wise direction at the rate of 6 revolutions per minute. A common unit to use for this service has a 24 inch reflector and accommodates a 1000 watt, 110 volt T-20 bulb. This provides a 3,000,000 candle power beam and can be seen for from 10 to 80 miles depending on the weather conditions.

Marker lighting, which covers boundry, approach, obstruction, and roof sign lighting, is an application of the principles of good sign lighting practice. All of these lighting fixtures are standard equipment by the various manufacturers and are listed in their catalogs so that they may be purchased as units. No special theory is involved in their application except that the floodlighting of the roof and walls of the hangers should be carefully carried out as outlined in the section devoted to floodlighting of buildings.

Landing field floodlighting is the most talked about, the most expensive, and many times the most unscientific part of an installation.

The fundamental considerations of satisfactory landing field floodlighting, in their order of importance, are the following:

1. Low vertical divergence of the beam
2. Uniform illumination of the field.
3. Sufficient intensity of illumination on the field.

The reason for the low vertical divergence is quite evident when consideration is given to the fact that it is much easier to look from a dark place into a brightly illuminated area than it is to see after one gets into the

beam, [illegible] facing the floodlights. Low divergence intensifies the visual light on the field as well as keeps the air above free from light reflections. The most satisfactory and best controlled lighting source is the arc. Some are now made with a 4,000,000 candle power beam, a horizontal divergence of 15°, and a vertical divergence of 1-3/4°. This type of unit is by far the best developed to date and is recommended and used by the Army, Navy, Transcontinental Air Transport, and many other responsible operators. The average vertical divergence of floodlights which use the present bulbs varies from 4° to 10°. This shows that considerable light will escape upward with the wider divergence and the area is apt to confuse the incoming pilot unless he is landing across or with the beam. Careful location of the banks of lights will do much to help this condition, and provide safe lighting for landing.

Uniform illumination of the field is the most considerable [illegible] and may manifest in several ways. Suppose, for instance, a arc is a light used in the center of the landing area. The floodlights must be located at the edge of the field so they will not be a hazard to the incoming planes, and the long low beam stretching out over the port will be intercepted by the rise of ground and a shadow will be cast across the remainder of the field. This is not a good condition for landing and can be partially overcome by mounting the lights higher. In no case,

however, should the units be mounted higher than 20 feet above the ground as it creates too much light in the air above the field. The field should be graded down if this does not remedy the shadows, or else spread the units along one side and even up the lighting as much as possible. Reference to the type "L" and "T" airports included will illustrate this method.

It is well, wherever possible, to illuminate the port from one side and one end, the locations being chosen such that with the prevailing winds the majority of landings can be made either across or with the beam. Only the one bank of lights need be used in normal wind and weather but when it is foggy the second bank will help considerably by bringing up the average intensity.

Among other things, the government requires that to obtain an A-1-A rating an airport must be a minimum of 250 feet square and have a minimum of .15 foot candles of illumination on the vertical surface at all points on the usable portion of the field. It follows that if the field is 5000 feet square, it still must have the minimum of .15 foot candle as called for in the requirements. This more than doubles the work of the lighting engineer because he is not allowed any larger vertical divergence or higher mounting height than before and he has twice as far to project the light. An analysis of the results obtained with the high intensity arc will show a standard for reference.

The [illegible] 1000 min. are illuminated as shown on the model airport enclosed, [illegible] candle-power of 4,000,000 with a vertical divergence of 1-1/2° and a beam spread of 1.0°. As the unit is installed from 10 to 15 feet high and is tilted slightly downward, the actual upward divergence is 1/2°. The unit is guaranteed to cover an area 3800 by 3800 feet to a minimum of .15 foot candles. Actual test results, however, show that under average clear weather, the area covered to .15 foot candles is approximately 5000 feet wide by 4000 feet deep; and the area immediately in front of the unit 3400 feet wide by 3800 feet deep is illuminated to an intensity of .35 foot candles. This gives quite a factor of safety for bad weather and almost no vertical divergence. The unit comes equipped with a 10 K W bulb so mounted in line that when it is desired to change the carbons, or in case of an arc failure, a control button on the outside is pushed which lights the 10 K W bulb and swings it around into the focal center as the arc mechanism backs away to an accessible location where the necessary adjustments can be made. The 10 K W bulb with its large light center provides a beam of 1,280,000 candle power and a vertical divergence of 5°.

Illuminating an airport with anumber of floodlights is carried out in a similar manner to the one described except that the high beam intensities are built up by a multiplicity of units, each unit contributing its share

of 1km ns to the total. Reference to the enclosed la - outs will show how this is accomplished.

Smaller sore lights and many uses of floodlights are manufactured to give various lighting characteristics. A complete description of these units is included in the various catalogs of the manufacturers but information such changes are being made periodically which are apt to influence the results, the lighting engineer should refer to the company before specifying a unit.

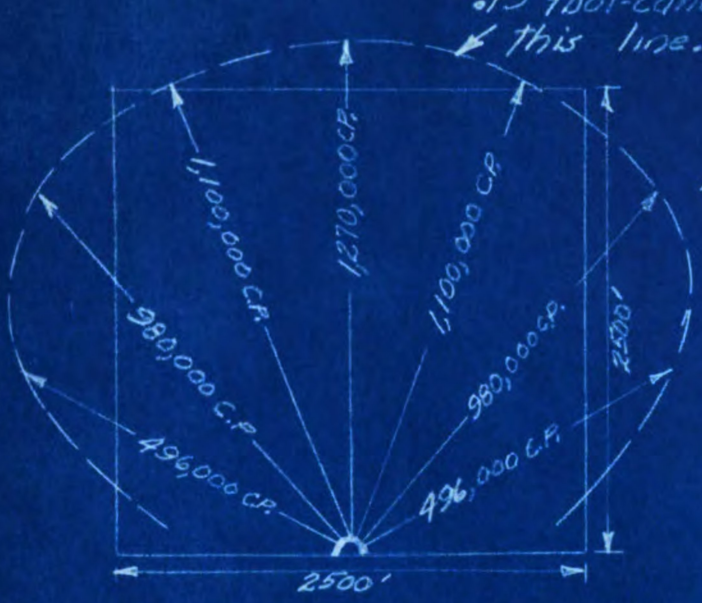
The lens mechanism in these two types of units are distinctly different. The are has a dioptric lens consisting of thirteen 180° segments, is 1000 m.m. in diameter, is of high quality optical glass, and is ground as a Fresnel lens. This is the most efficient unit and gives best control of the light. The most commonly used floodlight has a 24 inch diameter, 10 inch lens, precision parabolic glass reflector and can be obtained in either a 40° or 80° horizontal spread while the vertical divergence is 4 °. Several units are used so that their beams overlap and provide even illumination of the necessary intensity. Cumulative beam candle powers are shown on the attached drawings and illustrate how the required lighting is built up for the larger airports.

TYPICAL LIGHTING LAYOUT FOR A LARGE AIRPORT

The Sperry AGA 1000 MM Unit provides a minimum of .15 f.c. on the 5000 x 4000 ft. area and .35 f.c. (minimum) on the 3000 x 2500 ft. area immediately in front of the light. It is 125 volt, 150 Amp, 4,000,000 candle power arc. 180° spread.

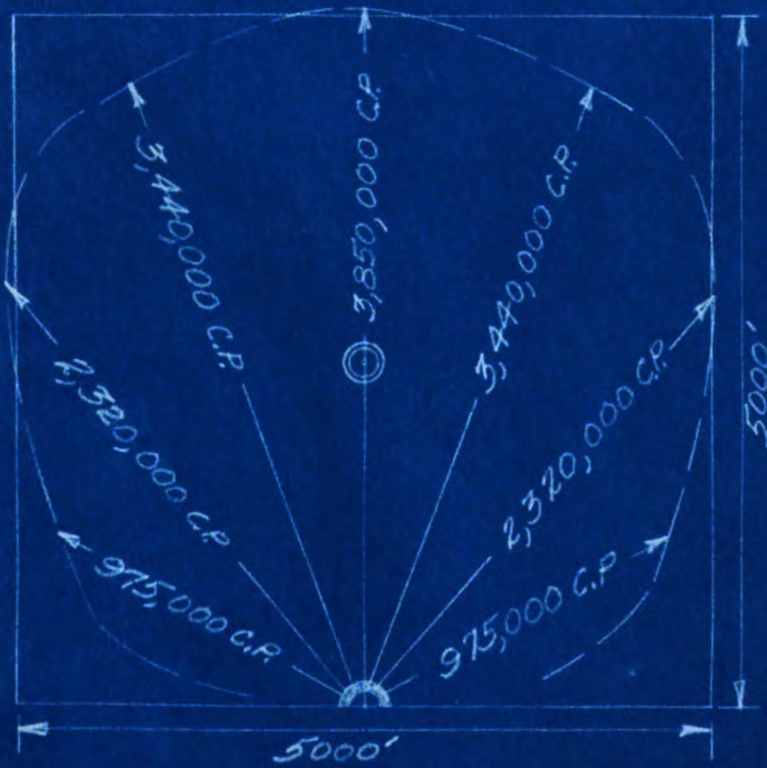
M.G.H.

ILLUMINATION FOR SQUARE AIRPORTS



Airport 2500 ft. square. Minimum for A-1-A rating Illuminated by one bank of 6 units. Each unit with one 3000 watt, 32 volt, 76,000 lumen, GT38 bulb and a 40° spread lens.

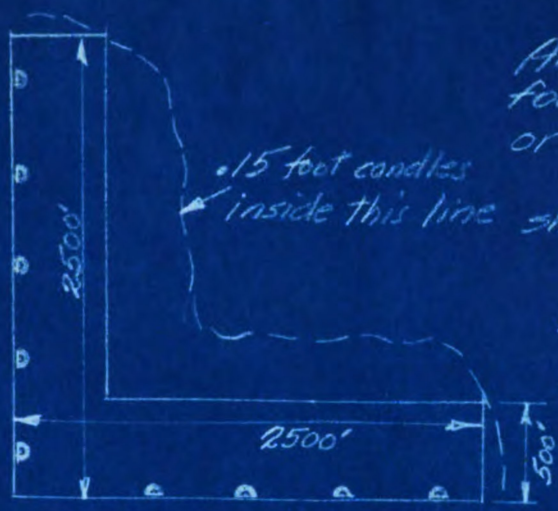
Beacons, boundry, and obstruction lights are not shown.



Airport 5000 x 5000 ft. illuminated with one bank of 14 units with 3000 watt, 32 volt, GT38 bulbs each bulb emitting 76,000 lumens. 40° spread lens.

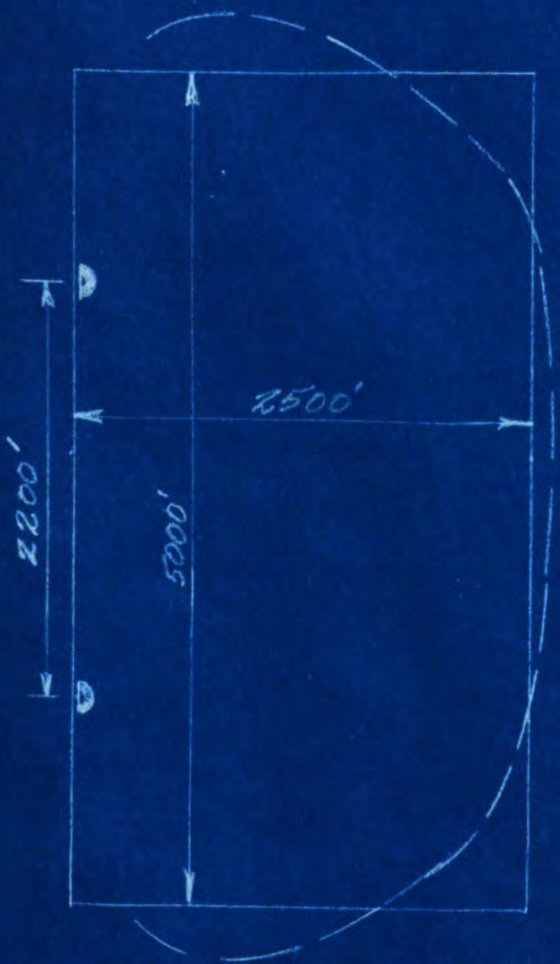
M.G.H

ILLUMINATING IRREGULARLY SHAPED AIRPORTS - T, L, AND X.



An L shaped airport is often found in clensly populated or mountainous districts. Use same layout for T shaped airports.

9 units, each with 1500 watt, 32 volt, T24 bulb give distribution as shown. The T24 bulb emits 34500 lumens. Unit efficiency is 65%



5000 x 2500 ft. Airport

Use two banks of units. Each unit with 3000 watt, 32 volts, GT38 bulb. This provides .15 foot candles within the marked area.

This method particularly good for airports with a very uneven contour.

There are 6 units per bank and each bulb emits 78,000 lumens. 40° spread lens.

M.G.H.

ELECTRIC FOUNTAINS

The classifying of an electric fountain under building illumination or area lighting would be hard to justify so it will be referred to as "Space Lighting" because that explains more nearly what actually takes place in a fountain.

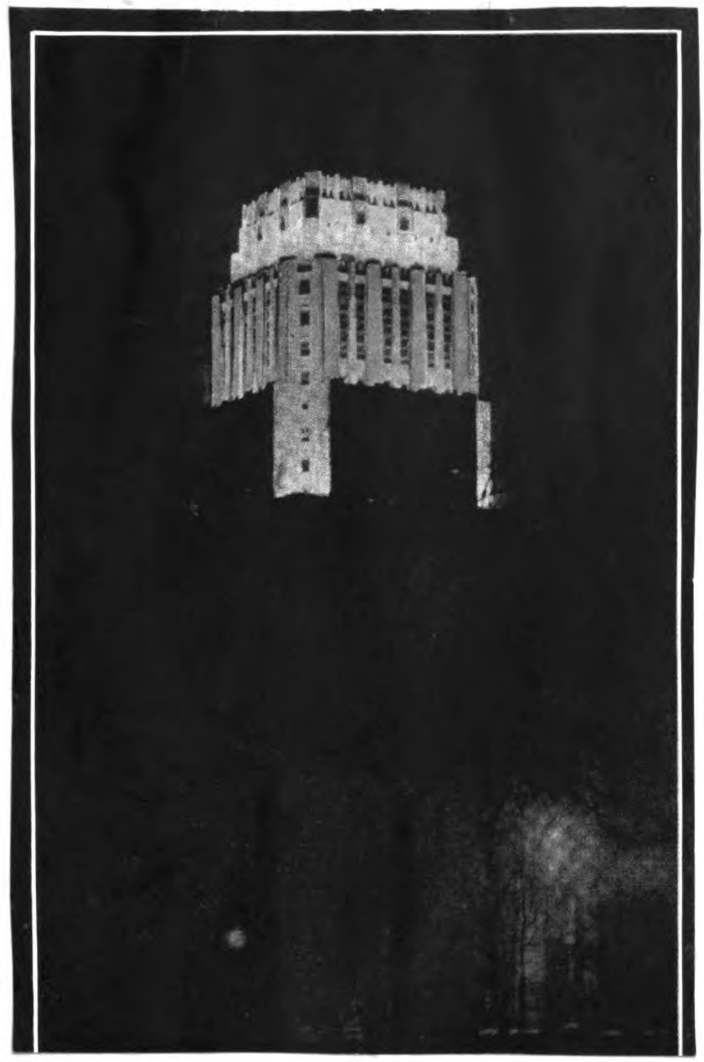
Being given a fountain, either one which has many water effects or just the one change, the task of illuminating it is comparatively easy. The lighting units are submerged in the water basin out of sight and they project their beams upward into space where they pass through the streams of water and spray giving the very pleasing appearance with which we are all familiar. Additional colors are furnished by extra sets of lighting units. All of the lighting units are, as a rule, connected to a cyclic dimmer so that the water is brilliantly lighted in ever-changing colors of red, amber, green and blue as it rises and falls.

To give a better idea of the equipment usually used, the manufacturer of one line of fountains lists the following as the standard line. The smallest has 9 projectors and provides 7 colors and 7 water effects - 49 changes in 7 minutes. This installation uses 250 watt bulbs while all of the others use 1000 watt bulbs. Next comes the 15 projector fountain. It has 10 color and 6 water effects - 60 changes in 6 minutes. Thirty-five projectors furnish illumination to the next larger size and it has 12 color and 8 water effects which take place in a 10 minute cycle.

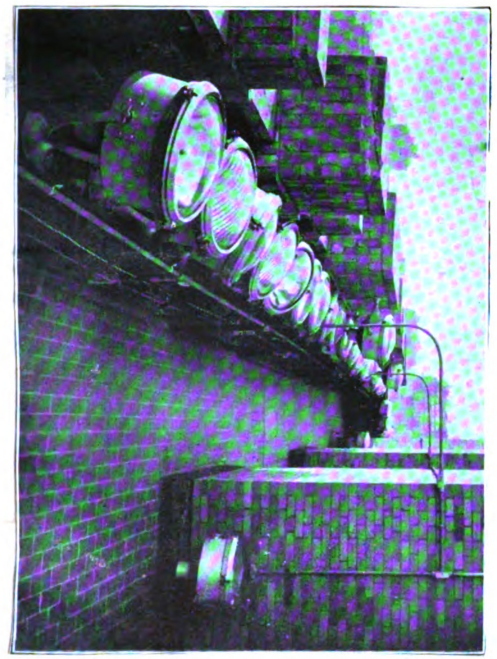
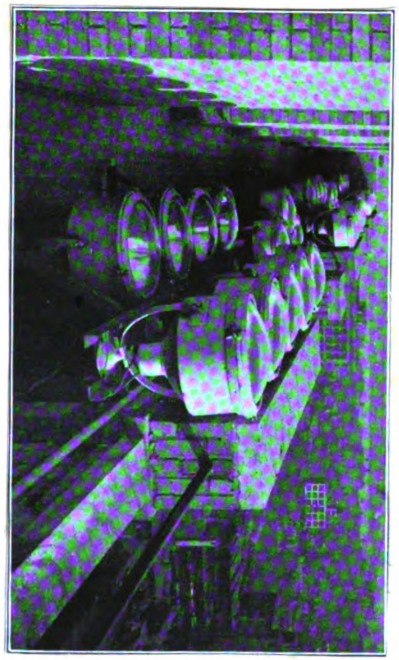
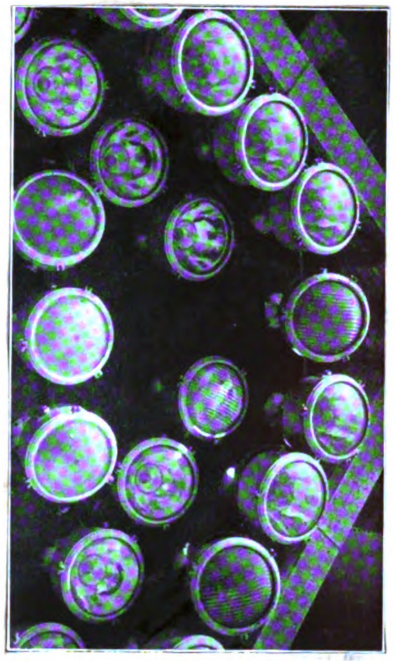
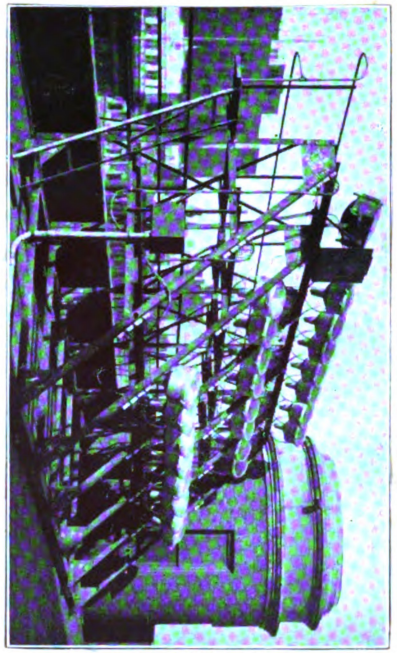
This one is particularly effective with its 70 foot central geyser. The largest one and by far the most pretentious boasts sixty-three 1000 watt projectors, which furnish 12 colors to 8 water effects, 96 changes in a 10 minute cycle. The largest also has a 70 foot central geyser and harmonizes well either in a large basin or as a lake type.

The projectors should be arranged uniformly around the fountain and located at the places which will produce the most inclusive effects on the water. This can easily be decided by drawing a diagram of the water pattern created by the fountain and placing the floodlights at the base of the spill water. Minor re-arrangements after putting the fountain in service will correct any apparent defects.

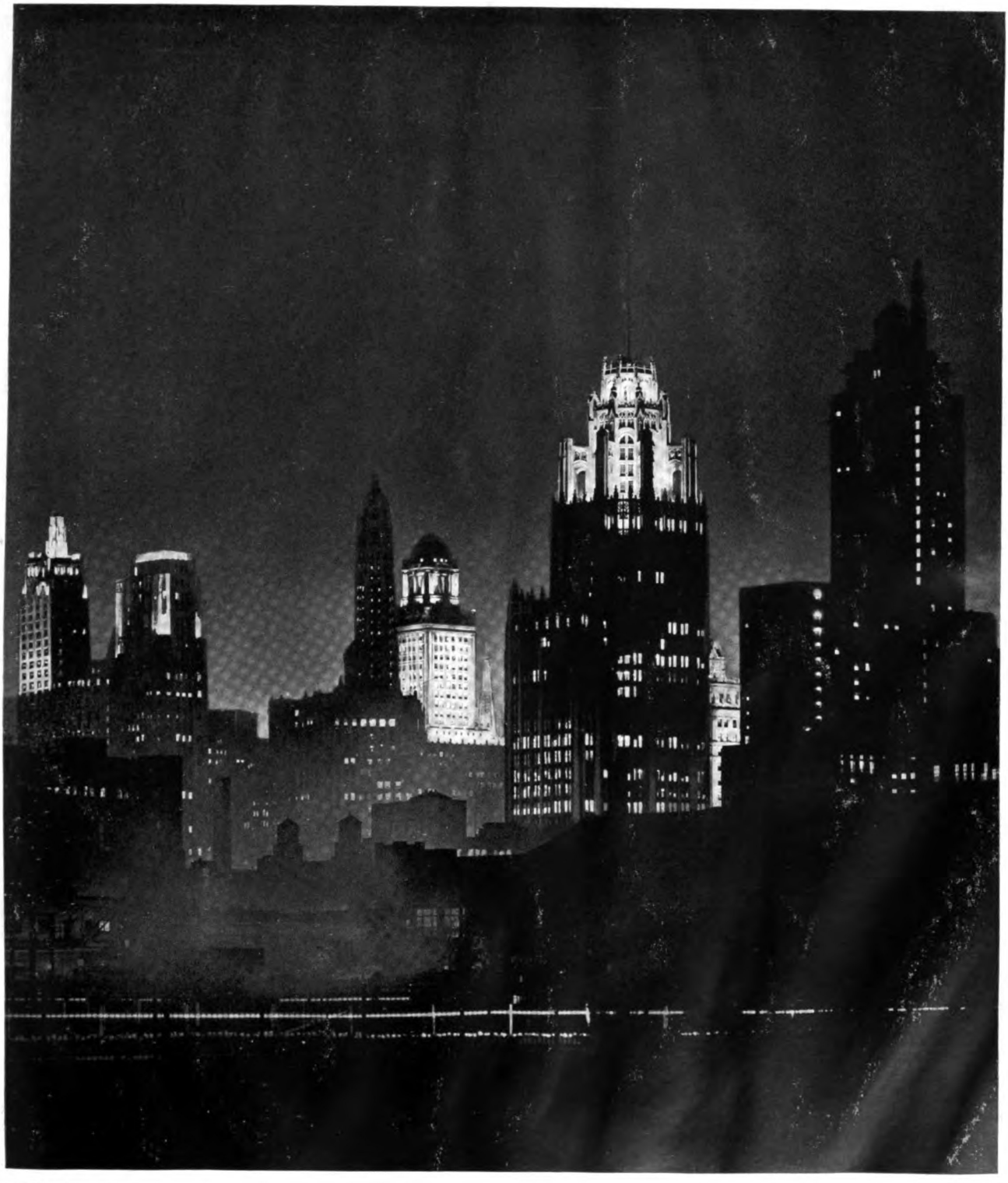
THE FAMOUS BUCKINGHAM MEMORIAL FOUNTAIN
GRANT PARK, CHICAGO



EDISON BUILDING. PHILADELPHIA.

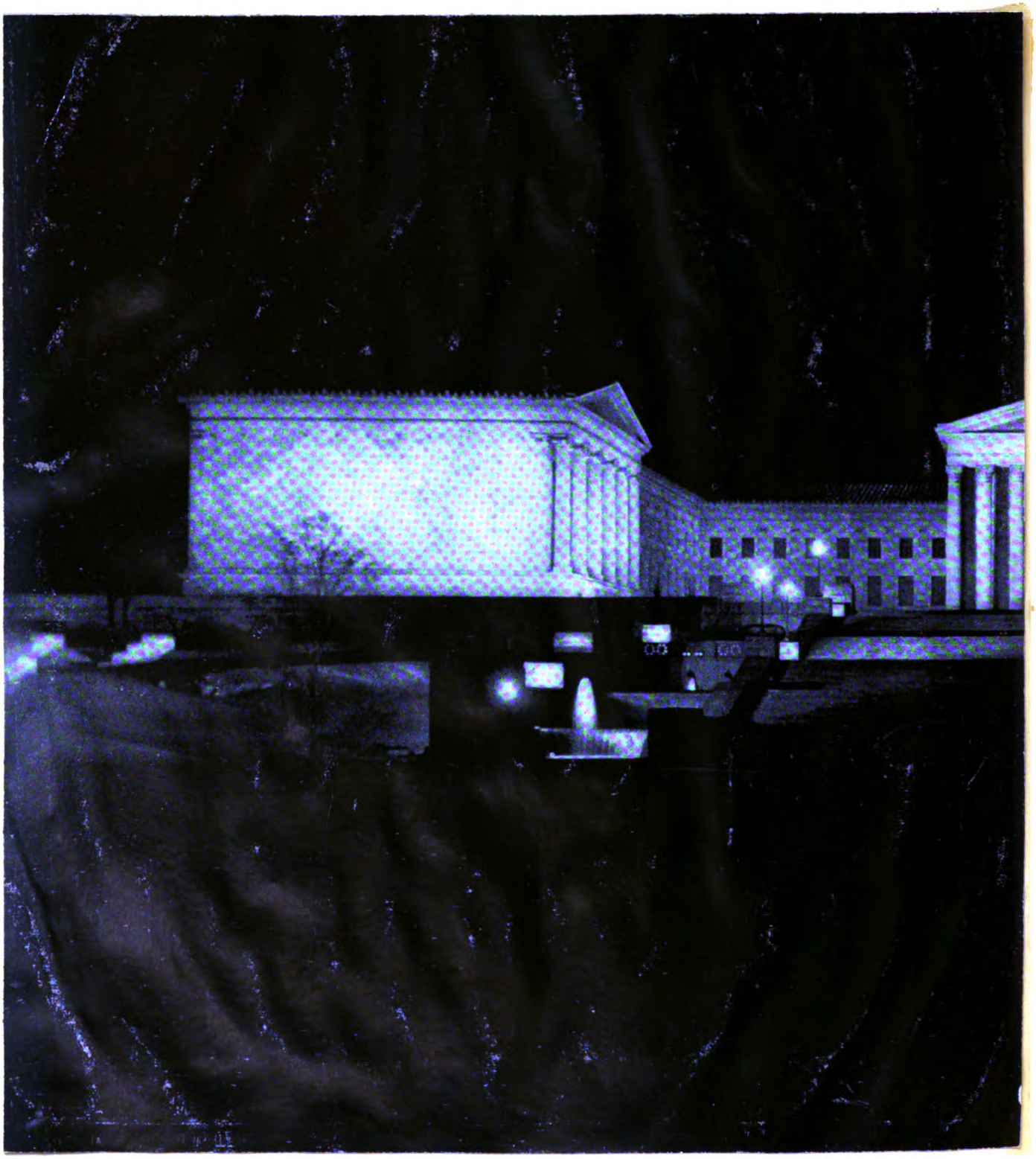





UNITS FOR EDISON BUILDING.



