COYNE
Electrical School
CHICAGO ~~ ILLINOIS

ESTABLISHED 1899

ILLUMINATION

Incandescent Lamps, Nature of Light
Illumination Principles, Light Measurement
Reflectors, Light Distribution
Factory Lighting, Office Lighting
Store Lighting
Show Windows, Electric Signs
Flood Lighting, Street Lighting
Aviation Lighting
Mercury Vapor Lamps
Home Lighting

ILLUMINATION

The history of artificial light is a very interesting one, and is almost romantic in many ways.

In a practical Reference Set of this kind we have not much time or space for detailed history, but a few of the high spots in the development of artificial lighting will probably make the study of our present lighting equipment much more interesting, and enable us to more fully appreciate the equipment itself.

Mankind has been trying to create better forms of artificial light for many hundreds of years. Not being satisfied with the daylight hours given them by the sun, men have tried by a number of means to create light, in order to be able to see during the hours of darkness and to make better use of some of this time.

Probably the first artificial lights were burning wood fagots carried about in the hands. Then came the first oil lamps for burning vegetable oils and whale oil from a vessel; and later the lamps with cloth wicks for burning kerosene.

These kerosene lamps are still used by the thousands where electricity is not yet available. But even on farms and in small villages kerosene lamps are rapidly giving way to electric lighting.

Wax and tallow candles were also a popular form of light for many years. Chandeliers, or candle holders, with large numbers of candles in them were used to get a greater source of light for large rooms and auditoriums.

However, all of these sources of light were inclined to flicker and give off smoke and fumes, and were very inconvenient.

141. EARLY ELECTRIC LIGHTS

Up to the time of the development of electric batteries and generators, and less than one hundred years ago, there were no very powerful or steady sources of artificial light.

Electric arcs or flames drawn between two carbon electrodes were one of the first types of electric light, and while they were not entirely steady or free from smoke, they were able to produce great amounts of very bright light.

The first arc lamp to be used commercially was one installed in the Dungeness light house in England in 1862, and from this time on arc lights came into quite general use for lighting interiors of large buildings and for street lighting.

Powerful arc lights of a highly improved type are used today for search lights, flood lights, and in motion picture work; while many of the older types are still in use in street-lighting systems.

142. EDISON'S INCANDESCENT LAMP

From 1840 on a number of experiments were made with incandescent lamps, or the heating of high resistance metal or carbon strips to a glowing temperature by passing electric current through them. But none of these were successful or practical until Thomas A. Edison invented the carbon filament incandescent lamp in 1879, or just a little over fifty years ago.

Edison's first lamps consisted of very thin filaments of carbonized thread, then paper, and later bamboo; all sealed in glass bulbs from which the air was removed by vacuum pumps, to eliminate oxygen and prevent the filament from burning up.

Later lamps of this type were developed with thin metal wire filaments, and the modern incandescent lamp has a tungsten filament, which can be heated to temperatures of 2800 to 3000 degrees centigrade before it will melt. This enables it to operate at glowing white or incandescent heat and give

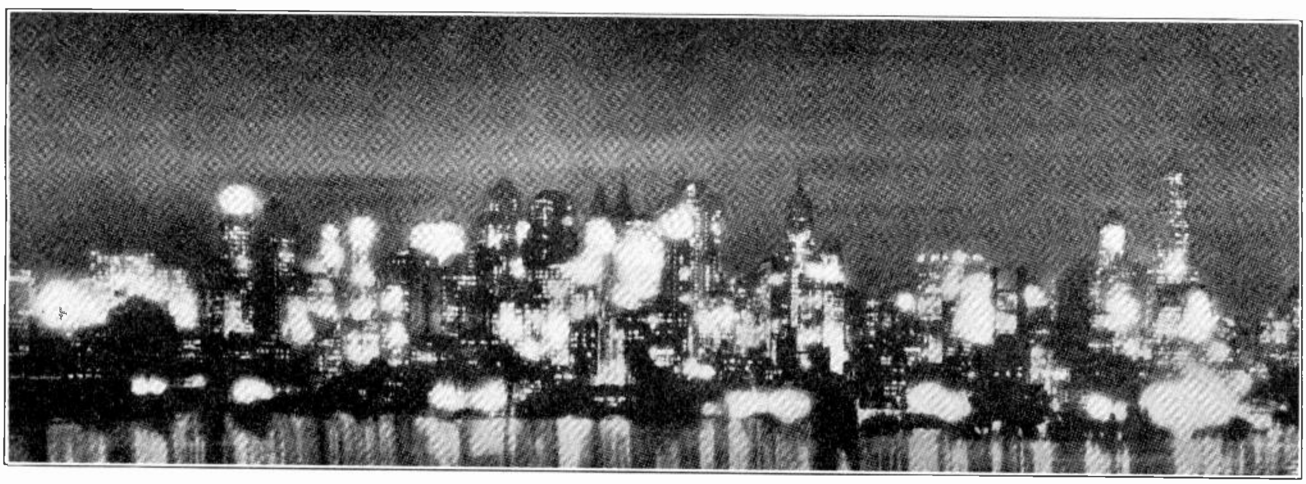


Fig. 152-B This night photograph of the business section of one of our large cities is a good illustration of the extensive use of electric light. A single one of these large buildings will use many thousands of electric lamps.

off great amounts of clean steady light of a nearly white color.

Edison also developed the first efficient electric generators to supply current for his lamps, and in 1882 built in New York City the first central station generating plant for supplying electricity for light and power. From that time on the development of electric lighting has been rapid, and today modern electric illumination is one of the greatest advantages of our civilization, and one of the greatest fields for the trained electrical man to enter.

143. USES AND ADVANTAGES OF ELECTRIC LIGHT

Electric light in the home greatly improves the appearance, increases comfort, speeds the work of the houswife, and reduces eye strain and makes it a pleasure for members of the family to read or study during evening hours. And the cost of electric light is low enough to be within the means of almost every family today. It is cleaner, safer and more convenient than any other form of artificial light we have.

In shops and factories, electric light speeds up production and improves its quality, increases safety and generally improves the morale of employees.

In stores, hotels, and office buildings electric illumination is used on a vast scale and makes the rooms as bright at night as at noon, and whether they have outside windows or not.

The outsides of buildings in cities are beautifully flood lighted and streets are lighted brightly with electric lamps; and now great airplane landing fields have their special lighting equipment which makes them nearly as bright at night as during the day.

Practically every new building erected in any town or city is wired for electric lights, and many older buildings which have not had lights are rapidly being wired for them today.

Thousands of homes, offices, and industrial plants with the older wiring systems are being rewired for modern and efficient electric illumination.

Almost everyone today realizes the value of better lighting; and its advantages and economics are so apparent, when properly presented, that this is one of the greatest fields of opportunity for the trained electrical man who knows the principles of modern illumination.

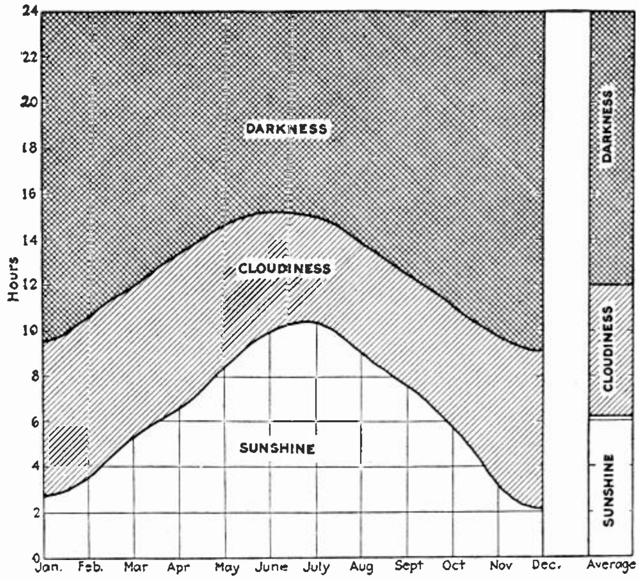
This field also provides some of the most fascinating and enjoyable work for any branch of the electrical profession.

144. NATURE OF LIGHT

In commencing our study of practical illumination, it will be well to get a general understanding of the nature of light.

Light is energy in wave form, and can be transmitted through space and through certain transparent objects. When these waves strike our eyes, they register through our eye nerves and upon our brain cells an impression which we call light. We are familiar with sound waves and how they are set up by disturbance or motion of air and transmitted by vibration through air, water, and some solids. We also know that electro magnetic waves are set up around conductors carrying electricity. In the case of radio energy, these waves are of very high frequency and short wave length. Light waves are considered to be of an electro-magnetic nature, and are known to be of extremely high frequency and much shorter wave length than the shortest radio waves.

Light is generally the result of intense heat, and the sun is, of course, our greatest source of light.



This chart shows how little actual daylight we have over a considerable period of the year

Fig. 152-C. Examine this chart carefully and note the number of hours per day that daylight is available, and you will see how necessary some form of efficient illumination becomes, in order to make good use of the hours of darkness.

145. LIGHT COLORS, WAVE FREQUENCIES

The different colors of light are due to the different wave frequencies. Ordinary sunlight, while it appears white, is really made up of a number of colors. In fact, it is composed of all the colors of the rainbow, and a rainbow is caused by the breaking up or separation of the various frequency waves of sunlight by the mist or drops of water in the air at such times.

White light or daylight is generally the most desirable form for illumination purposes, but it must contain certain of the colors which compose sunlight, as it is the reflection of these various colors from the things they strike to our eyes that enables us to see objects and get impressions of their color. Certain surfaces and materials absorb light of one color and frequency, and reflect that of another color; and this gives us our color distinction in seeing different things.

White and light colored surfaces reflect more light than dark surfaces do.

The ordinary incandescent lamp supplies a good form of nearly white light that is excellent for most classes of work, but for color matching and certain other jobs requiring close separation of colors, a light of more nearly daylight color is needed. For this work lamps are made with blue glass bulbs to supply more of the blue and white light rays, and less of the yellow and red rays of the ordinary electric light bulb. More on the units and measurement of light will be covered later.

146. PRINCIPLES OF GOOD LIGHTING

To secure good lighting, or effective illumination, we must not only **have sufficient light of the proper color,** but **must also avoid glare and shadows.**

No matter how much light we may have, if there are sources of bright glare in range of the eyes, or definite black shadows from standing or moving objects, it is still not good illumination.

Glare is very tiring to the human eye and we all know that if we look directly at the sun or a bright unshaded light bulb, it is painful to the eyes.

The pupils of our eyes must change their openings or adjust themselves to different intensities of light, and as they do not do this instantly, we cannot see things well when we first look away from a bright light to objects or spaces less brightly lighted.

The same thing applies with shadows which cause dark areas intermixed with the light ones. The eyes cannot change rapidly enough to see well or be comfortable when they must be continually moving from light to shadow, etc.

Glare and shadow are both caused by the same thing in general, or very bright sources of light concentrated in small spots, or a "point source" of light, as we say.

The more the light from a source is concentrated at one point, the brighter will be the glare if we look at this point, and the more distinct will be the shadows of objects illuminated by this source.

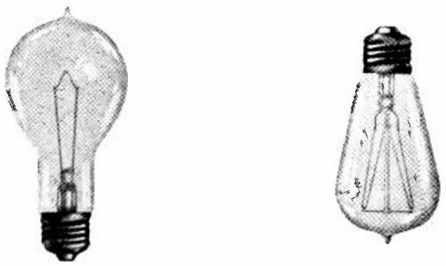


Fig. 153. Two common types of incandescent lamps of which there are many millions in use today.

147. REFLECTORS

While the incandescent lamp is a wonderful, clean, efficient, and convenient source of light, those of the larger sizes are bad sources of glare if they are down within the normal range of vision. This can be avoided by the use of proper shades and reflectors.

Because these lamps have their light produced at one small source, the filament, they are also producers of very definite shadows, unless they are covered with diffusing globes to soften and spread out their light over a greater area.

Reflectors, shades, and diffusing globes for the various classes of lighting installations will be covered a little later.

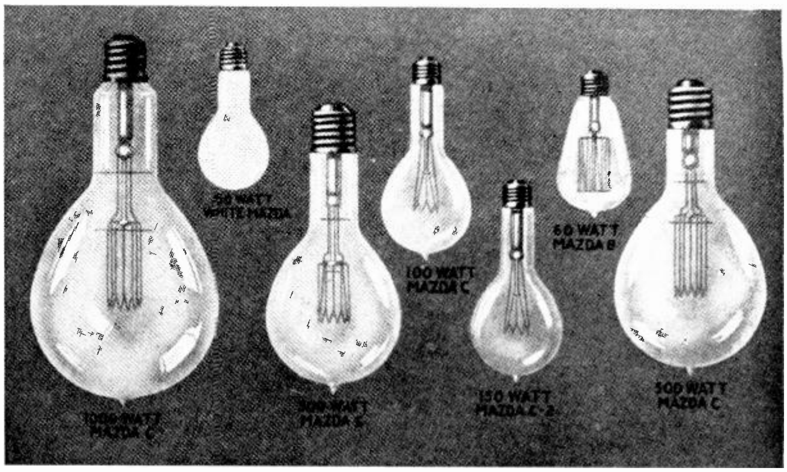


Fig. 154. This view shows various types and sizes of Mazda lamps, ranging from 50 to 1000 watts each.

148. TYPES OF INCANDESCENT LAMPS

Now that we know something of the nature of light and the most important fundamentals of good illumination, let us return to our common source of electric light, the incandescent lamp.

These lamps are now made in sizes from 10 watts to 50,000 watts each, and will fit practically every conceivable lighting need. Lamps smaller than 10 watts are also made, for automobiles, flashlights, etc.

Carbon filament lamps are not used much any more, although they can still be obtained for certain uses where they are desired.

The tungsten filament lamp, which is commonly known as the **Mazda Lamp,** is the one most generally used.

Two of these lamps are shown in Fig. 153. The one on the right is one of the smaller size, which are still used and have the same shaped bulb as the carbon lamps, and are known as type "B". The one on the left is one of the larger sized lamps with the newer shaped bulb, called the type "C".

Fig. 154 shows a number of bulbs of different shapes and sizes, such as are commonly used in general lighting today.

One of the newest styles of lamps is the type "A", which are made in sizes from 15 to 100 watts and are frosted on the inside of the bulb. This is a very great improvement as it softens the light and reduces glare without materially reducing their efficiency. These new bulbs have stronger filaments, and present a beautiful pearl-colored appearance. They are ideal for use where reflectors or bowls are not used over them. Fig. 155 shows four of these type "A" lamps of the more common sizes for home and general lighting use.

The larger Mazda lamps of 150 watts and over are usually made with clear glass bulbs and known as the type "C". As these larger lamps are generally enclosed in diffusing bowls or mounted high up and out of range of ordinary vision, their clear glass bulbs are not objectionable. Fig. 156 shows two of these type "C" lamps, and you will note that they have long necks to keep the heat of the filament farther away from the base and sockets. Some of the larger ones even have a mica heat barrier in the neck, as shown in the right-hand lamp in Fig. 156.

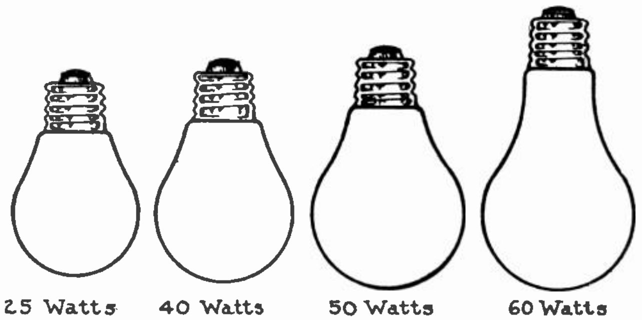


Fig. 155. These four lamps are the sizes most commonly used in general lighting, and show the shape of the newer type bulbs.

The smaller sized lamps have the air withdrawn from the bulbs before they are sealed, so the filaments operate in a vacuum to prevent their burning up, as before mentioned. The larger sizes are filled with an inert gas, such as nitrogen, to keep the filaments from burning up and also to keep the intense heat away from the glass bulb and permit the lamps to be operated at higher temperatures.

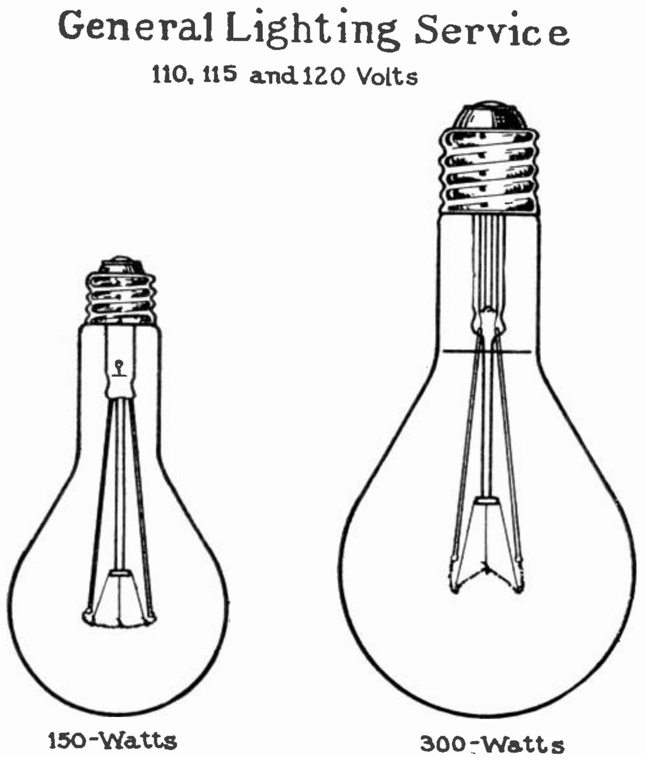


Fig. 156. Two of the larger Mazda lamps, such as used for office and factory lighting. Note the shape of the filament wires and the manner in which they are attached to the heavy "lead-in" wires, and supported by small brace wires.

Fig. 157 shows several types of special bulbs for decorative lights in homes, hotels, theatres, etc. The bulb on the left is an ordinary type "A" in shape, but can be obtained with orange or other colored glass, to give a soft colored light. The others are known as "flame tip" bulbs for candle type fixtures.

The blue glass lamps for producing the "daylight color" for color matching etc., are called the "C-2" type. While this color is very desirable in department stores, art studios, dye plants, etc., the yellower light of a clear bulb would be more desirable in foundries or forging shops, as rays of this color will penetrate a dusty, smoky atmosphere better.

Lamps of 500 watts, 1000 watts, and up are generally used for street lights, flood-lights, motion picture photography, lighting airplane landing fields, etc.

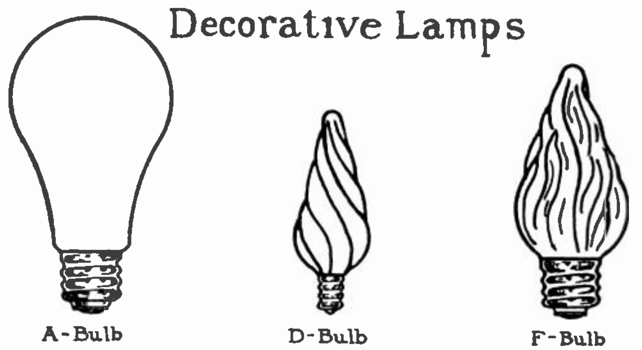


Fig. 157. Lamps of the above type are used for decorative lighting in homes, offices, theaters, etc. The type "A" lamp on the left has the ordinary shaped bulb but can be obtained in various colors.

149. LAMP LIFE AND RATED VOLTAGES

The life of the average Mazda lamp is about 1000 hours of burning time. Many of them will last much longer, as shown by the test data in Fig. 158, but others burn less time and, therefore, make about 1000 hours the average. After lamps have been operated a long time, their light output becomes less until in some cases it is better to discard them than to wait for them to burn out.

Hours Burned	0	200	400	600	800	1000	1200	1400	1600	1800
Number lamps remaining.	100	97	94	89	77	60	39	17	3	0

Fig. 158. These figures, taken from an actual test on 100 lamps, show the life in hours, or the number of hours which the various lamps burned.