NIGHT SKYLINE - CHICAGO

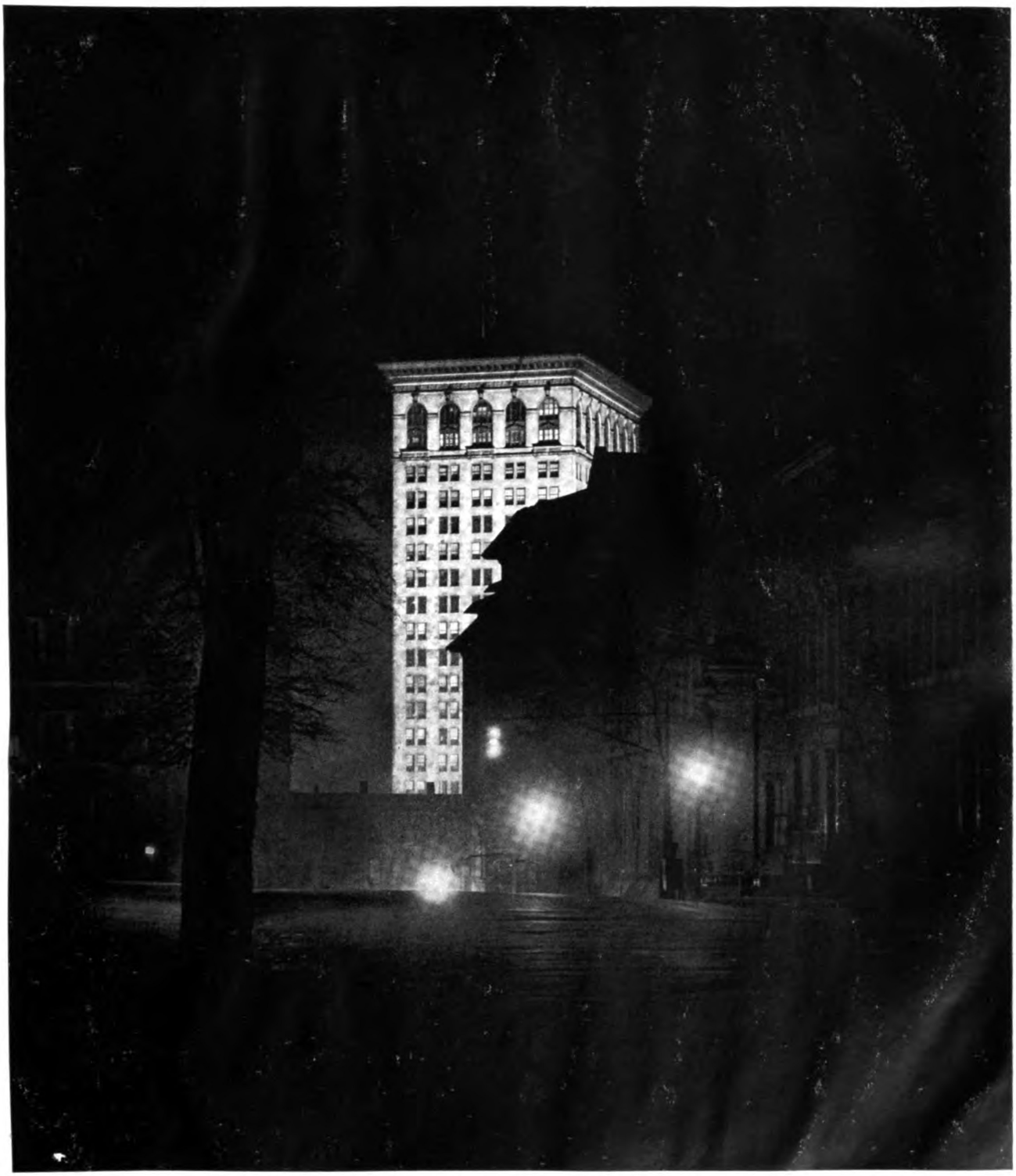
CHICAGO TRIBUNE TOWER



PHILADELPHIA ART MUSEUM

MISSOURI STATE CAPITOL

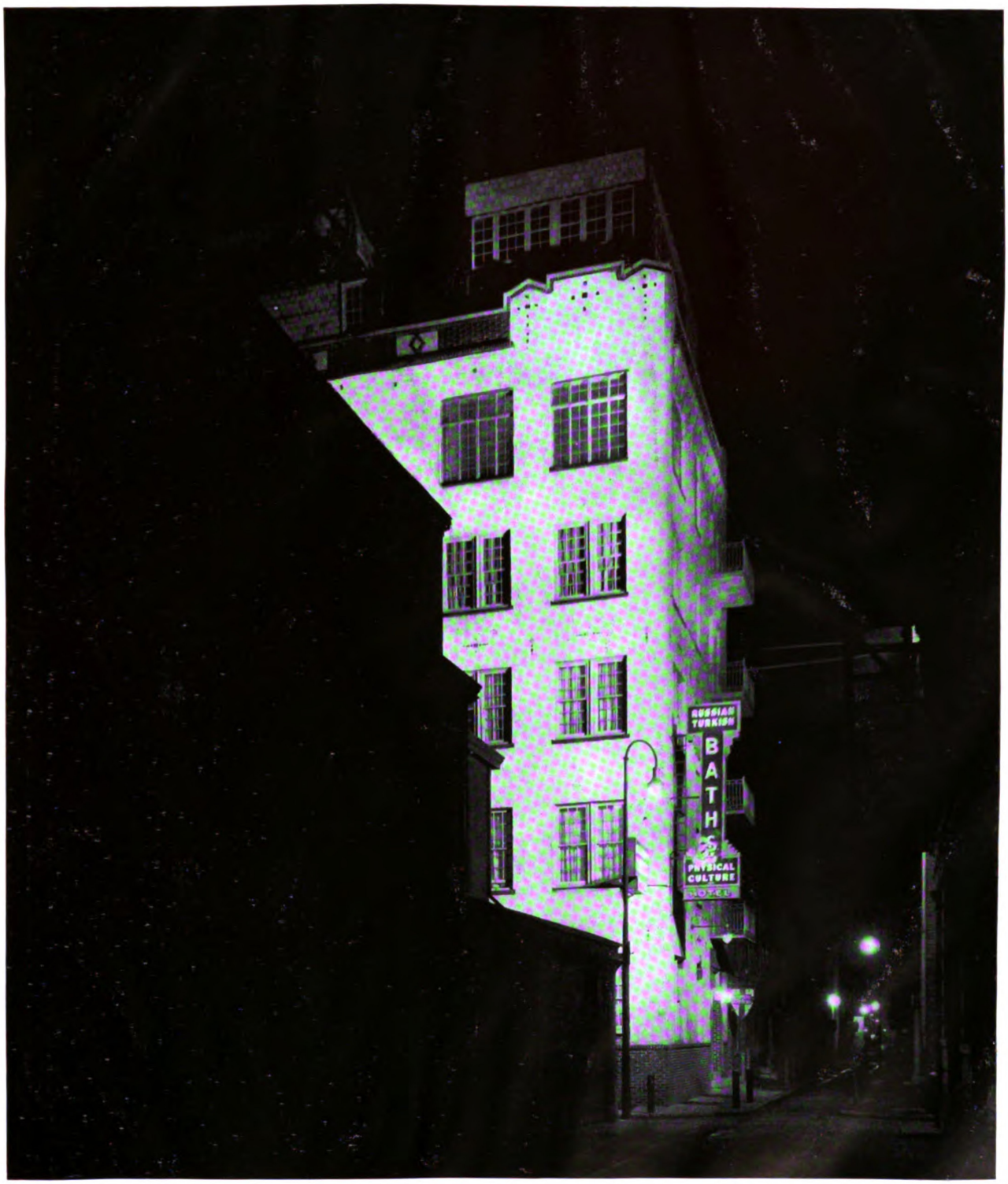
PURE OIL BUILDING - CHICAGO

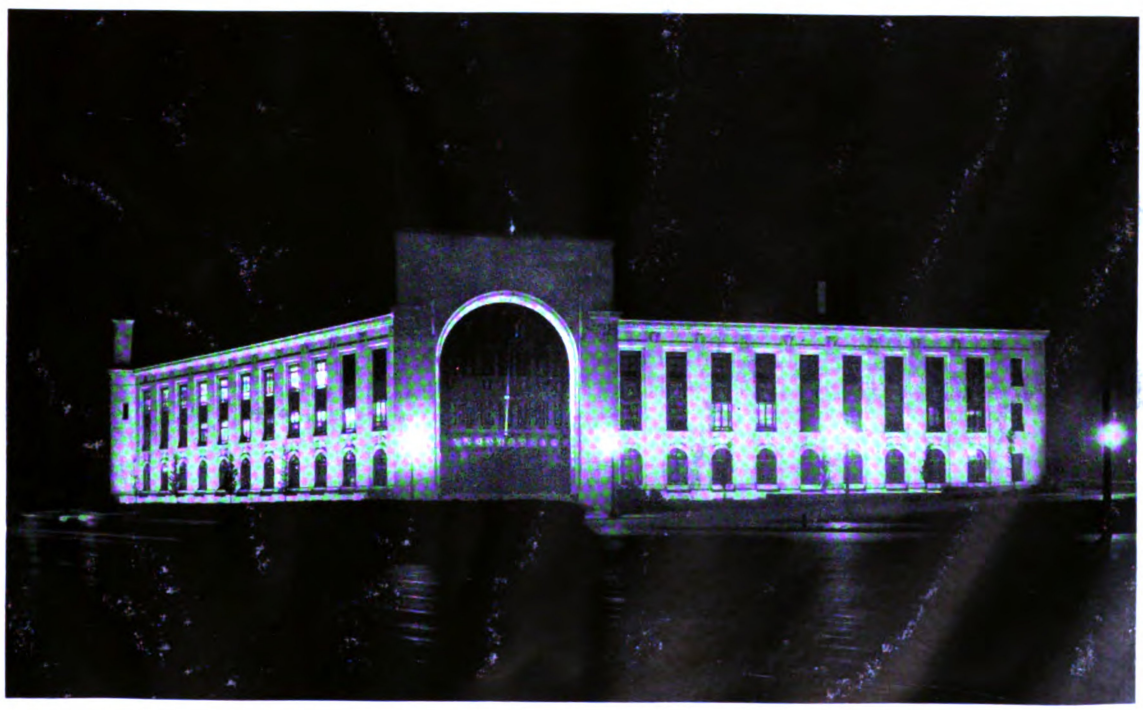


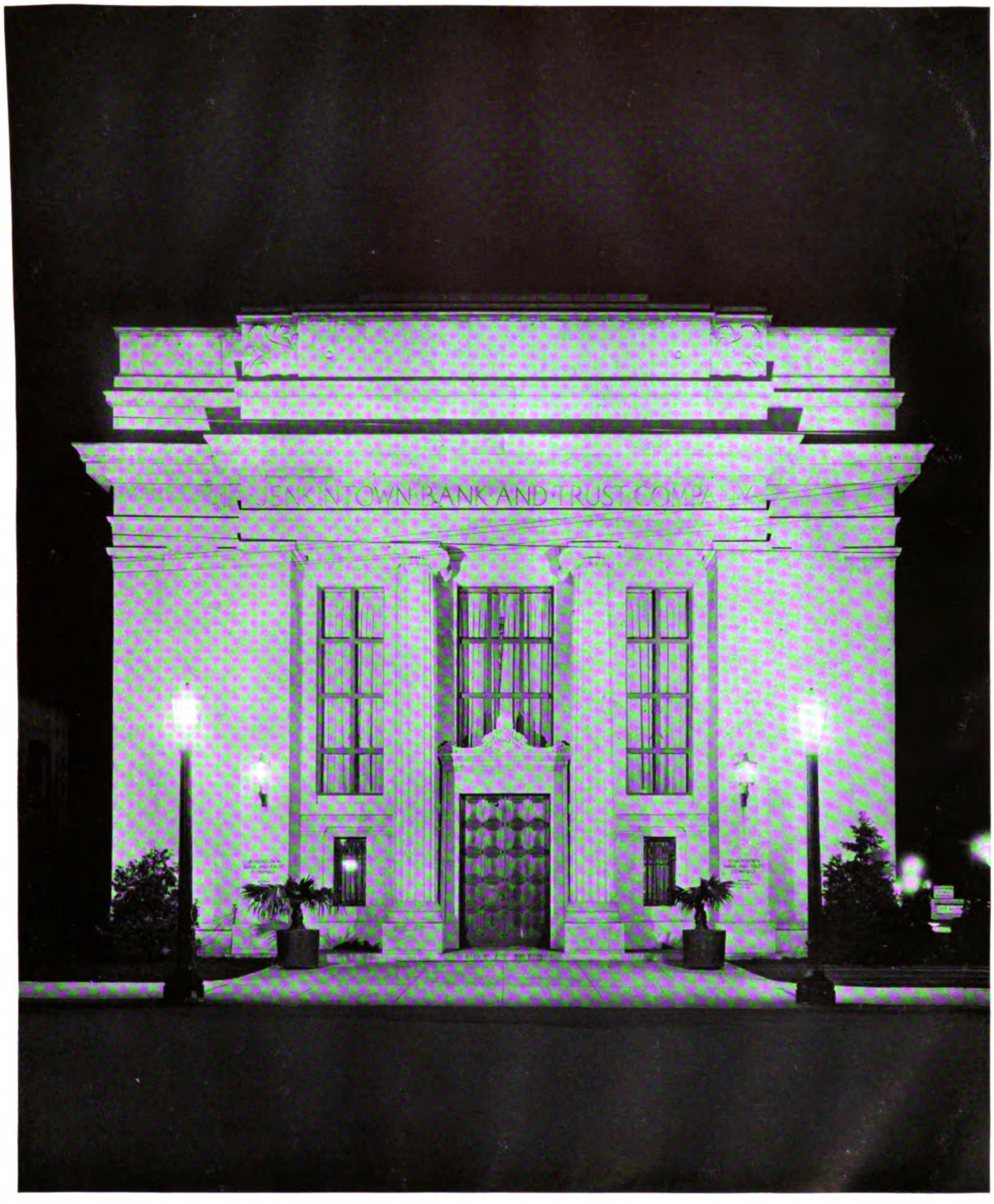
CONSOLIDATED GAS BUILDING.

CARBON - CARBIDE BLDG. - CHICAGO.

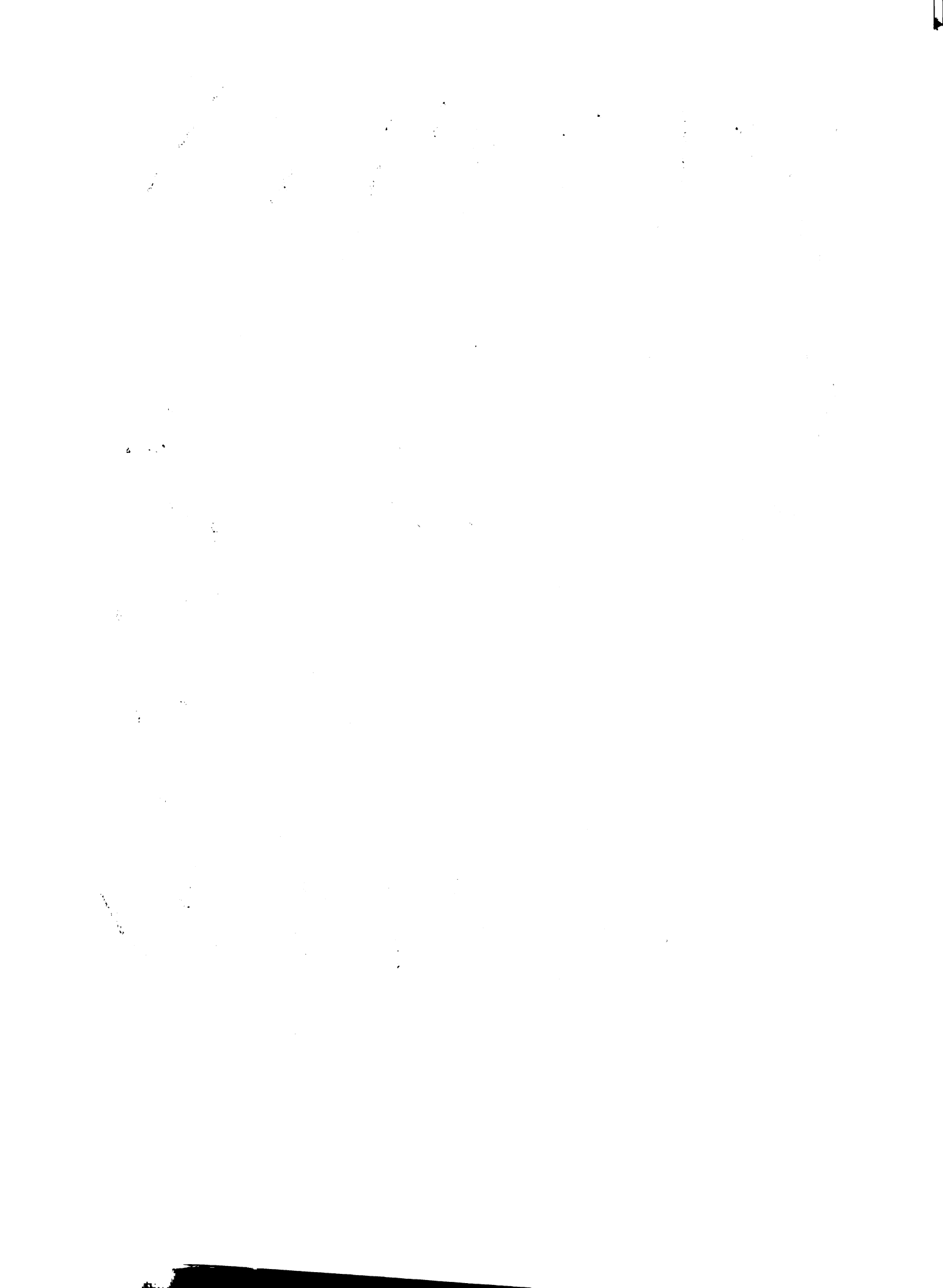
BERKS COUNTY TRUST CO. READING, PA.

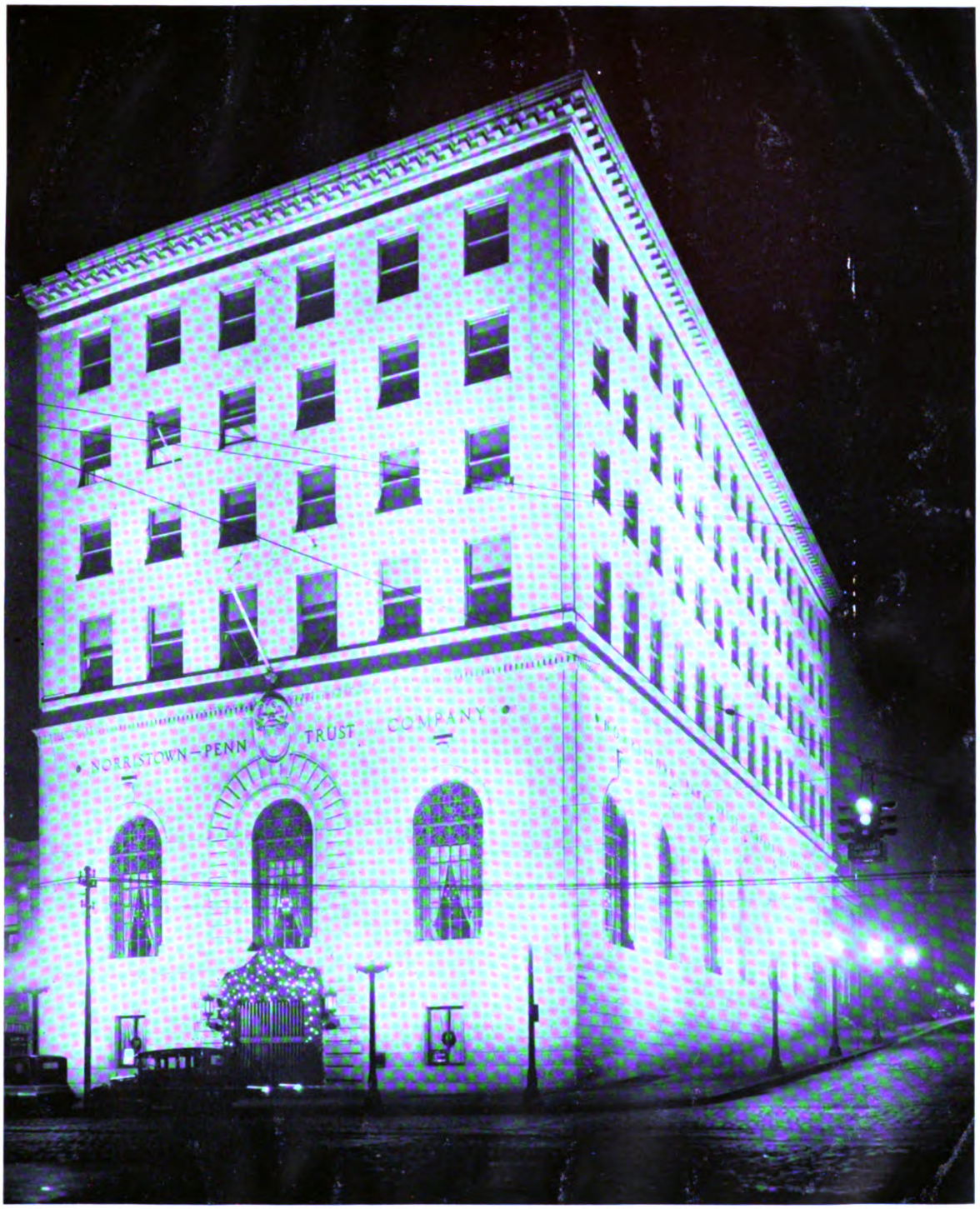

RUSSIAN
TURKISH
BATH
&
PHYSICAL
CULTURE
HOTEL





- Single Lantern Brackets. -





Double Lantern Brackets.

DADA

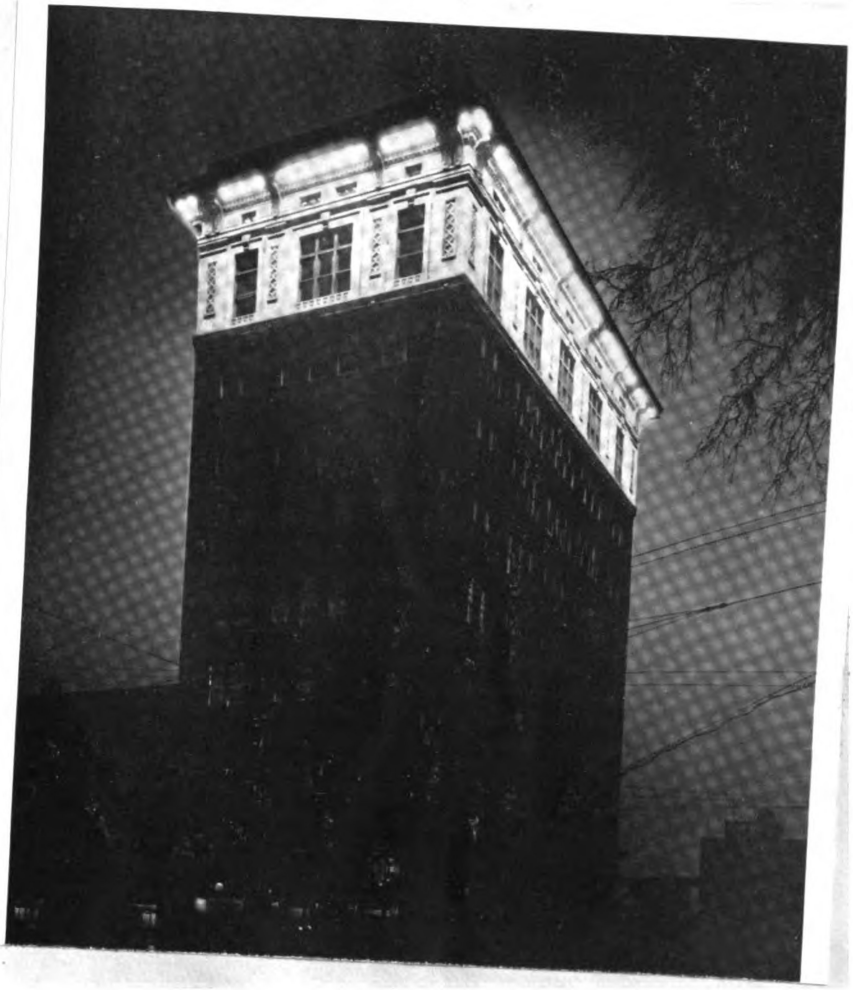
THE ARENA - ST. LOUIS, MO.

Double Lantern Brackets

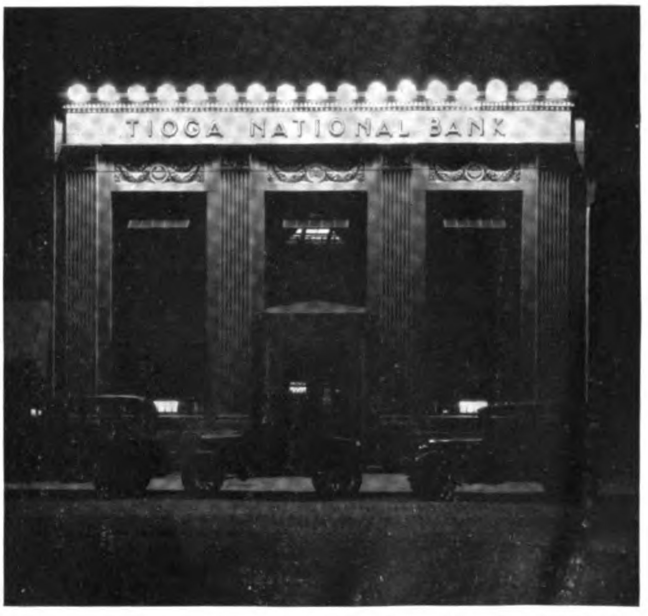
DALLAS NATIONAL BANK - DALLAS

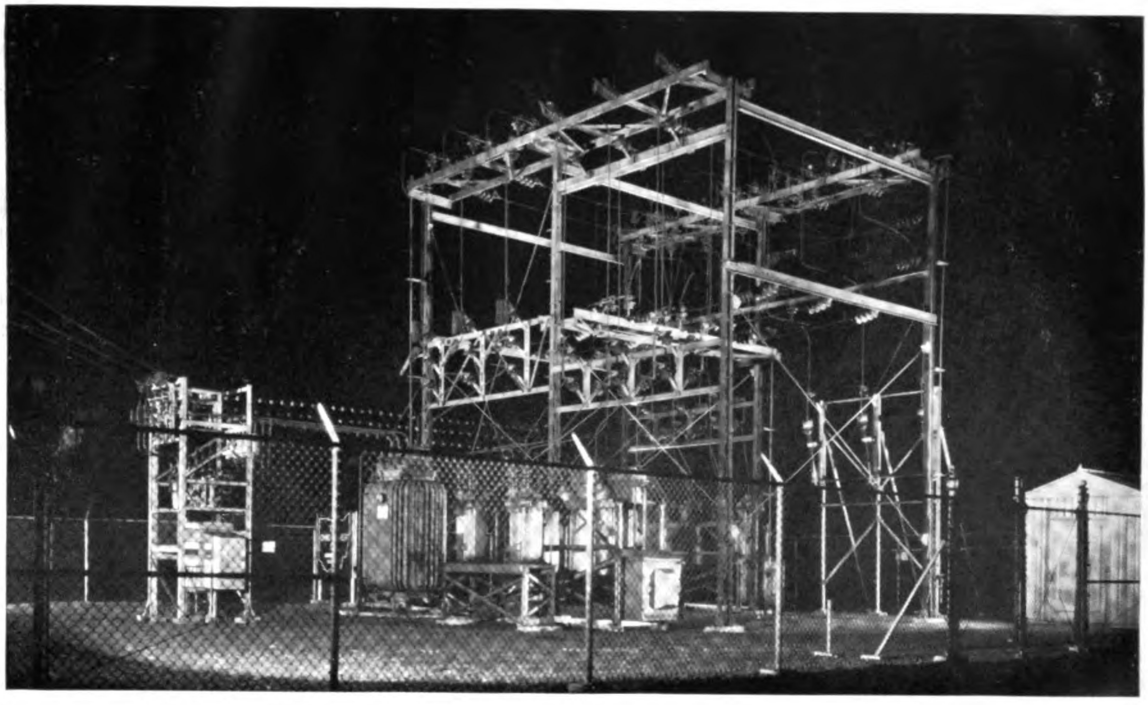
Floodlighted from two story building across the street. -

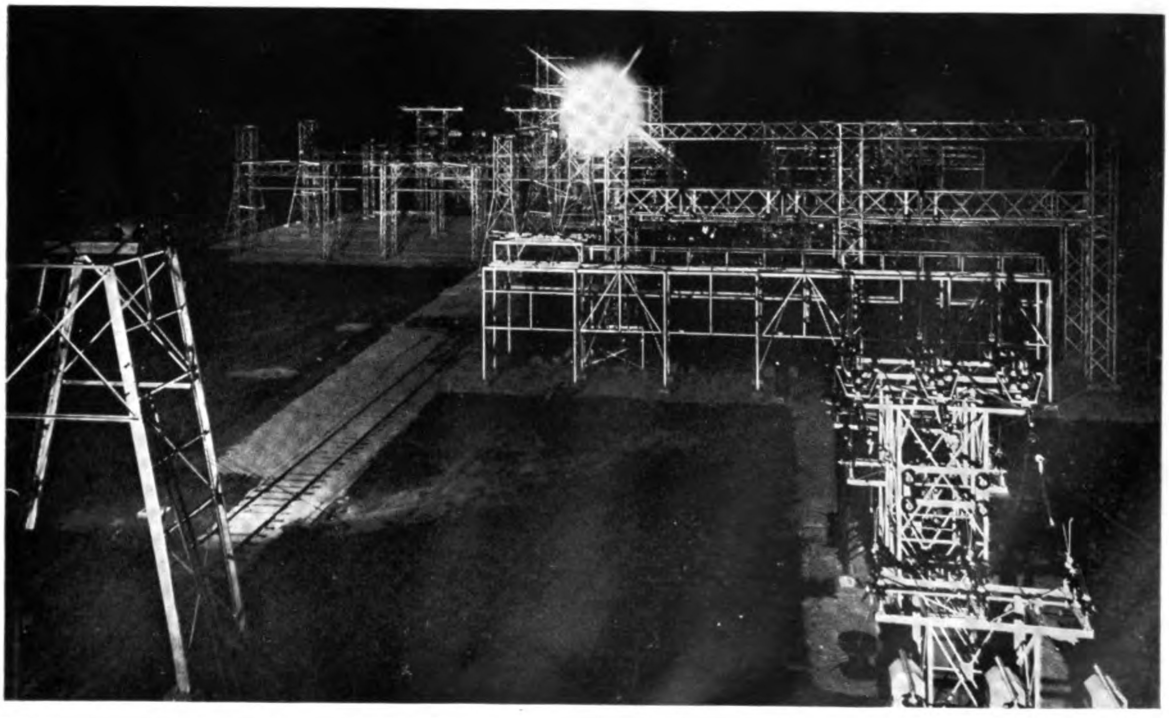
BROADWAY TRUST COMPANY



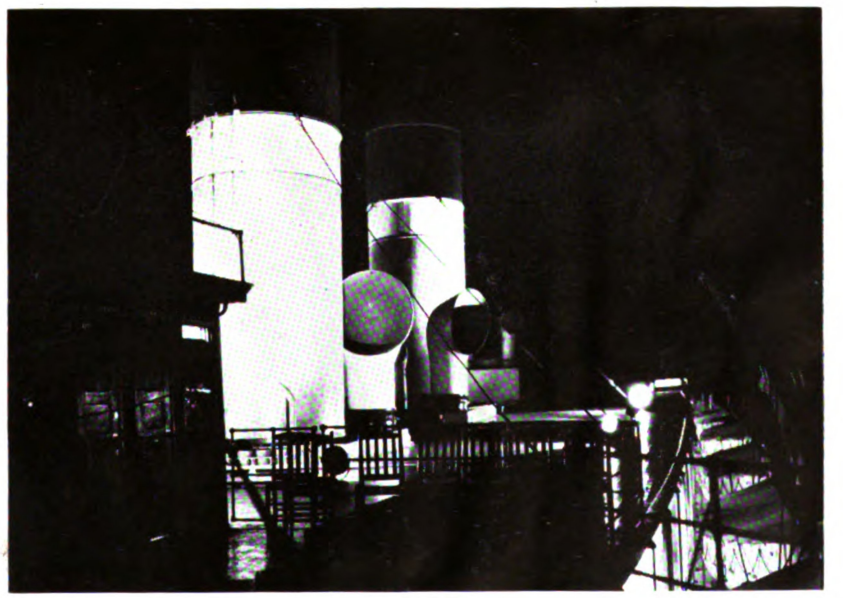
Mercantile
Commerce
Bank and Trust
Company
LARGE

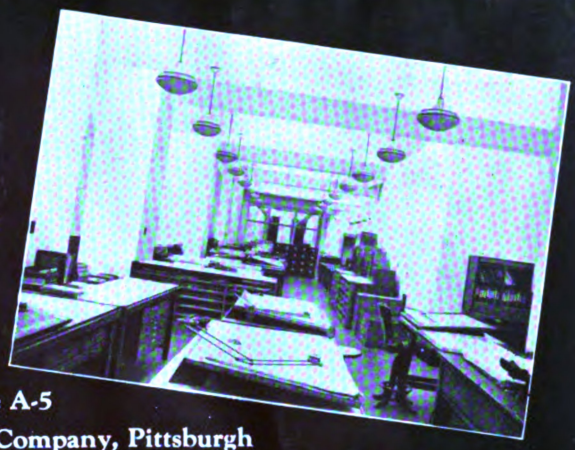

TIOGA NATIONAL BANK





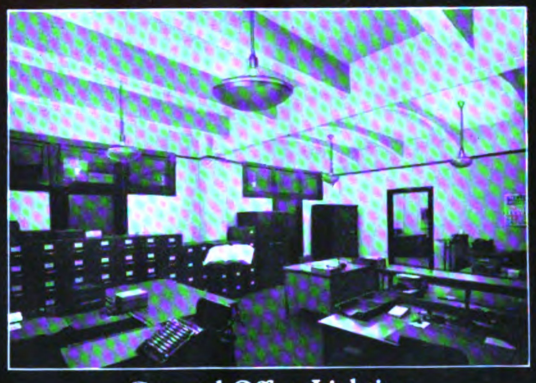
HORN & HARDART
BAKING COMPANY
COMMISSARY



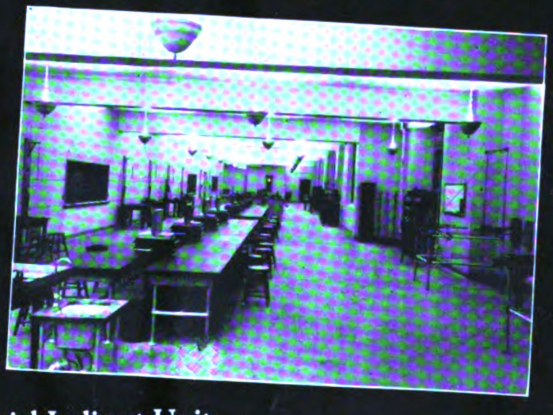


Luminaire A-5
Drafting Rooms, Koppers Company, Pittsburgh

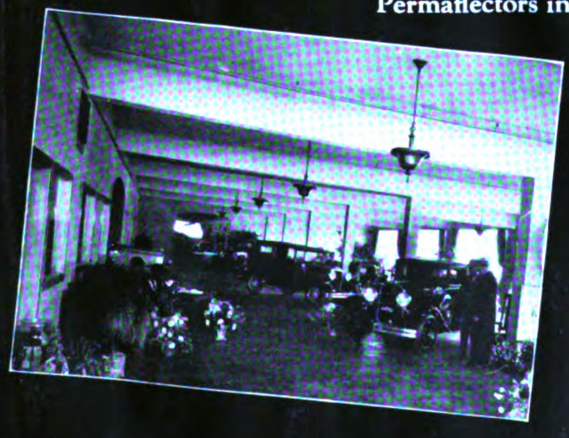
Textile Machine Works, Reading, Pa.

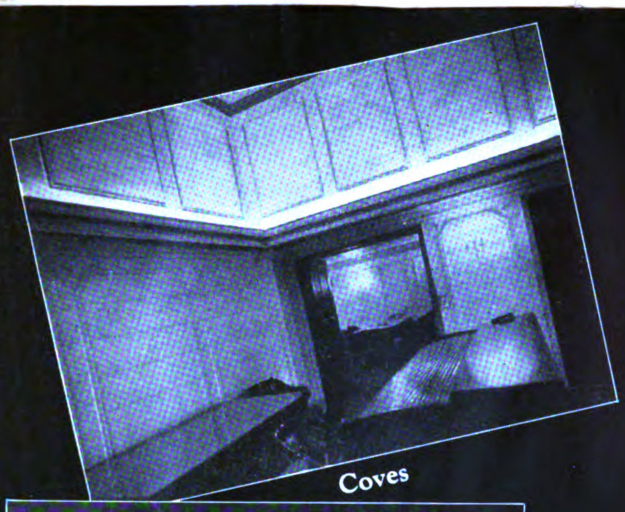


General Office Lighting

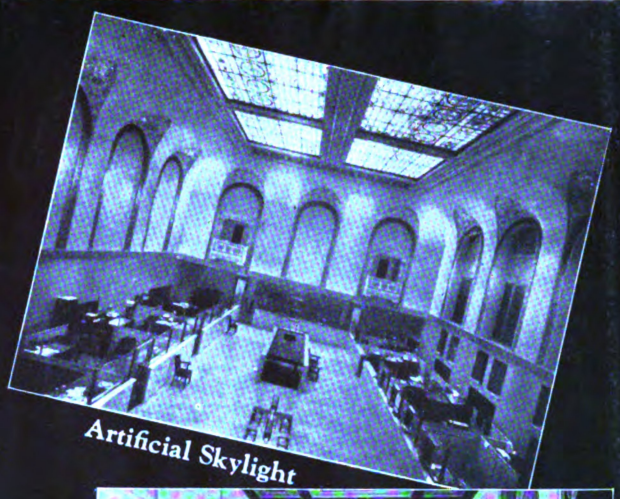


Permaflectors in Special Indirect Units

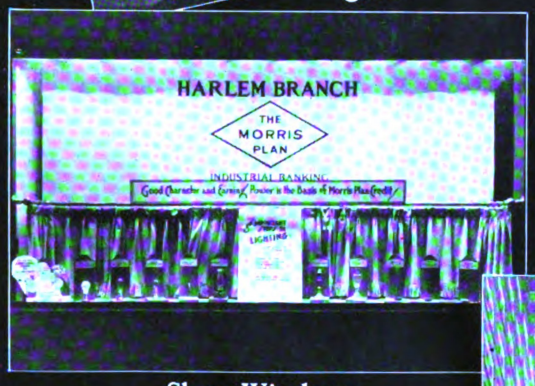




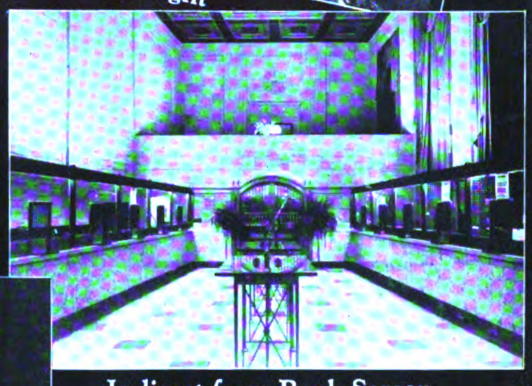
Coves



Artificial Skylight

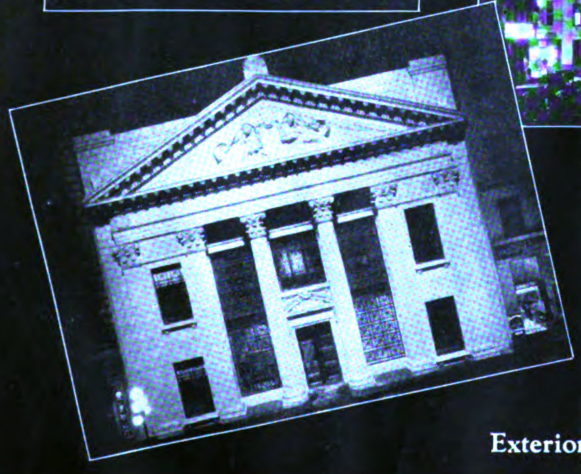


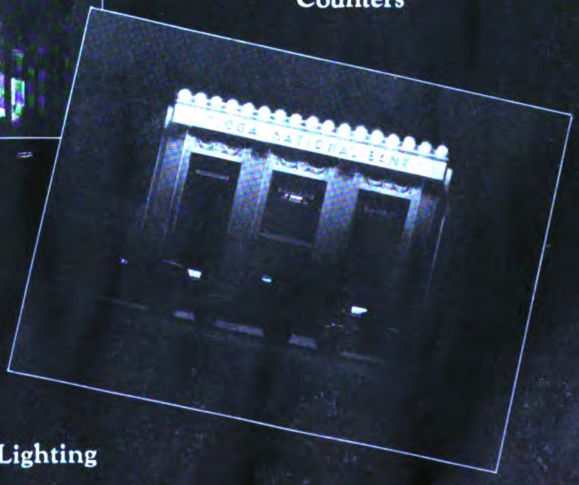
Show Windows



Indirect from Bank Screen

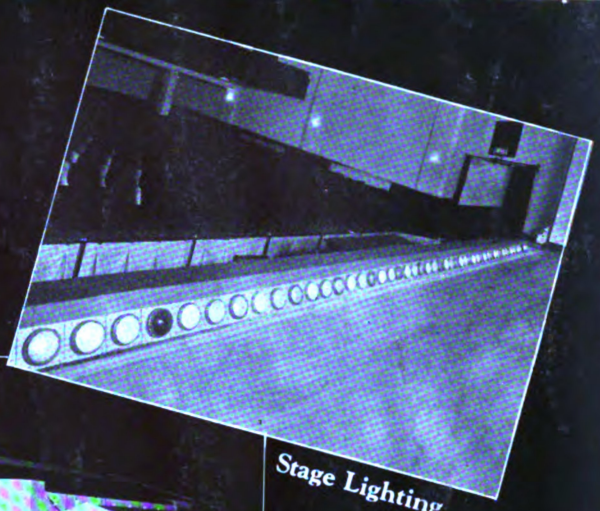
Counters





Exterior Flood Lighting

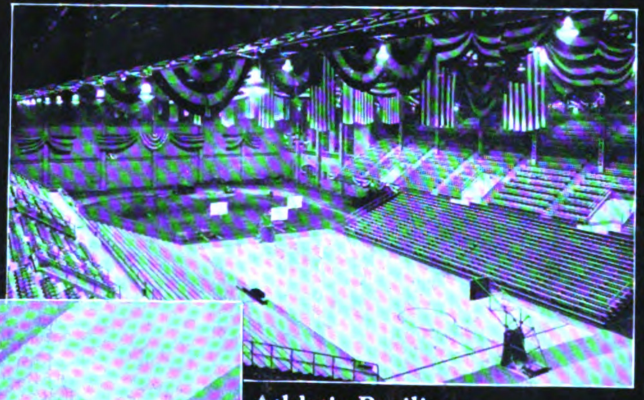
Cove Lighting in Colors



Stage Lighting

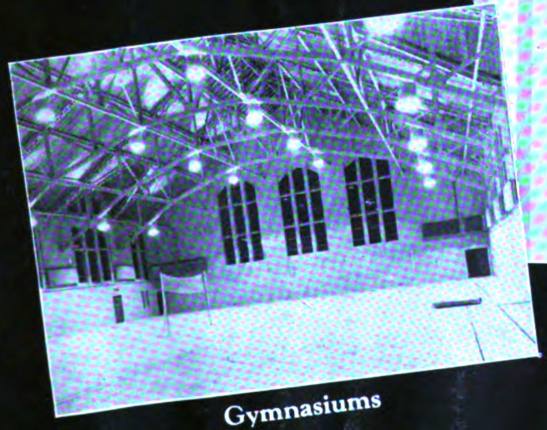
Flood Lighting

Disappearing Foot Lights



Athletic Pavilions

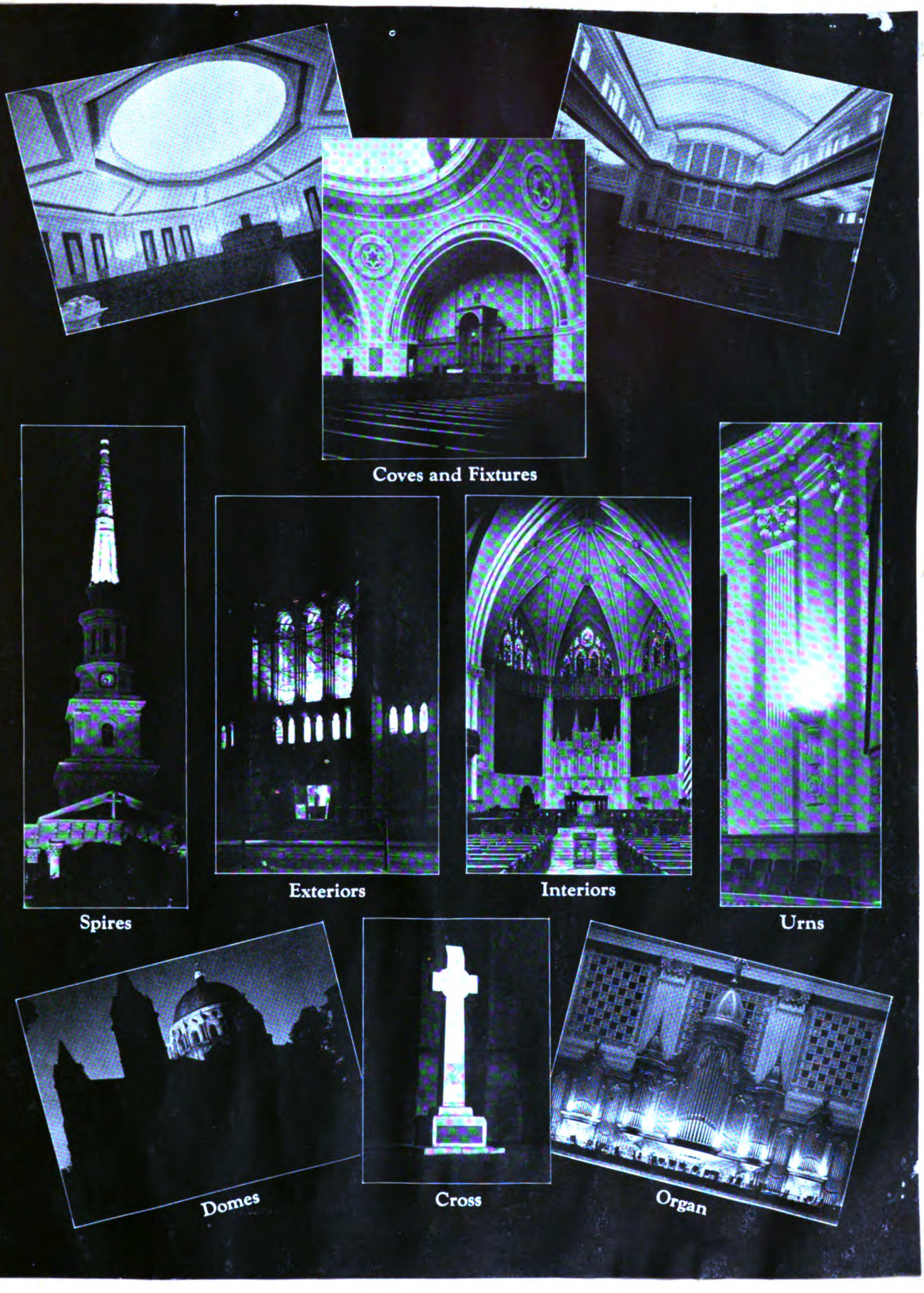
Emergency Lights



Gymnasiums

Class Rooms

Puget Sound Savings & Loan Association, Seattle
Medical Dental Building, Seattle
Seattle Theatre and Paramount Studio Apartment, Seattle
Mayflower Theatre, Seattle
1500 Walnut Street Building, Philadelphia
Lighting for night construction work, Louisville Hydro Electric Co., Ky.
Chimney Rock, Asheville, N. C.
Calvary Protestant Episcopal Church, Pittsburgh
Lighting of a Cross
Jones & Laughlin Monument "Steel" Sesqui Centennial, Philadelphia
Jones Oil & Supply Co. Filling Station, Scranton
Dallas (Texas) National Bank
The Mammoth Electric Fountain, Sesqui Centennial, Philadelphia


Coves and Fixtures
Spires
Exteriors
Interiors
Urns
Domes
Cross
Organ

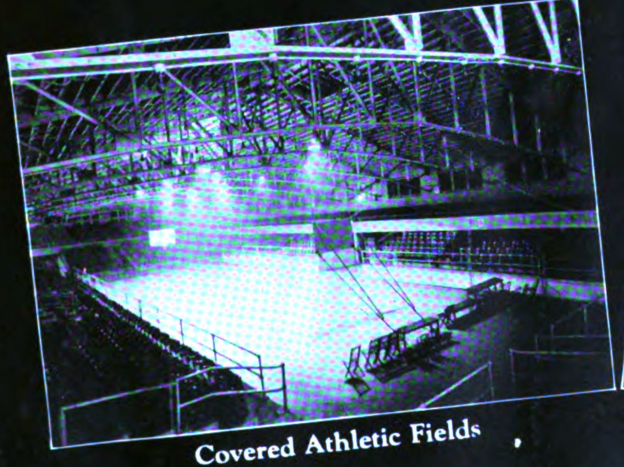
Swimming Pools

Roof Garden Golf

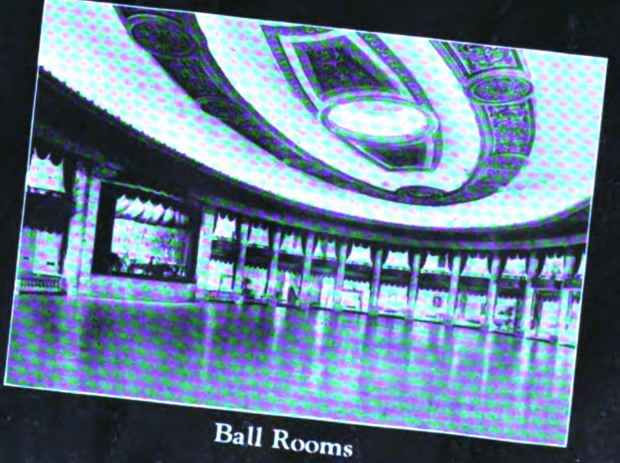
Above — Handball Court

Left — Bowling Alleys

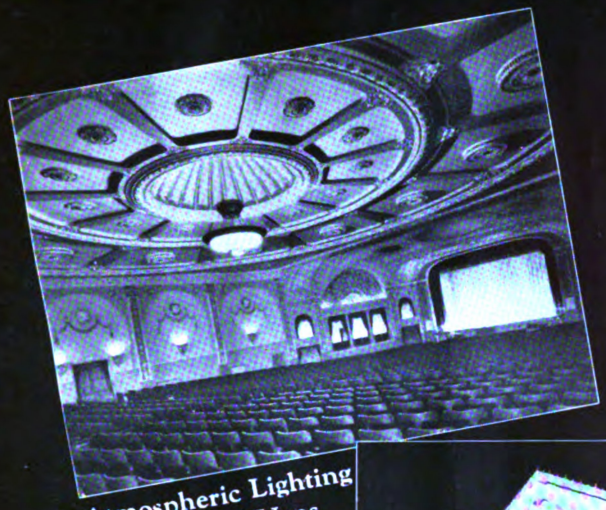
Right — Billiard Tables



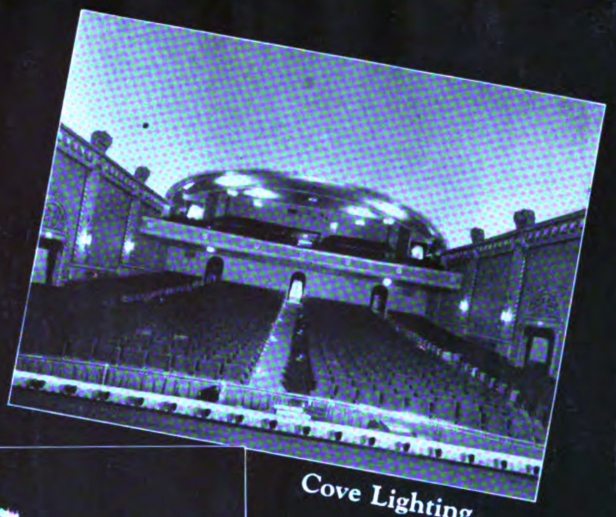
Covered Athletic Fields



Ball Rooms



Atmospheric Lighting
Coves and Urns



Cove Lighting

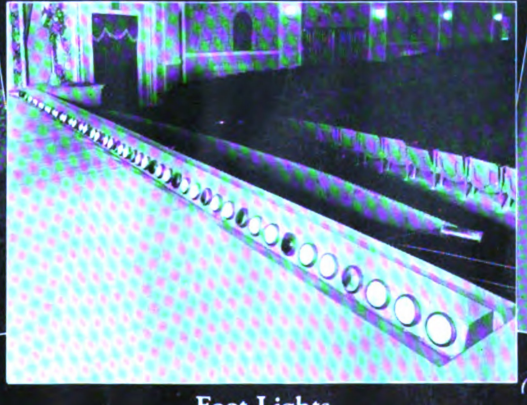
Publicity by Flood-Lighting
in Advance of Opening Day

Flood-Lighting
from Marquee

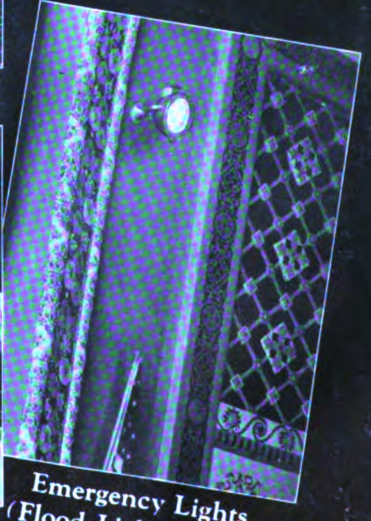
Flood-Lights
on Marquee

Stage Lighting

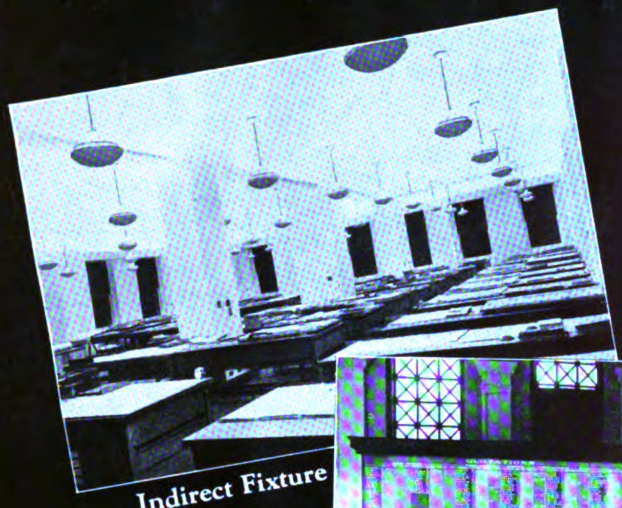
Borders



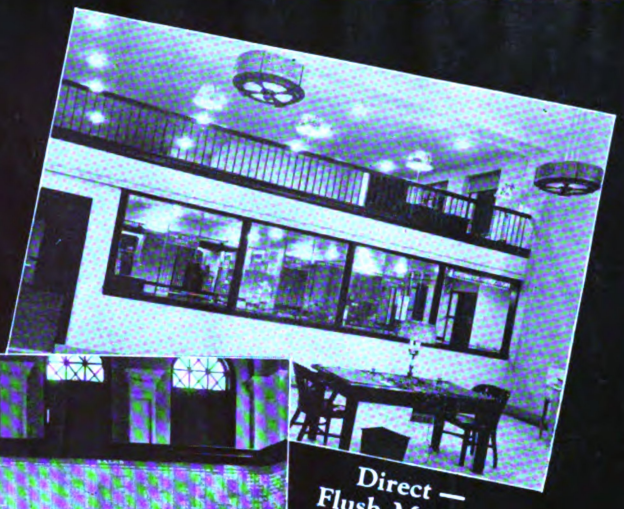
Foot Lights



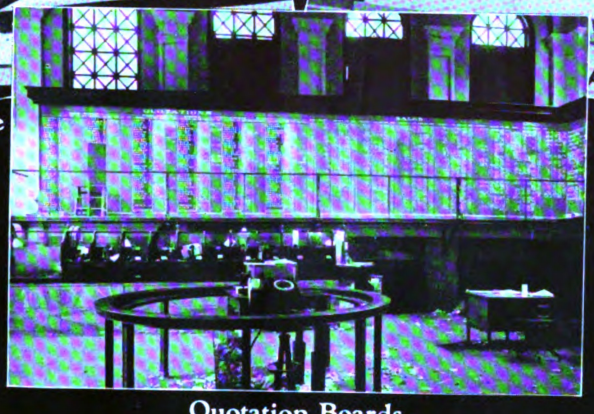
Emergency Lights
(Flood-Light FL-300)



Indirect Fixture



Direct — Flush Mounted in Ceiling



Quotation Boards

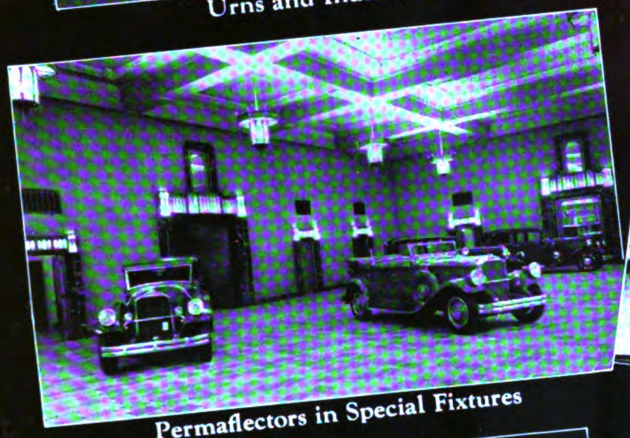
Lighting from Coves

Urn Lighting

Artificial Skylights

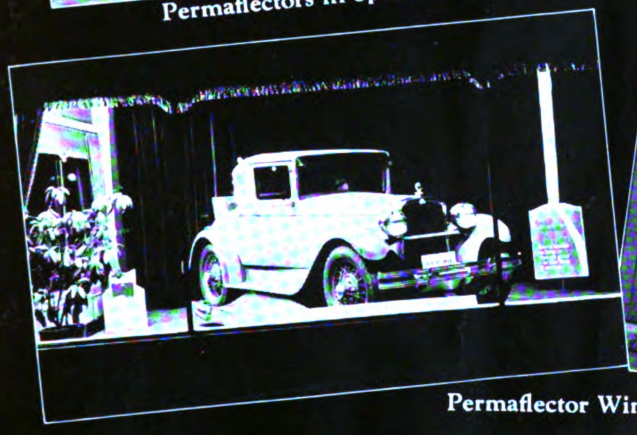
Urns and Indirect Fixtures

Permaflectors No. B-501



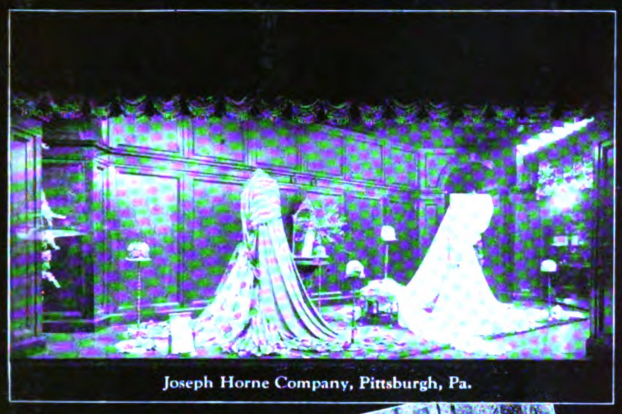
Permaflectors in Special Fixtures

Show Window Lighting



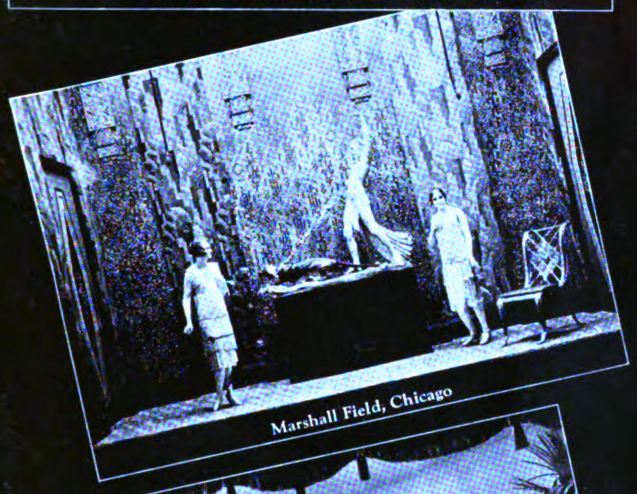
Permaflector Window Lighting

Special Lighting of High Intensity



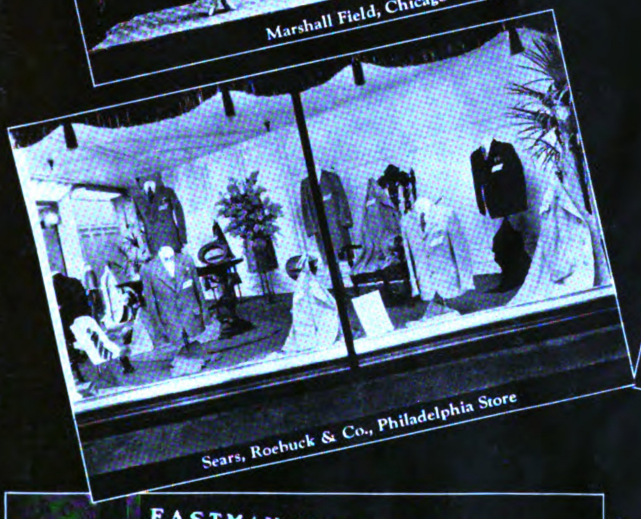
Joseph Horne Company, Pittsburgh, Pa.

B. Altman & Co., Inc., New York City

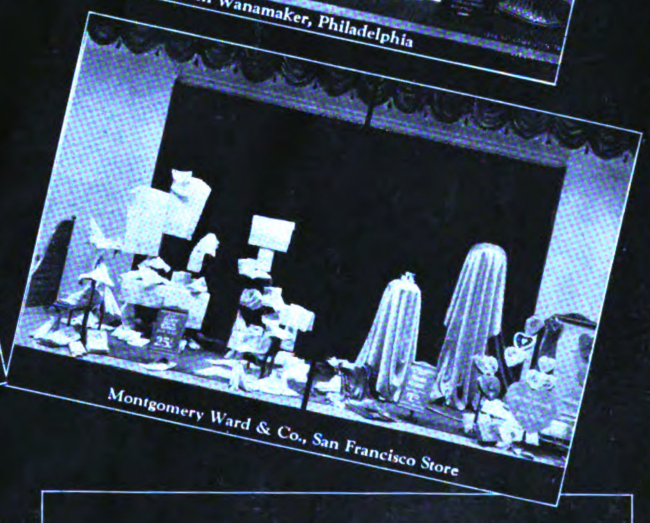


Marshall Field, Chicago

John Wanamaker, Philadelphia



Sears, Roebuck & Co., Philadelphia Store

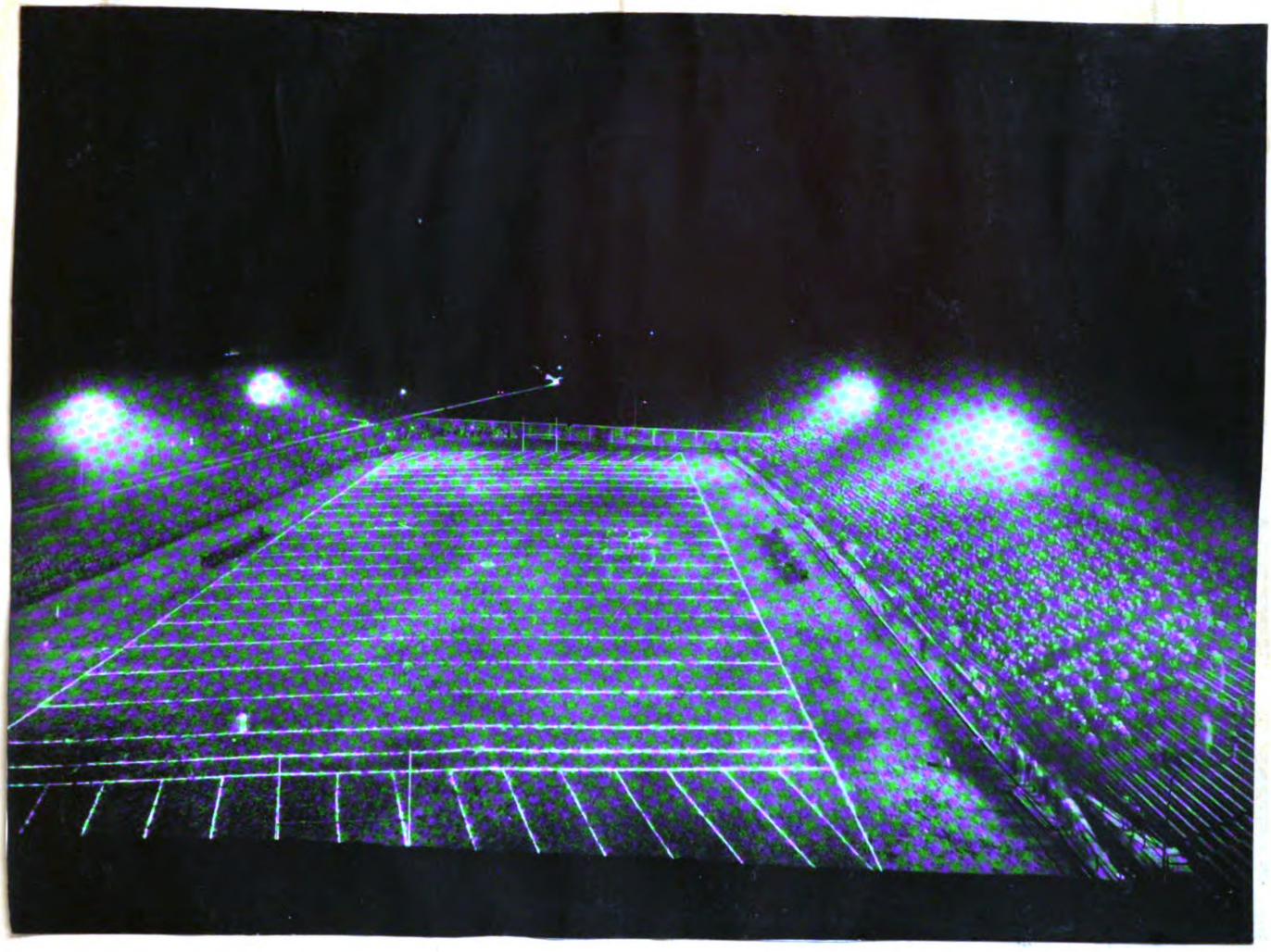


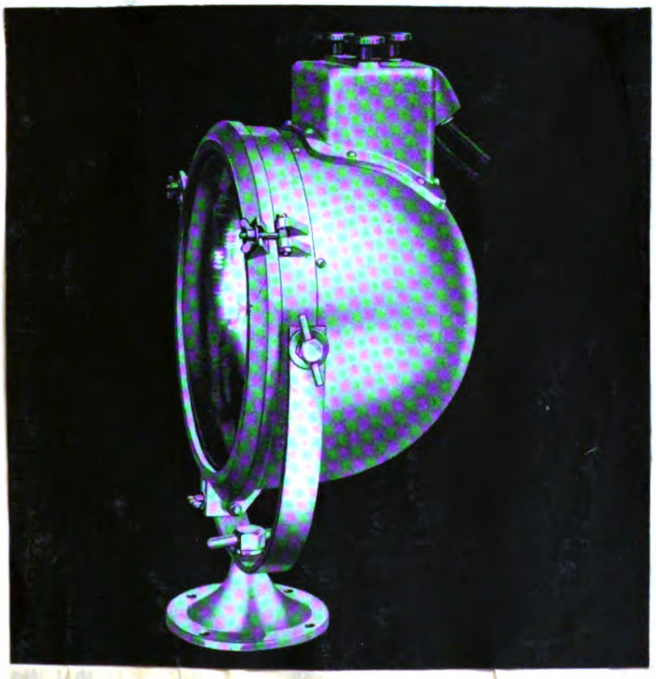
Montgomery Ward & Co., San Francisco Store