These lamps are commonly made for voltages of 110, 115, and 120; and some are made for 220, 240, and various other voltages. The 110 volt lamp is, however, the most common type. These various voltage ratings are obtained by slight changes in the filament resistance of the lamps.

150. EFFECT OF VOLTAGE ON LIFE AND EFFICIENCY OF LAMPS

Incandescent lamps should always be operated at their rated voltage. If they are operated on lower voltages they will not give nearly as much light or be as efficient in the amount of light produced per watt of energy consumed. If they are operated at voltages above their rating, they will burn very bright and operate at higher efficiency, but the life of the filament will be materially shortened. So the best balance between efficiency and lamp life is obtained by operating lamps at their rated voltages. A small change in voltage will make a considerable change in the lamp's efficiency and life, as shown by the table in Fig. 159 for lamps operated 5% below rated voltage. The term "Lumen" is the name of the unit used to measure light delivered by the lamp, and will be explained later.

For Lamps operated at 5% below normal voltage

Lumens will be	17% below normal
Watts " "	8% " "
Efficiency " "	10% " "
Lamp Life " "	Double

Fig. 159. This little table shows how important it is to have incandescent lamps operated at their proper rated voltage.

Fig. 160 shows another illustration of the changes that take place in the watts used and the light produced at different voltages below normal. This test data also shows the amount of electric energy in watts which is wasted when the lamp is operated at lower voltage and lower efficiency.

151. UNITS OF LIGHT MEASUREMENT

Now, before we undertake to plan illumination layouts or select equipment for certain applications,

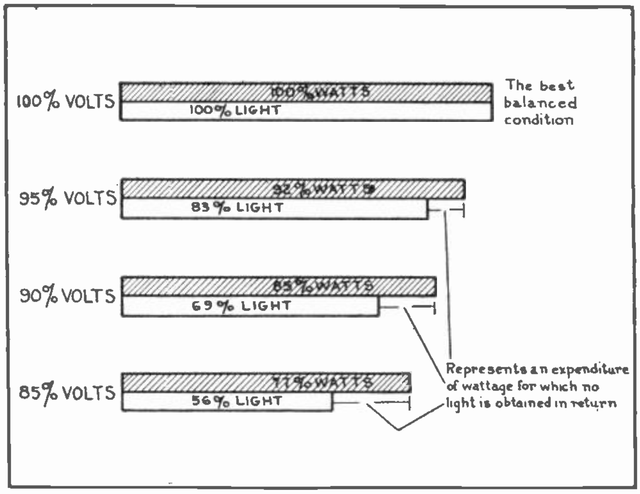


Fig. 160. This chart shows the actual amount of light lost and energy wasted when lamps are operated at less than their rated voltage.

let us find out a little more about actual quantities of light, units of measurement, etc. An understanding of these units and principles is just as important in illumination as Ohms Law is in general electrical work; and you will find them very interesting, as they show us still more about the nature of light.

We have been speaking of incandescent lamp sizes and their rating in watts, which is a very convenient term for general use and for buying lamps, etc. While the rating in watts will give us a general idea of the sizes of the lamps, it does not tell us just how much light a certain lamp can be expected to produce.

152. CANDLE POWER AND LIGHT MEASURING DEVICES

Lamps were formerly rated in **Candle Power**, using a standard candle as a basis of comparison.

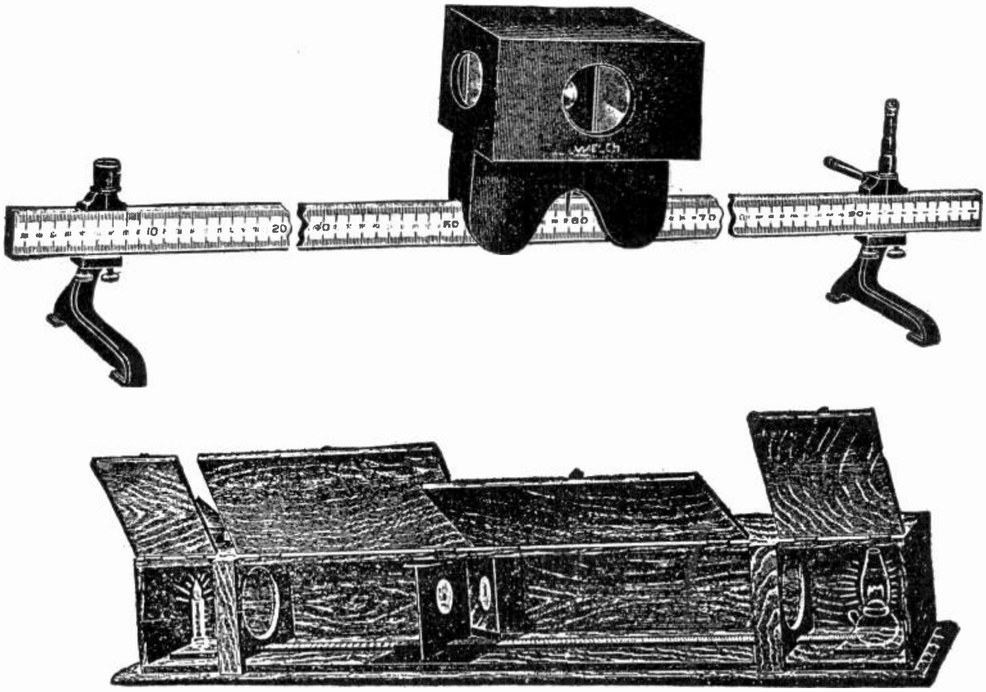


Fig. 161. Two types of photometers, such as used for measuring the light from any source by comparing it with that from a standard source. The readings are obtained from the scales at the point where the light from each source is balanced on the mirror or waxed paper, whichever may be used in the sliding element.

For measuring the candle power of a certain lamp or comparing it with the standard candle, we use a device called a **Photometer.** In principle this device works as follows: A piece of white paper, having in its center a spot which is oiled or greased to make it more transparent than the rest, is held up between the standard candle and the light source to be measured. Let us assume that we first place it exactly half way between them. We will now examine the oiled spot from the side on which our lamp under test is located. If the spot appears dark it shows that there is less light striking it from the candle on the opposite side than from the lamp under test. Then we can move the paper screen closer to the candle until the spot appears to be the same color as the rest of the paper, which will indicate an equal amount of light is striking it on both sides. Then by comparing the distance that the two light sources are from the screen we can find out how much brighter the tested lamp is, or how many candle power to rate it at.

Fig. 161 shows two types of photometers which operate on this principle. The upper one carries a mirror in a sliding dark box, which has small openings in each end for the light to enter from each source. The standard candle and the light to be tested are placed at opposite ends of the marked scale or bar. Then, by moving the mirror box back and forth along the slide until the light on both sides of the oil spot is equal, we locate the balance point, and the candle power of the new source can then be read on the scale at this point. This instrument should be used in a dark room.

The lower device in Fig. 161 has a "grease spot" screen arranged to slide along a scale in a "dark box", and between the two sources of light, until a balance point is found by the appearance of the grease spot as previously explained.

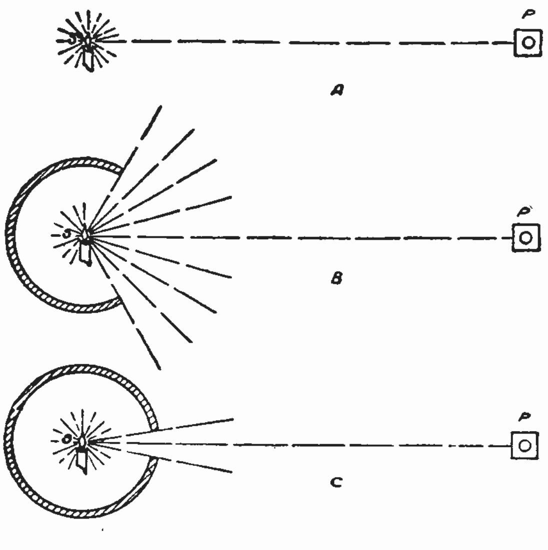


Fig. 162. If we have a photometer or light measuring device at "P," it shows that the amount of light coming in one direction from the candle to the instrument, will remain the same in all three of the above tests.

153. MEAN SPHERICAL CANDLE POWER

This method of measuring or comparing sources of light which we have just described, only takes into consideration the light coming from the source in one direction, or striking an object in one certain spot. For example in Fig. 162 we have a photometer at "P" to measure the light from a candle.

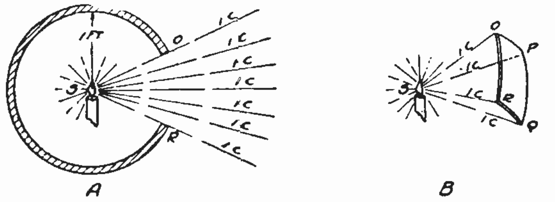


Fig. 163. The "lumen" or unit of light quantity is the measurement of a definite amount of light, such as that which escapes from the opening in the above illustration.

In view "A" the candle is entirely exposed and the photometer gets its reading only from the very small cone of light that comes in its direction.

In "B" we have the candle partly enclosed in a sphere, the inside of which is dead black, so that it absorbs all the light which strikes it and reflects none. The photometer will still read the same, however.

Again at "C" we have the opening closed still more, but the photometer will still read the same as long as the direct beam to it is not interfered with.

So these devices measure only the light coming from a source in one direction, and take no account of that escaping in all other directions.

The light around a lamp may not be quite as bright in all directions, because of the shape of the flame or filament as the case may be. If we measure the candle power in a number of places at equal distances all around a lamp and average these readings, the result is known as the **"Mean Spherical Candle Power".** This comes somewhat closer to giving the total light emitted from the source.

154. LUMENS, UNIT OF LIGHT QUANTITY

For stating the total **amount** of light actually given off by a source we use the unit **Lumen.**

Let us enclose a light which gives off 1 candle power in all directions, in a hollow sphere which has a radius of 1 foot, or diameter of two feet, and the inside of which is dead black so it will reflect no light. See Fig. 163. Now, if we cut a hole in the sphere 1 foot square as shown at OR, the amount of light that will escape through this hole will be 1 lumen. If the area of the opening was $\frac{1}{4}$ sq. ft., then the light emitted would be $\frac{1}{4}$ lumen; or if the opening was $\frac{1}{2}$ sq. ft., the escaping light would be $\frac{1}{2}$ lumen; etc. A sphere with a 1-foot radius has a total area of 12.57 sq. ft., so if we were to remove the sphere the total light emitted would be 12.57 lumens.

A Lumen may be defined as the quantity of light which will strike a surface of 1 sq. ft., all

points of which are 1 foot distant from a source of 1 candle power.

From this we find that we can determine the number of lumens of any lamp by multiplying its mean or average candle power by 12.57.

We can now rate or measure in lumens the total light of any lamp, and also compare the number of lumens obtained with the number of watts used by a lamp. All Mazda lamps of a certain size and type will give about the same number of lumens each, but the lumen output per watt, and their efficiency, varies with their size. The larger the lamp the higher the efficiency, and it ranges from about 10 lumens per watt for small lamps to 20 or more lumens per watt on lamps of 1000 watts and larger.

The table in Fig. 164 gives the lumen output of common Mazda lamps and their wattages. These values vary a little from time to time, with the improvement made in lamps, but this table will serve as a convenient guide in selecting the proper size of lamps to get a certain desired amount of light.

LUMEN OUTPUT OF MULTIPLE MAZDA LAMPS

110-115-120 Volt Standard Lighting Service Clear Lamps		110-115-120 Volt Standard Lighting Service Mazda Daylight Lamps		220-230-240-250 Volt Service Clear Lamps	
Size of Lamp in Watts	Lumen Output	Size of Lamp in Watts	Lumen Output	Size of Lamp in Watts	Lumen Output
100	1350	100	900	100	1040
150	2300	150	1500	....	.....
200	3300	200	2100	200	2700
300	5400	300	3500	300	4300
500	9600	500	6200	500	8100
750	14800	....	.....	750	13000
1000	21000	....	.....	1000	18200
1500	33000	....	.....	1500	27300

Fig. 164. This table shows the number of lumens of light delivered by various sizes and types of Mazda lamps, and will be very convenient for future reference on any lighting problems.

155. FOOT CANDLES. UNIT OF ILLUMINATION INTENSITY

Electric lamps are a **source of light,** and the result of this light striking surfaces we wish to see is **illumination.**

While the lumen will serve as a very good unit to measure the total light we can get from any source, we must also have a unit to measure the intensity of light or the illumination on a given surface, such as the top of a desk or work bench, or at the level of work being done on a machine, etc. The unit we use for this is the **Foot Candle.**

A foot candle represents the intensity of illumination that will be produced on a surface that is one foot distant from a source of one candle power, and is at right angles to the light rays from the candle. See Fig. 165. The foot candle, then, is the unit we use in every day illumination problems to determine the proper lighting intensity on any working surface.

Referring again to Fig. 163, we find that the surface O P Q R is illuminated at every point with an intensity of 1 foot candle, and we also know that the total amount of light striking this surface is 1 lumen. This shows the very simple and convenient relation that has been established between these units, in their original selection by lighting engineers. This relation can be expressed as follows: **When one Lumen of Light is evenly distributed over a surface of 1 sq. ft., that area is illuminated to an intensity of 1 foot candle.**

This is a very convenient rule to remember. It shows that, if we know the area in square feet that is to be lighted and the intensity in foot candles of desired illumination, we can then multiply these and find the number of lumens that will be required to light the area. For example, if we desire to illuminate a surface of 50 sq. ft. to an average intensity of 5 foot candles, 250 lumens must be utilized.

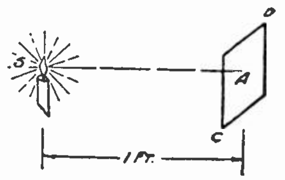


Fig. 165. The unit foot-candle refers to the intensity of illumination on a surface one foot distant from the standard source of one candlepower, as shown above.

156. FOOT CANDLE METER

There are a number of large and elaborate devices used in laboratories for making exact tests and measurements on light and lighting equipment: but for practical convenient use right on the job, the **Foot-Candle Meter** is extensively used.

Fig. 166 shows a foot-candle meter with its carrying case, and Fig. 167 shows a view of the back of one of these meters opened up. They consist of a flashlight battery, small standard lamp bulb, rheostat for adjusting the lamp voltage to proper value, and a voltmeter to check this voltage and make sure the lamp is being operated at proper voltage and brilliancy.

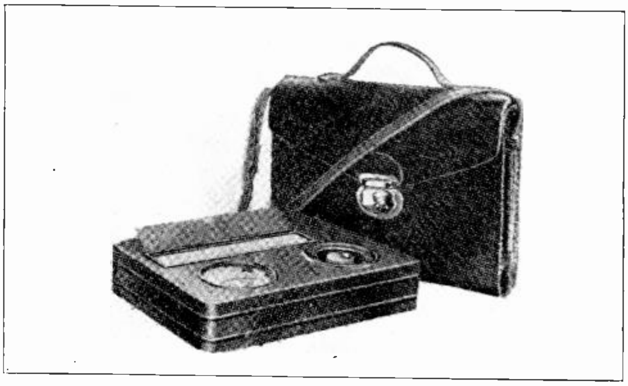


Fig. 166. A foot-candle meter is a very convenient instrument used for measuring illumination intensities right on the job.

In front of the lamp is a long square chamber, over the side of which is placed a piece of tough white paper. Along the center of this strip of paper is a row of uniform grease or oil spots which allow more light to show through them than the rest of the paper.

We all know that the farther any object is from a certain source of light, the less light will strike it. So the oil spots appear quite bright near the lamp, and are gradually dimmer as they get farther away from the lamp. Those still farther away appear darker than the paper, because, with normal light striking the paper from outside the instrument, there is less light behind these spots than on the observer's side, so they appear dark.

This, we find, is the same general principle of the photometer explained earlier. Between the bright appearing spots and the dark appearing ones, there will be one or two that appear the same color as the rest of the paper around them. This is the point at which the light within the instrument is exactly equal or balanced with that striking it from the outside, and at this point we can read the intensity of the outside light in foot candles, on a scale printed along the paper strip.

Fig. 167. This view shows the important parts of a foot-candle meter. Note the arrangement of the standard lamp behind the paper screen, and also the rheostat and voltmeter used in making proper adjustments.

To use a foot-candle meter, the rheostat switch should be turned on and the knob rotated until the voltmeter needle comes up to a mark on its scale, which indicates that the lamp is operating at proper voltage and brilliancy. Then the meter is held face up toward the light source, and at the level of the working surface where the illumination is required. The shadow of your body should not be allowed to fall on the face of the meter during tests. A number of such tests at various places in a room will give the average foot candle intensity and show us whether the illumination is sufficient for the class of work being done.

Tables of proper illumination standards for various classes of work will be given later.

The standard foot-candle meter is made to read intensities from 1 to 50 foot candles. It is possible to test intensities lower and greater than this by operating the lamp in the meter at less or more than its rated voltage, by setting the rheostat to hold the voltmeter needle at the extra marks which are provided for this purpose on the scale.

Ordinary daylight is far too bright to measure with these meters and is of a color that does not match the meter lamp accurately.

On a normal summer day with the sun shining, the intensity of illumination outdoors may be 500 foot candles even in the shade, and 5000 to 8000 in the direct rays of the sun.

157. INVERSE SQUARE LAW FOR LIGHT

We have already mentioned that the farther any object is from a source of light, the less light it receives from that source.

A very important rule to remember is that **the illumination on a surface varies directly with the candle power of the source of light, and inversely with the square of the distance from the source.**

So we find that a small change in distance from a light will make a great change in the illumination on an object. The reason for this is illustrated in Fig. 168. Here we have a standard candle, and if the surface at "A" is 1 foot from the candle, its illumination intensity will be 1 foot candle. If we move the surface or plane to "B", which is two feet from the source, the same number of light rays will have to spread over four times the area, as that area increases in both directions. Then the illumination intensity at double the distance is only ¼ what it was before, as the distance or 2 squared is 4, and this is the number of times the illumination is reduced.

If we move the surface to "C", which is 3 feet away from the light source, the rays now are spread over 9 times the original areas, and the intensity of illumination on the surface will now be only 1/9 of its former value, or 3^2 equals 9. So we call this the **Inverse Square Law for Light.**

158. LIGHT REFLECTION

We all know that light can be reflected from certain light-colored or highly-polished surfaces. This fact is made good use of in controlling and directing light in modern illumination.

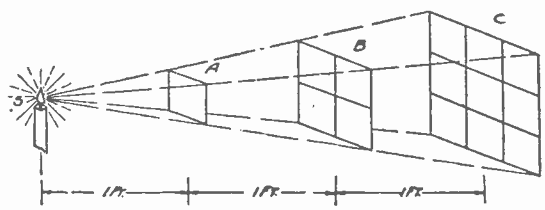


Fig. 168. Note how the illumination intensity becomes less on any surface as its distance from the light source increases. The farther the surface is from the source, the greater the area a given number of light rays must be distributed over.

Some surfaces and materials are much better reflectors than others. Generally the lighter the color, or higher the polish of a surface, the more light it reflects, and the less it absorbs.

The percentages of light that will be reflected from some of the more common materials are as follows:

Highly polished silver	92%
Good silvered-glass mirrors	70% to 80%
White blotting paper	82%
Yellow paper	62%
Pink paper	36%
Dark brown paper	13%

The better classes of reflectors are used in directing the light of sources where we want it. The ordinary colors and their reflecting ability must also often be considered in lighting interiors of buildings.

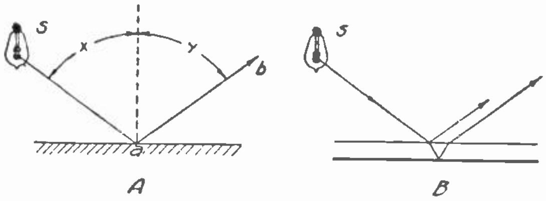


Fig. 169. Note the angle of light reflection from a smooth surface as shown at "A." The illumination at "B" shows how light is reflected from both surfaces of a piece of silvered glass.