Eastman Kodak Stores, Inc., Pittsburgh

Selfridge, London, England

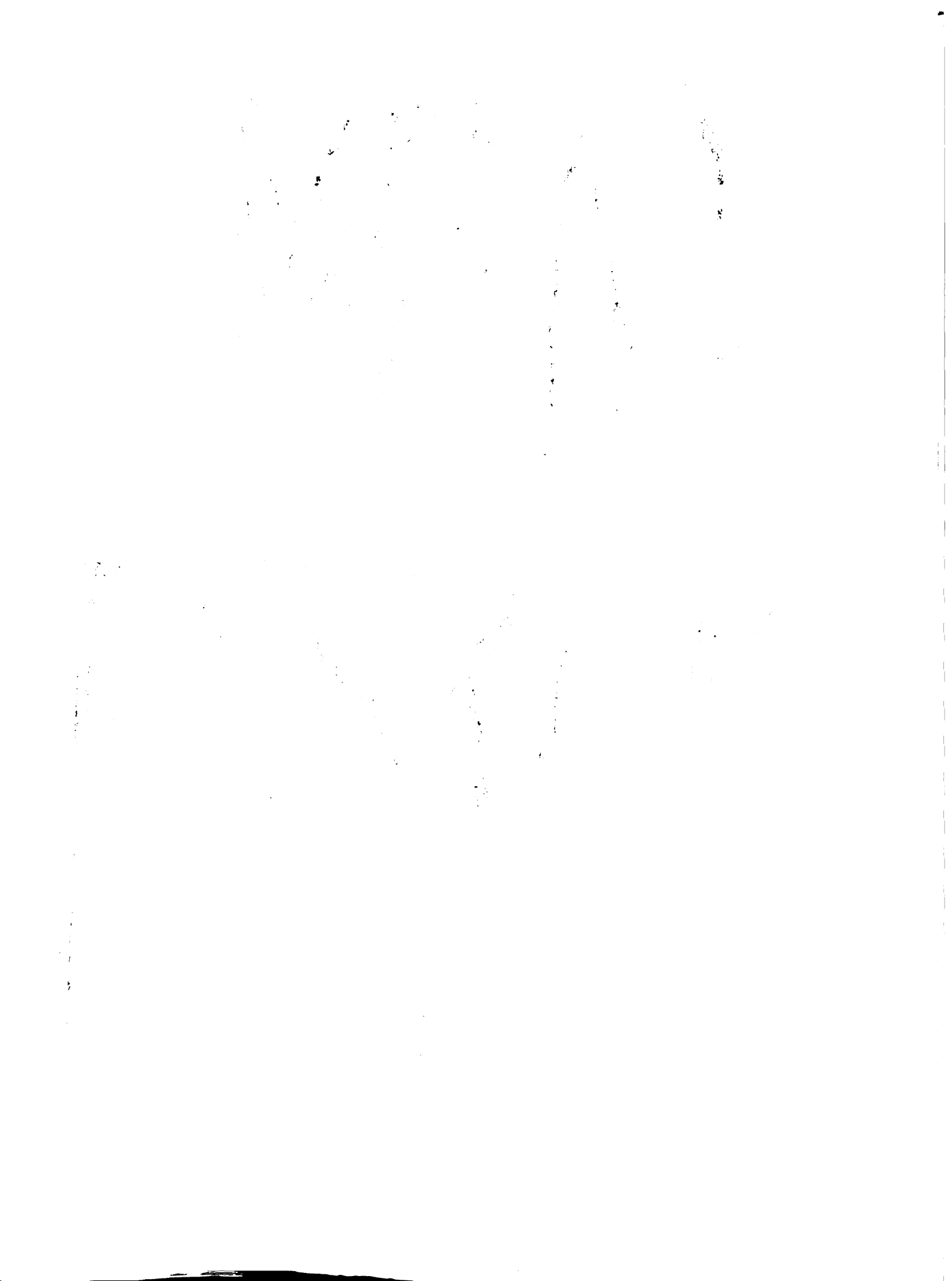
DAYTIME REFLECTIONS

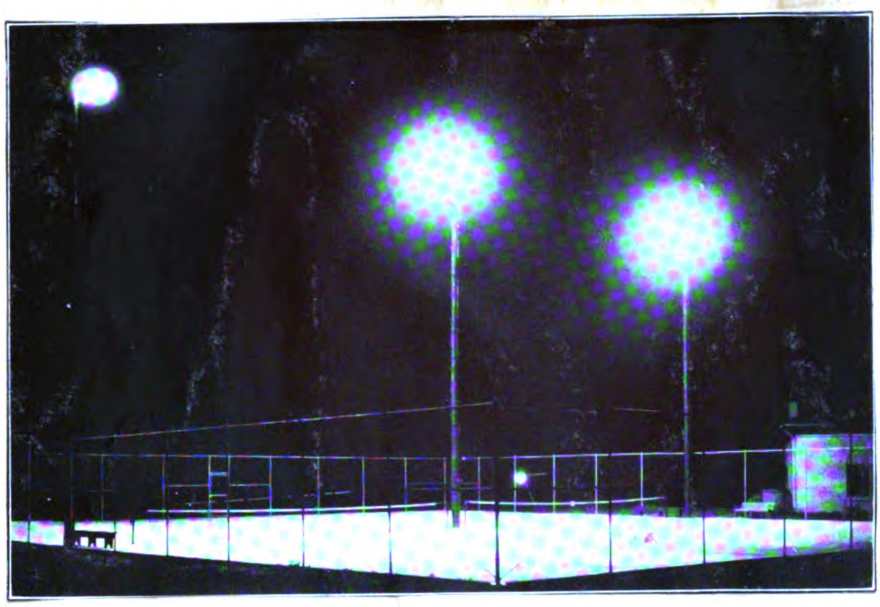


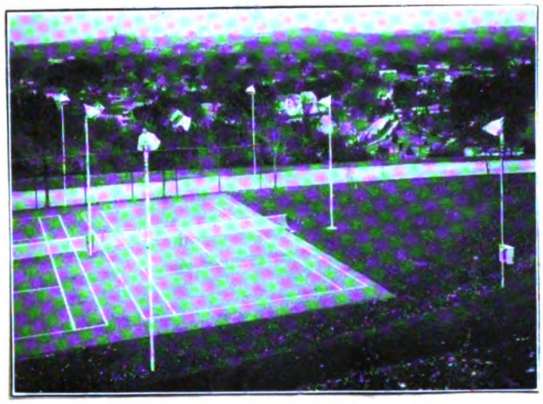


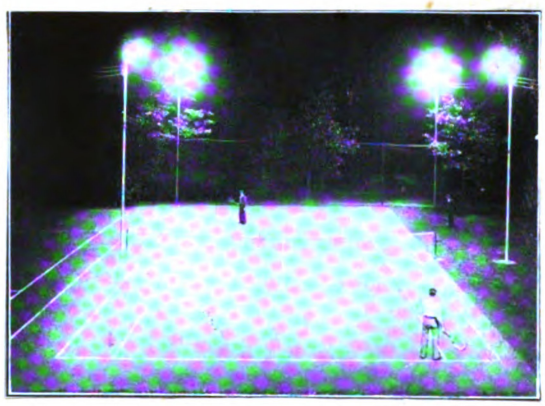
FOOTBALL FIELD

AND UNITS

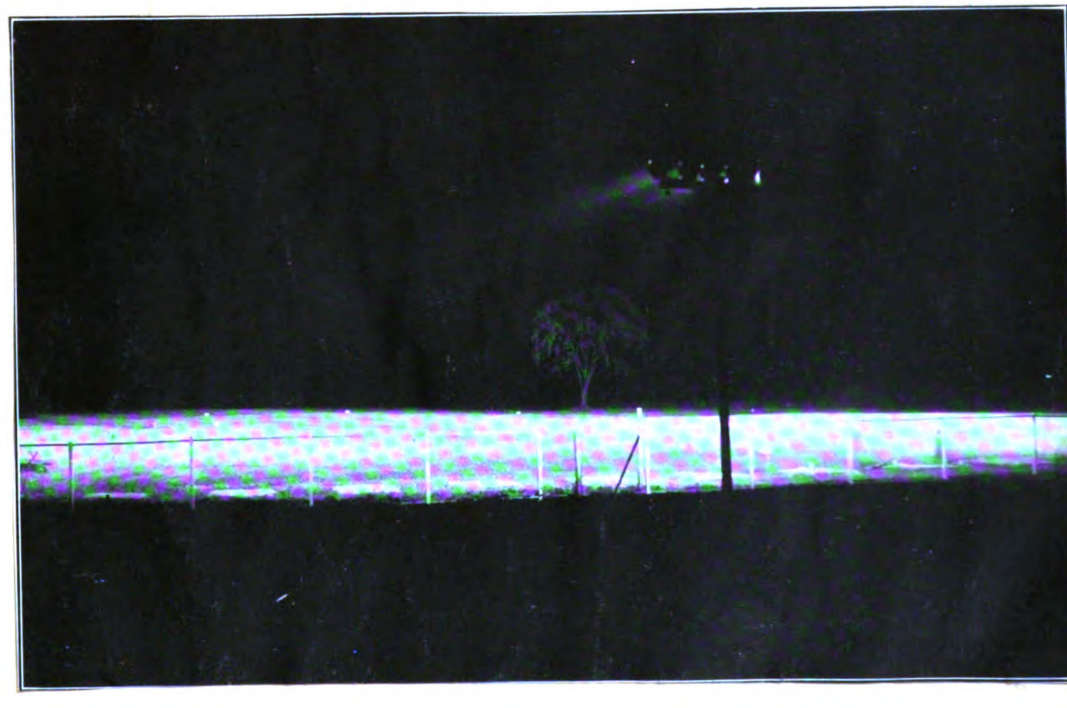




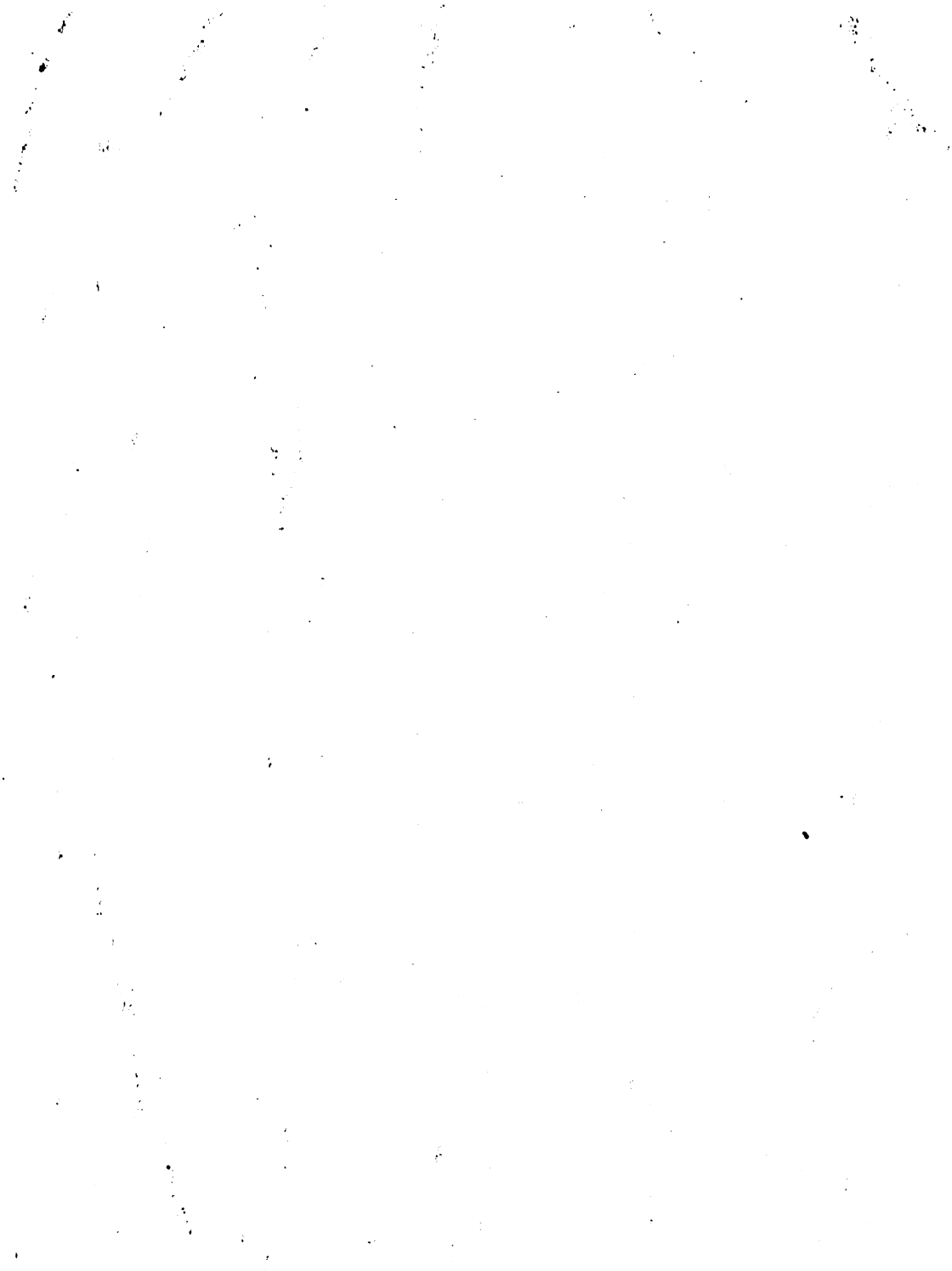


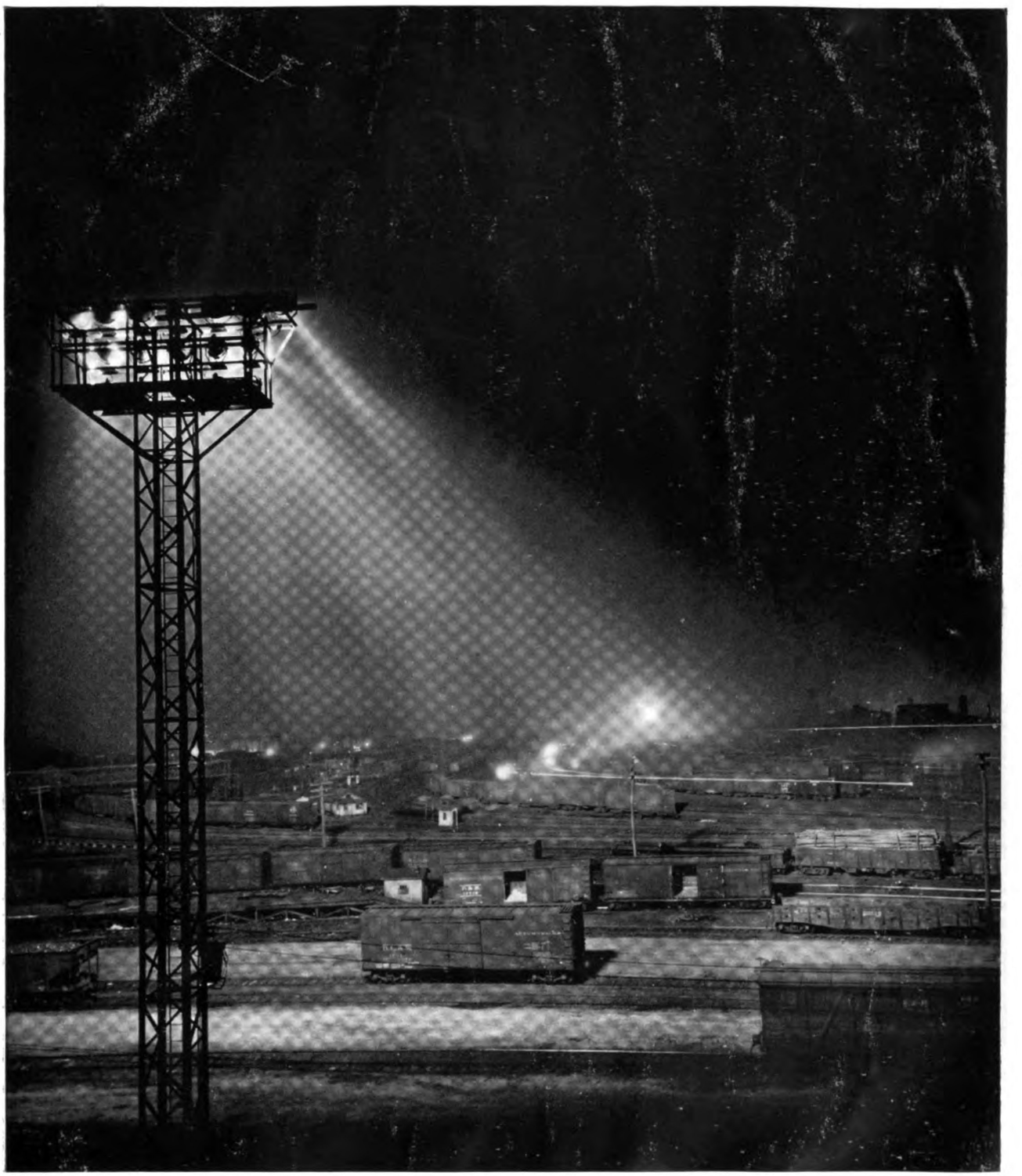


TENNIS COURTS AND UNIT

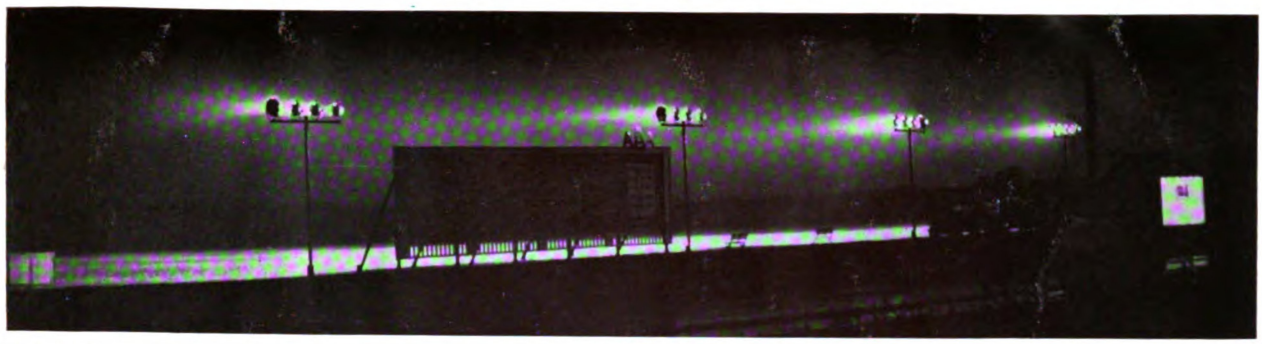


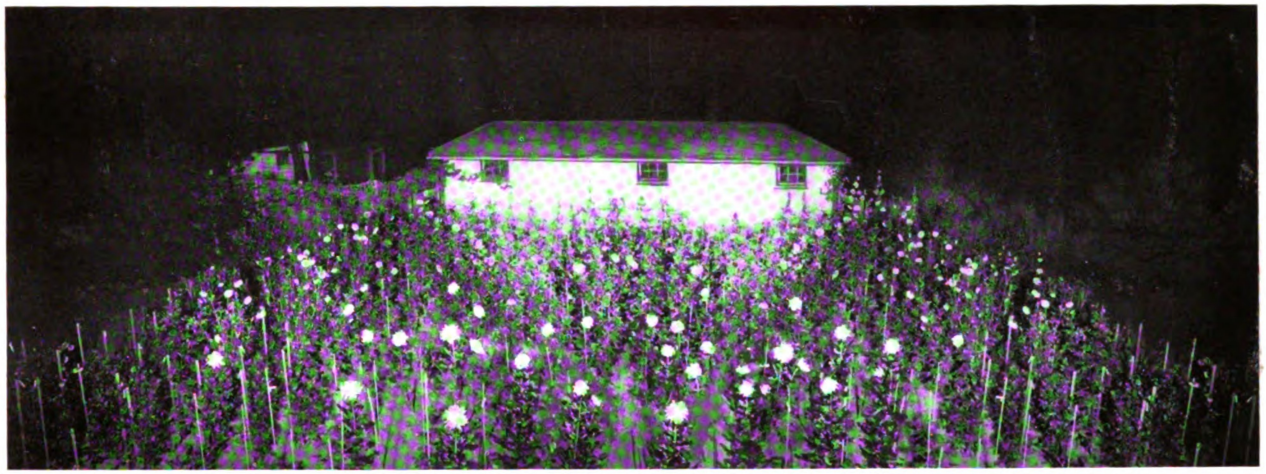
GOLF DRIVING RANGE

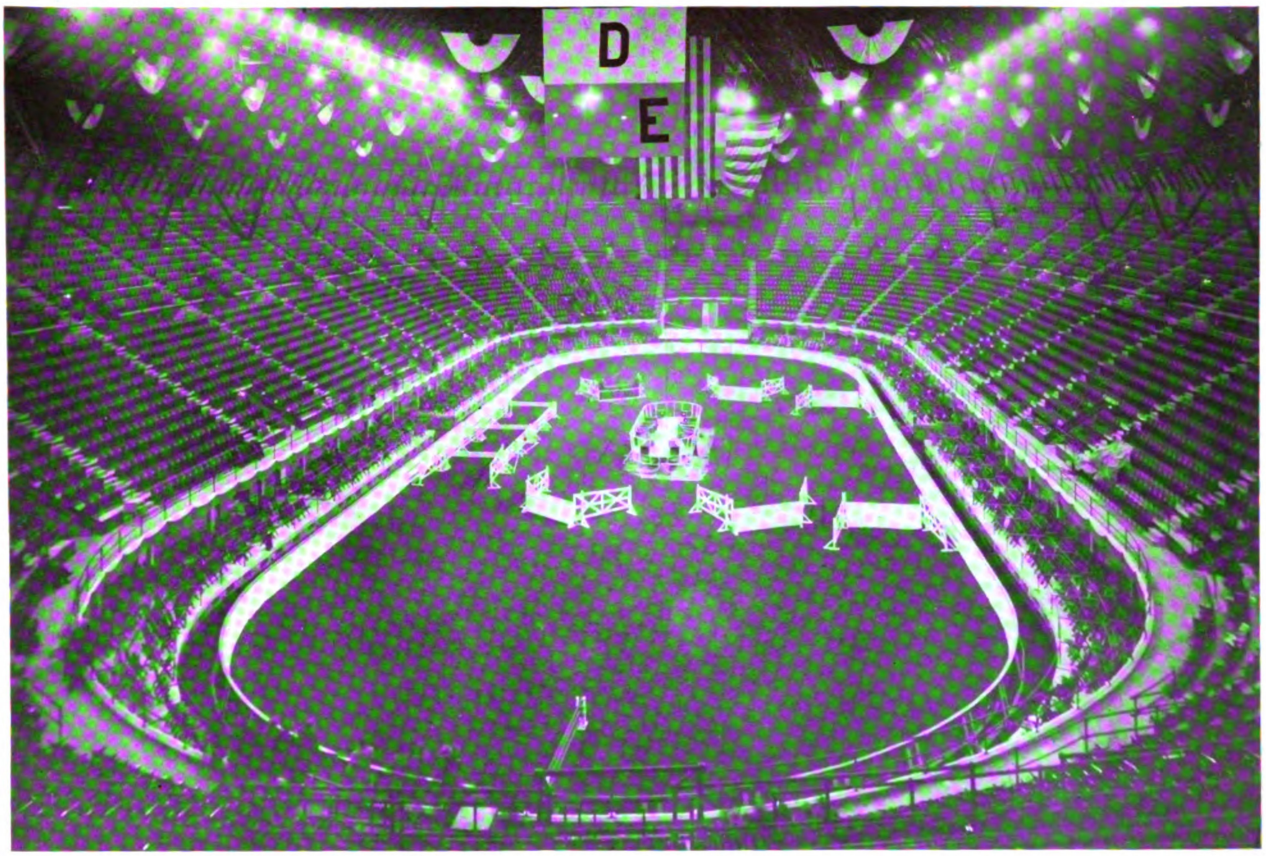




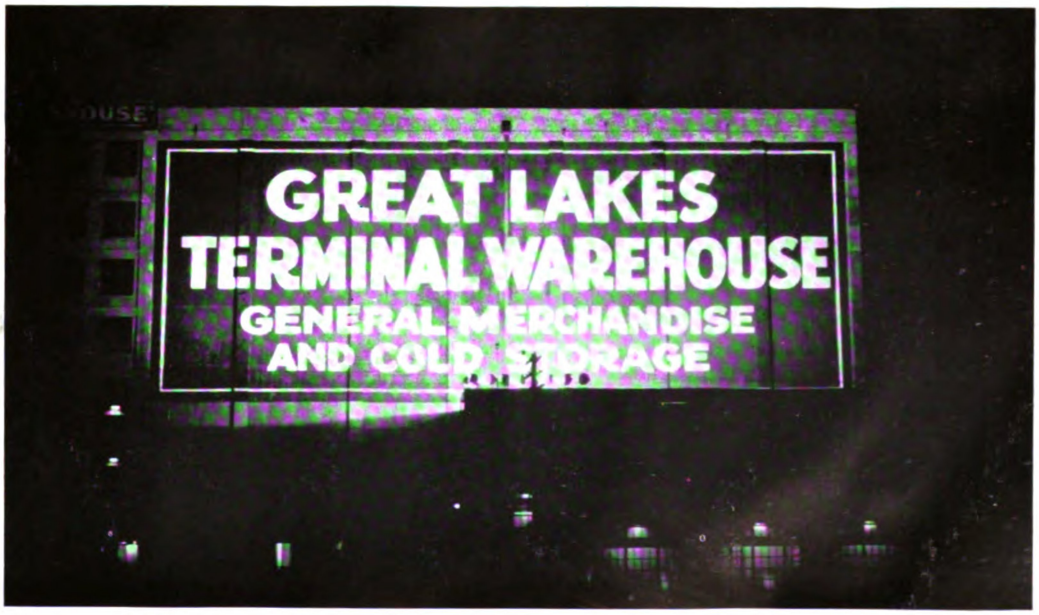
R.R. SWITCHING YARD AND "HUMP"

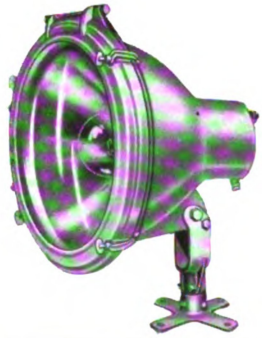






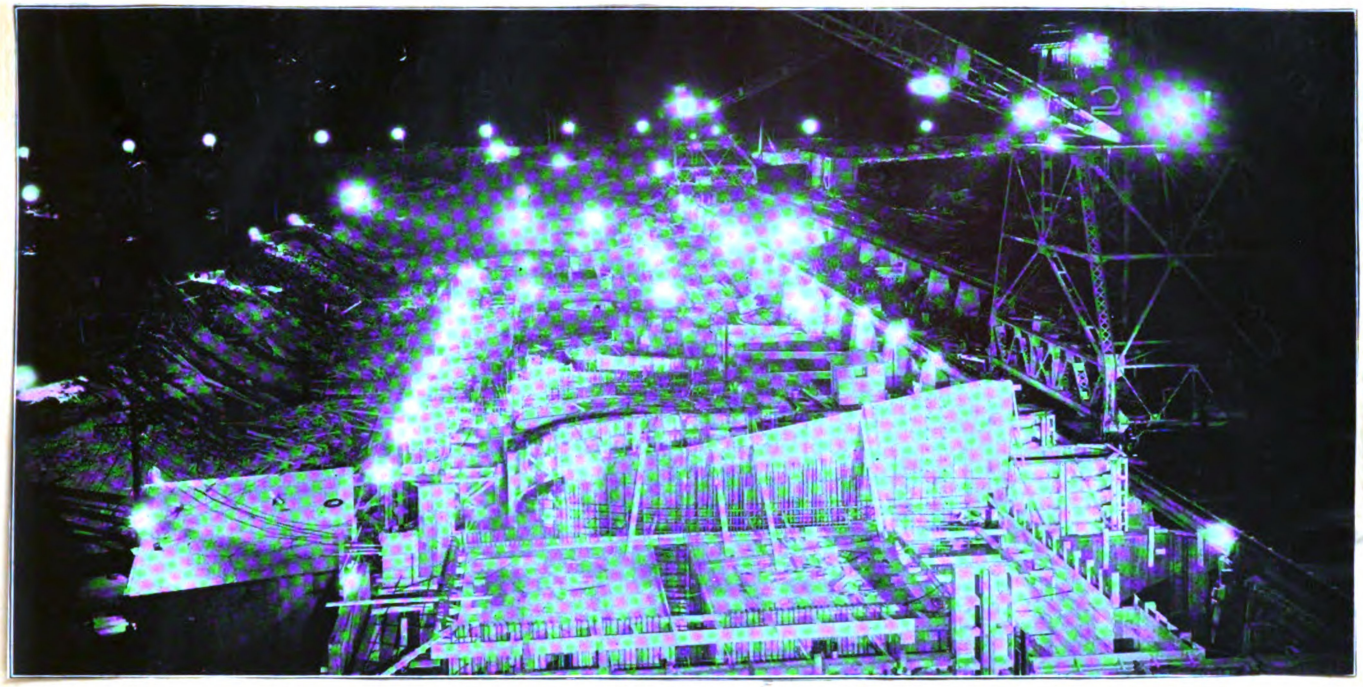
INTERIOR - THE ARENA - ST. LOUIS

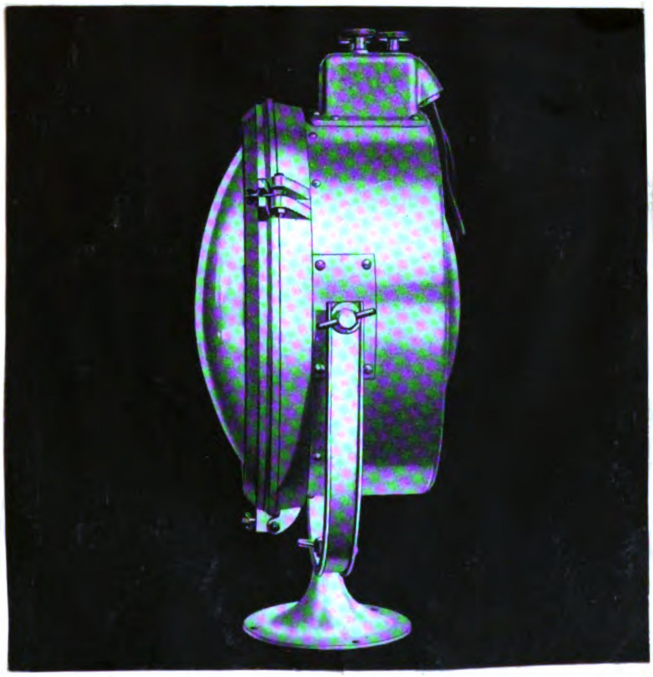




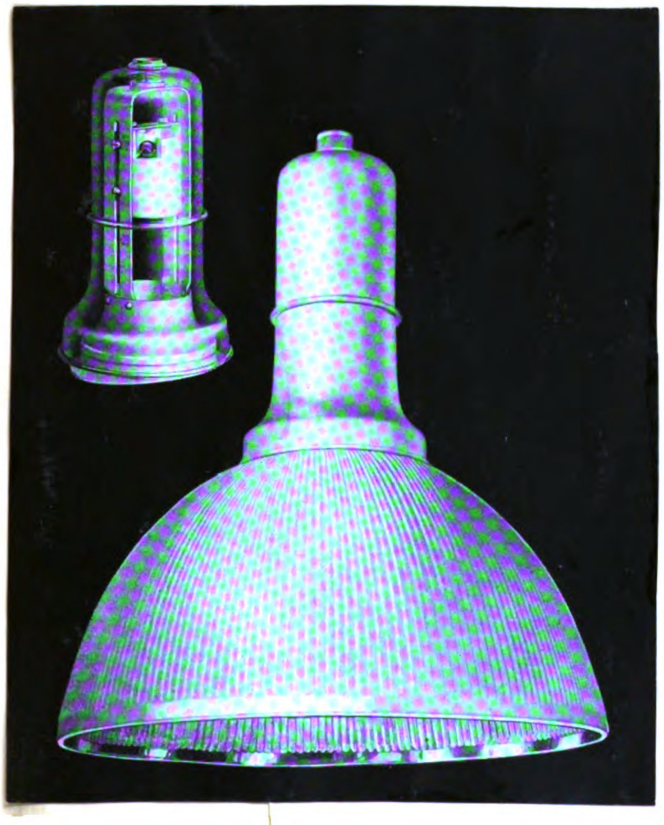
MINIATURE GOLF COURSE - UNITS.