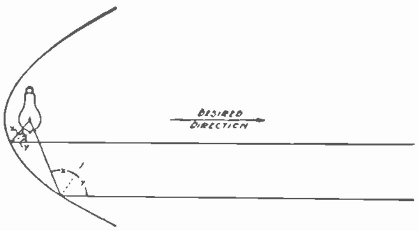


Fig. 170. This illustration shows how a curved reflector can be made to send all the light rays from a source in one direction. The shape of such a reflector is called a "parabola."

159. CONTROLLING AND DIRECTING LIGHT WITH REFLECTORS

Bare incandescent lamps are wonderful sources of light, when we consider their efficiency and the quantity and quality of light they produce, but they are very wasteful in the directing of that light to the places where we generally use it.

Bare Mazda lamps are a source of bad glare which is very tiring to the eye, and they create bad shadows which impair vision and are likely to cause accidents in industrial lighting.

A bare lamp also wastes a great deal of its light which goes upwards and sidewise and not down as we usually want it to. So, to direct the light as desired, we use reflectors with the proper shapes and curves. These reflectors turn back the light that would otherwise go up and sidewise, and send it down either in a broad or narrow beam as desired.

Fig. 171. Above are shown several types of porcelain enameled, metal reflectors. Note how their various shapes give different distribution of the light, as shown by the curves under each reflector.

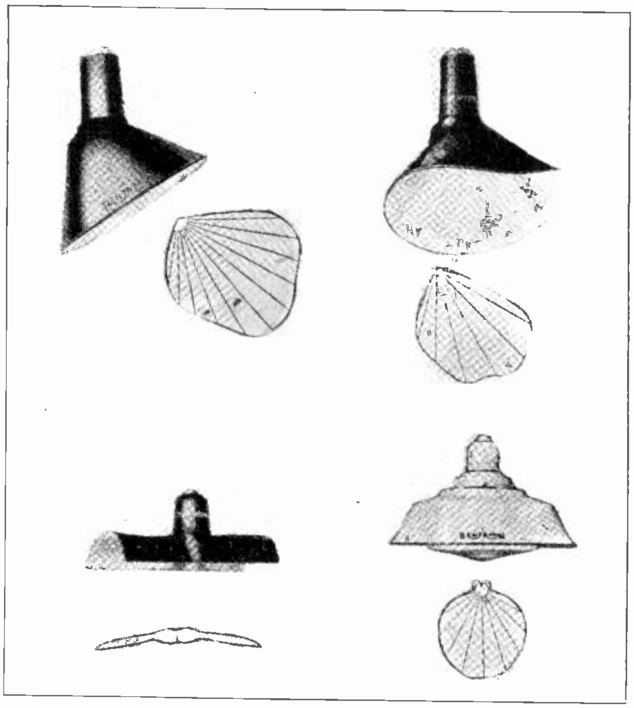


Fig. 172. The two top reflectors and the one at the lower left show how light can be controlled in any direction desired, by using the proper shape of reflector. The unit at the lower right shows a reflector which also has a glass diffusing bowl.

160. TYPES OF REFLECTORS

Fig. 171 shows several types of metal reflectors of different shapes, and beneath each one is shown the characteristic curve of light distribution for that type of reflector. From these curves it will be seen that the curvature of a reflector can be made to spread or concentrate the light more or less, as desired.

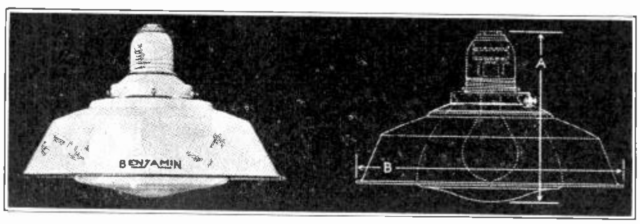


Fig. 173. This larger view of the diffusing unit shows the position of the bulb and glass bowl in the reflector. This is a very efficient and popular type unit for factory lighting and other similar work. (Illustration Courtesy of Benjamin Electric Co.)

Fig. 172 shows several other types of reflectors. The upper two are used for throwing the light to one side and downward, and the lower left one for spreading the light in two narrow horizontal beams. The lower right hand unit is a combined reflector and glass diffusing bowl.

The ordinary reflectors direct the light downward and shield the eyes from side glare of the lamps. This is often sufficient when the lamps are mounted high enough to be out of range of vision.

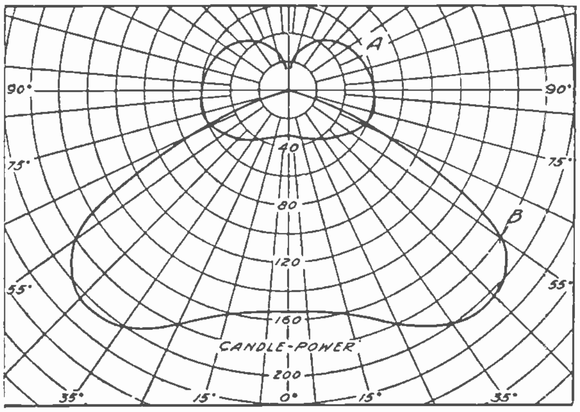


Fig. 174. This shows the manner in which the light distribution from a lamp or reflector can be plotted on a chart, to give a characteristic curve for that light or reflector.

The reflector unit with the glass bowl reflects the light downward, and the bowl enclosing the bulb has a milky white color and spreads or softens the light from the bulb so there is no glare even when looking up at the unit from underneath. Broadening the source of light in this manner also softens the shadows a great deal, making this type of lighting unit a very popular one for commercial and industrial buildings.

Fig. 173 shows a larger view of this unit and also a sketch which shows the shape of the glass bowl and the location of the lamp. These units have ring-shaped slots in the top of the reflector to allow a small amount of light to reach the ceilings, and eliminate the dark spots that would otherwise be above a metal reflector and cause quite a contrast to the lighter areas around them.

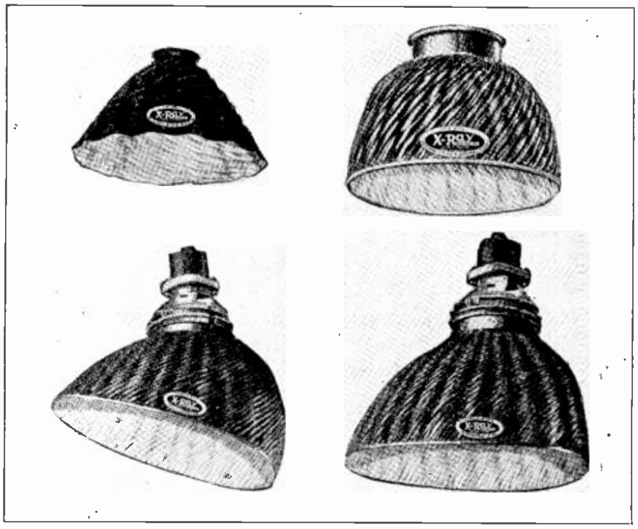


Fig. 175. Corrugated, mirrored glass reflectors of the above type are very efficient in preventing side glare and directing light downwards to the surface where it is desired.

161. ENAMELED METAL REFLECTORS

The inside surfaces of metal reflectors of the types here shown are covered with heavy white porcelain enamel, to give them a high reflecting efficiency. While polished metal can be used as a reflector it usually tarnishes in a short time and is then not much good. So porcelain enamel or glass is better.

Fig. 174 shows a curve of light distribution, and also the manner in which the various candle-power measurements are plotted on the chart to indicate the illumination intensities at different points along the curve.

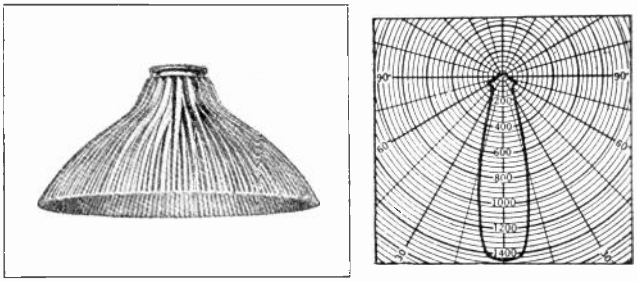


Fig. 176. Corrugated glass reflectors of this type break up or diffuse the side rays from a lamp and also reflect a greater portion of the light downwards, as shown in the curve at the right.

162. MIRRORED GLASS REFLECTORS

Glass shades and reflectors are also used extensively where there is not too great danger of breakage. Some glass reflectors have the outside silvered and then covered with dark paint. The silvered surface makes the inside of the unit of higher reflecting efficiency, and the dark paint stops all side light and glare.

Fig. 175 shows several types of glass reflectors of this kind. You will note that the glass is corrugated to break up the light rays, diffusing them enough to prevent reflection of the sharp outlines of lamp filaments. If this is not done the light from such a reflector might cause spots of glare on bright metal surfaces if they were worked upon under these lights.

Another type of glass reflector in quite common use is the sharply corrugated type shown in Fig. 176. These reflectors break up the light from the bulb enough to reduce the side glare considerably. While they don't soften the light source as much as some of the other types, they are very good for certain applications. Note the curve of light distribution for the reflector in Fig. 176 which shows that this type of unit directs a greater part of the light downward.

Fig. 177 shows one of these glass reflectors with a special type of holder which allows them to be easily removed for cleaning. This reflector has a different shape from the one in Fig. 176, which you will note changes its light distribution curve considerably.

163. PRISMATIC REFLECTORS

This type of glass reflector is made with grooves running in both directions, so that its outer surface

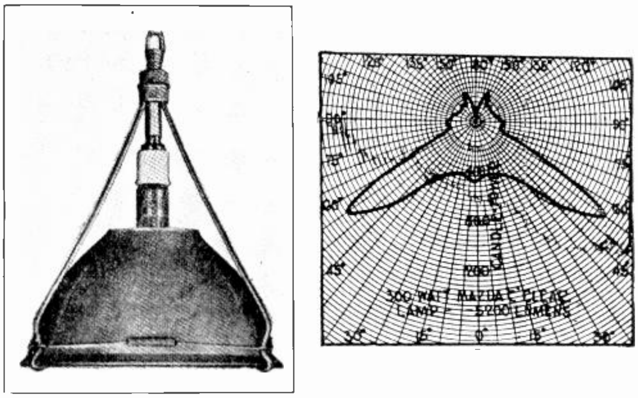


Fig. 177. These glass reflectors mounted in convenient hangers, as shown above, are very commonly used in factory lighting and in some classes of general office lighting.

in reality consists of a number of little prisms, which very effectively break up or diffuse the light. These reflectors present a very good appearance and are quite frequently used in office and store lighting. Fig. 178 shows three units of this type. You will note that the bulbs are entirely enclosed with these fixtures, so there is no chance of any direct glare from the lamp.

164. OPAL GLASS REFLECTORS AND DIFFUSING BOWLS

Glass lighting fixtures using white or opal-colored glass are made in a great variety of shapes and sizes for general lighting and offices and stores. Opal-colored glass diffuses the light very effectively, and thus softens the source so there are practically no glare and shadow effects if the fixtures are properly installed.

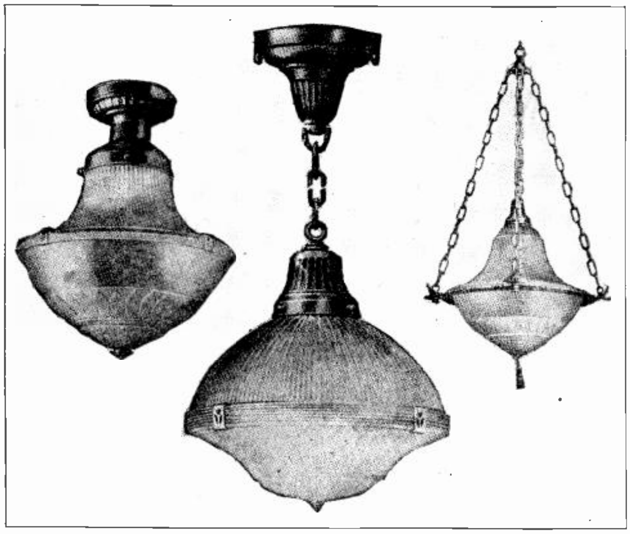


Fig. 178. Several styles of prismatic glass lighting units. Note that these units completely enclose the lamp so that all light is diffused or softened before reaching the eye.

There are two different grades of opal glass, known as light opal and dense opal, either of which will, of course, absorb or stop a certain amount of light from the bulb. But this small loss is more than made up for in the greater efficiency of lighting which is free from glare and shadows. Persons can actually see much better with a little less light if these effects which are so tiring to the eye are not present.

Fig. 179 shows two types of glass bowls of a very popular style. These are fastened in the metal canopy with thumb screws, which can be seen in this illustration. This enables the globes to be easily removed for cleaning and replacing the bulbs. When attaching the globes to a fixture of this type, the thumb screws should be tightened firmly and evenly; but not too tight, as it is possible to crack the glass globe in this manner.

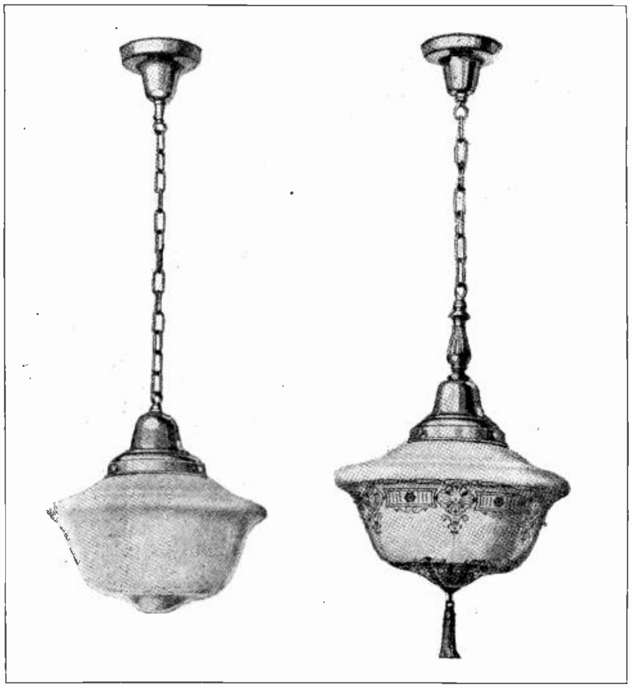


Fig. 179. Enclosing glass bowls with milky white or opal colored glass, make very efficient units for office lighting.

Fig. 180 shows two styles of glass fixtures which are made for mounting closer to the ceilings.

Glassware or fixtures of the types here described can be plain opal-colored, or made more ornamental with decorative painting on the outside. These decorations, of course, reduce the efficiency of the fixture somewhat by absorbing a certain amount of light. Fig. 181 shows another popular type of glass fixture in which the lower part of the bowl is opal-colored and the upper part is clear glass. Then, above the bowl, is suspended a broad opal reflector. The clear glass in the top of the bowl allows considerable light to go upward and strike the under side of the opal reflector, from which it is again deflected downward to the working surface. Glass lighting fixtures of these types allow a certain amount of light to go upward, lighting the ceilings more or less uniformly, and present a very cheerful appearance as well as softening the light generally and reducing shadows.

165. GENERAL CLASSES OF LIGHTING UNITS

Lighting fixtures are often classed in three general divisions called:—**Direct, Indirect, and Semi-**

Indirect. The direct lighting fixture is one from which the greater part of the light comes directly from the bulb down to the working plane. The metal and glass reflectors of the first types described come in this class. The indirect lighting fixture is one in which no light comes directly down from the bulb to the working plane, but instead is all first thrown upward to the ceiling or to a broad reflector above and then directed downward. Lights of this type are used where it is very essential to avoid even the slightest glare and to eliminate shadows almost entirely. With such fixtures we might say that the ceiling is our secondary source of light; and as we know that shadows are more pronounced when the light comes from small "point" sources, we can readily see that light coming from the broad area of a ceiling would produce almost no shadows.

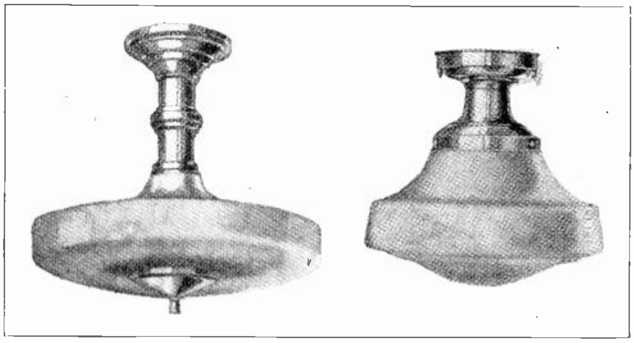


Fig. 180. Short fixtures of the type shown above can be used for mounting close to the ceiling in low rooms.

Fig. 182 shows a view in a drafting room which is lighted with indirect fixtures of this type. You will note that the light is all directed first to the ceiling and produces a very uniform light throughout the entire room. While this type of light is a little more expensive and requires more lamps and current than a direct lighting installation, it is one

Fig. 181. This fixture has a bowl, the lower part of which is white to diffuse the light, and the upper part is clear to allow the light to go upward and strike the reflector, from which it is directed back to the working surface in a well diffused manner.

of the very best classes of installations where exacting work is to be done.

Semi-indirect fixtures are those from which part of the light is directed downward through a diffusing globe, and the balance is thrown upward, and then reflected back by the ceiling. Some fixtures are also classed as **Direct Diffusing,** because while practically all of their light is thrown directly down to the working plane, it must pass through a diffusing bowl as with some of those previously described.

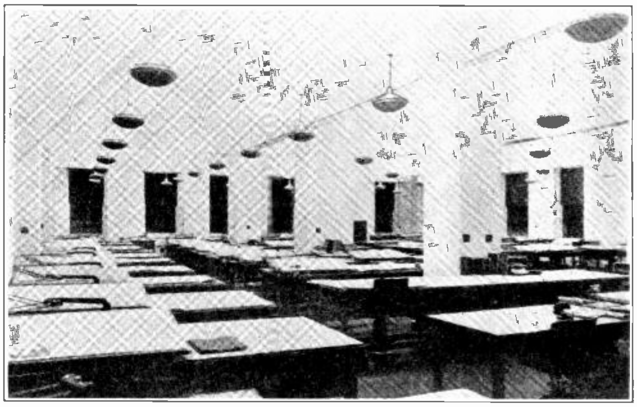


Fig. 182. This drafting room is lighted with indirect fixtures which throw their light to the ceiling first. The ceiling then reflects it downward to the working surface.

166. DEPRECIATION FACTOR

Almost all lighting fixtures are subject to a very definite reduction in efficiency from the collection of dust and dirt on their light transmitting or reflecting surfaces. Few people realize what an effective absorber of light a thin film of dust actually is.

In some installations where a beautiful selection of fixtures has been made and the lighting is of very sufficient intensity when the installation is new, after a few months the dirt that is allowed to accumulate on the fixtures absorbs from ¼ to ¾ of

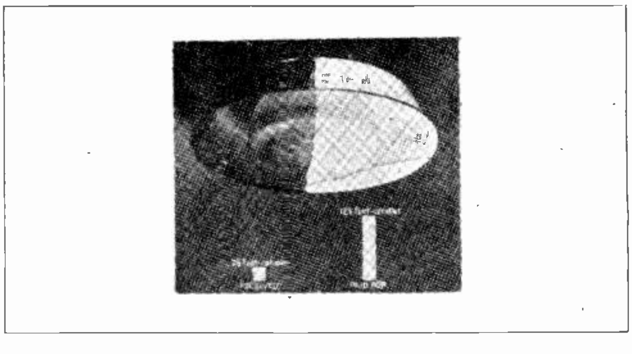


Fig. 183. This is an actual photo showing how much of the light can be lost if the reflectors are not kept cleaned.

the light. This is particularly true in certain industrial plants where smoky, oily, and dusty atmospheres exist. Fig. 183 shows an actual view of a fixture of which one side has been cleaned and the other side left with the remaining accumulation of oil and dirt. This is undoubtedly a worse case than is ordinarily encountered, but it serves as a good illustration of the necessity of keeping fixtures clean. Regardless of the amount of money spent in purchasing fixtures that will eliminate glare and shadow, a great deal of the electricity used will be wasted and the lighting will be unsatisfactory if the fixtures are not kept clean. An occasional washing with soap and water will remove ordinary dust and dirt from lighting fixtures, and where necessary special cleaners can be employed.

Of course, it is impossible to prevent some dust and dirt from accumulating, even if the fixtures are cleaned frequently; so when we are selecting fixtures we generally allow a certain amount for this **Depreciation Factor.** This will vary from 1.2 to 1.6, and a good, safe average value to use is 1.4. This means that in planning a lighting installation, after determining the foot candles of lighting intensity that would be required to produce the desired illumination, we should then multiply this by the figure 1.4, to have enough light reserve to keep the lighting satisfactory in spite of ordinary depreciation.

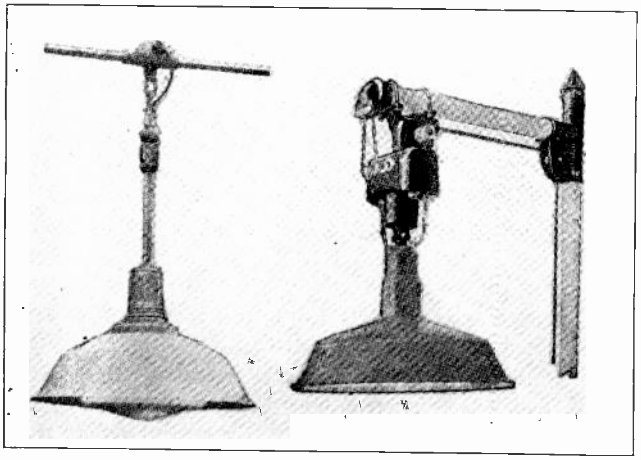


Fig. 183-B. Special hangers of the above type are often used with lamps which are mounted very high in shops or factories. They allow the lamps to be lowered with a chain for convenient cleaning and repairing.

Some fixtures, of course, collect more dust than others in the vital places where it interferes with their light distribution. In some cases when buying fixtures, the depreciation factor for that particular type will be given by the manufacturer or dealer, but when this value is not known, the average factor of 1.4 can be generally used.

167. COEFFICIENT OF UTILIZATION

Another very important item to consider in planning a lighting installation is what is called the **Coefficient of Utilization.** You will recall that earlier in this section we mentioned that, if we knew the number of square feet that had to be illuminated and the foot-candle intensity to which it was desired to illuminate the area, the product of these values would give the lumens that would have to be utilized to produce the desired illumination.

When we say these lumens must be utilized we mean that they must be effectively used and not absorbed or wasted in other places besides the working surfaces. Only a part of the total light emitted by any lamp reaches the working plane, as a certain amount will be absorbed by the reflector or enclosing glassware of the fixture, and some will be absorbed by the walls, ceilings and other objects. In some cases part of the light that is directed upwards and sidewise from the fixture is again reflected to the working surface.

The coefficient of utilization therefore refers to the percentage of light used at the working plane.

So we find that the coefficient of utilization depends on the type of fixtures; and on the color of walls and ceilings to quite an extent, as the darker colors absorb and waste much of the light from the source, while light colors reflect more of the light which strikes them back to the working surface.

Under average conditions a unit of the type shown in Fig. 173 has a coefficient of utilization of about .70.

Fig. 184 shows a table of coefficients of utilization for various types of reflectors. You will note that the figures given vary for light or dark walls and ceilings.

COEFFICIENTS OF UTILIZATION

This table applies to installations in *square rooms* having sufficient lighting units symmetrically arranged to produce reasonably uniform illumination. To obtain the coefficient for any rectangular room, find the value for a square room of the narrow dimension and add one-third of the difference between this value and the coefficient for a square room of the long dimension.

Reflection Factor	Ceiling		Light 70%			Medium 50%		Dark 30%
	Walls		Light 50%	Medium 35%	Dark 20%	Medium 35%	Dark 20%	Dark 20%
Reflector Type	Light Output	Ratio = Room Width / Ceiling Height						
Prismatic Glass / Bowl-Frosted Lamp	90° to 180°—22% / 0° to 90°—65%	1	.42	.38	.35	.36	.34	.33
		1½	.50	.46	.43	.44	.42	.41
		2	.56	.52	.49	.50	.47	.45
		3	.63	.59	.55	.56	.53	.51
		5	.70	.66	.63	.63	.60	.57
Light Opal / Bowl Frosted Lamp	90° to 180°—35% / 0° to 90°—50%	1	.31	.27	.24	.24	.21	.18
		1½	.37	.33	.30	.30	.27	.24
		2	.43	.39	.35	.34	.31	.27
		3	.49	.45	.41	.39	.36	.31
		5	.56	.52	.48	.45	.42	.36
Dense Opal / Bowl-Frosted Lamp	90° to 180°—20% / 0° to 90°—60%	1	.41	.37	.34	.35	.33	.32
		1½	.49	.45	.42	.43	.41	.39
		2	54	.50	.47	.48	.46	.44
		3	.60	.56	.53	.53	.51	.49
		5	.67	.63	.59	.59	.57	.54
Steel Bowl / Porcelain-Enameled	90° to 180°— 0% / 0° to 90°—65%	1	.38	.36	.34	.35	.33	.33
		1½	.45	.43	.41	.42	.40	.40
		2	49	.47	45	.46	.44	.44
		3	.54	.52	.50	.51	49	.49
		5	.59	.57	.55	.56	.54	.54
Steel Dome / Porcelain Enameled	90° to 180°— 0% / 0° to 90°—80%	1	.43	.40	.38	.39	.37	.37
		1½	.52	.49	.47	.48	.46	.46
		2	.57	.54	.52	.53	.51	.51
		3	.63	.60	.58	.59	.57	.57
		5	.69	.66	.64	.65	.63	.63
Indirect / Mirrored Glass	90° to 180°—80% / 0° to 90°— 0%	1	22	.19	.17	.14	.12	.07
		1½	.27	.24	.22	.17	.15	.09
		2	31	.28	.26	.20	.18	.11
		3	36	.33	.31	.24	.22	.13
		5	.42	.39	.37	.28	.26	.16
Semi-Indirect / Light Opal	90° to 180°—60% / 0° to 90°—25%	1	.27	.24	.21	.20	.17	.14
		1½	.34	.30	.27	.25	.22	.18
		2	.39	.35	.32	.29	.26	.21
		3	.45	.41	.38	.34	.31	.25
		5	.51	.47	.44	.40	.37	.29
Semi-Indirect / Dense Opal	90° to 180°—70% / 0° to 90°—10%	1	.24	.21	.19	.16	.14	.10
		1½	30	.27	.24	.20	.18	.13
		2	.34	.31	.28	.23	.21	.15
		3	.39	.36	.33	.27	.25	.18
		5	.45	.42	.39	.32	.30	.21
Enclosing / Light Opal	90° to 180°—35% / 0° to 90°—40%	1	23	.20	.17	.18	.16	.14
		1½	.30	.26	.23	.24	.21	.19
		2	.35	.31	.28	.28	.25	.22
		3	.41	.37	.34	.33	.30	.26
		5	.48	.44	.41	.39	.36	.31
Semi-Enclosing / Opal Bowl	90° to 180°—20% / 0° to 90°—60%	1	.32	.28	.26	.27	.25	.23
		1½	.40	.36	.33	.34	.32	.30
		2	.45	.41	.38	.39	.37	.35
		3	.52	.47	.44	.45	.42	.40
		5	.59	.54	.51	.51	.48	.46

Fig. 184. This table shows the percentage of light which we can expect to obtain at the working surface, from lamps used in different types of reflectors, and in rooms of different shapes. Note that the color of walls and ceilings also influences this percentage.

The ratio of the room width to its ceiling height is also considered, because in narrow high rooms more of the light strikes the walls. In wide rooms

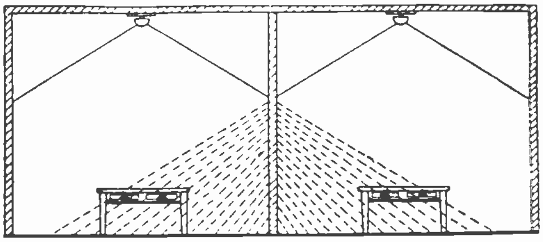


Fig. 185. This sketch shows how the walls of narrow rooms absorb a certain amount of the light. If the wall in this case was removed and the room was twice as wide, note how the light beams from the two lamps would overlap and produce more light on the benches.

which are not obstructed by partitions, the light from the several lamps overlaps and not as much of it is absorbed by walls; thus the utilization factor is raised somewhat. Fig. 185 shows a sketch of a room and what the effect on the light would be, both with and without the center partition.

Fig. 186 shows the amount of light absorption and reflection obtained from painted walls and ceilings of different colors, and from this we can see that in many cases it would pay to coat them with white or light colored paint, to reduce light waste by absorption. The white or lighter colored paints greatly improve the utilization factor by increasing reflection.

168. WORKING PLANE

Now that we have considered some of the more common types of lighting units for industrial and commercial lighting and some of the important points governing their efficiency, let us find out something about the proper location and arrangement of lights to obtain best results and efficiency.

In mounting fixtures for industrial or commercial lighting we must consider the distance the light will have to travel from them to reach the **Working Plane.** This term refers to the level at which the light is used. In an office, it may be the top of the desk; or in a drafting room, the top of the tables; in a store, the counter top; and in a machine shop, the height of the machine or bench at which the operator works.

As it is very seldom that the maximum light is wanted at the floor, we must plan to obtain the proper intensities at the working plane.

Examination of the equipment or work in a room or building, will readily show at what height from the floor the working plane is: but if no measurements can be made, it is usually assumed to be about 2½ feet from the floor.

169. MOUNTING HEIGHT

The next important point to consider in the location of the fixtures is the proper **Mounting Height.** This is the perpendicular distance from the working plane to the source of light: and it is, of course, this distance that affects the coefficient of utilization and the light intensity obtained at the working plane.

The distance from the floor to the ceiling in any room is called the **Ceiling Height.**

With direct lighting the source of light is the lamp itself and its reflector. In indirect and semi-indirect lighting the source is considered to be at the ceiling. Fig. 187 illustrates this.

170. NUMBER AND LOCATION OF LIGHTS

In general, we should never try to skimp on the number of lights or lighting circuits when planning a lighting installation. If good lighting is economy, then it is certainly false economy to try to save on wiring materials or fixture costs by cutting down on the number of lighting outlets or trying to spread them as far apart as possible.

At the rate standards of lighting are improving today in all classes of up-to-date buildings, it is far better to plan for the future and to put in adequate lighting while it is being installed.

Best results can be obtained by having sufficient outlets close enough together to give even distribution and uniform lighting.

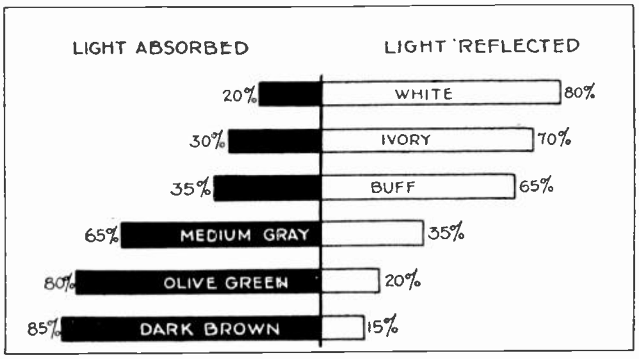


Fig. 186. The above chart shows the percentages of light that will be absorbed and also the percentage that will be reflected, by walls and ceilings painted with different colors.

171. SPACING DISTANCE

In small rooms that are enclosed by permanent partitions and where one lamp is sufficient, it is, of course, a simple matter to locate this unit in the center of the ceiling. In large rooms where a number of lamps are necessary, we need some rule or standard by which to determine the number and spacing of the lights.

The distance between lights or lighting outlets is known as the **Spacing Distance.** This distance will vary somewhat with the shape and height of the room, but it can easily be determined by the following simple rule: **For best efficiency the spac-**

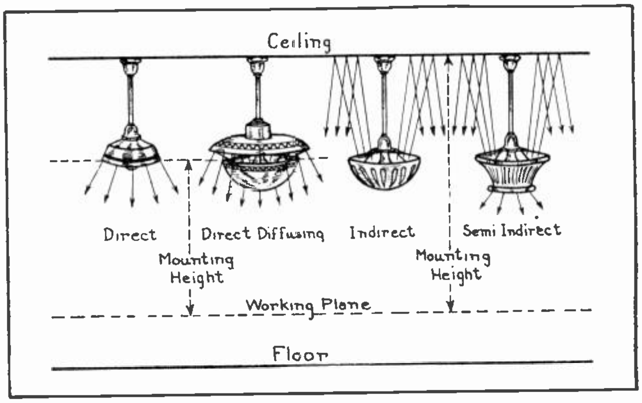


Fig. 187. This sketch shows how the mounting height is obtained with different types of fixtures.

ing distance should be the same as the mounting height.

In some cases this may seem unnecessarily close, but if good illumination is desired, lights should seldom be spaced more than 1½ times the mounting height. There may be certain cases where a building when it is first erected will not need that much general lighting, but if it is later changed to some other use, the standard amount of illumination may become very necessary.

172. LIGHTING BAYS

In large rooms where a number of lights are to be installed they should be lined up as neatly as possible for good appearance. In some buildings the larger rooms have posts or supports at uniform distances throughout them, which sort of divide them into **Bays.** If possible, the lights should be arranged uniformly in these bays.

In planning an illumination layout, however, we should divide the room or space into imaginary bays or squares, as soon as the mounting height and spacing distance have been determined. The width of each bay should be made the same as the spacing distance, and each bay should have a light in the center of it. See Fig. 188.

173. PRACTICAL ILLUMINATION PROBLEM

Let us assume that the size of the room shown in this Figure is 30x40 ft., and 13 ft. high. We will assume that the working plane is 2½ ft. from the floor, and that the lighting units will hang down 2½ ft. from the ceiling. In this case our mounting height will be 13′ — 5′, or 8′. Then, for maximum efficiency, the spacing distance should be about 8 ft., and not over 12 ft., if good lighting is desired. As the building is 30 ft. by 40 ft., a spacing distance of 10 ft. will give us 10-foot light bays, which will fit this space evenly. So we will adopt the 10-foot spacing distance, and bays 10′x10′, as shown by the dotted lines. This layout will require 12 lights.

Spacing the rows of lights 10 ft. apart leaves 5 ft. between the outside rows and the walls; which

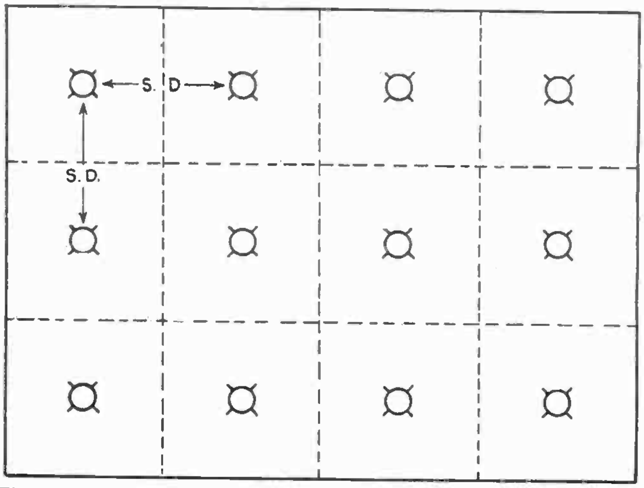


Fig. 188. Dividing the area which is to be illuminated into "light bays," as shown by the dotted lines, greatly simplifies an illumination problem.

Fig. 188-B. This photo shows a view in a well lighted machine shop. It is easy to understand why production can be increased and greater safety obtained in a shop which is lighted in this manner. (Photo Courtesy Light Magazine).

should be all right, unless some special bench work is to be done along the walls.

Now that we know the number of lights to use and that the area of the bays to be supplied by each light is 10x10, or 100 sq. ft., our next step is to choose the desired illumination intensity.

The required intensity in foot candles will vary considerably for various classes of work. For example, a shop doing nothing but coarse assembly work may only require 5 to 8 foot-candles (F.C.), while another shop doing very fine machine work may require 10 to 20 F.C. A store or office may need only 10 to 15 F.C., while a drafting room or sewing room requires 15 to 25 F.C.

Let us assume that our problem is for an office building where the owner desires 15 F.C. intensity.

Now, in order to determine the required lumens to produce this intensity, we recall that we must consider the utilization factor, according to the type of fixture and the color of the room walls and ceiling. We will use for this job a light opal-glass unit of the semi-enclosed type, and assume our walls and ceilings are both light colored.

Looking up this fixture in the table of utilization coefficients in Fig. 184, and in the column for light walls, light ceilings, and a room with a ratio of width to height of about 1½, we find the coefficient is .40.

If we wish to assure the proper lighting intensity after the fixtures are installed a while, we must also consider the depreciation factor of, say 1.4.

Now we are ready to lay out all this data in a simple formula to make our final calculation of required lumens as follows:

$$L = \frac{F.C. \times B.A. \times D.F.}{C.U.}$$

In which:

L = Lumens required per bay
F.C. = Foot-candles desired intensity
B.A. = Bay area (one bay)
D.F. = Depreciation factor
C.U. = Coefficient of utilization

So, substituting our values, we have:

$$L = \frac{15 \times 100 \times 1.4}{.40}, \text{ or } 5250 + \text{ Lumens per bay.}$$

Now, from our table of lumen output of Madza lamps in Fig. 164, we find that a 300-watt lamp gives 5400 lumens, so that would do very well for this job.

It will be well to review this problem until you thoroughly understand each step of it and the reasons for using each of the factors we applied in calculating the spacing distance, size of bays, number of outlets, size of lamps; as these are the important factors in any commercial illumination problem. Once you have obtained an understanding of these fundamentals and a little practice in using them in the simple formula given here, you will be able to lay out a practical illumination job very easily.

174. STANDARD ILLUMINATION INTENSITIES IN FOOT-CANDLES

For your convenience in determining the proper illumination intensity to use for various classes of work and different buildings, a list of the standard foot-candle intensities for the most common classes of lighting is given here:

RECOMMENDED FOOT-CANDLE INTENSITIES

COMMERCIAL INTERIORS	
Auditoriums	3 to 5
Automobile showrooms	10 to 15
Banks	6 to 15
Barbershops	10 to 15
Bowling alleys (general)	5 to 8
On pins	15 to 25
Pool and billiards (general)	5 to 8
On tables	15 to 25
OFFICES (private and general)	4 to 15
Close work	10 to 15
No close work	8 to 10
File rooms	4 to 6
Vaults	4 to 6
Reception rooms	4 to 6
RESTAURANTS	5 to 8
SCHOOLS	8 to 25
Auditoriums	5 to 8
Drawing rooms	15 to 25
Laboratories	8 to 12
Manual training rooms	8 to 12
Study rooms and desks	8 to 12
STORES	
General	8 to 15
Automobile	8 to 12
Bakery	8 to 12
Confectionery	8 to 12
Dry goods	8 to 12
Grocery	8 to 12
Hardware	8 to 12
Meat	8 to 12
Clothing	10 to 15
Drugs	10 to 15
Electrical	10 to 15
Jewelry	10 to 15
Shoe	10 to 15
SHOW WINDOWS	
Large cities	
Downtown	100 to 150
Outer districts	50 to 75
Neighborhood stores	30 to 50
Medium-sized cities	
Downtown	50 to 75
Outer districts	30 to 50
Small towns	30 to 50
THEATRES	
Auditoriums	2 to 3
Foyer	5 to 8
Lobbies	8 to 12

CHURCHES	
Auditorium	2 to 3
Sunday-school rooms	5 to 8
Pulpit or rostrum	8 to 12
Art-glass windows	15 to 50

INDUSTRIAL INTERIORS

ASSEMBLING	
Rough	5 to 8
Medium	8 to 12
Fine	12 to 20
Extra fine	25 to 100
MANUFACTURING	
Screw machines	10 to 15
Tool making	12 to 20
Inspecting	25 to 100
Drafting rooooms	15 to 25
ELECTRICAL MANUFACTURING	
Battery rooms	6 to 10
Armature winding	12 to 20
Assembly	8 to 15
FOUNDRIES	5 to 15
MACHINE SHOPS	
Rough work	6 to 10
Grinding and polishing	10 to 15
Fine machine work and grinding	15 to 50
ENGRAVING	25 to 100
JEWELRY MANUFACTURING	25 to 100

This list of recommended illumination intensities will give the proper values for most any kind of ordinary illumination. While it does not, of course, mention every possible class of work, a general study of the intensities required for the various types of work covered will enable you to determine the proper intensities to use on almost any problem you may encounter.