TWO MINIATURE GOLF COURSES



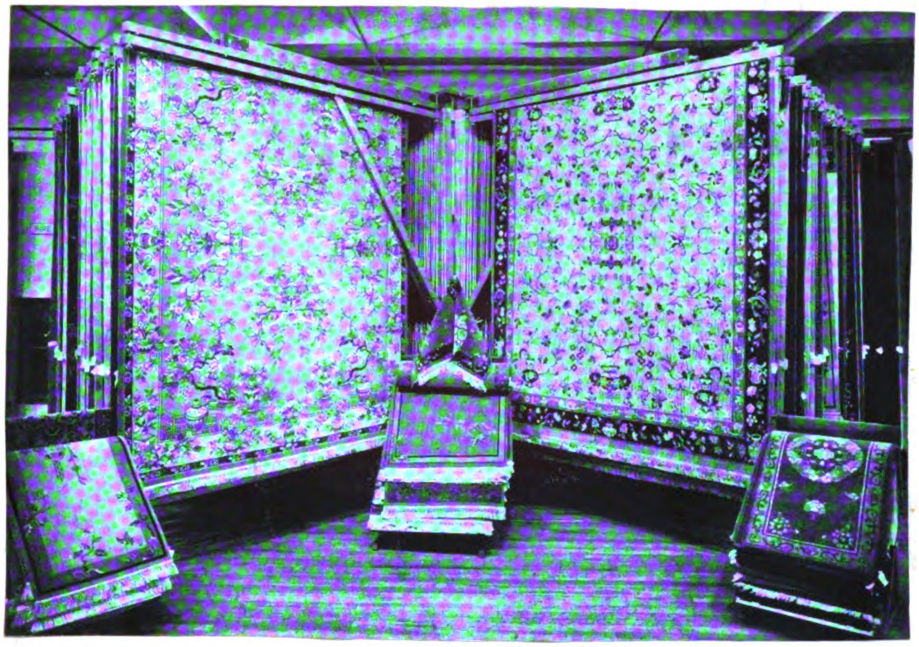


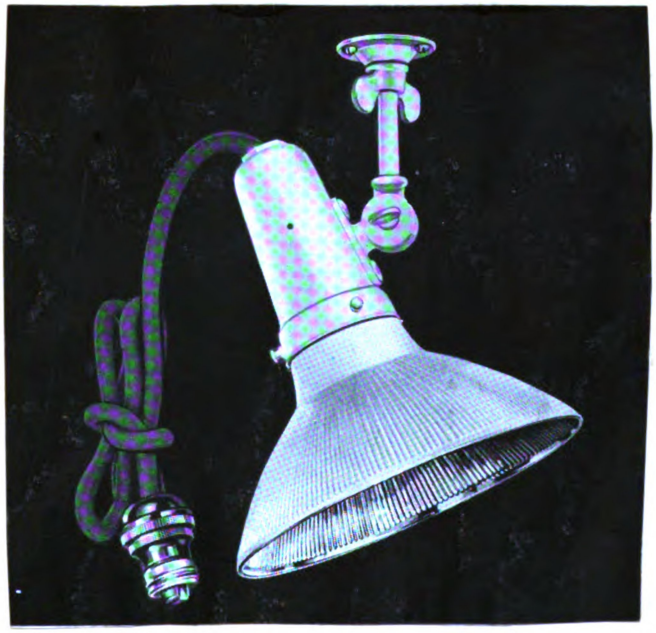
NIGHT CONSTRUCTION AND UNIT.



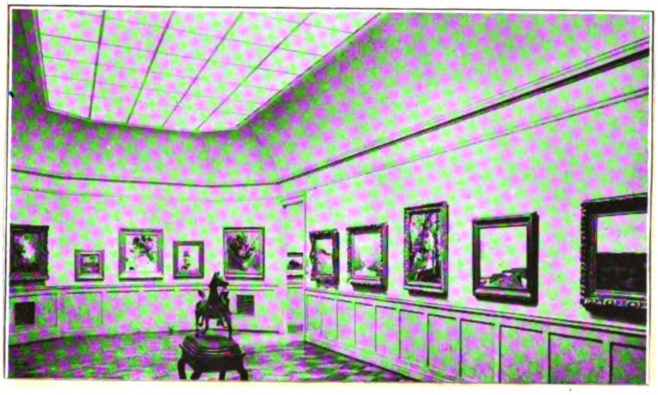
UNITS FOR WINDOW ILLUMINATION

TWO TYPES OF WINDOWS





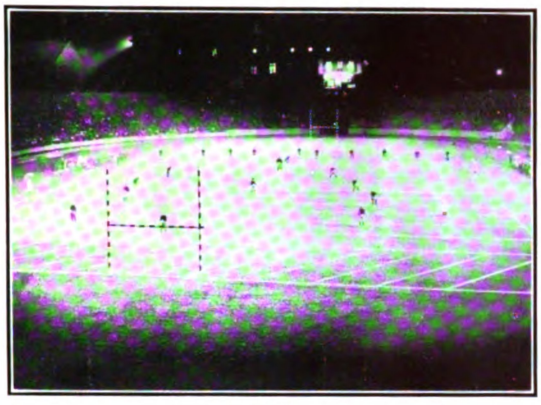
RUG DISPLAY USING WINDOW FLOODLIGHTS



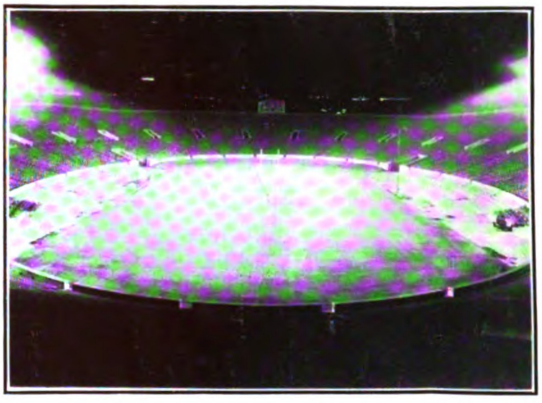
ART GALLERY

UNIT

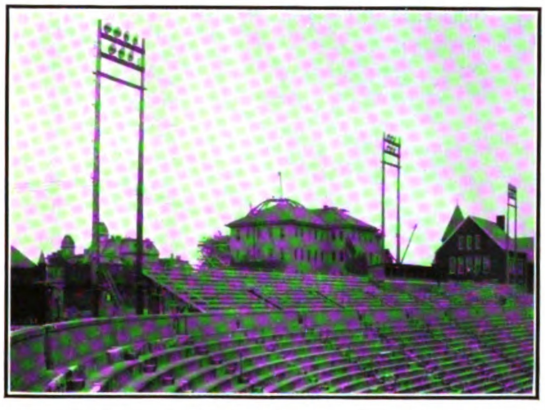
Artificial skylight illumination in an Art Gallery.
Upper view shows arrangement of units above skylight.



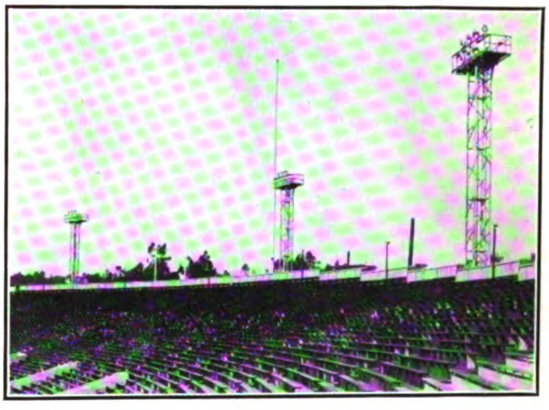
Syracuse University Stadium
Lighted with Type LCE-24 Floodlights



Rose Bowl—Pasadena, Calif.
Lighted with Type LCE-24 Floodlights

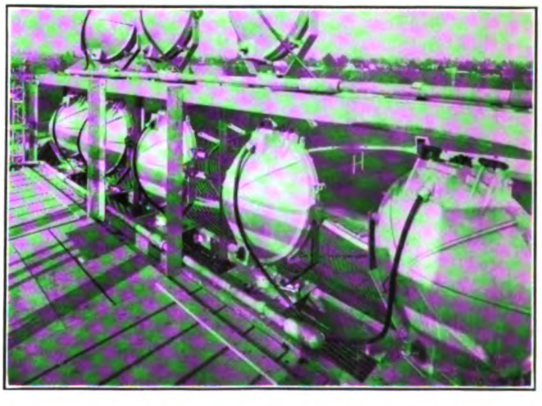


Syracuse University Stadium
Day View of Installation



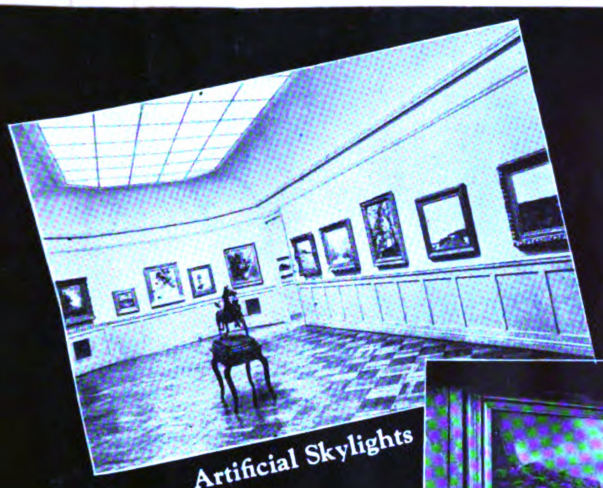
Rose Bowl—Pasadena, Calif.
Day View of Installation

Night Game Showing Close-up of Play

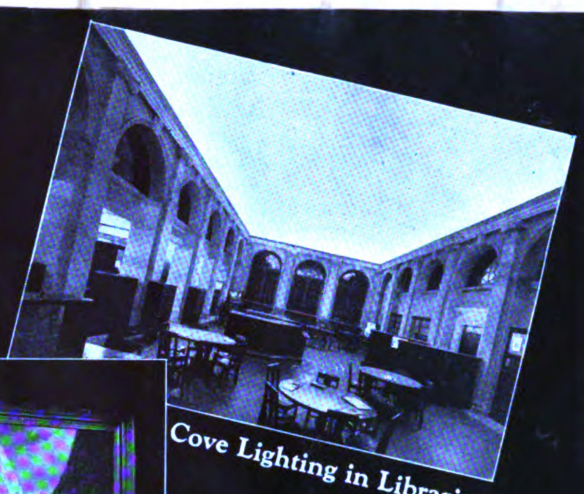


Close-up of Floodlights on Tower

FOOTBALL ILLUMINATION



Artificial Skylights



Cove Lighting in Libraries

Pictures

Museum Cases

Flood Lighting

Corridors — Indirect

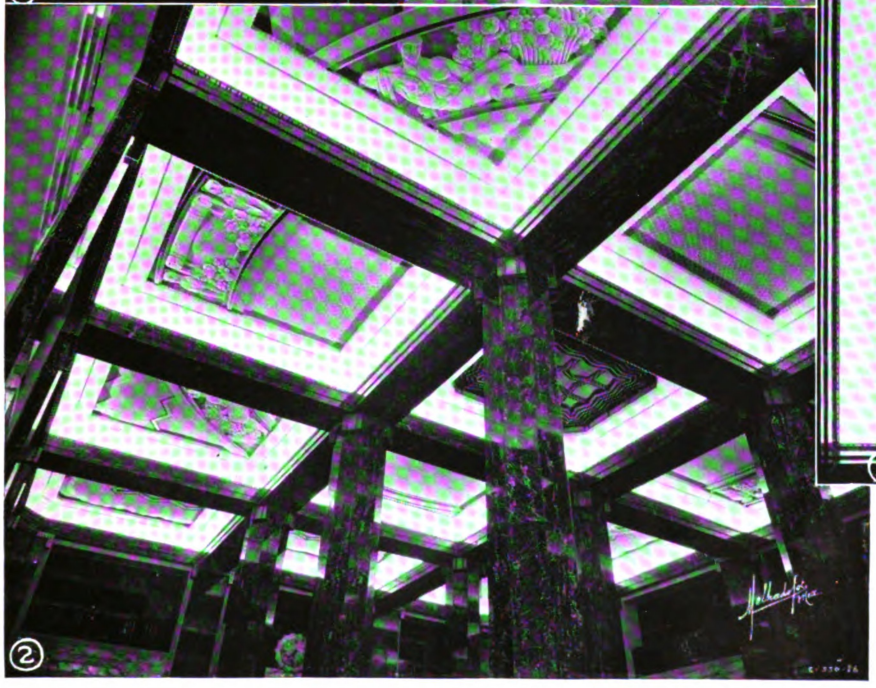
Court Rooms — Cove Lighting

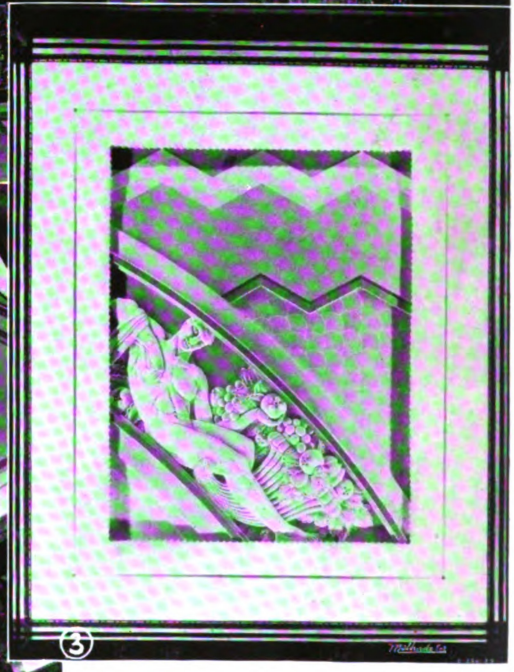
Memorials

ARTIFICIAL SKYLIGHTS FOR LIBRARIES

SECURITY TITEE AND TRUST CO. WILMINGTON, DEL.

TIOGA NATIONAL BANK, PHILADELPHIA
ARTIFICIAL SKYLIGHTS.



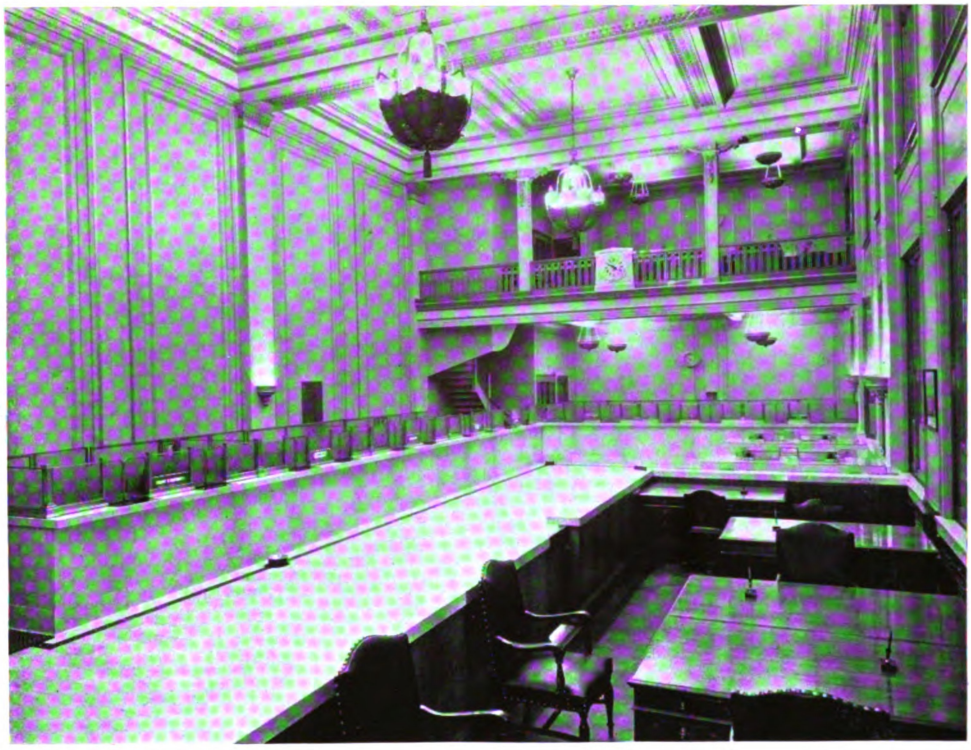


BANK OF MEXICO

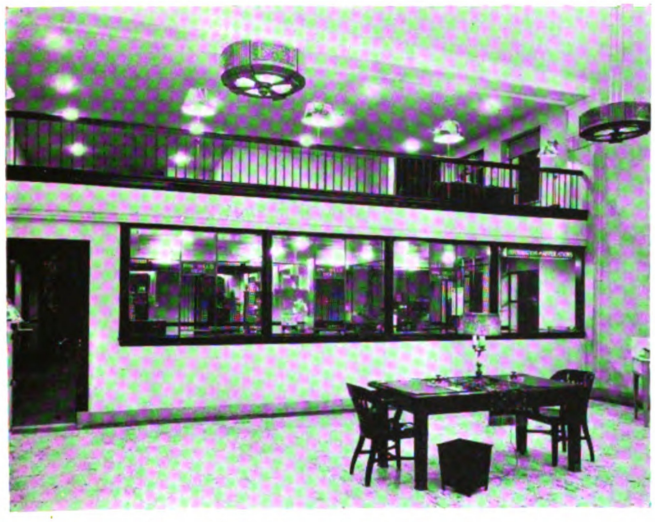
MEXICO CITY.

① General view of lobby.
② Close-up of ceiling
③ Detail of one bay

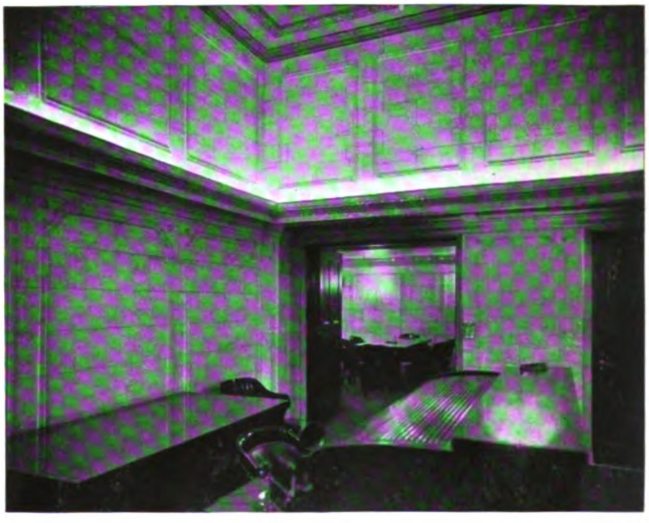
Lobby is cove illuminated from 15 art panels in the ceiling.



Totally indirect units and urns for bank lighting.



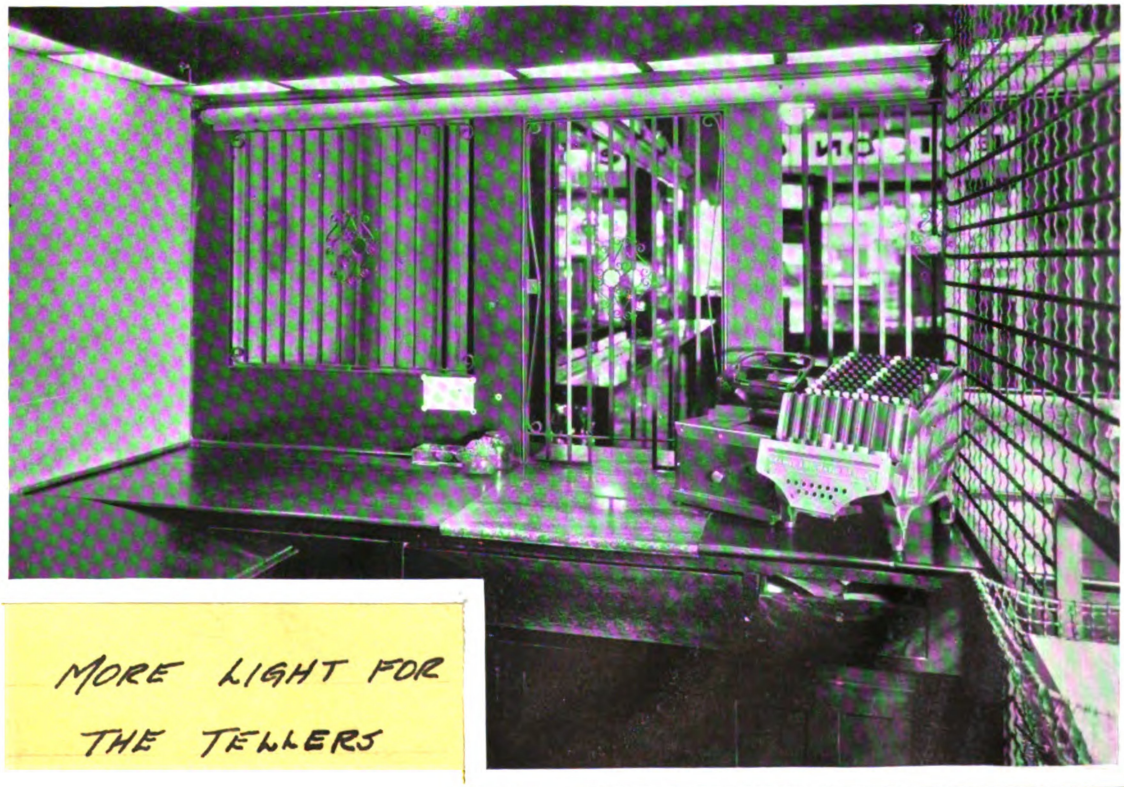
Pay Clerks Offices



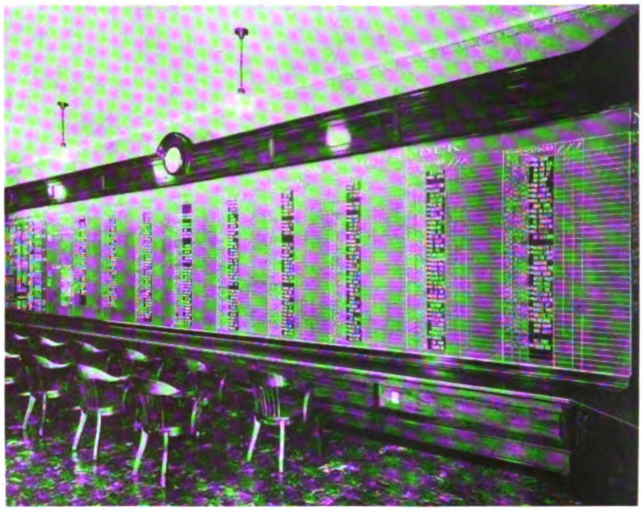
Board of Directors Room.
Cove illuminated.

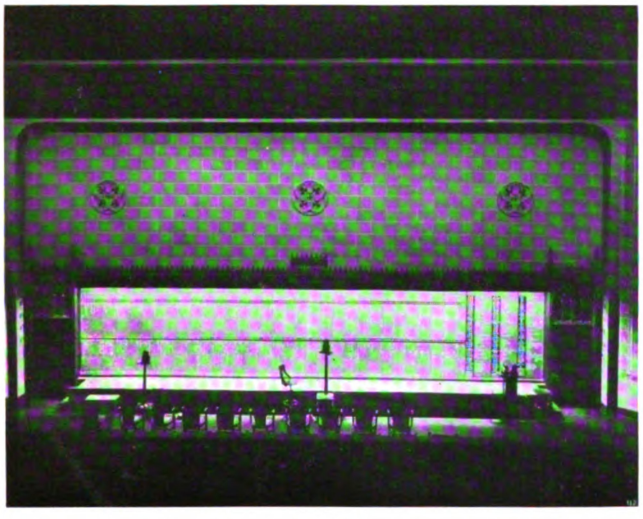
Examples of Cove Lighting

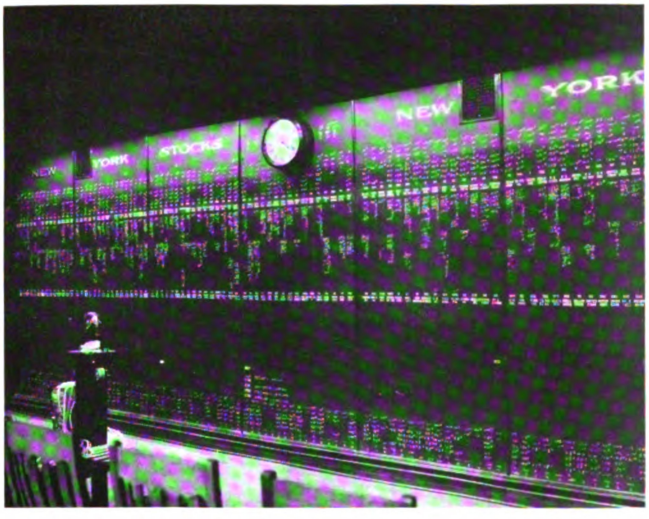
Totally indirect illumination - Office.

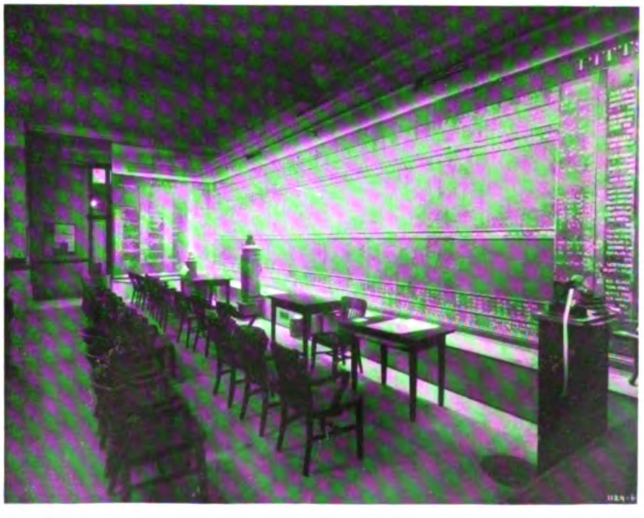


MORE LIGHT FOR
THE TELLERS

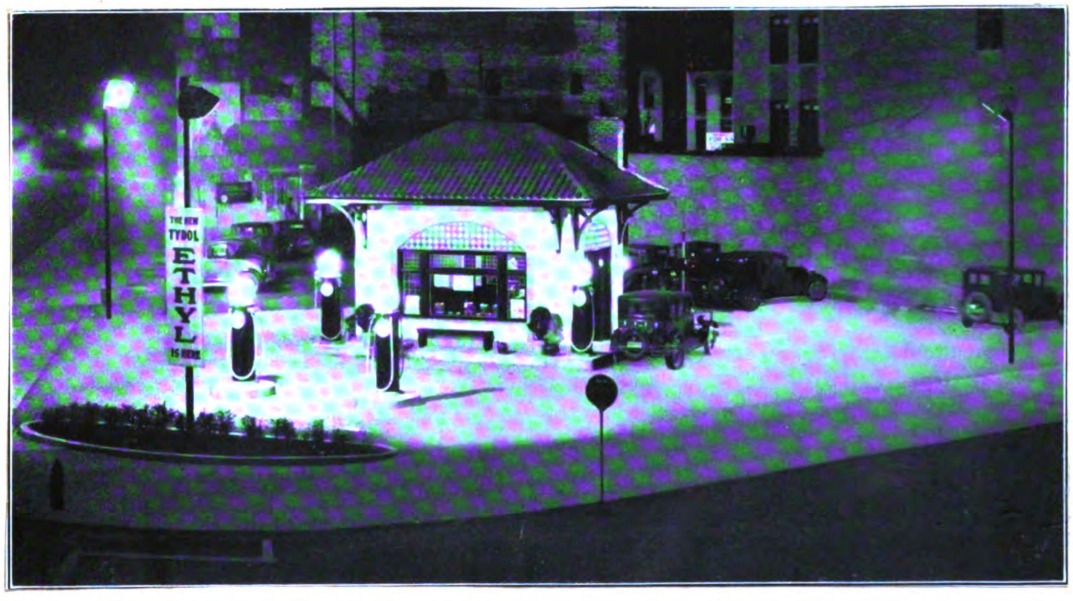




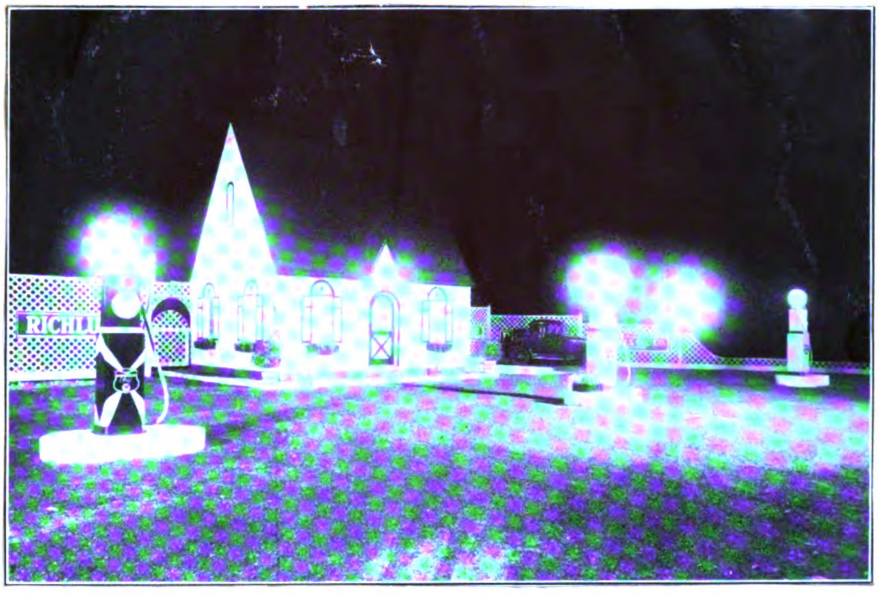




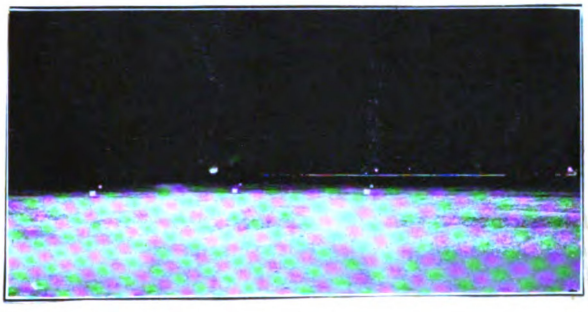
Stock quotation boards illuminated from above by an inverted cove carrying 100 watt reflectors on 12" centers.