The lower values given in the list are the minimum values for efficiency in the class of work for which they are given. The higher values are recommended as the best practice where maximum efficiency is desired.

When we sum up the recommendations given in the foregoing list, we find that a good general division of proper intensities to keep in mind is as follows:

5 to 10 FOOT-CANDLES
Suitable for coarse work, such as rough assembly and packing. Sufficient for warehouses, stockrooms, aisles, etc. This is enough light to prevent a gloomy appearance.

10 to 15 FOOT-CANDLES
Considered good lighting for most kinds of work on light-colored surfaces, but is not sufficient for fine details on dark-colored surfaces.

15 to 25 FOOT-CANDLES
Excellent lighting. Permits quick and accurate work, and stimulates workmen and speeds up production enough to more than pay for the small extra cost of the light.

50 to 100 FOOT-CANDLES
Needed only for extremely fine and accurate operations, inspection, etc. Generally used only at local spots where needed, and along with general lighting of lower intensities.

Another good general rule to remember is that, for ordinary factory lighting, 200-watt lamps in standard R.L.M. reflectors and spaced 10 ft. apart will usually give very satisfactory lighting. The R.L.M. dome is a common type of unit which is approved by the Reflector and Lamp Manufacturers Association, and is very commonly used in industrial lighting.

If there are certain sections which require more light, larger bulbs can be used in the units at these points, provided the outlets are wired to stand the increased load. For this reason it is usually better to install wires plenty large enough to carry a certain increase of load in case of future improvement in the lighting.

Observing the lighting needs and selecting and recommending the proper illumination intensities for various buildings and classes of work is a very interesting and profitable field, and should prove very easy and enjoyable work for the man with a good understanding of the fundamental principles of illumination covered in this section. Practice using the tables and simple formulas, until you can use them easily in planning any ordinary illumination system. Fig. 188-B shows a splendid example of good illumination in a machine shop.

175. FACTORY LIGHTING PROBLEM

Suppose we have a job of lighting a factory room 55 ft. wide, 100 ft. long, and 17 ft. high. The work to be handled is medium fine, the material is light-colored, and the owner desires very good illumination, which in this case should be obtained with an intensity of about 12 foot-candles.

Let us say the average working plane is about 30 inches, or $2\frac{1}{2}$ feet, from the floor; and that the lighting reflectors chosen will hang down $2\frac{1}{2}$ feet from the ceiling. Then if the room is 17 ft. high, the mounting height will be $17 - 5 = 12$ ft.

We decide to use the maximum efficient spacing distance, which we have learned is $1\frac{1}{2}$ times the mounting height. Then $1\frac{1}{2} \times 12 = 18$ ft. spacing distance.

Each light bay will then be $18' \times 18'$ or 324 sq. ft. This figure will be approximate and may need to be corrected to suit the shape of the room, for even rows of lights. Then, to find the number of outlets, we can divide the total floor area by the square feet per bay. The floor area will be $55' \times 100' = 5500$ sq. feet. Then $5500 \div 324 = 16.9+$; or, we will say, 17 outlets.

Now, as our room is nearly twice as long as it is wide, a good uniform arrangement will be the three rows of 6 outlets in each, or 18 outlets. This will be one more than our figures call for, but when balancing up the rows for appearance, it is always better to add a light or two than to remove any. See the layout for this problem in Fig. 189. This arrangement will give a spacing of 18⅓ ft. between the rows of lamps, and 16⅔ ft. between the lamps in the rows. It also leaves a space of 9⅙ ft. between the rows and the walls on the sides, and 8⅓ ft. at the ends.

Now that we have decided upon the number of outlets, our next step is to determine the exact number of sq. ft. per bay. So we will divide the total floor area by the number of outlets, or 5500 ÷ 18 = 305.5+ sq. ft. per bay.

Before we can complete our problem and determine the number of lamp lumens required per bay to maintain 12 foot-candles of illumination, we must consider our utilization and depreciation factors.

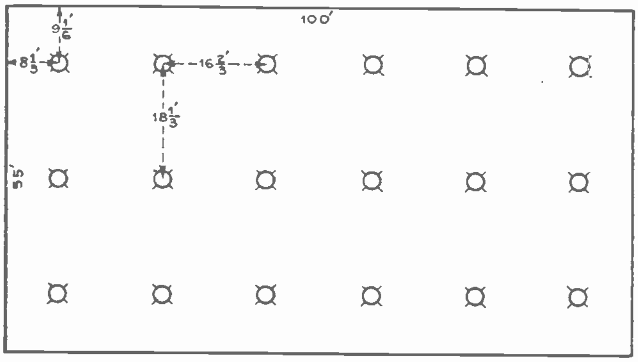


Fig. 189. This sketch shows the arrangement and spacing of lights for a practical factory lighting job.

We will assume that we are going to use steel dome, porcelain-enameled reflectors, and that the walls and ceilings of the room are both light-colored.

By referring to the table in Fig. 184, we find that for this fixture used with light walls and ceilings, and in a room whose ratio of width to height is about 2, the utilization factor is .57. Then, using 1.4 as our average depreciation factor, our problem can be completed by the formula for lumens, which we have previously used.

$$L = \frac{12 \text{ F.C.} \times 305 \text{ B.A.} \times 1.4 \text{ D.F.}}{.57 \text{ C.U.}}$$

In which we will recall—

F.C. = Desired foot-candles
B.A. = Bay area in sq. ft.
D.F. = Depreciation factor
C.U. = Coefficient of utilization

Working out this formula with our figures for this job, we find it gives 8989.4+ lumens required. Then, from the table in Fig. 164, we find that a 500-watt lamp gives 9600 lumens, so it will be plenty large enough for this job.

If the glare from bare bulbs in these units should be objectionable to any of the operators, we can install bowl frosted lamps.

The upper view in Fig. 190 shows what happens when lighting units are spaced too far apart. This produces contrasting spots of bright light with shadows in between, and is very poor practice. The lower view shows the more uniform illumination obtained by proper spacing of the units at distances not to exceed 1½ times their mounting height.

176. OFFICE LIGHTING PROBLEM

In another problem, suppose we have a room 92 ft. square and 13 ft. high which we wish to illuminate to an intensity of 10 foot-candles, with indirect lighting fixtures. Assume the working plane to be 3 ft. from floor.

When using indirect fixtures, we will remember, our source of light is considered to be at the ceiling, so in this case we do not subtract the length of the fixture from the ceiling height to obtain the mounting height. Instead, we subtract just the height of the working plane; so 13 — 3 = 10 ft., which will be the mounting height.

In this case we will use the proper spacing distance for maximum efficiency, which is the same as the mounting height, or 10 ft. Then the first estimate for the bays will be 10′ × 10′ or 100 sq. ft.

The total floor area is 92′ x 92′ = 8464 sq. ft. Then the estimated number of outlets will be 8464 ÷ 100 = 84.6+.

As the room is square, we can use 9 rows of 9 lights each, or a total of 81 outlets; which is close enough, because we are using close spacing anyway.

Now to get the accurate number of sq. ft. per bay, we divide the total floor area by the chosen number of outlets, or 8464 ÷ 81 = approximately 104½ sp. ft. per bay.

We will assume the walls and ceilings to be light-colored, as the ceilings should certainly be to get reasonable efficiency from indirect fixtures, with which the light must be reflected from the ceiling.

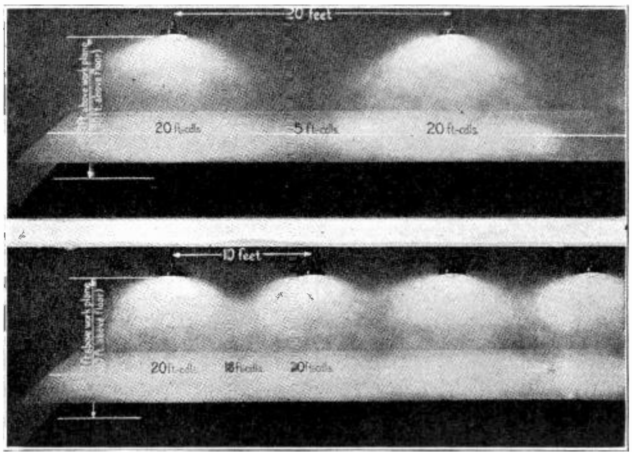


Fig. 190. Note in the upper view the very undesirable effect of uneven illumination, which results from spacing lighting units too far apart. Below is shown the much more efficient lighting obtained with proper spacing distance.

Referring to Fig. 184 again, we find the coefficient of utilization for indirect fixtures and light-ceilings and walls is .42. This is for a room of 5 to 1 ratio of width to ceiling height; as the one in our problem has a ratio of about 7 to 1, or 92 ÷ 13. But the table only gives these ratios up to 5, and we will recall that on ratios above 5 the difference is very little anyway.

With indirect fixtures the depreciation factor is likely to be rather high unless both the fixtures

Fig. 191. This photo shows a view in a well lighted store. Plenty of good light always pays in such places as this. (Photo Courtesy Light Magazine).

and ceiling are kept very clean; so we will use 1.6, or the maximum average depreciation factor.

Then our final problem can be stated in the formula:

$$L = \frac{10 \times 104.5 \times 1.6}{.42}, \text{ or 3981-lamp lumens required.}$$

From the table in Fig. 164, we find that the next size larger than this is a 300-watt lamp, which gives 5400 lumens. This is more than our estimate calls for but it is a good general rule always to select a lamp with the next larger rating in lumens, rather than to use one smaller.

Of course, if we find that for a certain layout the next larger lamp has a considerably greater lumen output than is actually required, we can, if desired, rearrange the layout to slightly increase the spacing distance and size of bays. But, in general, it is a good plan to have a little extra light, to keep it up to standard after the bulbs and fixtures start to depreciate.

Another thought to always keep in mind, is that, while a certain illumination system may be considered excellent today, in a year or two it may be desired to increase the intensity considerably with improving standards.

Fig. 191 shows a well-lighted store in a medium-sized town, using 500-watt lamps on 10-ft. centers.

For store and office lighting, it is general practice to use direct-diffusing, indirect, or semi-indirect fixtures. Both the opal glass bowls and prismatic glass are quite popular.

In office lighting jobs, one should always inquire whether the present layout of desk, equipment, and

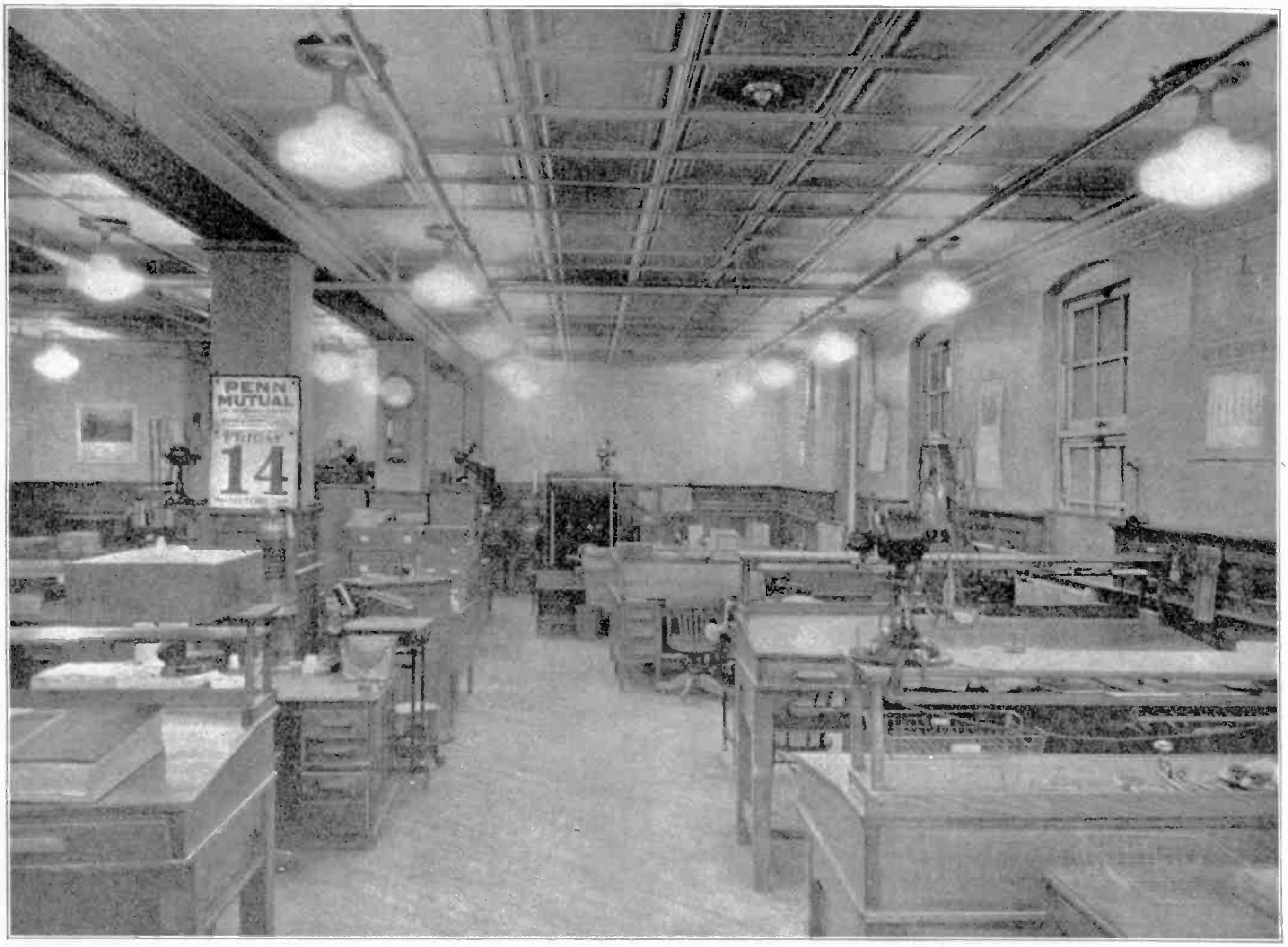


Fig. 192. A well lighted office, such as shown above, permits much faster and more efficient work with less eye strain for employees. It also provides a more cheerful atmosphere which improves the morale of those working in such places. (Photo Courtesy Light Magazine).

small private offices is permanent or not. Many offices change these things around quite frequently, and in such cases good general lighting which is sufficient for almost any work or condition in the office will save a lot of trouble and remodeling of the lighting system.

Fig. 192 shows a very good office lighting system using enclosed glass bowls, which diffuse the light nicely over the desks and equipment.

Fig. 193 is an installation of indirect lighting units, which shows the soft even light distribution obtainable with such fixtures and the absolute freedom from glare or noticeable shadows.

Fig. 193. This office is lighted with indirect units which are ideal for avoiding all glare and shadow effects. (Photo Courtesy Light Magazine).

177. SHOW-WINDOW LIGHTING

Show-window lighting is a branch of store lighting which has proven to be one of the best sales stimulants that the modern store has. On busy streets where large numbers of people pass by, a well lighted show window with goods interestingly displayed will attract a great amount of attention to a store that many people might otherwise pass by.

A number of tests made on stores with various show-window lighting intensities showed the interesting average results listed in Fig. 194.

In show-window lighting the light sources should be concealed, as we must remember it is not the lights the store owner wants to sell but rather the goods the light is to shine on.

Effect of lighting intensities on show window results

Foot candles intensity	Increase in no of people stopping	Estimated hourly profit on sales	Hourly lighting cost	Merchants net hourly gain
15		7.50	3.5 cents.	
40	33%	10.00	7.5 "	2.46
100	73%	13.00	18. "	5.36

Fig. 194. The above table shows the results obtained with different lighting intensities in show-windows. Such tests as this certainly prove that good show-window lighting pays.

The reflectors should be set so their light shines downward and back into the window, in order to put proper light on the side of the objects which faces toward the customer. The light should never be directed toward the window glass or passers by, as it would then have a tendency to cause glare in people's eyes and defeat its entire purpose. Fig. 195 shows how a lighting unit can be concealed in the front top corner of the window, and the manner in which it should distribute its light rays over the depths of the window.

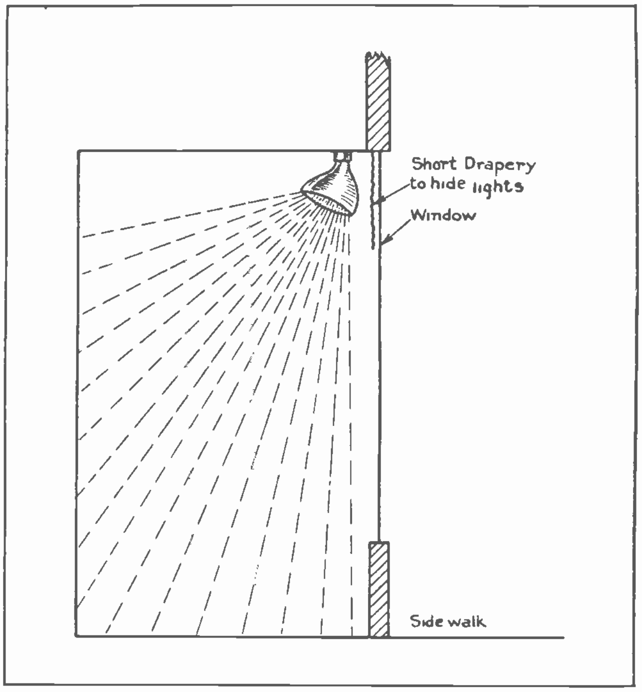


Fig. 195. This illustration shows how the light should be directed on the objects displayed, and not toward the window or observers.

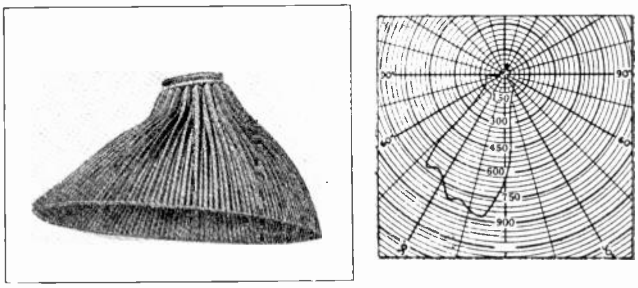


Fig. 196. A common type corrugated glass show-window reflector. Note how the light distribution curve compares with the desired angle of light shown in Fig. 195.

178. SHOW-WINDOW REFLECTORS

Fig. 196 shows a typical show-window reflector of the corrugated glass type, and also its curve of light distribution and the manner in which its shape directs the light to fit show-window needs.

Fig 197 shows two of the corrugated glass show-window reflectors with silvered and painted outer surfaces. The one on the left is shaped to throw the light down and slightly back into a shallow window, while the one on the right is curved to direct the light farther back into deep show-windows.

Fig. 198 shows a group of show-window reflectors mounted behind the concealing curtain, as mentioned before. A row of 150-watt lamps in such reflectors as these, spaced on 12-inch centers, will give excellent show-window lighting. If the same

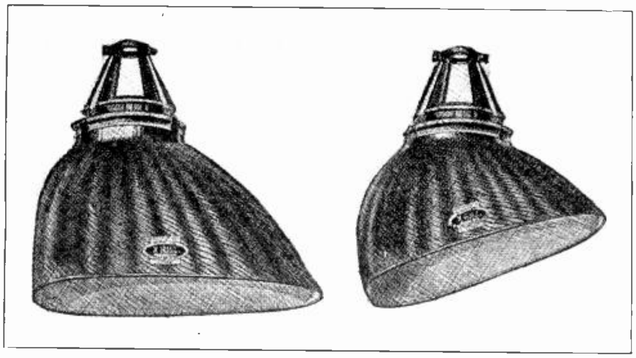


Fig. 197. Mirrored glass show-window reflectors with different shapes, to properly direct the light in windows of different depths.

sized lamps and reflectors are spaced on 18-inch centers, it will give good lighting, and on 24-inch centers fair lighting.

Foot-candle intensities for show windows were given in the list in Article 174.

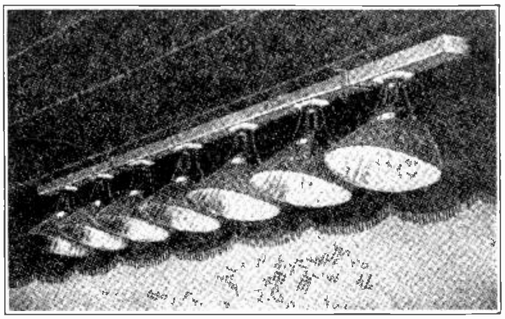


Fig. 198. This photo shows the manner in which show-window reflectors should be mounted and concealed for best results.

179. SPOT AND COLOR FLOOD LIGHTS

Proper use of special show-window flood lights and colored spot lights on certain objects will give very beautiful and attractive effects that in practically every case will pay well for the cost of installing and operating. Fig. 199 shows an adjustable show-window flood light with a detachable color screen which can be fitted over it. A number of different color screens can be obtained at very low cost, to make changes in color effects, and to keep up interest in a window display. Fig. 200 shows a spot light on the left, and on the right is a small reflector used for lighting display cases in store interiors.

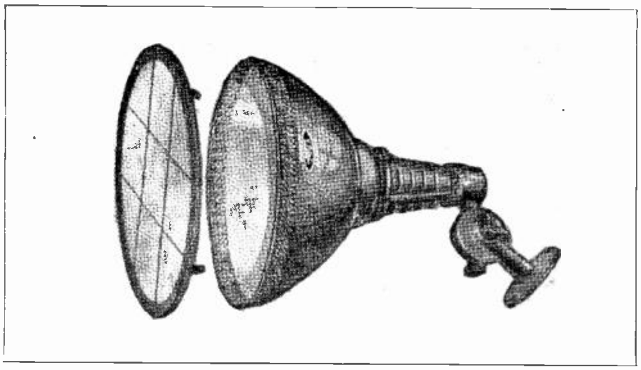


Fig. 199. Adjustable flood lights with colored screens can be used to produce beautiful and decorative effects.

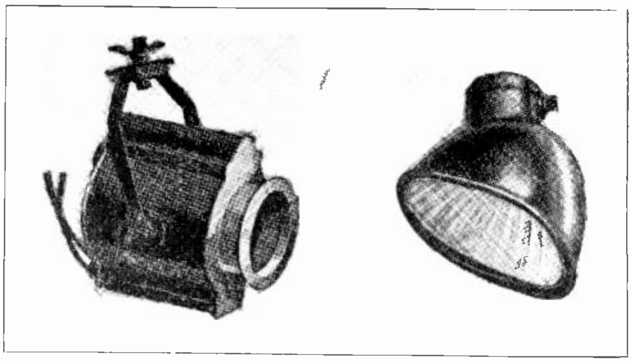


Fig. 200. On the left is shown a spotlight for concentrating bright light on certain objects in show-windows. The small reflector on the right is of the type commonly used in glass counters and display cases.

180. COUNTER LIGHTING

For lighting display cases and interiors of glass counters we can also use compact tubular reflectors with special long slender bulbs made for the purpose. These reflectors fit neatly under the wood or metal corner frames of the counters, so they do not obstruct the view or create a bad appearance in the case. Fig. 201 shows the method of installing this material in a glass show-case. Fig. 202 shows several different lengths of these trough-like reflectors and a number of the fittings used with them. The wires can be run in special small tubing, some of which is also shown.

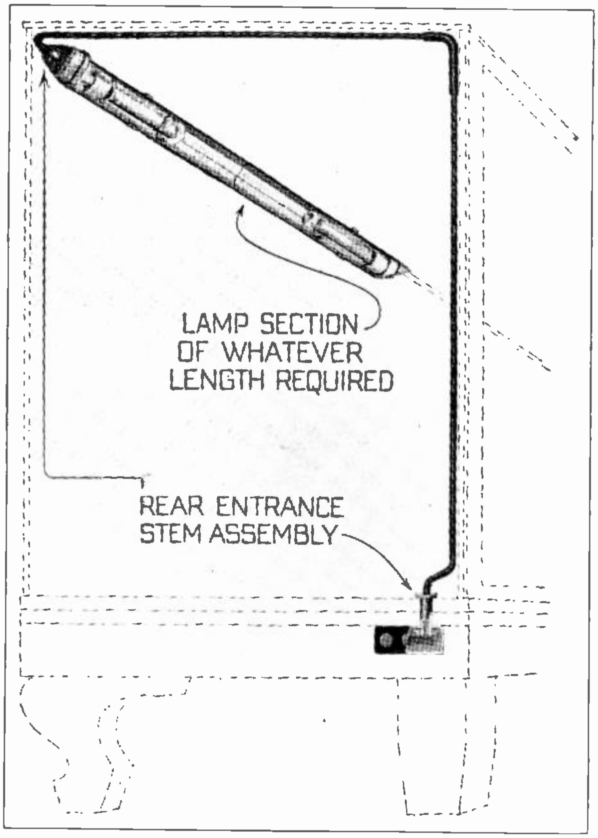


Fig. 201. Long trough-shaped reflectors with special tubular lamps are obtainable for convenient installation in glass counters as shown above.

Fig. 203 shows what remarkable effects can be obtained with properly concealed show-window lights, and properly distributed illumination in the window.

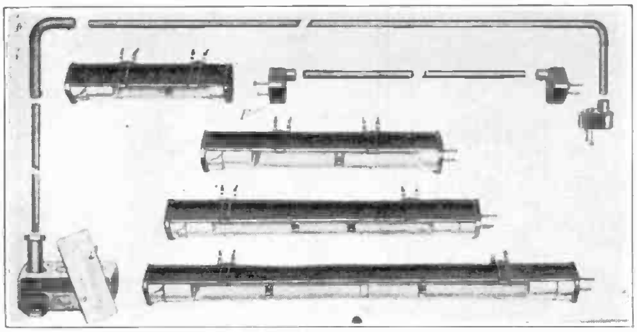


Fig. 202. Show case and counter lighting units are made in convenient sections which can be easily plugged together for lighting cases of different lengths.

181. ELECTRIC SIGNS AND BILLBOARDS

Electric signs today are made in such a great variety of styles and types and to produce such beautiful and life-like effects in some cases, that one might think them very complicated devices. While some of the larger ones are marvelous pieces of mechanical construction and use very ingenious arrangements of electrical circuits, they are really not hard to understand for one who knows the principles of electric circuits and the general principles of sign construction and operation.

182. BILLBOARD LIGHTING

One of the simplest forms of illuminated signs is the billboard type which consists simply of large flat panels on which are painted the pictures and words of the advertisement. Many of the illustrations for such signs are made up on large paper sections and pasted on the boards. This makes it economical to change or renew them as desired.

Billboards of this type are quite commonly equipped with electric lights, because, in many cases, they actually attract the attention of more people when lighted at night than they do during daylight hours.

Fig. 204 shows the common method of mounting the reflectors on conduit extensions out over the top edge of the board. With the reflectors in this position they do not obstruct the view of observers, and they direct their light toward the sign and away

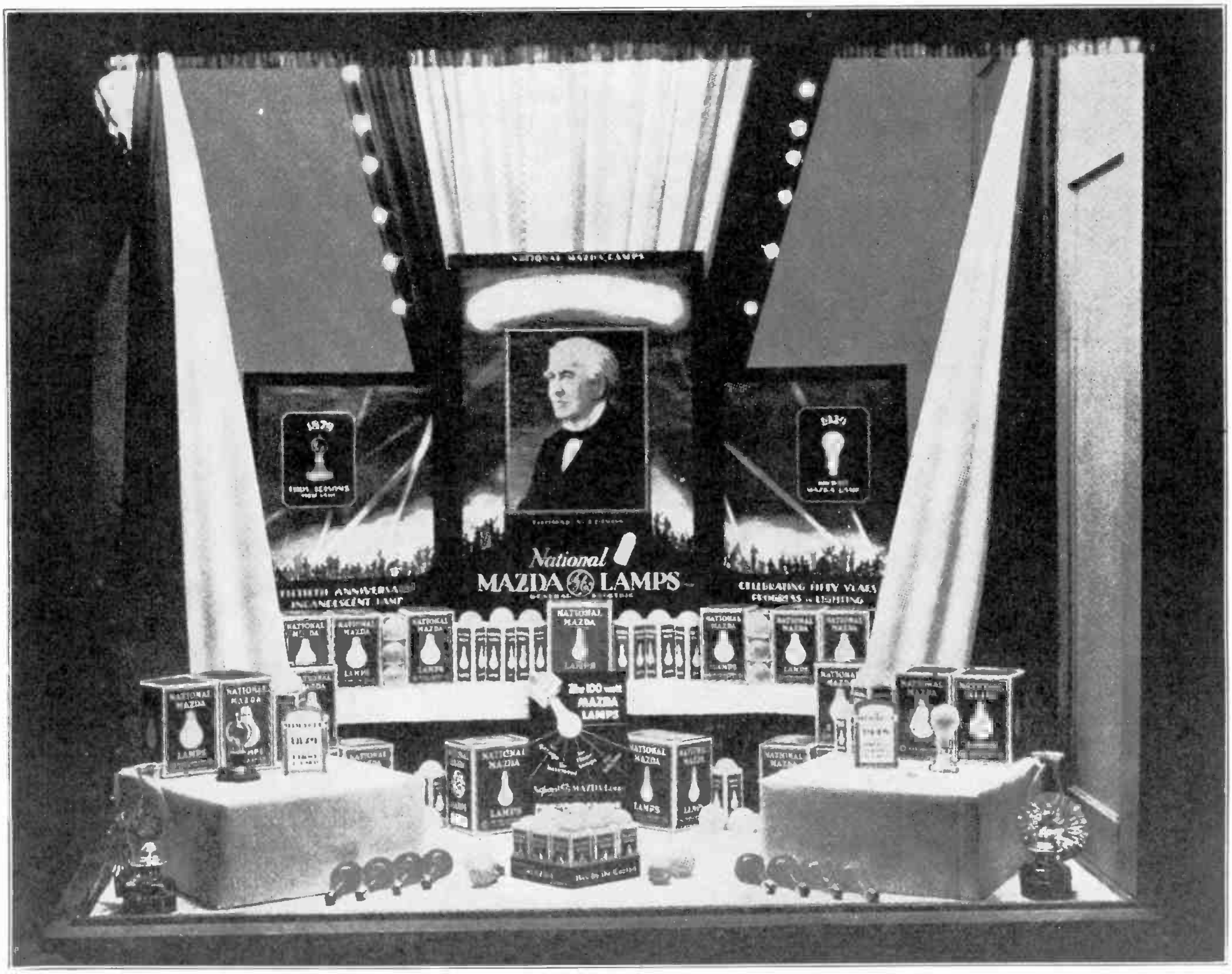


Fig. 203. This exhibit of Mazda lamps in a show-window of an electric store, shows the very beautiful and decorative effects which can be produced by proper show-window lighting. (Photo Courtesy of Light Magazine).

from the observers' eyes, so that the lights themselves are hardly noticeable.

This is ideal, because it is the sign we want people to see and not the lights. This principle is a very good one to keep in mind in illuminating problems, as the best results are often obtained by having the light sources practically concealed, or at least very inconspicuous; leaving the illuminated object to be the principal attraction to the eye.

Billboard lights should be mounted several feet out in front of the boards as shown in Fig. 204, because if they are placed close to the top edge, the light strikes the board at a sharp angle and causes glare and shadows. Mounting them out the proper distance from the board allows their light to diffuse evenly over the board.

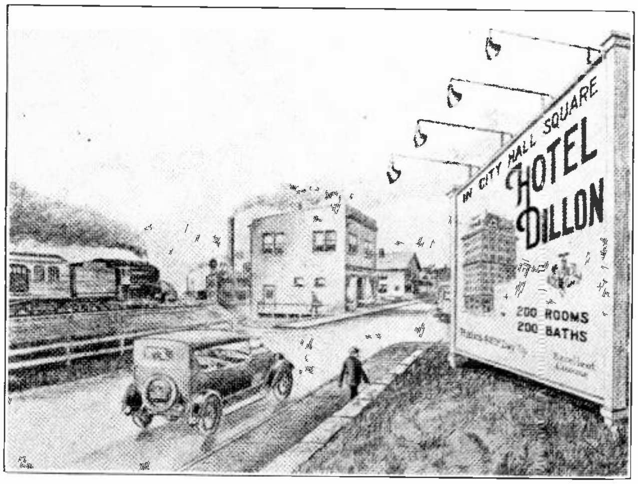


Fig. 204. This view shows the manner of mounting reflectors on conduit extensions for billboard lighting. Note how the reflectors are curved to direct the light on the board, but away from the observers.

In some cases where reflected glare from the lamps above the board comes at just the exact angle to strike the eyes of observers who are slightly below the board, the lights can be arranged out in front of the bottom edge of the board and pointed upward, as shown in Fig. 205-B. This method of mounting can also be used where billboards are viewed from above and we desire to keep the reflectors out of the direct range of vision.

The mounting as shown in Fig. 205-A is to be preferred whenever it is possible to use it, because the position of the reflectors keeps their inside surfaces and the bulbs more free from dirt and rain.

Billboard reflectors mounted on conduit extensions should usually be braced with steel wires running to the top of the board, to prevent the wind from blowing the reflectors sidewise.

183. ELECTRIC SIGNS, CONSTRUCTION AND OPERATION

Many electric signs are made of steel framework covered over with sheet metal. These can be made in square, round, high narrow, or long horizontal shapes; as well as ornamental designs. Some signs of this type merely have letter shapes cut in the sheet metal on both sides and covered with opal or

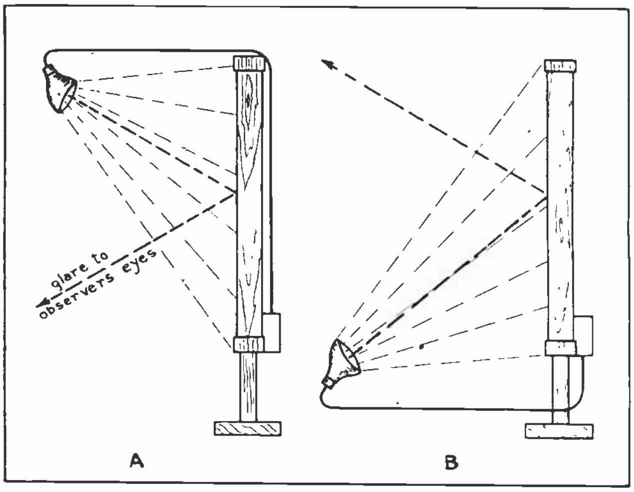


Fig. 205. If objectionable glare is produced by mounting the units above the board as in "A," they can be reversed and mounted below as shown at "B."

colored glass. Light bulbs inside them cause the glass letters to show up brightly at night.

Other signs have lamp receptacles screwed into small round holes in the sheet metal, and bulbs screwed in these receptacles and projecting out from the face of the sign. These bulbs can be obtained in various colors, and arranged in rows to form letters or patterns of almost any desired shape.

Beautiful action effects can then be obtained by connecting the bulbs to motor-driven flashers. By causing groups in sign borders to light up and go out progressively or in numerical order, they can be made to appear as though they are actually moving, thus giving the "chaser" and "fountain" border effects, and other action displays so commonly used on large signs.

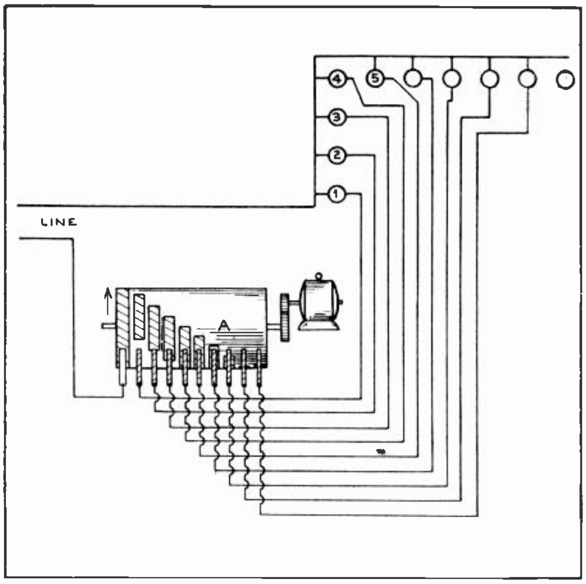


Fig. 206. This diagram shows connections for a sign flasher to be used to light the lamps 1, 2, 3, 4, etc., in rotation.

184. FLASHER CIRCUITS

Fig. 206 shows how a flasher can be connected to light lamps in order in a row, and then extinguish them in the same order. A motor-driven drum has a number of circular metal segments attached to it, and arranged with their ends staggered, or one behind the other in a slanting row. A number of spring-brass or copper brush contacts slide on these segments as the drum is rotated. The metal strip on the left end of the drum may be continuous, or nearly so, in the form of a ring around the drum. This ring is connected by a "jumper" to all other segments, so with one line wire connected to the left brush contact, all segments are kept alive or in contact with the lower live wire throughout the rotation of the drum.

If the drum rotates in the direction shown by the arrow, the segments will strike the stationary contacts in order, from left to right, closing the circuits to the lamps in order—1, 2, 3, 4, 5, etc. All lamps are connected by a common wire back to the top line wire.

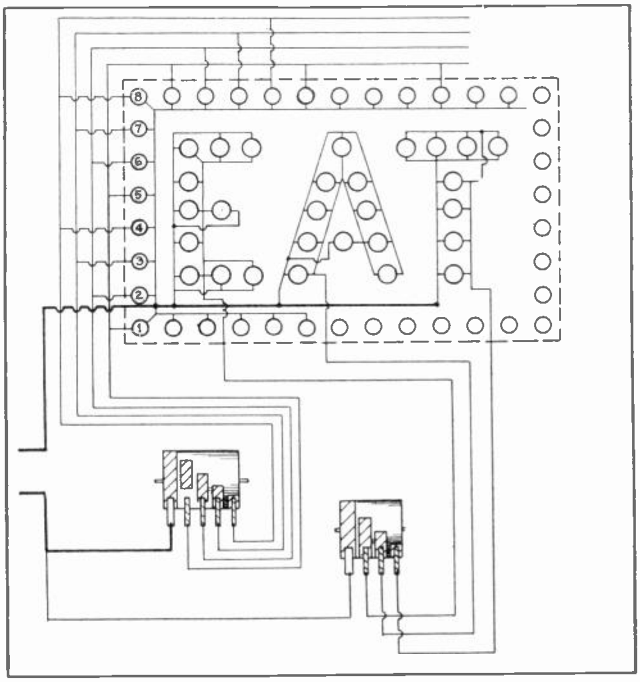


Fig. 206-A. Wiring diagram for two flashers used to obtain combination effects on an electric sign. The flasher at the left controls the border lamps only, while the one on the right controls the letters of the sign.

Flashers of this type can be obtained with many dozens of contacts, to be used to gradually spell out whole words composed of lamps on the sign.

Several flashers of this type with different numbers of contacts and operated at different speeds may be used together on one large sign to get the various combination effects desired. Fig. 206-A shows how two flashers are used, one to provide a "chaser" border effect, and the other to flash the letters of the word "Eat" on in rotation, and then all off.

You will note that to produce the motion effect in the border, it is not necessary to use a flasher with as many contacts as there are lamps. Instead, these lamps are connected in parallel groups, so that every fourth one is connected to the same flasher contact. This makes the lamps come on in the order 1, 2, 3, 4, and also 5, 6, 7, 8, coming on at the same time; or lamps 1 and 5 together, 2 and 6 together, etc. The segments on the drum are usually of the proper length so that one lamp of the four is out all the time, and as the drum rotates, the dark lamp is first No. 1, then 2, 3, 4, and repeat. This matches up with the next group, as all groups are operated from the same flasher; so it produces an appearance of continuous motion around the sign border.