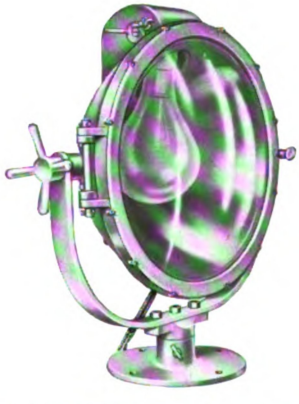
TWO MODEL GAS STATIONS AND THE UNIT ILLUMINATING THEM



A WELL ILLUMINATED GAS STATION



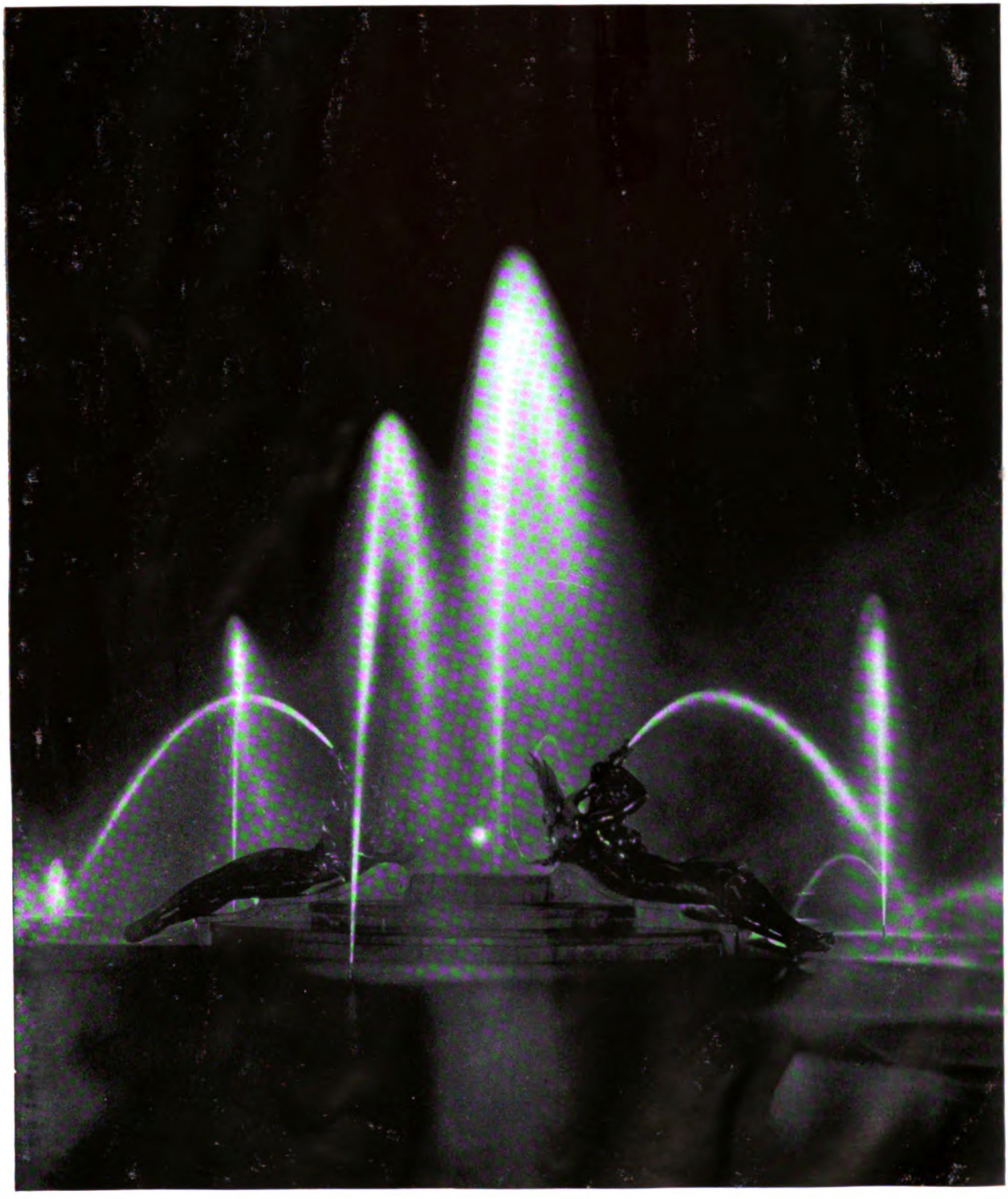
NIGHT VIEW - GOLF DRIVING RANGE



THE UNITS USED.

THREE MODEL GAS STATIONS. LIGHT FROM LANTERN BRACKETS

200 WATT LANTERN BRACKETS FURNISH THIS LIGHT



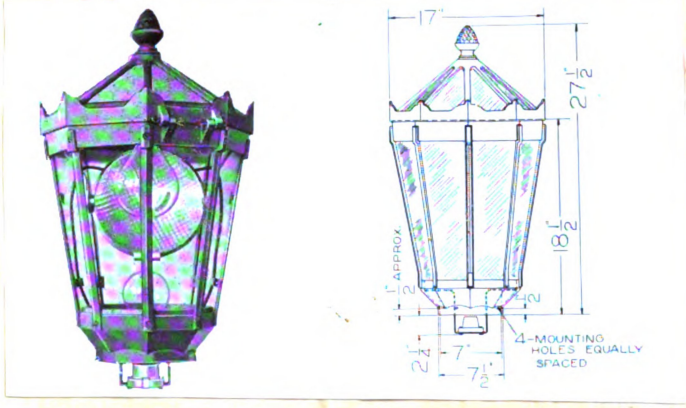
FOUNTAIN IN LOGAN SQUARE, PHILADELPHIA.

Today's ceiling shower or ca
is the artistic developmen
chandelier of the early days of
lighting.

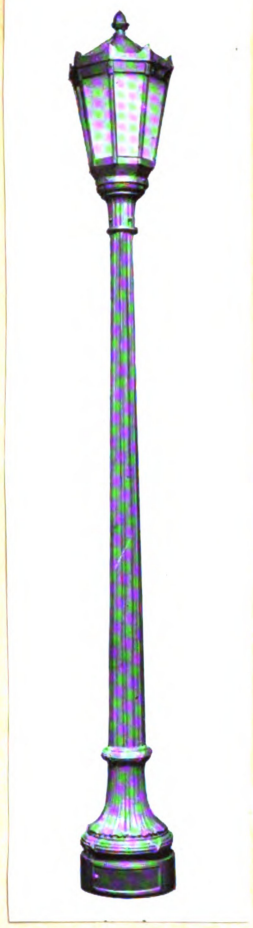
More light—true—but a drab lifeles
ness prevails—

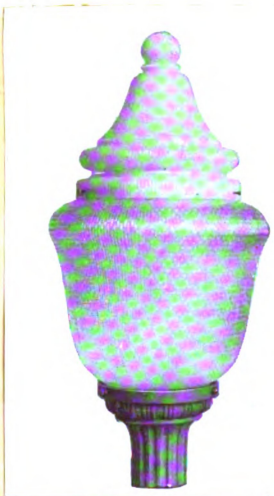
A "MODEL" HOME FURNISHED THIS

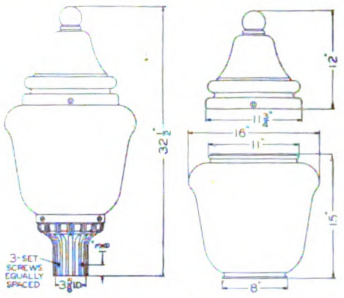
Glass panels removed



THREE TYPES OF LANTERN BRACKETS

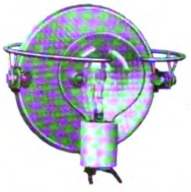




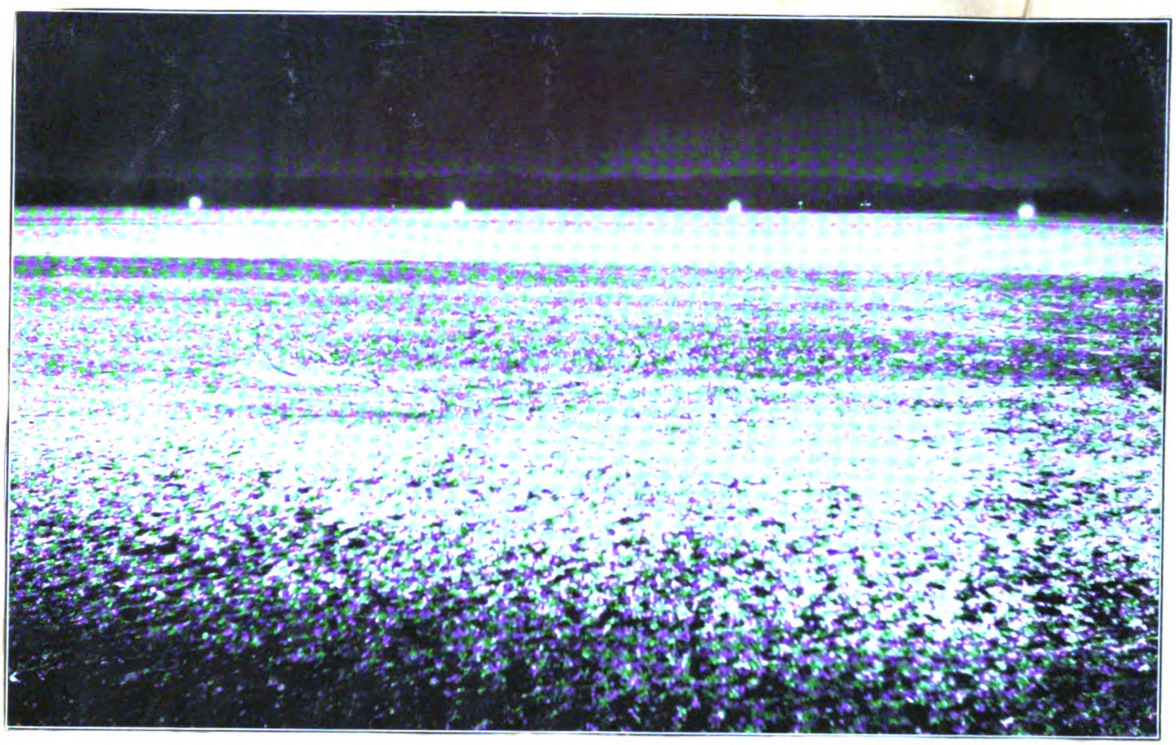


Complete Assembly

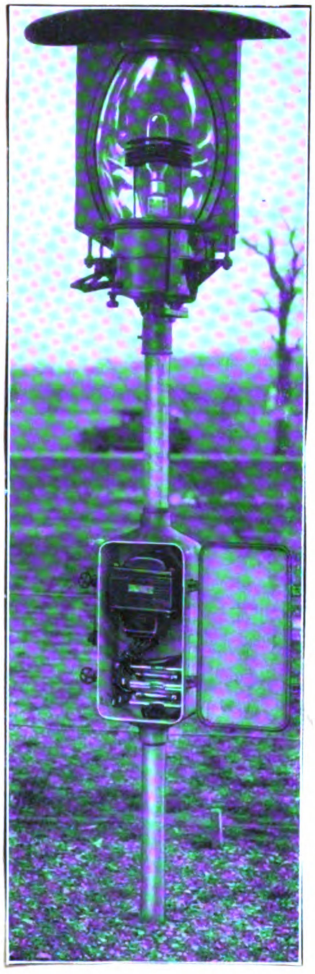
Glassware Only



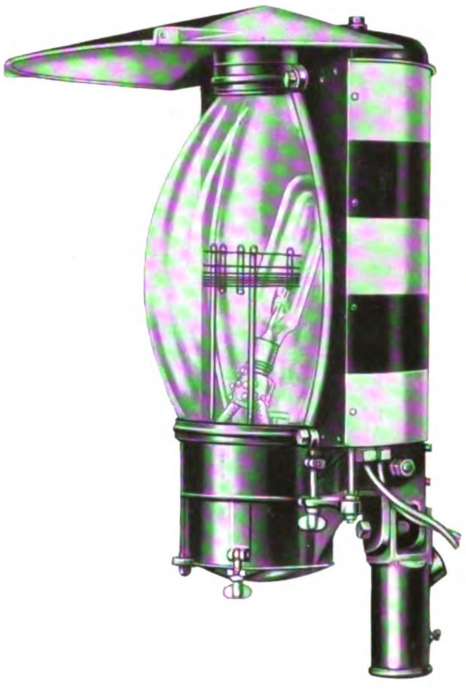
LANTERN BRACKET ASSEMBLIES



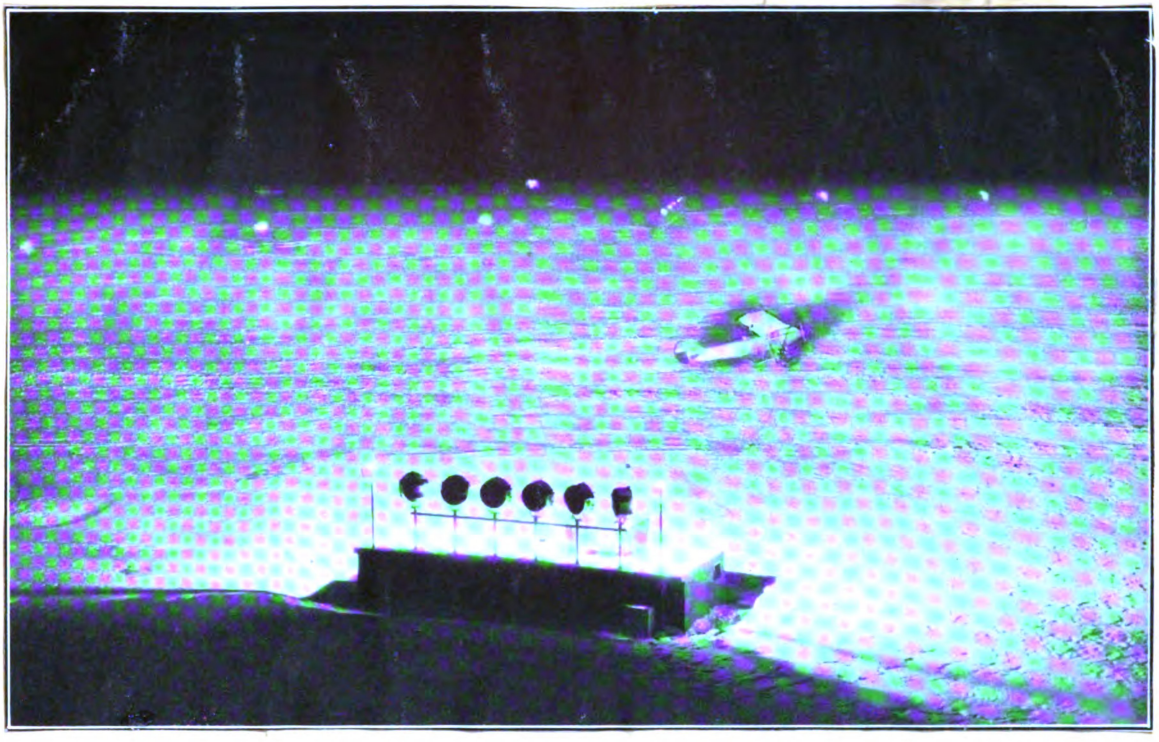
SYRACUSE, N.Y. AIRPORT. Illuminated by units placed around the boundry.



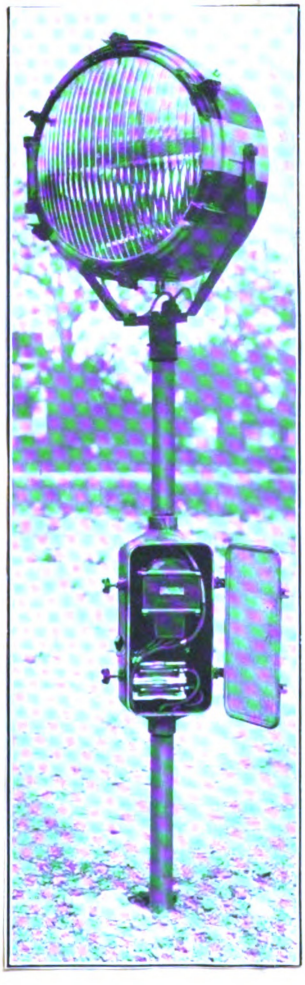
UNIT MOUNTING

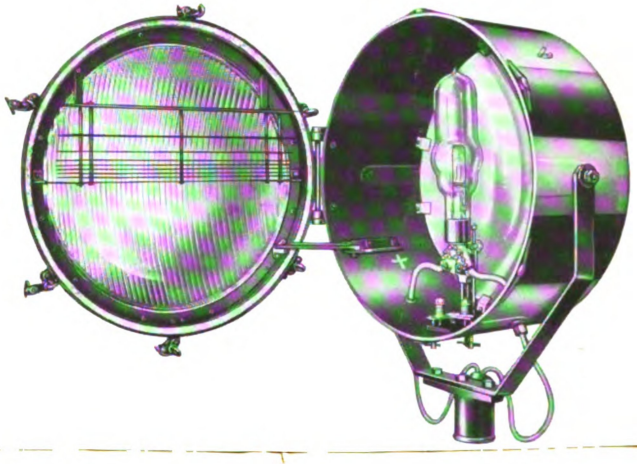


TYPE AKP-14 UNIT.

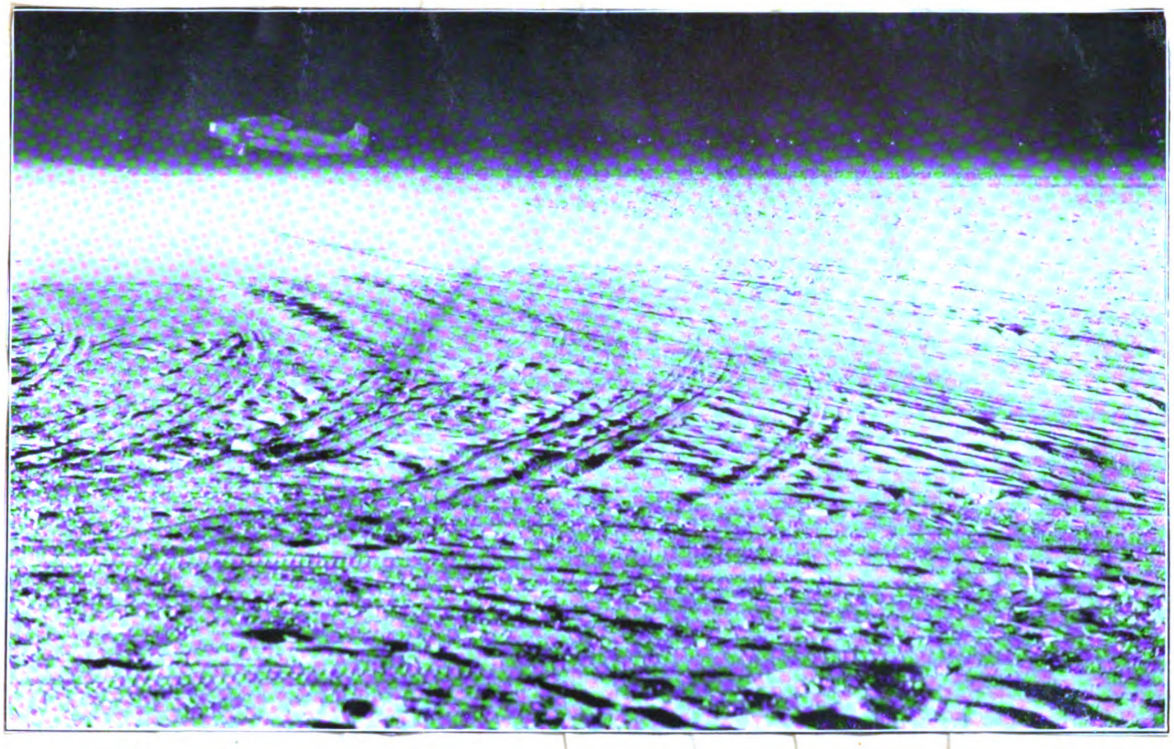


MUNICIPAL AIRPORT - GRAND RAPIDS, MICHIGAN

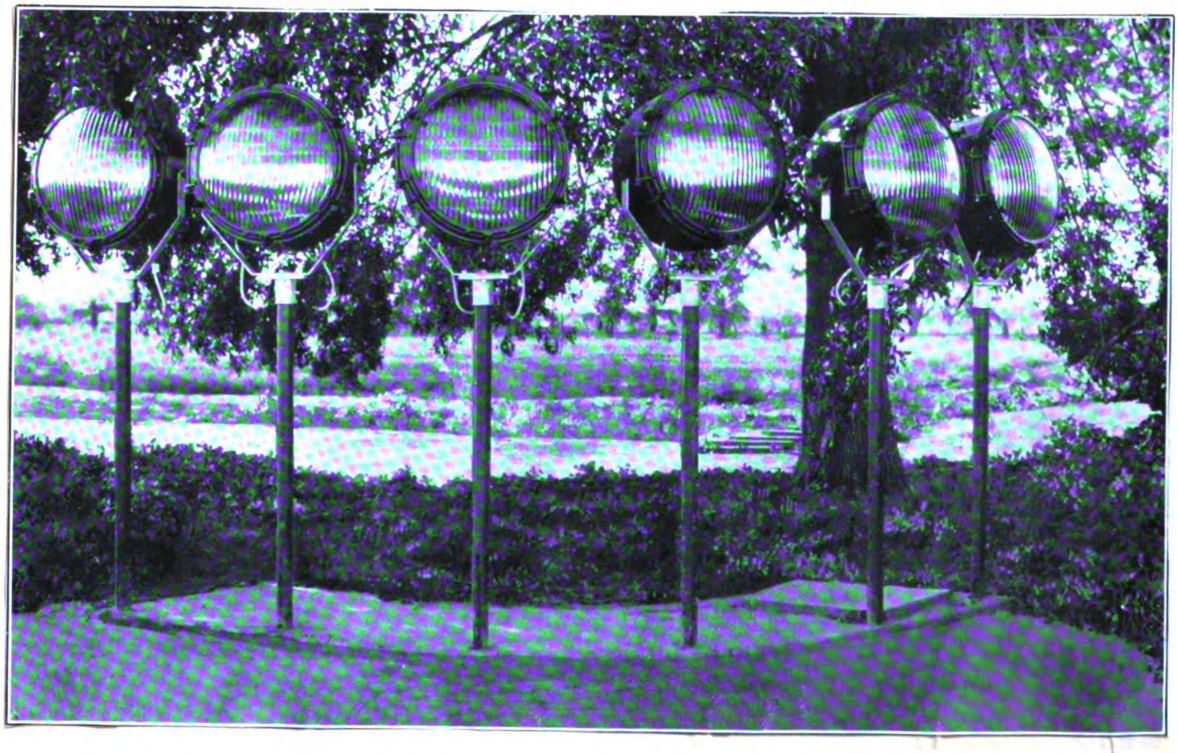




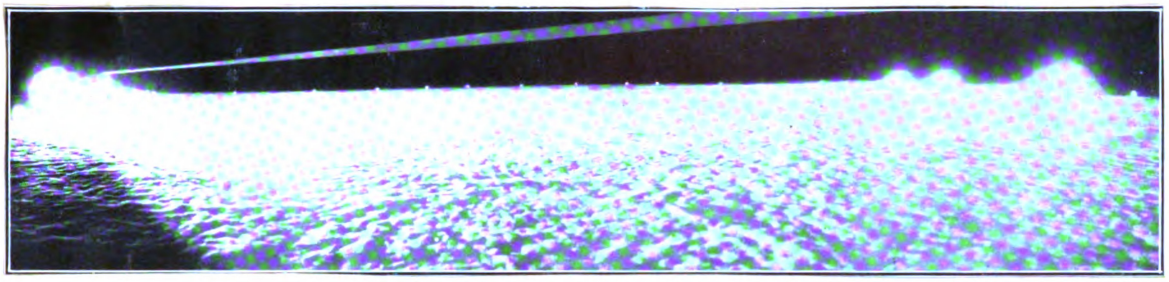
Unit with door open, showing bulb, reflector and louvers.



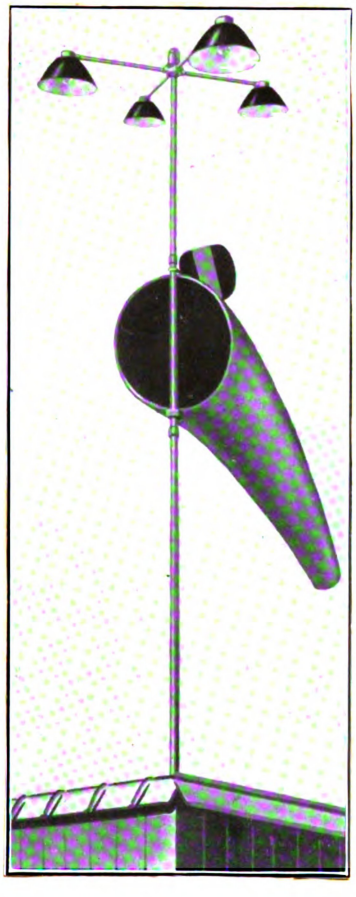
SCENIC AIRWAYS - PHOENIX, ARIZONA



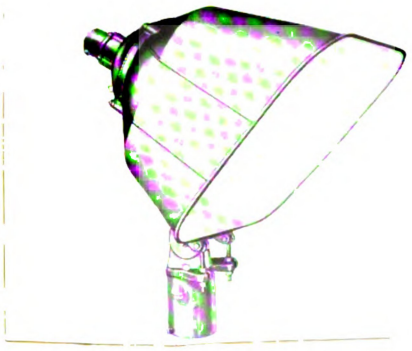
UNITS WHICH FURNISH ILLUMINATION TO THE AIRPORT



MUNICIPAL AIRPORT. UTICA, N.Y.

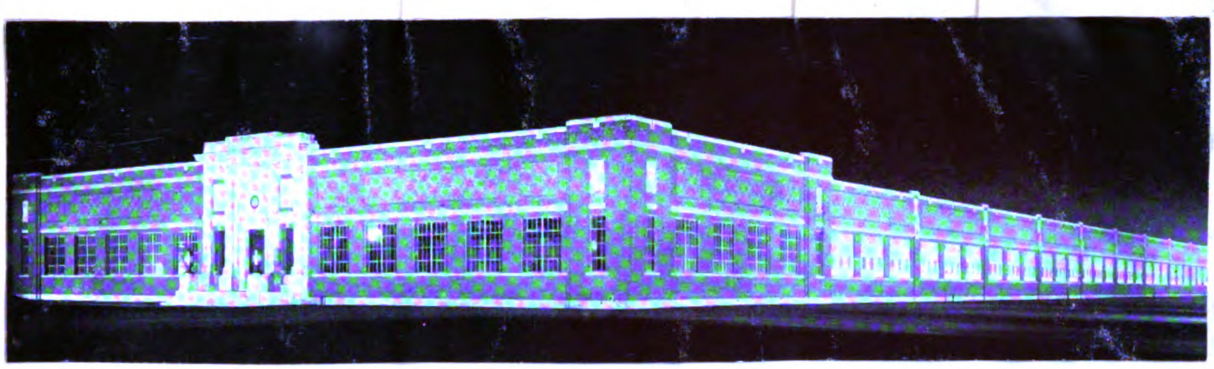


ILLUMINATED HANGAR

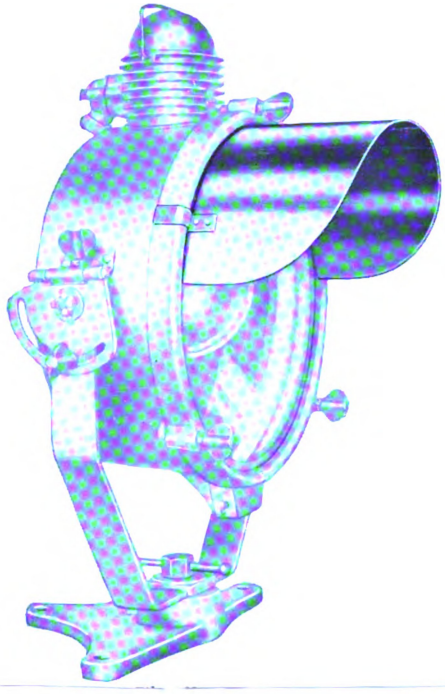


Wind Cone, Illuminated.

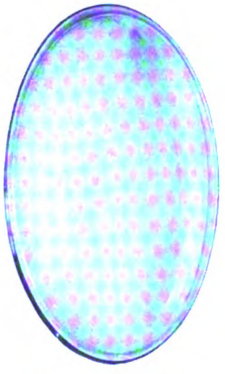
Type MSA-1 unit, a wide angle projector for hanger illumination.



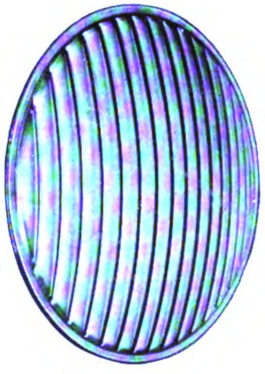
John Warren Watson Co., Philadelphia, Pa.



14" Unit Used.



Plain Curved Lens



Fanlite Lens
Medium Angle

[illegible] Output of Mazda Lamps

110 Volt Standard Lighting Service Lamps

Watts	-	Lumen Output
100		1350
150		2300
200		3200
300		5300
500		9500
750		14000
1000		21000

General Lighting and Floodlight Lamps

Watts	Volts	Bulb	Lumens	Burning Position
200	115	P30	3340	Any
300	115	P35	5370	"
500	115	P40	9650	"
750	115	P52	14550	"
1000	115	P52	20200	"
250	115	G30	3570	Base Down
500	115	G40	8300	" "
400	115	G30	6240	" "
1000	115	G40	17800	" "
1500	115	P52	31050	Any
1500	115	G40	27000	Base Down
1500	32	T24	34500	Field Floodlights
3000	32	GT38	78000	" "
5000	115	G64	130000	" "
10000	115	G80	260000	" "

[illegible] Control [illegible] Lamps

110 Volt Standard Lighting Service Lamps

Watts	-	Lumen Output
100		1750
150		2500
200		3200
300		5300
500		9500
750		14000
1000		21000

General Lighting and Floodlight Lamps

Watts	Volts	Bulb	Lumens	Burning Position
200	115	PS30	3340	Any
300	115	PS35	5370	"
500	115	PS40	9680	"
750	115	PS52	14580	"
1000	115	PS52	20200	"
250	115	G30	3570	Base Down
500	115	G40	8300	" "
400	115	G30	6240	" "
1000	115	G40	17800	" "
1500	115	PS52	31080	Any
1500	115	G40	27000	Base Down
1500	32	T24	34500	Field Floodlights
3000	32	G38	78000	" "
5000	115	G64	130000	" "
10000	115	G80	260000	" "

The foot-candle values given in the following pages correspond to present standards for different classes of industrial operations, offices, stores, etc. They are merely an index to good practice. In most cases, where higher foot-candle values than shown in this table are being used, it is found that the benefits derived more than offset the slightly increased cost. The desirable illumination for any particular installation depends upon actual conditions, such as the accuracy of the operation, the fineness of detail to be observed, the color of the goods worked on or handled, and, in the case of stores, the advertising value resulting from the attractiveness of a well-lighted interior.