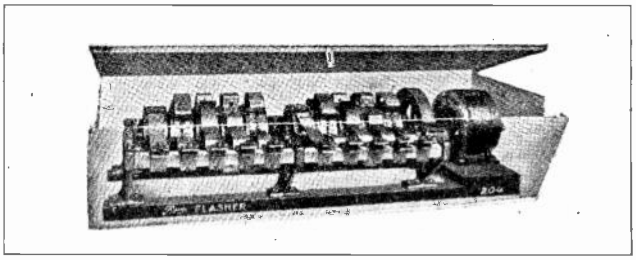


Fig. 207. Motor-driven sign flasher mounted in weather-proof box. Flashers of this type are made with different numbers of drum units and contacts, to produce a great variety of effects.

A large sign may have several thousand lamps on it, connected in groups to several branch circuits or return wires, and one wire from each lamp connected to its proper flasher wire.

You can see, however, from Fig. 206-A, that the manner of grouping the connections simplifies them, and makes it only an easy matter of circuit testing to connect each wire to its proper flasher brush.

Fig. 207 shows a photo of a sign flasher such as commonly used with signs of the type just described. Note that this flasher has two separate sections, and rotating segments made of strips of brass or copper bent to shape and attached to the shaft-like separate wheels. Fig. 208 shows a large sign which uses this type of flasher.

Fig. 208. Large signs of the above type often use several flashers, and a combination of lamps and Neon tubes to produce very beautiful effects.

Sign lamps are often mounted in sheet metal channels or troughs which have the inner sides and back painted white. This gives a more sharply defined shape to letters and figures, as it prevents the light from spreading so much. Very striking effects can also be produced by using lamps under black inverted trough-shaped letters, mounted so they stand out slightly from a white background as shown in Fig. 209.

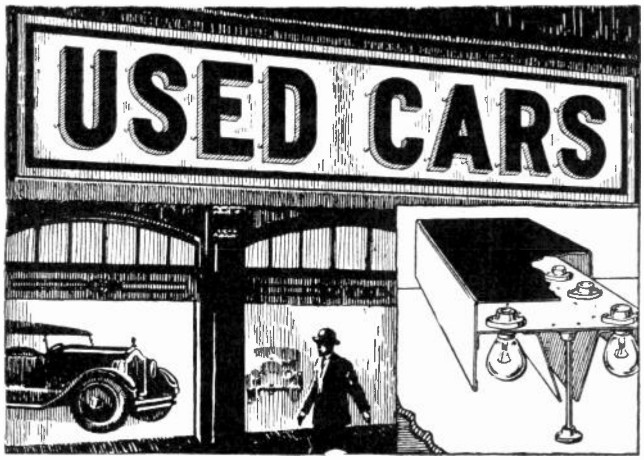


Fig 209. Very attractive signs can be made with inverted trough units, to produce outstanding black letters on white background as shown above.

Many large flasher signs also have lighted billboard areas combined with the motion effects. Some of the largest flasher signs which have special "moving letters", or continuous reading effects, use a paper roll with holes punched in it, similarly to a player piano roll. This paper is in the form of an endless belt, and is drawn slowly along between a large metal plate and a "bank" of small contact "fingers". The holes in the paper are arranged in the form of letters or shapes which are to travel across the sign. The sign face has a bank of lamps arranged in rows both ways, the same as the contacts are; so as groups of contacts drop through the holes in the moving paper and strike the metal plate completing their circuits, corresponding lamps light up on the sign.

Fig. 210 shows the arrangement of the contacts and lamps, and the method of connecting them. The wires are grouped or cabled together but can be easily traced from the contacts to the lamps and you can see that any contact that is allowed to touch the metal plate will close a circuit to a corresponding lamp.

The sketch in this figure shows only a comparatively few lamps, but on a sign of this type they are so numerous and close together that almost any letter or figure can be made to light up by having the groups of holes punched in the paper in the desired shape. Then as the paper moves and the holes slide from one set of contacts to another, the lighted letter on the sign shifts from one set of lamps to the next and moves across the sign.

Fig. 211 shows a splendid example of the advertising value and beautiful effects of combined electric sign and decorative lights on the front of a theatre building.

185. NEON TUBE SIGNS

Neon gas signs are very attractive and the peculiar reddish color is one that draws the eye and penetrates foggy or smoky atmospheres very effectively.

These signs are made of long glass tubes which are bent into the shapes of letters or figures desired, and then filled with neon gas. They are then sealed air and gas tight and mounted on a background or frame, or in some cases in sheet metal channels or trough letters.

Neon is a rare gas which is extracted from the air where it exists in very small quantities. When high voltage electricity is passed through it, it glows with the peculiar reddish hue already mentioned. Neon tubes are operated at voltages ranging from 1000 to 20,000, according to the size and length of the tubes.

These high voltages are usually obtained by use of small step-up transformers right at the sign, and the high voltage wires must be very carefully insulated along the sign framework.

Some of the smaller signs of this type are operated with ordinary spark coils, but their light is not as steady as that of signs operated with transformers.

One of the particular advantages of neon signs is that the tubing can be heated and bent to form letters written out in complete words, and also the most intricate curves and designs for decorative figures.

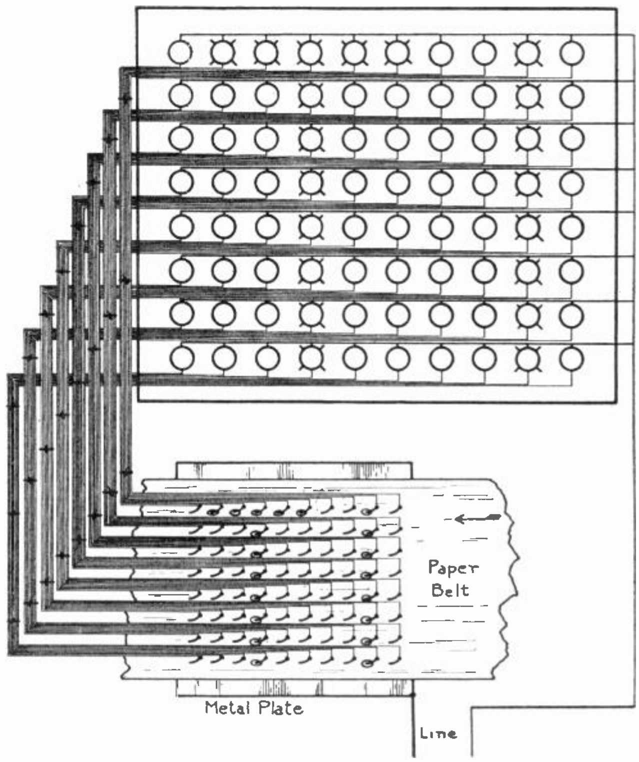


Fig. 210. The above diagram illustrates the principle of signs with traveling reading matter. Note how each contact on the paper belt is wired to a lamp in a corresponding position on the sign above.

In addition to neon gas, some signs use tubes with mercury vapor, which give a beautiful blue color when high voltage is applied to them. Green color is obtained with mercury vapor in amber colored glass tubes. By using helium gas and amber colored glass, gold, pink and other colors can be obtained.

Various letters and sections of tube signs can be operated with flashers, and some large signs use a combination of neon and mercury vapor tubes with various colored bulbs, to create some very beautiful and striking effects.

The glass tubes of neon signs must be very carefully handled, as they are easily broken; and the least crack in a tube will allow the gas to leak out.

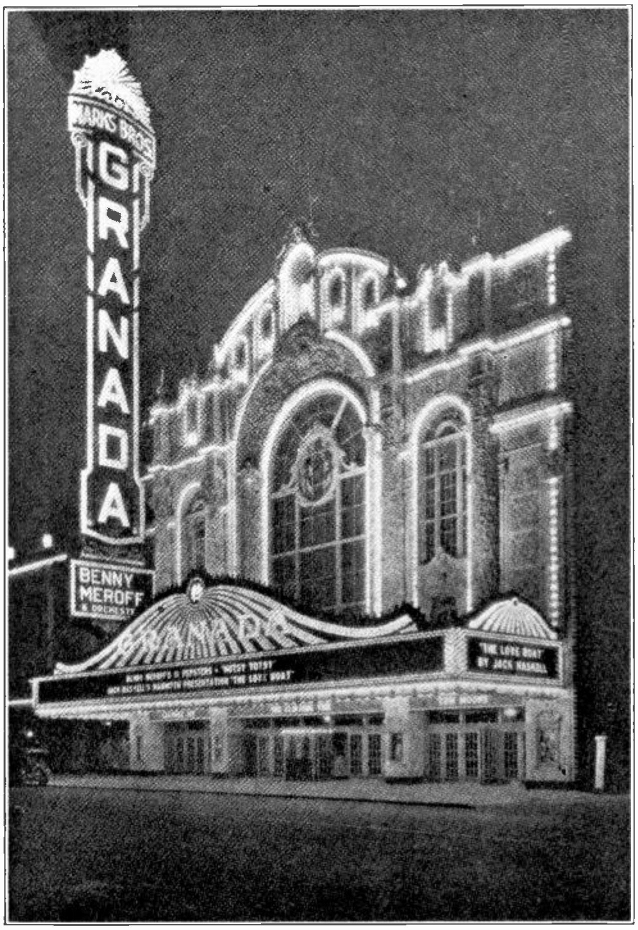


Fig. 211. This photo of the front of a large theatre shows what beautiful effects can be obtained by the use of flasher signs and lights on the building itself.

186. SIGN WIRING, AND CONSTRUCTING SMALL SIGNS

Electric signs are one of the most profitable forms of advertising illumination, and in many localities offer a very good field for the trained man to install or service them.

Sign manufacturers will make almost any type or design of metal sign to the specifications of the customer or electrician. You can also build the smaller ones very easily in your own shop if you desire.

The frame should be of angle iron, and covered with substantial sheet metal to form a box of the desired shape and size. The letters and figures can be painted on, after the sign has had a coat of weather-resisting paint.

A color combination that serves well both for day and night visibility is a dark blue background with white letters. If the sign is to be lighted with bulbs, cut 1½" round holes in rows along the letter shapes. Two-piece threaded sign receptacles can be screwed tightly into these openings. Then wire up the receptacles, either in parallel or with one common wire and separate wires to a flasher if desired. All connections, including the binding screws on receptacles, should be soldered to prevent corrosion.

Then the connections, backs of receptacles, and all exposed metal edges should be covered with a good coat of weather-proof paint or sealing compound. If the sign is large its circuits should be divided so that none carries over 15 amperes, and each circuit should be fused separately.

In small towns one can often have the local tinsmith or metal shop build the sign bodies, and a sign painter decorate them. In this case the electrician can wire and hang them, and share the profits.

In hanging any signs over sidewalks, they should be fastened very securely so there will be no chance of their ever falling and injuring anyone. They should be bolted to a substantial part of the building and braced with chains from above and both sides.

The local authorities should also be consulted on their rulings before any signs are hung over public walk-ways.

187. FLOOD LIGHTING

Flood lighting of building exteriors is another interesting branch of advertising illumination. It is a particularly attractive form of display on buildings having light-colored walls and good appearing architecture.

Flood lights on buildings are usually concealed on a ledge or balcony of the building so their rays are directed upward and at the proper angle against the sides of the structure.

They should never be placed in a position where they can shine into the eyes of passers-by.

Fig. 212 shows several styles and sizes of flood light **Projectors.** Note their weather-proof housings and adjustment feature, to allow them to be "aimed" or focused on the area desired.

Fig. 213 shows the shape of the concentrated beams thrown by shallow-type reflectors and also those from deeper reflectors which spread the beams over a greater area.

In many cases where it is not convenient or possible to locate flood light projectors on the same building they are to light, they are located on some other building nearby, and perhaps across a street.

For best efficiency, the beams must be able to come from a short distance out from the vertical walls, rather than be directed too nearly parallel with the walls they are to light. Certain effects, however, can be produced by units quite close to the walls or columns to be lighted.

Fig. 214 shows a row of powerful flood lights on the parapet of a skyscraper, and used to light the narrower portion of the building which projects on up from this level.

Beautiful effects can be obtained by properly using mixed colors on buildings of striking architecture, and also by use of "dimmer rheostats" auto-

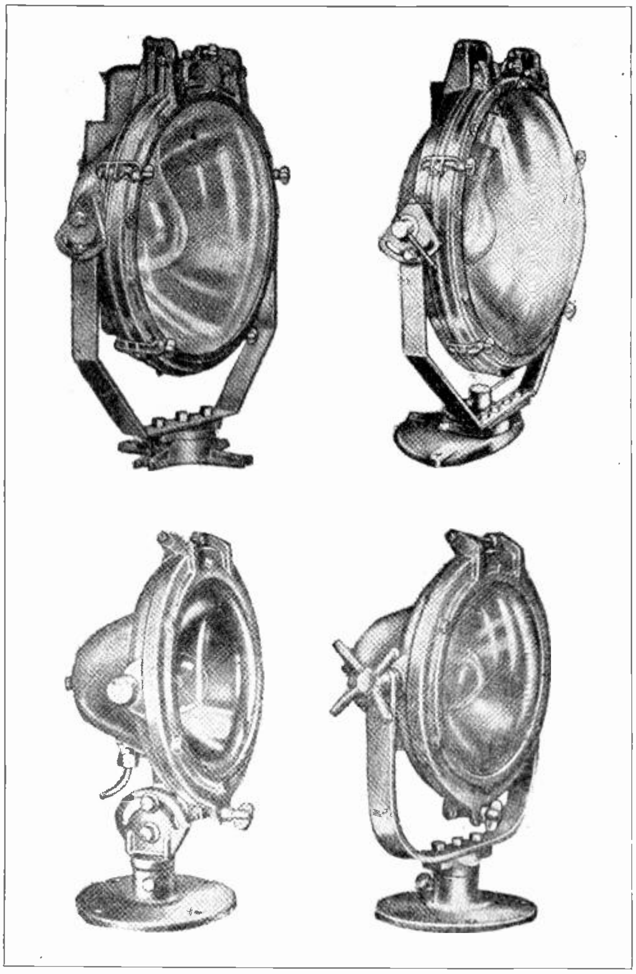


Fig. 212. Several types of flood light projectors. Note the weather-proof construction and adjustment features of these units.

matically operated by small motors in connection with automatic tilting mechanisms, to cause changing and moving colors to play over the building.

The deeper-colored lights such as red and blue are, of course, not as efficient as the white or amber ones, because the color lenses absorb some of the light. The effects obtained with colors, however, are well worth their cost.

Fig. 215 shows the effect of flood lighting on the top of a large office building.

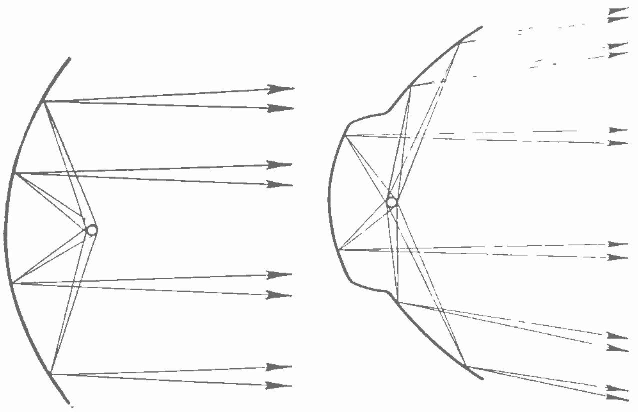


Fig. 213. This diagram shows how reflectors with shallow or deeper curves can be made to concentrate or spread the beams of light as desired.

Flood lights are also very extensively used for lighting railway yards, race tracks, bathing beaches, and places where construction work is being done at night. In public parks flood lights are often used to illuminate fountains and monuments, with very beautiful results. Fig. 216 shows an illuminated fountain which uses water-proof projectors mounted right in the water. In the background is a beautiful example of flood lighting on a tower.

Fig. 214. This photo shows a row of flood light projectors in use on the top of a skyscraper office building. (Photo Courtesy Light Magazine).

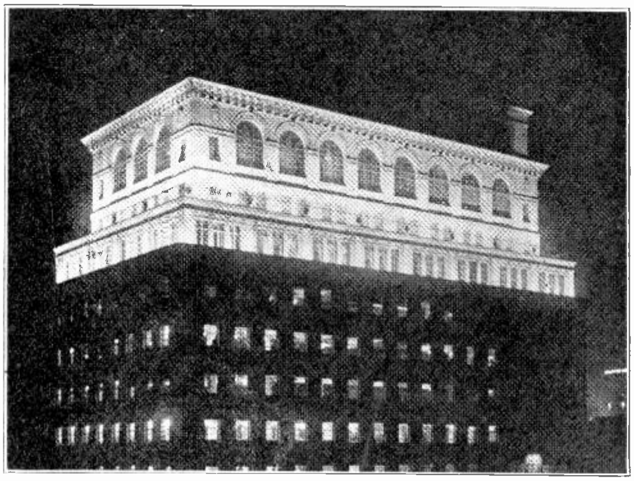


Fig. 215. This building is a very good example of the beautiful effects obtainable with modern flood lighting. (Photo Courtesy Light Magazine).

188. STREET LIGHTING

Street lighting is becoming so common that many of us fail to notice or appreciate it any more. But when we think of the benefits derived, in the reduction of accidents and increased business on well lighted streets, and that in many of the larger cities great lamps of 1000 to 3000 watts each light the streets nearly as bright at night as in the daytime, we find it is really a wonderful branch of electric illumination. The installation and maintenance of street lighting systems furnish profitable employment to great numbers of trained electrical men, and in the small and medium-sized towns often provide a worthwhile contract for some alert graduate

Fig. 216. The fountain in the foreground is illuminated by flood lights placed within its bowl, and in weather-proof projectors. In the background is shown a well flood-lighted tower.

who can convince the officials of his home town that better street lighting pays.

Arc lamps, which were formerly extensively used, are being rapidly replaced by Mazda lamps, because of their greater simplicity and reliability.

Where arc lamps are still in use, it is a simple matter for the trained man to make any necessary adjustments on their coils and mechanisms which feed the carbons as they burn away, or to locate any trouble on the system.

Incandescent lamps of from 200 to 2500 watts or more are commonly used for new street lighting installations.

189. SUSPENSION TYPE UNITS

For overhead lighting systems in small and medium-sized towns, clear lamps of 200 to 500 watts or larger are often placed in simple reflectors of the type shown in the lower left view in Fig. 217. These units are then suspended from overhanging arms on poles, or hung from steel wires stretched across the street between poles or buildings. Reflectors of this type are low in cost, and when mounted at the proper height, provide quite effective lighting. These bare lamps, however, are the cause of a certain amount of undesirable glare and shadows.

Directly above the reflector in Fig. 217 is shown a swivel cross-arm used for hanging such reflectors. The porcelain insulators on the ends of the arm are for the purpose of attaching the wires of the lamp circuit.

On the right in Fig. 217 is shown a street lighting unit of the medium-priced, enclosed type which is also for overhead suspension. These units soften and diffuse the light and produce more even illumination, with less glare and shadows.

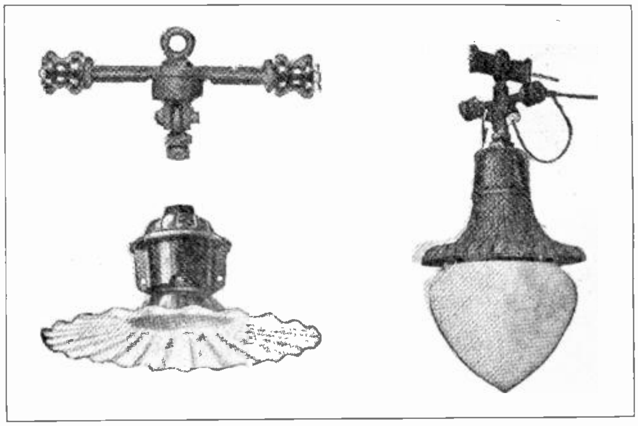


Fig. 217. Above are shown two types of street lighting units and also a swivel cross arm or hanger used in their mounting.

Fig. 218 shows two types of "cutout" or "disconnect" pulleys for use with overhead street lights. These pulleys allow the lamp to be lowered for cleaning, inspection, and repairs. When the lamp is lowered by releasing its supporting chain or rope, it is disconnected from the line by the prongs of the cutout pulley dropping out of their sockets. This makes the lamp safe to work on, and when it is pulled back in place, a guiding device causes the connecting prongs to slip back in their clips as the lamp is drawn up tight.