TABLE No. 5

Present Standards of Foot-Candles of Illumination for COMMERCIAL INTERIORS

	Foot-Candles Recommended	
	Good Practice	Minimum
Armories:		
Drill Sheds	10	6
Exhibition Halls	12	8
Art Galleries:		
General	5	3
On Paintings	25–100	10
Auditoriums	5	3
Automobile Show Rooms	15	10
Bank:		
Lobby	10	6
Cages and Offices	15	10
Barber Shop	15	10
Base Ball—Indoor Game	15	10
Basket Ball	15	10
Bowling:		
On Alley, Runway and Seats	8	5
On Pins	25	15
Billiards—General	6	4
On Table	25	15
Cars:		
Baggage, Day Coach, Dining, Pullman	8	5
Mail:		
Bag Racks	12	8
Letter Cases	15	10
Storage	6	4
Street Railway and Subway	10	6
Churches:		
Auditorium	3	2
Sunday School Room	8	5
Pulpit or Rostrum	12	8
Art Glass Windows	25–50	15
Club Rooms:		
Lounge	5	3
Reading Room	12	8
Court Rooms	10	6
Dance Halls	6	4
Dental Offices:		
Waiting Room	6	4
Operating Office	12	8
Dental Chair	50	25
Depot—Waiting Room	8	5
Drafting Room	25	15
Elevators:		
Freight and Passenger	6	4
Fire Engine House:		
When Alarm is turned in	8	5
At Other Times	3	2
Garage—Automobiles:		
Storage—Dead	3	2
Live	8	5
Repair Dept. and Washing	15	10
Gymnasiums:		
Main Exercising Floor	12	8
Swimming Pool	8	5
Shower Rooms	6	4
Locker Rooms	6	4
Fencing, Boxing, Wrestling	12	8
Halls, Passageways in Interiors	3	2
Handball	25	15
Hospitals:		
Lobby and Reception Room	6	4
Corridors	3	2
Wards (with local illumination)	5	3
Private Rooms	8	5
Night Illumination	0.2	0.1
Operating Table	100–200	75
Operating Room	15	10
Laboratories	15	10

TABLE No. 5 (Continued)

Present Standards of Foot-Candles of Illumination for COMMERCIAL INTERIORS (Continued)

	Foot-Candles Recommended	
	Good Practice	Minimum
Hotels:		
Lobby	8	5
Dining Room	6	4
Kitchen	10	6
Bed Rooms	8	5
Corridors	3	2
Writing Room	12	8
Library:		
Reading Rooms	12	8
Stack Room	6	4
Lodge Rooms	6	4
Lunch Room	12	8
Market	12	8
Moving Picture Theatre:		
During Intermission	5	3
During Pictures	..	0.1
Museum:		
General	8	5
Special Exhibits	25–100	10
Office Buildings:		
Private and General Offices—		
Close Work	15	10
No Close Work	10	8
File Room	6	4
Vault	6	4
Reception Room	6	4
Post Office:		
Lobby	10	6
Sorting, Mailing, etc	15	10
Storage	10	6
Private and General Offices	15	10
File Room and Vault	6	4
Corridors and Stairways	3	2
Railway:		
Depot—Waiting Room	8	5
Ticket Offices	12	8
Rest Room, Smoking Room	8	5
Baggage Checking Office	12	8
Storage	6	4
Concourse	6	4
Train Platform	4	2
Restaurants	8	5
Racquet	25	15
Schools:		
Auditorium	8	5
Class Rooms, Library and Office	12	8
Corridors and Stairways	5	3
Drawing	25	15
Laboratories	12	8
Manual Training	12	8
Sewing Rooms	25	15
Study Room—Desks and Blackboards	12	8
Skating Rink (Indoor)	8	5
Squash	25	15

	Foot-Candles Recommended	
	Good Practice	Minimum
Show Cases	Two to four times that of store proper	
Show Windows:		
Large Cities—		
Brightly Lighted District	150	100
Secondary Business Locations	75	50
Neighborhood Stores	50	30
Medium Cities—		
Brightly Lighted District	75	50
Neighborhood Stores	50	30
Small Cities and Towns	50	30
Lighting to Reduce Daylight Window Reflections	200–1000	..
Stores—Department and Large Specialty:		
Main Floors	15	10
Other Floors	12	8
Basement Store	15	10
Stores—Medium Size:		
Art	12	8
Automobile Supply	12	8
Bake Shop	12	8
Book	12	8
China	12	8
Cigar	15	10
Clothing	15	10
Confectionery	12	8
Dairy Products	12	8
Decorator	12	8
Drug	15	10
Dry Goods	15	10
Electrical Supply	15	10
Florist	12	8
Furrier	15	10
Grocery	12	8
Haberdashery	15	10
Hardware	12	8
Hat	15	10
Jewelry	15	10
Leather, Handbags and Trunks	12	8
Meat	12	8
Millinery	15	10
Music	12	8
Notions	12	8
Piano	12	8
Shoe	15	10
Sporting Goods	12	8
Tailor	15	10
Tobacco	15	10
Variety Store	15	10
Telephone Exchanges:		
Operating Rooms	8	5
Terminal Rooms	12	8
Cable Vaults	6	4
Tennis (Indoor)	25–50	15
Theatres:		
Auditorium	3	2
Foyer	8	5
Lobby	12	8
Toilet and Washrooms	6	4

TABLE No. 5 (Continued)

Present Standards of Foot-Candles of Illumination for INDUSTRIAL INTERIORS

	Foot-Candles Recommended	
	Good Practice	Minimum
Aisles, Stairways, Passageways	3	2
Assembling:		
Rough	8	5
Medium	12	8
Fine	20	12
Extra Fine	50–100	25
Automobile Manufacturing:		
Automatic Screw Machines	15	10
Assembly Line	15	10
Frame Assembly	12	8
Tool Making	20	12
Body Manufacturing—Assembly, Finishing and Inspecting	50–100	25
Bakeries	12	8
Book Binding:		
Folding, Assembling, Pasting, etc.	8	5
Cutting, Punching and Stitching	12	8
Embossing	15	10
Candy Making	12	8
Canning and Preserving	12	8
Chemical Works:		
Hand Furnaces, Boiling Tanks, Stationary Driers, Stationary or Gravity Crystallizing	5	3
Mechanical Furnaces, Generators and Stills, Mechanical Driers, Evaporators, Filtration, Mechanical Crystallizing, Bleaching	6	4
Tanks for Cooking, Extractors, Percolators, Nitrators, Electrolytic Cells	10	6
Clay Products and Cements:		
Grinding, Filter Presses, Kiln Rooms	5	3
Molding, Pressing, Cleaning and Trimming	8	5
Enameling	10	6
Color and Glazing	15	10
Cloth Products:		
Cutting, Inspecting, Sewing—		
Light Goods	15	10
Dark Goods	50–100	25
Pressing, Cloth Treating (Oil Cloth, etc.)—		
Light Goods	12	8
Dark Goods	20	12
Coal Breaking and Washing, Screening	5	3
Construction—Indoor General	5	3
Dairy Products	12	8
Electric Manufacturing:		
Storage Battery, Molding of Grids, Charging Room	10	6
Coil and Armature Winding, Mica Working, Insulating Processes	20	12
Elevator—Freight and Passenger	8	5
Engraving	50–100	25
Forge Shops and Welding	10	6
Foundries:		
Charging Floor, Tumbling, Cleaning, Pouring and Shaking Out	8	5
Rough Molding and Core Making	10	6
Fine Molding and Core Making	15	10
Garage—Automobiles:		
Storage—Dead	3	2
Live	8	5
Repair Dept. and Washing	15	10
Glass Works:		
Mix and Furnace Rooms, Pressing and Lehr, Glass Blowing Machines	10	6
Grinding, Cutting Glass to Size, Silvering	12	8
Fine Grinding, Polishing, Beveling, Inspection, Etching and Decorating	15	10
Glass Cutting (Cut Glass), Inspecting Fine	25–50	15
Glove Manufacturing:		
Light Goods—		
Cutting, Pressing, Knitting	12	8
Sorting, Stitching, Trimming and Inspecting	15	10
Dark Goods—		
Cutting, Pressing, Knitting	15	10
Sorting, Stitching, Trimming and Inspecting	50–100	25
Hat Manufacturing:		
Dyeing, Stiffening, Braiding, Cleaning and Refining—		
Light	10	6
Dark	15	10
Forming, Sizing, Pouncing, Flanging, Finishing, Ironing—		
Light	12	8
Dark	15	10
Sewing—		
Light	15	10
Dark	50–100	25

TABLE No. 5 (Continued)

Present Standards of Foot-Candles of Illumination for INDUSTRIAL INTERIORS (Continued)

	Foot-Candles Recommended	
	Good Practice	Minimum
Ice Making:		
Engine and Compressor Room	10	6
Inspecting:		
Rough	10	6
Medium	15	10
Fine	25	15
Extra Fine	50–100	25
Polished Surfaces	Usually requires glint reflections from specially located light source	
Jewelry and Watch Manufacturing	50–100	25
Laundries and Dry Cleaning	12	8
Leather Manufacturing:		
Vats	5	3
Cleaning, Tanning and Stretching	6	4
Cutting, Fleshing and Stuffing	10	6
Finishing and Scarfing	15	10
Leather Working:		
Pressing, Winding and Glazing—		
Light	12	8
Dark	15	10
Grading, Matching, Cutting, Scarfing, Sewing—		
Light	15	10
Dark	50–100	25
Locker Rooms	6	4
Machine Shops:		
Rough Bench and Machine Work	10	6
Medium Bench and Machine Work, Ordinary Automatic Machines, Rough Grinding, Medium Buffing and Polishing	15	10
Fine Bench and Machine Work, Fine Automatic Machines, Medium Grinding, Fine Buffing and Polishing	20	12
Extra Fine Bench and Machine Work, Grinding (Fine Work)	50–100	25
Meat Packing:		
Slaughtering	8	5
Cleaning, Cutting, Cooking, Grinding, Canning, Packing	12	8

	Foot-Candles Recommended	
	Good Practice	Minimum
Milling—Grain Foods:		
Cleaning, Grinding and Rolling	8	5
Baking or Roasting	12	8
Flour Grading	25	15
Offices:		
Private and General—		
Close Work	15	10
No Close Work	10	8
Drafting Room	25	15
Packing:		
Crating	6	4
Boxing	10	6
Paint Manufacturing	10	6
Paint Shops:		
Dipping, Spraying, Firing	8	5
Rubbing, Ordinary Hand Painting and Finishing	12	8
Fine Hand Painting and Finishing	15	10
Extra Fine Hand Painting and Finishing (Automobile Bodies, Piano Cases, etc.)	50–100	25
Paper Box Manufacturing:		
Light	10	6
Dark	12	8
Storage of Stock	5	3
Paper Manufacturing:		
Beaters, Machine, Grinding	6	4
Calendering	10	6
Finishing, Cutting and Trimming	12	8
Plating	8	5
Polishing and Burnishing	12	8
Power Plants, Engine Rooms, Boilers:		
Boilers, Coal and Ash Handling, Storage Battery Rooms	5	3
Auxiliary Equipment, Oil Switches and Transformers	8	5
Switchboard, Engines, Generators, Blowers, Compressors	10	6
Printing Industries:		
Matrixing and Casting, Miscellaneous Machines, Presses	12	8
Proof Reading, Lithographing, Electrotyping	15	10
Linotype, Monotype, Typesetting, Imposing Stone, Engraving	50–100	25
Receiving and Shipping	6	4

TABLE No. 5 (Continued)

Present Standards of Foot-Candles of Illumination for INDUSTRIAL INTERIORS (Continued)

	Foot-Candles Recommended	
	Good Practice	Minimum
Rubber Manufacturing and Products:		
Calendars, Compounding Mills, Fabric Preparation, Stock Cutting, Tubing Machines, Solid Tire Operations, Mechanical Goods Building, Vulcanizing	12	8
Bead Building, Pneumatic Tire Building and Finishing, Inner Tube Operation, Mechanical Goods Trimming, Treading	15	10
Sheet Metal Works:		
Miscellaneous Machines, Ordinary Bench Work	12	8
Punches, Presses, Shears, Stamps, Welders, Spinning, Fine Bench Work	15	10
Tin Plate Inspection	25	15
Shoe Manufacturing:		
Hand Turning, Miscellaneous Bench and Machine Work	12	8
Inspecting and Sorting Raw Material, Cutting, Lasting and Welting (Light)	15	10
Inspecting and Sorting Raw Material, Cutting, Stitching (Dark)	50–100	25
Soap Manufacturing:		
Kettle Houses, Cutting, Soap Chip and Powder	8	5
Stamping, Wrapping and Packing, Filling and Packing Soap Powder	10	6
Steel and Iron Mills, Bar, Sheet and Wire Products:		
Soaking Pits and Reheating Furnaces	3	2
Charging and Casting Floors	6	4
Muck and Heavy Rolling, Shearing, rough by gauge, Pickling and Cleaning	8	5
Plate Inspection, Chipping	25	15
Automatic Machines, Red, Light and Cold Rolling, Wire Drawing, Sheering, fine by line	12	8
Stone Crushing and Screening:		
Belt Conveyor Tubes, Main Line Shafting, Spaces, Chute Rooms, Inside of Bins	3	2
Primary Breaker Room, Auxiliary Breakers under Bins	5	3
Screen Rooms	8	5
Store and Stock Rooms:		
Rough bulky material	3	2
Medium or fine material requiring care	8	5
Structural Steel Fabrication	10	6
Sugar Grading	25	15
Testing:		
Rough	8	5
Fine	15	10
Extra Fine Instruments, Scales, etc	50–100	25
Textile Mills:		
(Cotton)— Opening and Lapping, Carding, Drawing-frame, Roving, Dyeing	8	
Spooling, Spinning, Drawing-in, Warping, Weaving, Quilling, Inspecting, Knitting, Slashing (over beam end)	12	8
(Silk)— Winding, Throwing, Dyeing	12	8
Quilling, Warping, Weaving and Finishing— Light Goods	15	10
Dark Goods	20	15
(Woolen)— Carding, Picking, Washing and Combing	6	4
Twisting and Dyeing	10	
Drawing-in, Warping— Light Goods	10	6
Dark Goods	15	10
Weaving— Light Goods	12	8
Dark Goods	20	12
Knitting Machines	15	10
Tobacco Products:		
Drying, Stripping, General	3	2
Grading and Sorting	25	15
Toilet and Wash Rooms	6	4
Upholstering:		
Automobile, Coach and Furniture	15	10
Warehouse	3	2
Woodworking:		
Rough Sawing and Bench Work	8	5
Sizing, Planing, Rough Sanding, Medium Machine and Bench Work, Gluing, Veneering, Cooperage	12	8
Fine Bench and Machine Working, Fine Sanding and Finish	15	

TABLE No. 5 (Continued)

Foot-Candles Illumination for OUTDOOR LIGHTING

These values are included for reference purposes although the special considerations of design are not covered in this bulletin.

	Foot-Candles Recommended	
	Good Practice	Minimum
Automobile Parking Spaces	1	0.5
Baseball Diamond (Indoor Game)	10	9
Basket Ball	6	4
Bathing Beaches	1	0.5
Bulletin and Poster Boards:		
Bright Surroundings—		
Light Surface	30	20
Dark Surface	50	30
Dark Surroundings—		
Light Surface	15	10
Dark Surface	30	20
Boxing:		
Seats	3	2
Ring	80	50
Building:		
Construction Work	6	4
Excavation	2	1
Building Exteriors and Monuments—Floodlighted:		
Bright Surroundings—		
Light Surface	10	6
Dark Surface	20	15
Dark Surroundings—		
Light Surface	6	4
Dark Surface	12	8
Church Windows (Art Glass)	25–50	15
Circus:		
Seats	3	2
Arena	10	6
Clock Golf	10	6
Croquet	6	4
Dredging	2	1
Drill Fields	3	2
Flags—Floodlighted	25–50	15
Football:		
Practice	6	4
Games	12	8

	Foot-Candles Recommended	
	Good Practice	Minimum
Gasoline Filling Stations:		
At Pumps	15	10
Yard and Driveways	4	2
Horseshoe Pitching	6	4
Ice Hockey	8	5
Loading Docks	3	2
Lumber Yards	1	0.5
Motordromes:		
Seating	3	2
Track	15	10
Monuments (See Building Exteriors)		
Piers:		
Freight (See Loading Docks)		
Passenger	4	2
Playgrounds	4	2
Polo	8	5
Prison Yards	3	2
Protective Industrial	1	0.5
Quarries	3	2
Railway Yards:		
General	0.25	0.15
Scale House	3	2
Roque	6	4
Signs—Painted (See Poster Boards)		
Ship Yard Construction	6	4
Skating	2	1
Storage Yards	1	0.5
Swimming Pools	5	3
Target Shooting	20	15
Tennis Court	25–50	15
Toboggan Slides	2	1
Traffic Officers	20	10
Trap Shooting	15	10
Volley Ball	15	10

STREETS AND THOROUGHFARES

	Lamp Lumens per Linear Foot of Street
Business District:	
White Way—Large City	500–2000
Small City	200–500
Park Boulevards	50–100
Thoroughfares and Wholesale Districts	50–200
Residence Streets	20–40
Outlying Districts and Alleys	5–10
Highways	10–20

ROOM EFFICIENCY AND REFLECTOR CHARACTERISTICS

Illumination on Horizontal Surfaces is a prime requisite in offices, drafting rooms and those shops where the problem is to provide the best illumination for sustained vision of flat surfaces on the horizontal or slightly oblique planes in which papers, books and other flat objects are usually examined. For relative performance of various units compare coefficients of utilization for any given condition.

Illumination on Vertical Surfaces is essential in many industrial operations where working surfaces are in vertical or oblique planes. It is likewise important in stores with vertical shelving, rug racks, etc., in art museums, library stock rooms, office file rooms. Without supplementary units, the illumination on vertical surfaces from ordinary general lighting units is of the order of one-half to one-third of the horizontal illumination values.

Appearance of Lighted Room refers only to the general or casual effect produced by the complete system, and is not intended to rate the unit as to satisfaction from the standpoint of good vision or freedom from eye fatigue.

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

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

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

Maintenance Requirements depend upon contour of reflector, construction of fixture, and average maintenance conditions. The rating is based upon the likelihood of breakage, the labor involved in maintaining the units at comparable degrees of efficiency, and indication given of need of cleaning.

TABLE 6

ROOM INDEX FOR NARROW AND AVERAGE ROOMS

For Indirect Lighting Use Ceiling Height		FEET						
		9 and 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30
For Direct Lighting Use Mounting Height		FEET						
		7 and 7½	8 and 8½	9 and 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20
Room Width (Feet)	**Room Length (Feet)**	ROOM INDEX						
9 (8½-9½)	8-10	1.0	0.8	0.6	0.6			
	10-14	1.0	0.8	0.8	0.6			
	14-20	1.2	1.0	0.8	0.6	0.6		
	20-30	1.2	1.2	1.0	0.8	0.6	0.6	
	30-42	1.5	1.2	1.0	0.8	0.6	0.6	0.6
	42-up	2.0	1.5	1.2	1.0	0.8	0.6	0.6
10 (9½-10½)	10-14	1.2	1.0	0.8	0.6	0.6		
	14-20	1.2	1.0	0.8	0.6	0.6	0.6	
	20-30	1.5	1.2	1.0	0.8	0.6	0.6	
	30-42	1.5	1.2	1.2	1.0	0.8	0.6	0.6
	42-60	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	60-up	2.0	1.5	1.5	1.0	1.0	0.8	0.6
12 (11-12½)	10-14	1.2	1.0	0.8	0.8	0.6	0.6	
	14-20	1.5	1.2	1.0	0.8	0.6	0.6	
	20-30	1.5	1.2	1.2	1.0	0.8	0.6	0.6
	30-42	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	42-60	2.0	1.5	1.5	1.2	1.0	0.8	0.6
	60-up	2.0	2.0	1.5	1.2	1.0	0.8	0.6
14 (13-15½)	14-20	1.5	1.2	1.0	1.0	0.8	0.6	0.6
	20-30	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	30-42	2.0	1.5	1.5	1.2	1.0	0.8	0.6
	42-60	2.0	2.0	1.5	1.5	1.0	0.8	0.6
	60-90	2.5	2.0	2.0	1.5	1.2	1.0	0.6
	90-up	2.5	2.0	2.0	1.5	1.5	1.2	0.8
17 (16-18½)	14-20	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	20-30	2.0	1.5	1.5	1.2	1.0	0.8	0.6
	30-42	2.5	2.0	1.5	1.2	1.0	1.0	0.6
	42-60	2.5	2.0	2.0	1.5	1.2	1.2	0.8
	60-110	2.5	2.0	2.0	1.5	1.2	1.2	0.8
	110-up	3.0	2.5	2.0	2.0	1.5	1.2	1.0
20 (19-21½)	20-30	2.5	2.0	1.5	1.2	1.0	0.8	0.6
	30-42	2.5	2.0	2.0	1.5	1.2	1.0	0.8
	42-60	2.5	2.5	2.0	2.0	1.5	1.2	0.8
	60-90	3.0	2.5	2.0	2.0	1.5	1.2	1.0
	90-140	3.0	2.5	2.5	2.0	1.5	1.5	1.0
	140-up	3.0	2.5	2.5	2.0	1.5	1.5	1.0
24 (22-26)	20-30	2.5	2.0	2.0	1.5	1.2	1.0	0.8
	30-42	3.0	2.5	2.0	1.5	1.2	1.2	0.8
	42-60	3.0	2.5	2.5	2.0	1.5	1.2	1.0
	60-90	3.0	2.5	2.5	2.0	1.5	1.5	1.0
	90-140	3.0	3.0	2.5	2.0	2.0	1.5	1.2
	140-up	3.0	3.0	2.5	2.0	2.0	1.5	1.2
30 (27-33)	30-42	3.0	2.5	2.5	2.0	1.5	1.2	1.0
	42-60	3.0	3.0	2.5	2.5	1.5	1.5	1.0
	60-90	4.0	3.0	3.0	2.5	2.0	1.5	1.2
	90-140	4.0	3.0	3.0	2.5	2.0	2.0	1.5
	140-180	4.0	3.0	3.0	2.5	2.0	2.0	1.5
	180-up	4.0	3.0	3.0	2.5	2.0	2.0	1.5
36 (34-39)	30-42	4.0	3.0	2.5	2.0	1.5	1.5	1.0
	42-60	4.0	3.0	3.0	2.5	2.0	1.5	1.2
	60-90	5.0	3.0	3.0	3.0	2.0	2.0	1.5
	90-140	5.0	4.0	3.0	3.0	2.5	2.0	1.5
	140-200	5.0	4.0	3.0	3.0	2.5	2.0	1.5
	200-up	5.0	4.0	3.0	3.0	2.5	2.0	1.5
40 or more	42-60	5.0	4.0	3.0	These values are given on the opposite page			
	60-90	5.0	4.0	4.0				
	90-140	5.0	4.0	4.0				
	140-200	5.0	5.0	4.0				
	200-up	5.0	5.0	4.0				

TABLE 6

ROOM INDEX FOR LARGE HIGH ROOMS

For Indirect Lighting / Use Ceiling Height		FEET							
		14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50		
For Direct Lighting / Use Mounting Height		FEET							
		10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50
Room Width (Feet)	**Room Length (Feet)**	ROOM INDEX							
14 (13-15½)	14-20	1.0	0.8	0.6	0.6				
	20-30	1.0	0.8	0.6	0.6				
	30-42	1.2	1.0	0.8	0.6	0.6			
	42-60	1.5	1.0	0.8	0.6	0.6	0.6		
	60-90	1.5	1.2	1.0	0.6	0.6	0.6		
	90-up	1.5	1.5	1.2	0.8	0.6	0.6		
17 (16-18½)	14-20	1.0	0.8	0.6	0.6				
	20-30	1.2	1.0	0.8	0.6				
	30-42	1.2	1.0	1.0	0.6	0.6	0.6		
	42-60	1.5	1.2	1.2	0.8	0.6	0.6	0.6	
	60-110	1.5	1.2	1.2	0.8	0.6	0.6	0.6	
	110-up	2.0	1.5	1.2	1.0	0.8	0.6	0.6	
20 (19-21½)	20-30	1.2	1.0	0.8	0.6	0.6			
	30-42	1.5	1.2	1.0	0.8	0.6	0.6		
	42-60	2.0	1.5	1.2	0.8	0.6	0.6	0.6	
	60-90	2.0	1.5	1.2	1.0	0.6	0.6	0.6	
	90-140	2.0	1.5	1.5	1.0	0.8	0.8	0.6	0.6
	140-up	2.0	1.5	1.5	1.0	1.0	0.8	0.6	0.6
24 (22-26)	20-30	1.5	1.2	1.0	0.8	0.6	0.6		
	30-42	1.5	1.2	1.2	0.8	0.6	0.6		
	42-60	2.0	1.5	1.2	1.0	0.8	0.6	0.6	
	60-90	2.0	1.5	1.5	1.0	0.8	0.6	0.6	0.6
	90-140	2.0	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	140-up	2.0	2.0	1.5	1.2	1.0	0.8	0.8	0.6
30 (27-33)	30-42	2.0	1.5	1.2	1.0	0.8	0.6	0.6	
	42-60	2.5	1.5	1.5	1.0	1.0	0.8	0.6	
	60-90	2.5	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	90-140	2.5	2.0	2.0	1.5	1.2	1.0	0.8	0.6
	140-180	2.5	2.0	2.0	1.5	1.2	1.0	0.8	0.6
	180-up	2.5	2.0	2.0	1.5	1.2	1.0	0.8	0.6
36 (34-39)	30-42	2.0	1.5	1.5	1.0	0.8	0.8	0.6	
	42-60	2.5	2.0	1.5	1.2	1.0	0.8	0.6	0.6
	60-90	3.0	2.0	2.0	1.5	1.0	1.0	0.6	0.6
	90-140	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6
	140-200	3.0	2.5	2.0	1.5	1.5	1.2	1.0	0.8
	200-up	3.0	2.5	2.0	1.5	1.5	1.2	1.0	0.8
42 (40-45)	42-60	3.0	2.0	1.5	1.2	1.0	0.8	0.8	0.6
	60-90	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6
	90-140	3.0	2.5	2.5	2.0	1.5	1.2	1.0	0.6
	140-200	3.0	2.5	2.5	2.0	1.5	1.2	1.0	0.8
	200-up	3.0	2.5	2.5	2.0	1.5	1.5	1.2	0.8
50 (46-55)	42-60	3.0	2.5	2.0	1.5	1.2	1.0	0.8	0.6
	60-90	3.0	3.0	2.5	1.5	1.5	1.2	1.0	0.6
	90-140	3.0	3.0	2.5	2.0	1.5	1.5	1.2	0.8
	140-200	3.0	3.0	2.5	2.0	2.0	1.5	1.2	0.8
	200-up	3.0	3.0	2.5	2.0	2.0	1.5	1.2	1.0
60 (56-67)	60-90	4.0	3.0	2.5	2.0	1.5	1.2	1.0	0.8
	90-140	4.0	3.0	3.0	2.5	2.0	1.5	1.2	1.0
	140-200	4.0	3.0	3.0	2.5	2.0	1.5	1.5	1.0
	200-up	4.0	3.0	3.0	2.5	2.0	2.0	1.5	1.0
75 (68-90)	60-90	5.0	4.0	3.0	2.5	2.0	1.5	1.2	0.8
	90-140	5.0	4.0	3.0	2.5	2.0	1.5	1.5	1.0
	140-200	5.0	4.0	4.0	3.0	2.5	2.0	1.5	1.2
	200-up	5.0	4.0	4.0	3.0	2.5	2.0	1.5	1.2
90 or more	60-90	5.0	4.0	3.0	2.5	2.0	1.5	1.2	1.0
	90-140	5.0	5.0	4.0	3.0	2.5	2.0	1.5	1.2
	140-200	5.0	5.0	4.0	3.0	2.5	2.0	1.5	1.2
	200-up	5.0	5.0	4.0	3.0	3.0	2.5	2.0	1.5

TABLE No. 7
A GUIDE TO THE SELECTION OF REFLECTING EQUIPMENT

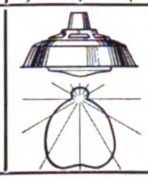
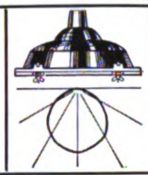
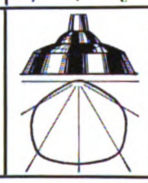
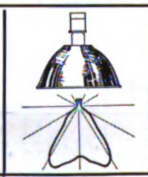
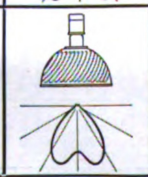
LIGHTING UNIT		RELATIVE FOOT-CANDLES FOR A GIVEN LAMP SIZE		APPEARANCE OF LIGHTED ROOM	DIRECT GLARE	REFLECTED GLARE	SHADOWS	MAINTENANCE
		On Horizontal	On Vertical					
Direct Lighting—General Industrial Reflectors								
1 **RLM** White Bowl Lamp 90° to 180°—0% 0° to 90°—66%		A Excellent	B Good	B Good	B+ Very Good	B Good	B+ Very Good	A− Very Good
2 **Glassteel Diffuser** Clear Lamp 90° to 180°—7% 0° to 90°—60%		A− Very Good	B Good	A− Very Good	A− Very Good	B+ Very Good	A Excellent	B Good
Special RLM Applications								
3 **RLM Dome Dust-tight Cover** 90° to 180°—0% 0° to 90°—54%		B Good	B− Very Fair	B Good	B Good	B− Very Fair	B+ Very Good	A+ Excellent
4 **RLM Dome** Clear Lamp 90° to 180°—0% 0° to 90°—76%		A+ Excellent	B+ Very Good	C+ Very Fair	C Satisfactory above 20-foot mounting Height	D Unsatisfactory above Polished Surfaces	C+ Very Fair	A+ Excellent
Industrial Reflectors for High Narrow Bays								
5 **Concentrated Prismatic Reflector Aluminum Cover** Clear Lamp 90° to 180°—5% 0° to 90°—72%		A+ Excellent	B Good	B Good	C+ Very Fair	D Unsatisfactory above Polished Surfaces	C Fair	A Excellent
6 **Mirrored Glass Reflector** Clear Lamp 90° to 180°—3% 0° to 90°—73%		A+ Excellent	B Good	B Good	C+ Very Fair	D Unsatisfactory above Polished Surfaces	C Fair	A Excellent
7 **Oxidized Aluminum Reflector** Clear Lamp 90° to 180°—0% 0° to 90°—72%		A+ Excellent	B Good	B Good	C Very Fair	D Unsatisfactory above Polished Surfaces	C+ Fair	A− Very Good

TABLE No. 7

AND COEFFICIENTS OF UTILIZATION

PROBABLE AVERAGE ILLUMINATION—AS FRACTION OF INITIAL ILLUMINATION			CEILING	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
			WALLS	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
Clean Conditions	Average Conditions	Dirty Conditions	ROOM INDEX	COEFFICIENTS OF UTILIZATION							
Calculation Data—General Units											
.80	.75	.65	0.6	.32	.28	.25	.32	.28	.25	.27	.25
			0.8	.40	.36	.34	.39	.35	.33	.35	.33
			1.0	.43	.39	.37	.42	.39	.37	.39	.37
			1.2	.46	.43	.41	.45	.43	.41	.43	.41
			1.5	.48	.45	.43	.47	.45	.43	.45	.43
			2.0	.52	.50	.48	.51	.49	.47	.49	.47
			2.5	.56	.54	.52	.55	.53	.51	.53	.51
			3.0	.57	.55	.53	.56	.54	.52	.54	.52
			4.0	.60	.58	.56	.59	.57	.55	.57	.55
			5.0	.61	.59	.57	.60	.58	.57	.58	.56
.75	.70	.60	0.6	.29	.25	.21	.28	.24	.21	.23	.21
			0.8	.36	.32	.29	.35	.31	.28	.31	.28
			1.0	.39	.36	.33	.38	.35	.33	.34	.32
			1.2	.42	.39	.36	.41	.38	.36	.37	.35
			1.5	.45	.42	.39	.43	.40	.38	.39	.38
			2.0	.49	.46	.43	.48	.45	.43	.44	.42
			2.5	.53	.50	.47	.51	.49	.47	.47	.46
			3.0	.54	.52	.49	.52	.50	.49	.49	.47
			4.0	.57	.55	.53	.55	.53	.51	.51	.50
			5.0	.58	.56	.54	.56	.54	.53	.52	.51
Calculation Data—RLM Special Service											
.80	.75	.70	0.6	.29	.26	.24	.28	.26	.24	.26	.24
			0.8	.35	.32	.31	.34	.32	.31	.32	.30
			1.0	.37	.36	.35	.37	.35	.34	.35	.34
			1.2	.40	.38	.37	.39	.38	.37	.37	.37
			1.5	.42	.41	.38	.41	.39	.38	.39	.38
			2.0	.44	.43	.41	.44	.43	.41	.42	.41
			2.5	.48	.45	.44	.46	.45	.44	.44	.44
			3.0	.49	.47	.45	.48	.46	.45	.45	.44
			4.0	.50	.48	.48	.49	.47	.46	.46	.46
			5.0	.52	.49	.48	.50	.48	.47	.48	.46
.80	.75	.70	0.6	.34	.29	.24	.34	.29	.24	.28	.24
			0.8	.42	.38	.34	.42	.37	.33	.37	.33
			1.0	.46	.43	.39	.45	.42	.39	.42	.39
			1.2	.50	.47	.43	.49	.46	.43	.45	.42
			1.5	.53	.50	.46	.52	.49	.46	.48	.45
			2.0	.58	.55	.51	.57	.54	.51	.53	.51
			2.5	.62	.59	.56	.61	.58	.56	.58	.56
			3.0	.64	.61	.58	.63	.60	.58	.60	.58
			4.0	.67	.65	.63	.66	.64	.62	.63	.61
			5.0	.69	.67	.65	.67	.66	.64	.65	.63
Calculation Data—High Bay Units											
.80	.75	.65	0.6	.42	.39	.38	.41	.39	.38	.40	.37
			0.8	.50	.48	.47	.49	.47	.46	.47	.45
			1.0	.54	.53	.52	.53	.52	.51	.51	.50
			1.2	.58	.57	.56	.56	.55	.54	.54	.53
			1.5	.61	.59	.57	.58	.57	.56	.57	.55
			2.0	.63	.62	.60	.62	.61	.59	.59	.58
			2.5	.67	.64	.63	.65	.63	.62	.62	.61
			3.0	.68	.67	.64	.66	.65	.63	.63	.62
			4.0	.69	.68	.67	.67	.66	.65	.64	.63
			5.0	.72	.69	.68	.68	.67	.66	.65	.64
.80	.70	.60	0.6	.42	.40	.39	.42	.40	.39	.41	.38
			0.8	.51	.49	.48	.49	.48	.47	.48	.46
			1.0	.55	.54	.53	.54	.53	.52	.52	.51
			1.2	.59	.58	.57	.57	.56	.55	.55	.54
			1.5	.61	.60	.58	.59	.58	.57	.58	.56
			2.0	.64	.63	.61	.62	.61	.60	.61	.59
			2.5	.68	.65	.64	.65	.64	.63	.63	.62
			3.0	.69	.67	.65	.67	.65	.64	.64	.63
			4.0	.70	.69	.68	.68	.66	.65	.65	.64
			5.0	.72	.70	.69	.69	.67	.66	.66	.65
.80	.70	.60	0.6	.41	.39	.37	.40	.39	.37	.40	.37
			0.8	.49	.47	.47	.48	.47	.46	.47	.44
			1.0	.52	.52	.51	.52	.51	.50	.51	.50
			1.2	.55	.54	.54	.54	.54	.52	.54	.52
			1.5	.59	.57	.56	.57	.56	.55	.56	.54
			2.0	.61	.60	.59	.60	.60	.58	.59	.57
			2.5	.65	.63	.62	.63	.62	.61	.61	.60
			3.0	.66	.65	.63	.64	.63	.62	.62	.61
			4.0	.67	.65	.65	.65	.64	.63	.63	.62
			5.0	.69	.67	.65	.66	.65	.64	.64	.63

TABLE No. 7 (Continued)

A GUIDE TO THE SELECTION OF REFLECTING EQUIPMENT

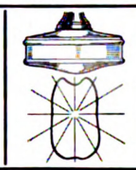
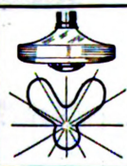
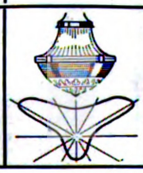
LIGHTING UNIT		RELATIVE FOOT-CANDLES FOR A GIVEN LAMP SIZE		APPEARANCE OF LIGHTED ROOM	DIRECT GLARE	REFLECTED GLARE	SHADOWS	MAINTENANCE
		On Horizontal	On Vertical					
Store and General Utility Enclosing Units								
8 Flattened White Glass Enclosing Globe 90° to 180°—35% 0° to 90°—45%		B+ Very Good	B+ Very Good	A Excellent	B Good	B+ Very Good	A− Very Good	B+ Very Good
9 Prismatic Glass Enclosing Unit 90° to 180°—27% 0° to 90°—53%		A− Very Good	B+ Very Good	A Excellent	B Good	B− Very Fair	B Good	B Good
Enclosed Semi-Indirect Lighting Units								
10 Enclosed Semi-Indirect Enameled Bottom Etched Top Skeleton Glass Holder 90° to 180°—50% 0° to 90°—27%		B− Very Fair	B− Very Fair	A Excellent	A− Very Good	B+ Very Good	A− Very Good	B Good
11 Enclosed Semi-Indirect Enameled Bottom Etched Top 90° to 180°—48% 0° to 90°—32%		B Good	B− Very Fair	A Excellent	A− Very Good	B+ Very Good	A− Very Good	B Good
12 Enclosed Semi-Indirect Enameled Bottom Etched Top (Close Ceiling Only) 90° to 180°—53% 0° to 90°—22%		B− Very Fair	C+ Very Fair	A Excellent	A Excellent	A− Very Good	A Excellent	B Good
13 Enclosed Semi-Indirect Cased-Glass Bottom Etched Top 90° to 180°—51% 0° to 90°—21%		C+ Very Fair	C+ Very Fair	A Excellent	A Excellent	A Excellent	A Excellent	B− Very Fair
14 Enclosed Semi-Indirect Prismatic Glass 90° to 180°—69% 0° to 90°—17%		B− Very Fair	C+ Very Fair	A Excellent	A Excellent	A Excellent	A Excellent	B Good

TABLE No. 7 (Continued)
AND COEFFICIENTS OF UTILIZATION

PROBABLE AVERAGE ILLUMINATION—AS FRACTION OF INITIAL ILLUMINATION			CEILING	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
			WALLS	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
Clean Condition	Average Condition	Dirty* Condition	ROOM INDEX	COEFFICIENTS OF UTILIZATION							
Calculation Data—Enclosing Units											
.80	.75	.65	0.6	.22	.17	.14	.20	.16	.13	.14	.12
			0.8	.27	.22	.19	.25	.21	.18	.19	.17
			1.0	.31	.26	.23	.28	.24	.21	.22	.19
			1.2	.35	.30	.26	.31	.27	.24	.25	.22
			1.5	.38	.33	.29	.34	.30	.27	.27	.24
			2.0	.42	.38	.33	.38	.34	.31	.31	.28
			2.5	.46	.41	.37	.41	.37	.34	.34	.31
			3.0	.49	.45	.40	.43	.39	.36	.36	.33
			4.0	.53	.48	.44	.47	.43	.40	.38	.36
			5.0	.55	.51	.47	.49	.45	.42	.40	.38
.80	.70	.60	0.6	.28	.22	.18	.26	.21	.17	.19	.16
			0.8	.35	.29	.25	.33	.28	.24	.26	.23
			1.0	.38	.33	.29	.36	.32	.28	.30	.27
			1.2	.43	.37	.33	.40	.35	.31	.33	.30
			1.5	.46	.41	.36	.43	.38	.34	.35	.33
			2.0	.51	.46	.42	.47	.43	.40	.40	.38
			2.5	.55	.51	.46	.51	.47	.44	.44	.42
			3.0	.58	.54	.50	.54	.50	.47	.46	.44
			4.0	.62	.58	.55	.57	.54	.51	.50	.48
			5.0	.65	.61	.57	.60	.56	.53	.52	.50
Calculation Data—Semi-Indirect and Indirect Units											
.75	.70	. . .	0.6	.17	.13	.10	.14	.11	.09	.08	.07
			0.8	.21	.17	.14	.18	.14	.12	.12	.10
			1.0	.24	.20	.17	.21	.17	.15	.14	.12
			1.2	.28	.23	.20	.23	.19	.17	.16	.14
			1.5	.31	.26	.23	.26	.22	.19	.18	.16
			2.0	.35	.30	.27	.29	.25	.22	.20	.18
			2.5	.38	.34	.30	.32	.28	.25	.23	.20
			3.0	.41	.37	.33	.34	.30	.27	.25	.22
			4.0	.45	.41	.37	.37	.34	.31	.27	.25
			5.0	.47	.43	.40	.39	.36	.33	.29	.27
.75	.70	. . .	0.6	.19	.14	.11	.16	.12	.10	.10	.08
			0.8	.24	.19	.16	.21	.16	.14	.14	.12
			1.0	.27	.22	.19	.23	.19	.17	.16	.14
			1.2	.30	.25	.22	.26	.22	.19	.18	.16
			1.5	.34	.29	.25	.29	.25	.22	.20	.18
			2.0	.38	.33	.29	.32	.28	.25	.23	.21
			2.5	.41	.37	.33	.35	.32	.28	.26	.24
			3.0	.44	.40	.36	.38	.34	.31	.28	.26
			4.0	.49	.44	.40	.41	.37	.35	.31	.29
			5.0	.51	.47	.43	.43	.39	.37	.33	.31
.75	.70	. . .	0.6	.18	.14	.11	.15	.12	.10	.09	.08
			0.8	.22	.18	.16	.19	.15	.13	.12	.11
			1.0	.25	.21	.19	.21	.18	.16	.15	.12
			1.2	.28	.24	.21	.24	.20	.18	.16	.14
			1.5	.31	.27	.24	.26	.22	.20	.18	.16
			2.0	.35	.31	.28	.29	.26	.23	.20	.19
			2.5	.38	.34	.31	.31	.29	.26	.23	.21
			3.0	.40	.37	.34	.33	.31	.28	.24	.22
			4.0	.44	.41	.38	.36	.34	.32	.26	.25
			5.0	.46	.43	.40	.38	.35	.33	.28	.26
.75	.65	. . .	0.6	.16	.12	.10	.13	.10	.08	.08	.07
			0.8	.20	.16	.14	.17	.14	.11	.11	.09
			1.0	.23	.19	.17	.19	.16	.14	.13	.11
			1.2	.26	.22	.19	.22	.18	.16	.14	.13
			1.5	.29	.25	.21	.24	.20	.19	.16	.14
			2.0	.32	.28	.25	.27	.23	.21	.18	.17
			2.5	.35	.31	.28	.29	.26	.24	.20	.19
			3.0	.38	.34	.31	.31	.28	.26	.22	.21
			4.0	.41	.38	.35	.34	.31	.29	.24	.23
			5.0	.43	.39	.37	.36	.33	.31	.26	.24
.75	.70	. . .	0.6	.18	.14	.11	.14	.11	.09	.07	.06
			0.8	.22	.18	.15	.18	.14	.12	.10	.09
			1.0	.25	.21	.18	.20	.17	.14	.12	.10
			1.2	.29	.24	.21	.23	.19	.17	.14	.12
			1.5	.33	.28	.24	.26	.22	.19	.16	.14
			2.0	.36	.32	.28	.29	.25	.22	.18	.16
			2.5	.40	.35	.32	.31	.28	.25	.20	.18
			3.0	.43	.38	.35	.33	.30	.27	.22	.20
			4.0	.47	.43	.39	.37	.34	.31	.24	.23
			5.0	.49	.45	.42	.39	.36	.33	.26	.24

* Semi-indirect and indirect units unsuitable under very dirty conditions or where ceiling and sidewalls are very dark colored.

TABLE No. 7 (Continued)
A GUIDE TO THE SELECTION OF REFLECTING EQUIPMENT

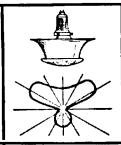
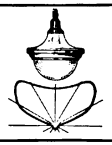
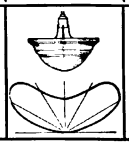
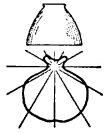
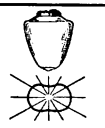
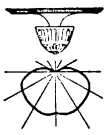
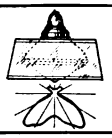
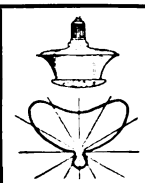
LIGHTING UNIT		RELATIVE FOOT-CANDLES FOR A GIVEN LAMP SIZE		APPEARANCE OF LIGHTED ROOM	DIRECT GLARE	REFLECTED GLARE	SHADOWS	MAINTENANCE
		On Horizontal	On Vertical					
Semi-Indirect and Indirect Lighting Units								
15 Open Semi-Indirect Enameled Deflector Medium Density Glass Bottom Plate 90° to 180°—54% 0° to 90°—18%		B− Very Fair	C Fair	A Excellent	A− Very Good	B+ Very Good	A− Very Good	C Fair
16 Enclosed Luminous Bowl Indirect 90° to 180°—64% 0° to 90°—6%		C+ Very Fair	C Fair	A Excellent	A+ Excellent	A+ Excellent	A Excellent	B− Very Fair
17 Open Indirect 90° to 180°—80% 0° to 90°—0%		C+ Very Fair	C Fair	B+ Very Good	A+ Excellent	A+ Excellent	A+ Excellent	C Fair
SPECIAL UNITS FOR COMMERCIAL INTERIORS								
18 Dense White Glass Reflector Frosted Lamp 90° to 180°—12% 0° to 90°—70%		Recommended in sizes of 100 watts and below. In larger sizes, glare and shadows make the open type unit less satisfactory than totally enclosing white units. Its principal application is in such locations as small rooms, closets, stock bin aisles, and other places of occasional use where low wattage lamps are suitable. Coefficients of Utilization average about the same as for Unit No. 9.						
19 Round and Stalactite Globes 90° to 180°—38% 0° to 90°—42%		Units of this type merely diffuse the light and do not appreciably improve the distribution of light as obtained from a bare lamp. Flattened units like No. 8 distribute light more efficiently downward and are usually to be preferred. Stalactite and spherical globes are, however, applicable in waiting rooms, banks and other interiors including certain stores where little importance is attached to the efficient distribution of light. Coefficients of Utilization about 10% lower than values given for Unit No. 8.						
20 Large Opaque Reflector Open Diffusing Bowl 90° to 180°—13% 0° to 90°—60%		The diffusing qualities in both the bowl and the large diameter reflector render the unit low in brightness with corresponding freedom from glare and sharp shadows. From the standpoint of dirt collection it retains the disadvantage of the open bowl. This unit is applicable for close ceiling mounting, permitting a wider spacing between units often desirable in large stores; it serves well in interiors where indirect lighting is preferred but impractical because of unfavorable ceiling finish. Coefficients of Utilization slightly higher than those given for Unit No. 8.						
21 Enclosing Unit Large Decorative Shade 90° to 180°—21% 0° to 90°—56%		Paper, parchment, silk, or other material may often be effectively used as shades in connection with enclosed opal glass or prismatic units. Such shades not only add an element of decoration, lending themselves to a variety of designs or stencils, but they are also effective in reducing the candlepower and brightness in the direction of the eye, with slight loss in efficiency. Very suitable in exclusive stores and certain millinery or clothing sections of department stores. Shades can be added to existing fixtures. Coefficients of Utilization a little lower than those for Unit No. 8.						

TABLE No. 7 (Continued)
AND COEFFICIENT OF UTILIZATION

PROBABLE AVERAGE ILLUMINATION—AS FRACTION OF INITIAL ILLUMINATION			CEILING	VERY LIGHT (70%)			FAIRLY LIGHT (50%)			FAIRLY DARK (30%)	
			WALLS	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY LIGHT (50%)	FAIRLY DARK (30%)	VERY DARK (10%)	FAIRLY DARK (30%)	VERY DARK (10%)
Clean Condition	Average Condition	Dirty* Condition	ROOM INDEX	COEFFICIENTS OF UTILIZATION							
.70	.60	...	0.6	.18	.15	.13	.15	.12	.10	.10	.08
			0.8	.22	.19	.17	.19	.16	.14	.13	.11
			1.0	.25	.22	.20	.21	.18	.16	.15	.13
			1.2	.28	.25	.22	.24	.21	.19	.16	.15
			1.5	.31	.27	.24	.26	.22	.21	.17	.16
			2.0	.34	.31	.28	.28	.25	.24	.20	.19
			2.5	.37	.34	.32	.30	.28	.26	.22	.21
			3.0	.39	.36	.34	.32	.29	.28	.23	.22
			4.0	.43	.40	.37	.34	.32	.31	.25	.24
			5.0	.44	.41	.40	.36	.34	.32	.26	.25
.75	.65	...	0.6	.14	.11	.10	.11	.09	.07	.06	.05
			0.8	.18	.14	.13	.14	.11	.10	.07	.06
			1.0	.20	.17	.15	.15	.13	.11	.09	.07
			1.2	.23	.20	.17	.18	.15	.13	.10	.09
			1.5	.26	.22	.19	.20	.17	.15	.11	.10
			2.0	.29	.26	.23	.22	.19	.17	.13	.12
			2.5	.31	.28	.26	.24	.21	.20	.14	.13
			3.0	.34	.31	.28	.25	.23	.21	.15	.14
			4.0	.37	.34	.32	.27	.26	.24	.17	.16
			5.0	.39	.36	.34	.30	.27	.26	.18	.17
.70	.60	...	0.6	.15	.12	.10	.11	.09	.07	.05	.04
			0.8	.18	.15	.13	.13	.11	.09	.07	.06
			1.0	.22	.19	.16	.15	.13	.11	.08	.07
			1.2	.25	.22	.19	.18	.15	.13	.09	.08
			1.5	.27	.24	.21	.20	.17	.15	.10	.09
			2.0	.30	.27	.25	.22	.19	.17	.11	.10
			2.5	.34	.31	.28	.24	.22	.20	.13	.12
			3.0	.36	.33	.30	.26	.24	.22	.14	.13
			4.0	.40	.37	.34	.28	.26	.24	.15	.14
			5.0	.42	.39	.37	.30	.28	.26	.17	.15

SPECIAL UNITS FOR COMMERCIAL INTERIORS

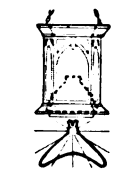
22
Enclosed Semi-Indirect Enameled Deflector tched Glass Top
90° to 180°—48%
0° to 90°—10%



Units of this design have the same character of distribution as open types, with cover plate serving to exclude the dust and dirt from the lamp and reflecting surfaces of the unit. They have the decided advantage from the standpoint of cleaning accompanied, however, by considerable sacrifice in the total light output of the unit.

Coefficients of Utilization about 20% less than open top units of the same design.

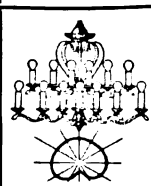
23
Ornamental Lantern Art Glass Panels Diffusing Bottom Plate Internal Reflector
90° to 180°—8%
0° to 90°—40%



Lanterns of period designs to conform architecturally to interiors, are frequently used in public buildings, notably churches. Reflectors inside of the ornamental housing increase the lighting efficiency and if made of glass may be made to transmit varying amounts of light to illuminate the side panels. Subject to a variety of design in which distribution ranges from direct to totally indirect lighting.

Coefficients of Utilization for the type of unit illustrated will average about two-thirds of the values given for Unit No 2.

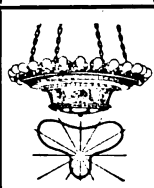
24
Multiple Light Clusters
Small Frosted Lamps



Multi-light clusters are in favor as decorative elements in public buildings and other monumental interiors. When mounted high with a large number of low wattage lamps, the result is not unsatisfactory. However, when mounted low, the uncontrolled distribution of light and the glare from the unshielded sources, spoils what would otherwise be an artistic effect.

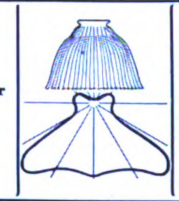
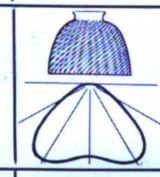
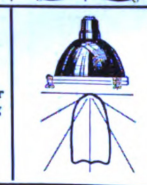
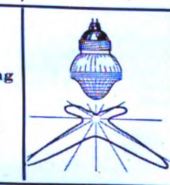
Lighting efficiency about 50% lower than same wattage in single lamp unit.

25
Large Main Unit
Small Decorative Lamps



The application of shades to multi-light units will, in many instances, raise the over-all effectiveness of the installation. On the other hand, the illuminating qualities of large decoration designs can be materially improved if the decorative lamp clusters are built around a central large-lamp unit either of the indirect type or of dense enclosing glassware. A combination of this sort offers a greater flexibility in control of lighting effects, and, in most cases, will allow the illumination level to be raised by the use of a larger lamp in the main unit at any time if the occasion requires.

TABLE No. 7 (Continued)
SPECIAL PURPOSE INDUSTRIAL UNITS

26 **Deep Bowl Enameled Steel Clear Lamp** 90° to 180°—0% 0° to 90°—65%		Generally inferior to RLM Dome with because of lower efficiency, sharp shadows, when used above shiny surfaces. Contra impression the light at any angle from a deep is generally less than that from the RLM S Coefficients of Utilization average abou those given for Unit No. 4.
27 **Prismatic Reflector** Clear Lamp 90° to 180°—20% 0° to 90°—74%		Highly efficient reflector which, by mod can be made to give extensive, broad, or nar tion characteristics. With clear lamps it is sharp shadows and reflected glare, and these handicaps to a more general use of this type o at usual mounting heights. White-bowl positioned, help these factors, although thei some extent, accurate control of light distr the efficiency. Coefficients of Utilization about 15% l given for Unit No. 9.
28 **Mirrored Glass Reflector** Clear Lamp 90° to 180°—0% 0° to 90°—69%		This unit like all deep-bowl types has a la to protect against direct glare; it likewise has in that it does not protect against reflected avoid sharp shadows when used with clear l white-bowl lamps lowers the efficiency of the due to the light being bottled up in the general, are not recommended. Coefficients of Utilization are about 10% given for Unit No. 4.
29 **Concentrating Aluminum Reflector Dust-tight Housing** 90° to 180°—0% 0° to 90°—57%		This unit has an aluminum reflector insi housing. The reflector insert gives a concent and a consequent higher utilization factor interiors than would be the case with Unit efficiency, compared to Unit No. 7, limits the to locations where excessive dirt and smoke pr Coefficients of Utilization average about those given for Unit No. 7.
30 **Vapor-proof Fitting Enameled Steel Reflector with Glass Enclosing Globe** 90° to 180°—0% 0° to 90°—68%		Designed for locations where corrosive va gases, or explosive dusts are likely to be moisture laden atmospheres such as canning rooms, shower baths; also where gases and processes as oil refining, varnish making, spray and the like are present, units of this chara mended. See also Unit No. 31. Coefficients of Utilization about 10 to for an open reflector.
31 **Vapor-proof Fitting Prismatic Enclosing Globe** 90° to 180°—28% 0° to 90°—57%		Applications same as for Unit No. 30; th is usually not subject to corrosive action obtainable in a variety of metals and compositi corrosion from acid vapors of chemical plants, also in grain elevators, spice, flour and feed mi facture of powdered sugar, cornstarch, sulph explosive dusts are present. Coefficients of Utilization about the same a
32 **Angle Reflector Enameled Steel** Output 74%		Often used in craneways mounted below cra ment general overhead system in building up lateral surfaces. Used also to light individual processes demand special distribution or dir Special care must be taken in locating units to general, they should be placed high.
33 **Local Lighting Unit Substantial Reflector and Holder Cover Plate** Output 45-55%		To supplement general lighting where op high levels of illumination of the order of 50 to where general lighting of at least 10 foot-cand Local lamps are subject to much handling and glass cover plates are recommended to pro surface from grease and dirt; construction must reflectors should not be supported by socket s 25 to 60-watt inside frosted lamps will ge the level of illumination required.

Continued)

DUSTRIAL UNITS

y inferior to RLM Dome with white-bowl lamp
ower efficiency, sharp shadows, and reflected glar
above shiny surfaces. Contrary to a comm
the light at any angle from a deep bowl steel reflect
less than that from the RLM Standard Dome.

ients of Utilization average about 15% lower tha
en for Unit No. 4.

y efficient reflector which, by modification in desig
ade to give extensive, broad, or narrow light distribu
acteristics. With clear lamps it is difficult to avoi
adows and reflected glare, and these factors are seriou
ps to a more general use of this type of unit, particularly
al mounting heights. White-bowl lamps, properly
ed help these factors, although their use sacrifices a
xtent, accurate control of light distribution as well a
ciency.

efficients of Utilization about 15% higher than thos
for Unit No. 9.

his unit like all deep-bowl types has a large shielding angle
tect against direct glare; it likewise has the disadvantage
t it does not protect against reflected glare nor does it
sharp shadows when used with clear lamps. The use of
-bowl lamps lowers the efficiency of the unit about 20%,
o the light being bottled up in the reflector, and, a
al, are not recommended.

efficients of Utilization are about 10% lower than thos
for Unit No. 4.

his unit has an aluminum reflector inside of a dust tight
ng. The reflector insert gives a concentrated distribution
a consequent higher utilization factor in high narrow
iors than would be the case with Unit No. 3. Its lower
iency, compared to Unit No. 7, limits the use of this unit
ocations where excessive dirt and smoke prevail.

Coefficients of Utilization average about 20% lower than
ose given for Unit No. 7.

Designed for locations where corrosive vapor, inflammable
ses, or explosive dusts are likely to be encountered. In
isture laden atmospheres such as canning processes, engine
oms, shower baths; also where gases and vapors from such
ocesses as oil refining, varnish making, spray lacquer painting
d the like are present, units of this character are recom-
nded. See also Unit No. 31.

Coefficients of Utilization about 10 to 15% lower than
an open reflector.

pplications same as for Unit No. 30; the glass reflector
ually not subject to corrosive action and holders are
nable in a variety of metals and compositions to withstand
sion from acid vapors of chemical plants. Recommended
grain elevators, spice, flour and feed mills, in the manu-
e of powdered sugar, cornstarch, sulphur, etc., where
ve dusts are present.

efficients of Utilization about the same as for Unit No. 9.

used in craneways mounted below cranerail to supple-
neral overhead system in building up illumination on
rfaces. Used also to light individual machines where
demand special distribution or direction of light.
re must be taken in locating units to avoid glare; in
hey should be placed high.

plement general lighting where operations require
of illumination of the order of 50 to 100 foot-candles
ral lighting of at least 10 foot-candles is provided.
s are subject to much handling and for this reason
plates are recommended to protect reflecting
n grease and dirt; construction must be substantial;
hould not be supported by socket shell.

)-watt inside frosted lamps will generally provide
illumination required.

COLOR QUALITY—APPLICATION OF ARTIFICIAL DAYLIGHT

A few years ago discussions of artificial daylight were centered about units built on theoretical lines and of somewhat uncertain performance. Today, good practical units are being marketed and consequently the field for such units has broadened beyond the original conception of limited applications in stores and textile industries.

The duplication of natural daylight is confined largely to those industrial and commercial applications involving accurate color discrimination or color rendition in varying degree, depending upon the specific requirements. Even in this field difficulties arise because the colorist has been accustomed, perhaps through years of habit, to a specific daylight quality peculiar to his location. It is practical and expedient, however, to provide exact reproductions of daylight for any given requirement with the attendant advantage of constancy and 24-hour availability.

Although color quality is accurately specified by color temperature designations, equipments for reproducing daylight for working purposes may be grouped roughly into (1) skylight units, (2) sunlight units, and (3) units which provide a whiter light than the common types of general lighting equipment, but not so white as those listed under (1) and (2).

34

Skylight Quality

Special Color Filter

Clear Lamp

Equipments of this character employ accurately correcting filters by means of which it is possible to duplicate the color of outdoor daylight. Generally designed for *localized* lighting over counters in stores, for small areas or special operations in industrial plants where precision in color identification, grading, and other color inspection is required. Illumination of the order of 100 foot-candles is desirable for this sort of work.

Color factories, paint and dye mixing, art studios, chemical analysis, dental mechanics, surgery, textile and cigar sorting and grading are examples suggesting the application of skylight reproducing equipment.

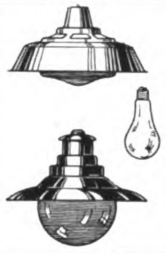
As compared to unmodified artificial light, from 6 to 8 times the wattage is required for the same foot-candle values.

35

Sunlight Quality

Reflector and Color Correcting Globe

Clear Lamp



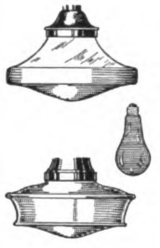
Enclosing globes of special crystal blue glass frosted on the inside modify the light from a lamp to approximate the color of direct sunlight at noon. Their applications are to some extent the same as skylight units, the actual choice depending on specific requirements; in general, noon sunlight equipment is used for less exacting color discrimination. For example, ink and dye mixing, and inspection may be done locally under skylight quality, and a general system of noon sunlight equipment may be installed in certain rooms or over small areas restricted to manufacturing operations requiring clear color rendition—such, for example, as lithographing processes, color printing and the like.

As compared to unmodified artificial light, from 2 to 3 times the wattage is required for the same foot-candle values.

36

Ordinary Equipment

Blue Bulb Daylight Lamps



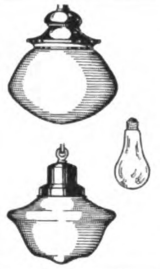
Lamps with blue bulbs, commercially known as MAZDA "Daylight" lamps, emit a whiter light which is but a partial step toward daylight whiteness. In many instances of color rendition, their use gives sufficient color correction to be of considerable advantage over the warmer tones of unmodified light. For example, they are widely used in stores and show windows to improve the display of merchandise. Again the light blends well with natural daylight; in fact in many cases it is about the same color as the daylight which one gets indoors taking into account the prevalence of warm tones in window shades, walls and hangings; for this reason the use of daylight lamps in offices and many other places will be found to correct an unsatisfactory mixture of ordinary artificial light and inadequate daylight.

The next larger size of lamp will be required to produce approximately the foot-candle level as computed for a clear lamp of a given size. They are used in all common types of equipment.

37

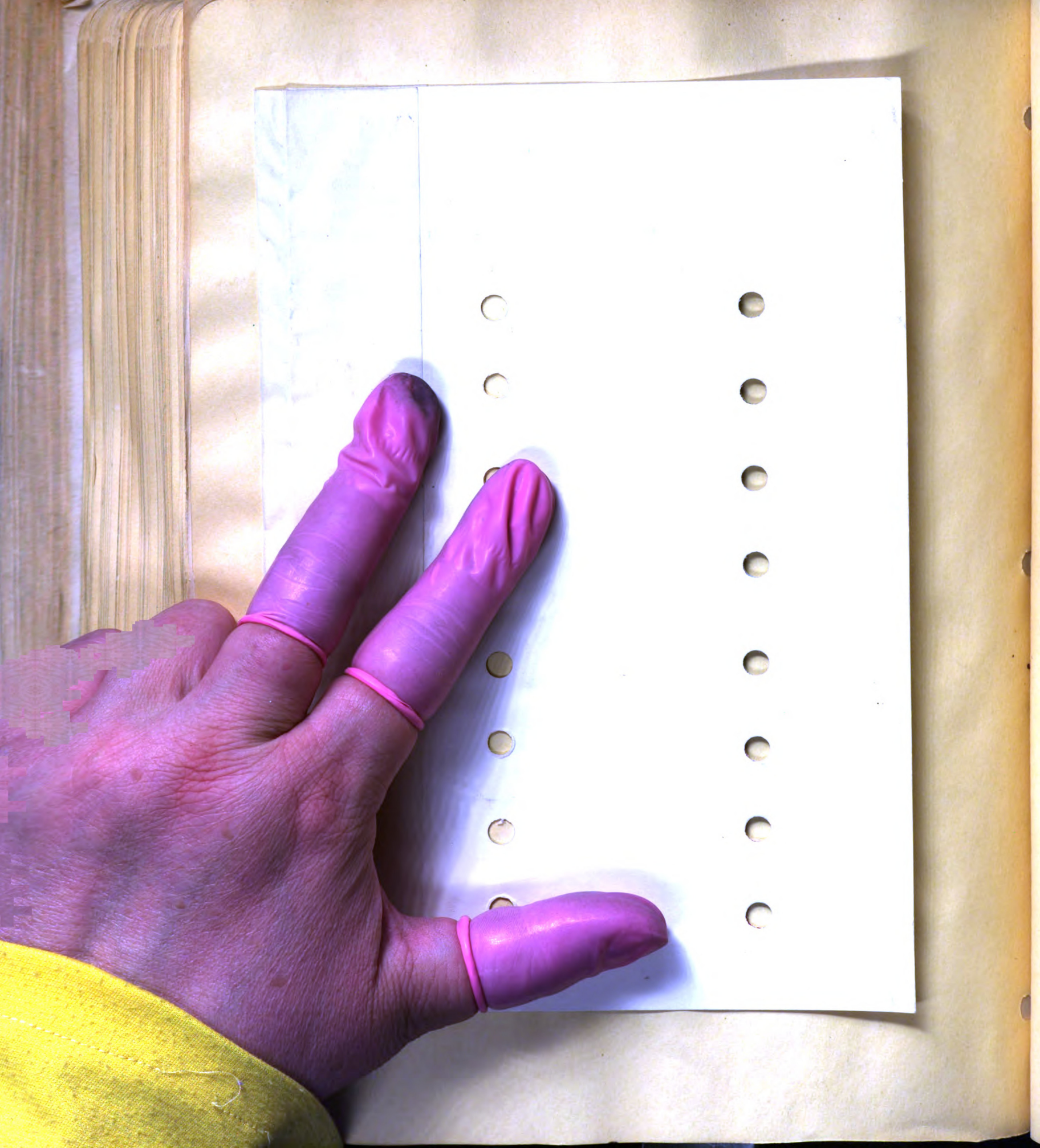
Color Modifying Globes

Clear Lamp



Enclosing globes with slight bluish ingredient do not appreciably modify the color quality of illumination for utilitarian purposes, but have a considerable field of application by virtue of their whiter appearance. Such equipment is correct for the yellowish tone usually noticeable with ordinary opal glassware. These usually give far less color correction than MAZDA Daylight lamps. The units are very pleasing, appear white and clean, and are often more satisfactory than units of yellowish tone, particularly when supplementing natural daylight. The spectral quality of illumination is usually not far from that of a clear bulb MAZDA C lamp.

Coefficients of Utilization will be about 10% to 30% less than the values given for Unit No. 8.



Reflection Factors

The proportion of light reflected by walls and ceilings of various colors, that is, their Reflection Factors, has an important bearing on both the natural and the artificial lighting. The proportion reflected will depend somewhat upon the color of the incident light. The figures here given show what proportion of

No. 1
White
Paper
80%

No. 9
Ivory
White
80%

No. 2
Gray
70%

No. 10
Caen
Stone
78%

No. 3
Gray
60%

No. 11
Ivory
71%

No. 4
Gray
56%

No. 12
Ivory
Tan
63%

No. 5
Gray
44%

No. 13
Primrose
78%

No. 6
French
Gray
40%

No. 14
Lichen
Gray
63%

No. 7
Gray
28%

No. 15
Pearl
Gray
72%

No. 8
Gray
19%

No. 16
Silver Gray
and Caen
Stone
52%

# of Colored Surfaces

the light of MAZDA lamps these painted surfaces reflect. Reflection Factors are of special 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 colored surface can be approximated by comparing it with these samples.

No. 17
Buff Stone
and Pale
Azure
39%

No. 25
Forest
Green
20%

No. 18
Buff
64%

No. 26
Olive
Green
21%

No. 19
Buff Stone
41%

No. 27
Pale Azure
and White
55%

No. 20
Tan
35%

No. 28
Pale Azure
40%

No. 21
Cocoanut
Brown
19%

No. 29
Sky Blue
37%

No. 22
Satin
Green
56%

No. 30
Shell Pink
54%

No. 23
Bright Sage
and Ivory
Tan
48%

No. 31
Pink
52%

No. 24
Bright Sage
41%

No. 32
Cardinal
Red
20%

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