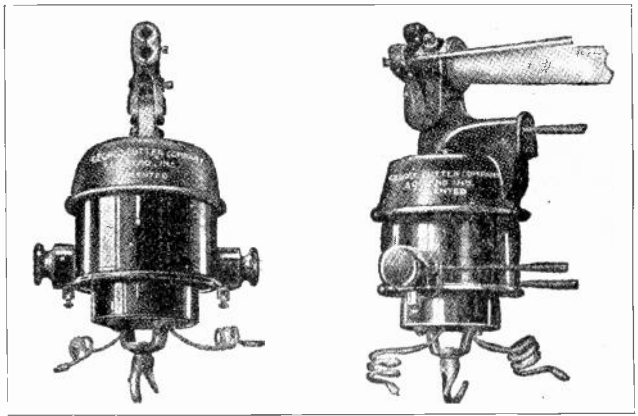


Fig. 218. Cut-out pulleys used for disconnecting and lowering street lights for cleaning and inspection.

190. POST TYPE UNITS AND STREET LIGHT CIRCUITS.

Where more elaborate street lighting is desired, enclosed glass units on top of posts at the side of the streets are commonly used. Fig. 219 shows several styles of these units both for single and double lamps.

Street lights are commonly connected in series on high-voltage circuits, to cut down the cost of copper wires, as the distances between them are considerable. You will remember that when devices are connected in series the current is the same in all parts of the circuit, and that which flows through one device flows through all the others as well. These circuits are often operated on 2300 volts and higher, so the wires must be well insulated, and considerable care should be used in working around such circuits. We can now see the advantage of using cut-out pulleys when working on these lamps.

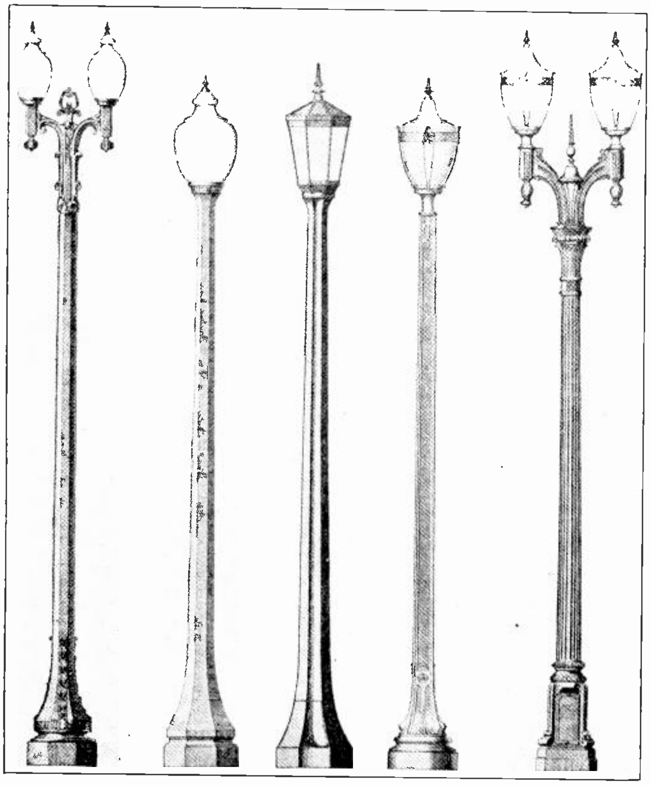


Fig. 219. Hollow concrete or metal posts with large globes, as shown above, are used in many of the better appearing street lighting installations.

191. SERIES LAMP "CUTOUTS"

On the older series street-lighting circuits, if one lamp burned out, all lamps on that circuit went out, because they were all in series. Nowadays there are in use special sockets which have short-circuiting springs that cut out the lamp if it opens the circuit. Fig. 220 shows a sectional view of a socket of this type from which the operation of prongs can be easily understood. A thin film or strip of insulating material is placed between the tips of these spring contacts and remains there as long as the lamp is in good condition.

If we have, for example, a circuit of 100 lamps in series and 2300 volts is applied to this circuit, the voltage drop across each lamp when operating will be about 23 volts. This voltage drop we know is proportional to the current flow and to the lamp resistance. This low voltage will send current through the lamp, but will not puncture the insulating film in parallel with the lamp. However, if a lamp burns out and opens the circuit, all current momentarily stops flowing. With no current flowing there is no voltage drop at any of the lamps, and the full 2300 volts will be applied for an instant across the springs of the lamp which has opened the circuit. This voltage is high enough to puncture the insulating film and burn it out, thus shorting the defective lamp out of the circuit, and allowing the others to operate once more.

Special transformers at the sub-station compensate for the reduced resistance and voltage drop due to the loss of the one lamp. These will be explained later in the section on transformers.

Instead of applying the high voltage of the line circuit directly to the lamps and sockets, many modern series street lighting systems use small transformers at each lamp to reduce the voltage for its filament. All of these transformer primaries are connected in series, as in Fig. 221. This increases the safety and reduces lamp socket insulation costs. It also permits the use of lamps with filaments of larger diameter and lower resistance. They are, therefore, stronger and more rugged and also of higher efficiency.

The current through these low-voltage lamps may be from 6 amperes to 20 amperes, or more on the different sizes; and they are made for voltages from 6.6 to 60.

Wiring for street lights can be run on the poles where suspension type units are used, and underground for better appearance with post type units. Underground wiring can consist of lead covered cable buried in a trench and run up through the hollow poles to the lamps, or of rubber covered wires or lead covered wires in underground ducts of tile or fibre conduit.

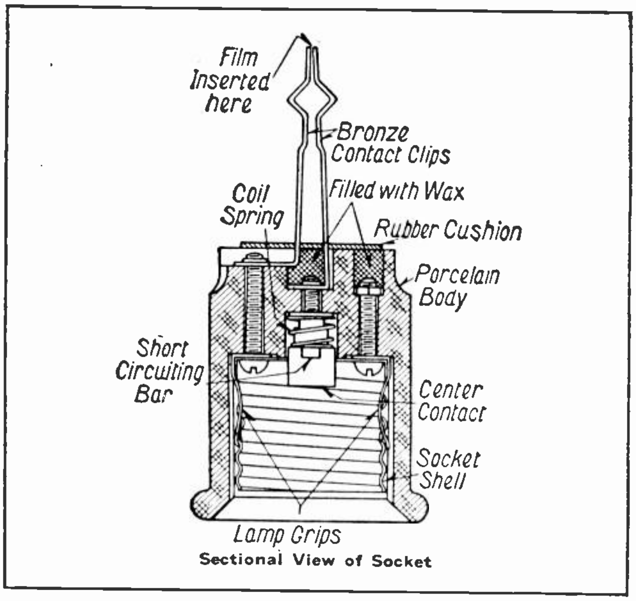


Fig. 220. This sketch shows a sectional view of a socket and "film cut-out" used with series street lamps. Note how these cut-out springs on contact clips short circuit the shell and center terminals of the lamp socket. The insulating film is not shown between the contact clips in this illustration.

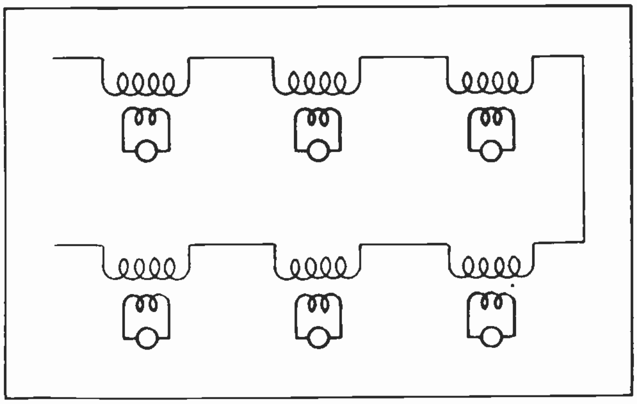


Fig. 221. This diagram shows the manner of connecting series street lighting transformers which are used to reduce the voltage at each light.

192. MOTION PICTURE LIGHTING

Electric light is used on a tremendous scale in the motion picture industry, both in the photography and in the operation of projector machines in theatres; and the lighting of the theatres themselves.

In the taking of motion pictures there are used some of the highest foot-candle intensities that are encountered in any branch of illumination. While it was formerly thought that such pictures had to be taken in sunlight, powerful electric lights now reproduce effects of sunlight or moonlight in almost any required intensity.

Arc lamps were formerly used very extensively and still are to some extent, as the color of their light rays is particularly good for exposing the older types of film. However, there has been developed a new type of film that is sensitive to the yellow and white rays of incandescent lamps, and, therefore, these lamps because of their quieter and cleaner operation are rapidly replacing many of the arc units. Mazda lamps require much less attention and adjustment than arc lights, and provide a steadier light. Their quieter operation is a great advantage in their favor for the filming of talking pictures.

The constantly changing lighting requirements on various movie "sets" and the care and maintenance of the lighting units provide a great field of fascinating work for trained electrical men who know practical illumination.

Single lamps of 10,000 watts each and larger are commonly used in motion picture photography, and "banks", or portable units, consisting of 4 to 12 or more lamps are used.

An interesting problem, and one which will help you to realize the size of this equipment, will be to calculate the current that will be required by two banks of six 10,000 watt lights each, and two single 20,000 watt lights if they are operated on a 110-220 volt, three-wire circuit. Also determine the size of cable necessary to carry this current to the lights in a temporary location 150 feet from their generator, with not over 5 volts drop.

AVIATION LIGHTING

The aviation industry is fast becoming one of the greatest users of modern and efficient electric illumination.

A great deal of night flying as well as daylight flying must be done to maintain fast air-mail and passenger schedules, and the safety of night flying depends on electric illumination in many ways.

Aviation lighting can be divided into the following classes:

- Airport lighting
- Route beacons
- Lights on planes

Many millions of dollars have already been spent in airport lighting, and it is undoubtedly safe to say that within a very few years every town of any size in this country will have a lighted airport.

193. AIRPORT LIGHTING EQUIPMENT

A well-lighted airport requires the following equipment:

- Landing field beacon light
- Landing field flood lights
- Boundary lights
- Obstruction lights
- Approach lights
- Illuminated wind-direction indicator
- "Ceiling" projector
- Hangar lights
- Shop lights.

Many of these lights are rated by government standards, and the airports are given ratings by the government according to the type and completeness of lighting equipment used.

194. AIRPORT BEACONS

The purpose of the airport beacon is to direct pilots to the airport. These beacons are rotating or flashing searchlights of 15.000 to 100,000 candlepower, and are usually mounted on a tower or on the top of one of the hangers, so their beams will be unobstructed in all directions. If a flashing light is used, the flashes should not be less than 1/10 of a second in duration, and should be frequent enough to make the light show 10 per cent of the time. Beacon lights for airports or route beacons usually have two bulbs mounted on a hinged socket base, so if one bulb burns out the other is immediately swung into place by a magnet. This is necessary to make these units dependable at all times.

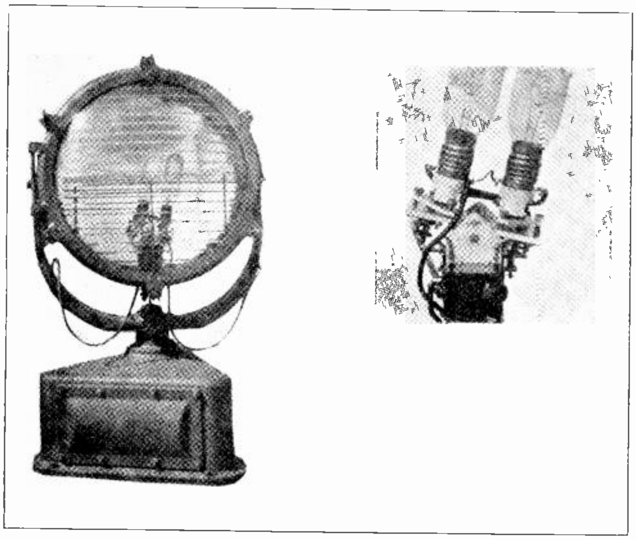


Fig. 222. On the left is shown a typical rotating beacon, such as used at airports and along air routes. On the right is a view of the double lamp mechanism, which swings a new lamp in place if the one in use burns out.

Fig. 222 shows on the left a beacon light unit mounted on the case which contains the revolving motor and mechanism. On the right is shown the double lamp unit which can also be seen inside the light at the left. This light has a 24 inch diameter, and uses a 1000 watt. 115 volt bulb, and develops 2,000,000 beam candlepower. Such a light can be seen by the pilot from a distance of 10 to 35 miles in fair weather, and is a great help in guiding him to the airport.

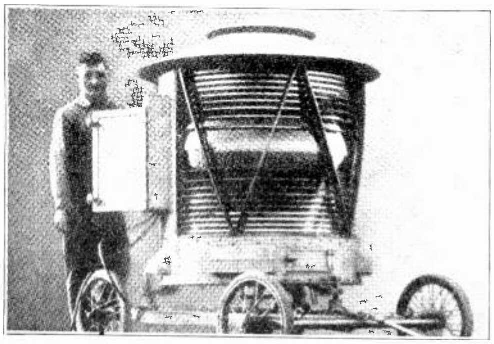


Fig. 223. This large landing field light has a lens similar to those used in lighthouses, and is mounted on a light truck for portable use at airports.

195. LANDING FIELD FLOOD LIGHTS

Landing field flood lights are used to illuminate the surface of the landing field, in order to enable pilots to land their planes safely. In landing a plane it is very important for the pilot to be able to see the ground and judge his distance from it, also to see the length of the field or runways on which he has to bring the plane to a stop.

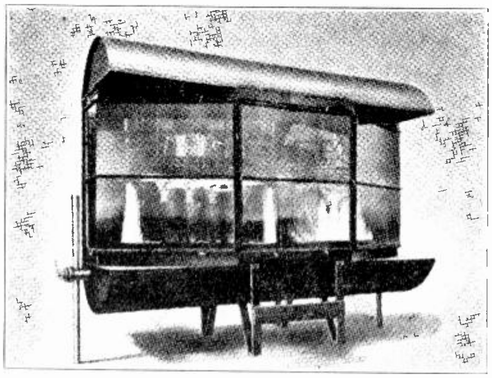


Fig. 224. A landing field lighting unit which has a number of powerful lamps mounted behind the glass front, in a manner to spread their light over a wide area.

Flood lights should also illuminate the field well enough to show up any uneven surfaces. Some fields are lighted by several different flood lights located on opposite sides of the field, while others use a bank or group of lights located near the hangars. Sometimes a large portable light is used, so it can be moved about by hand on a light weight wheeled truck. Fig. 223 shows a unit of this last mentioned type.

Fig. 224 shows a large unit in which a number of lamps are mounted, and you will note that its shape allows the beams from the several lamps to spread over a wide angle in order to cover the entire field from this one light source.

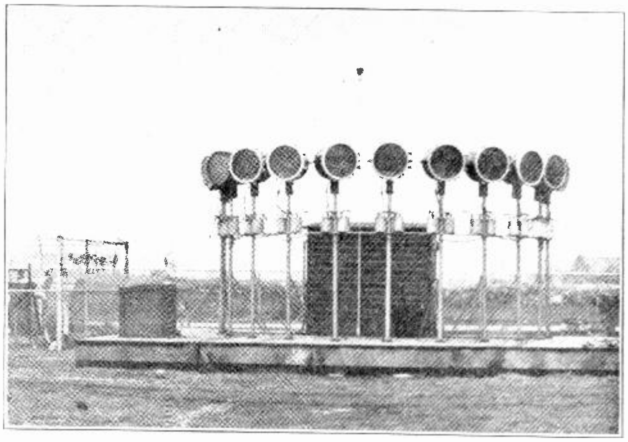


Fig. 225. A number of smaller projectors, arranged as shown, provide very effective distribution of light over the field.

Fig. 225 shows a number of smaller flood lights arranged to throw their separate beams over the field in a wide spread fan shape. Whatever type of flood lights are used, they should light the field uniformly and without harsh shadows, and their color should be such that they do not distort normal

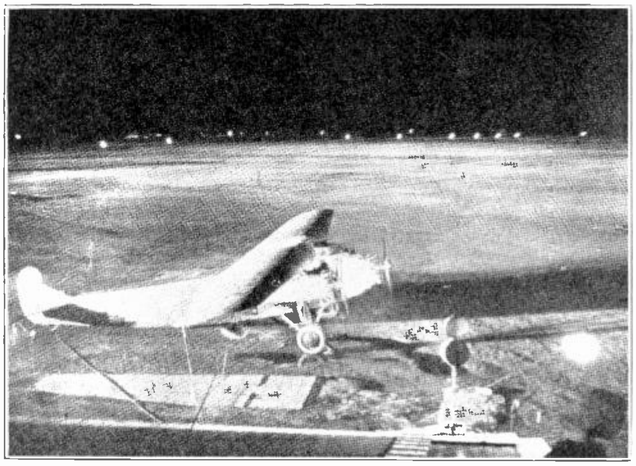


Fig. 226. This photo shows a well-lighted airport at night, and illustrates the great advantage and safety feature of such lighting for night flying.

colors or appearance of objects. They should keep all light in an upward direction at an absolute minimum, to avoid glare in the pilots' eyes. For this reason flood light units are equipped with reflectors and lenses which spread their beams in a wide angle horizontally, but very narrow in the vertical plane.

The vertical beam spread is usually not over 5 or 10 degrees, and the units should be so adjusted that the top edge of this beam does not point above a horizontal line. Flood light units should be kept down close to the ground, preferably within 10 feet. If the top of their beams is higher than this it often makes the ground surface appear closer to the pilot than it really is, when he views it from above the beam.

Fig. 226 shows a well lighted landing field which is illuminated by a 24 KW floodlight. Fig. 227 shows a bank of smaller 3000-watt flood lights in action at night.

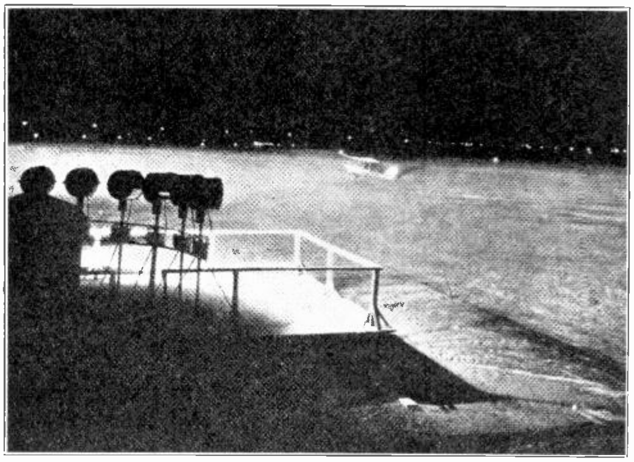
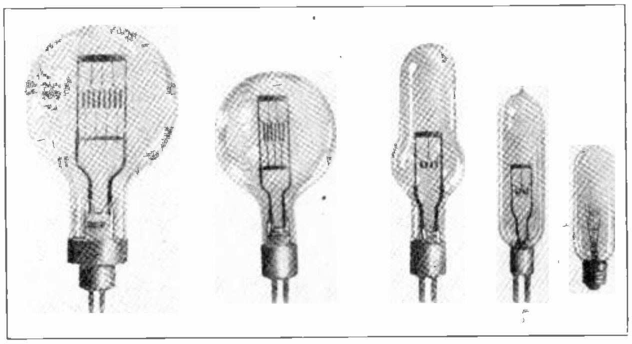


Fig. 227. This landing field is lighted with a group of small flood lights such as shown in Fig. 225.

The four lamps on the left in Fig. 228 are some of the types and sizes commonly used in airport flood lights, while the one on the right is of the type used in beacon lights. Note the special construction of the filaments and sockets of the larger lamps, and the peculiar shaped bulb of the middle one, which keeps the glass farther from the heat of the filament.

Planes should always be landed against the wind, so as the wind changes the pilot must change his direction of approach and landing run. For this reason it is best to have either portable lights, or lights located on two or more sides of the field, so the direction of the light beams can be changed with the wind and avoid making it necessary for the pilot to ever face the beams.



10,000 Watts | 5000 Watts | 3000 Watts | 1500 Watts | 1000 Watts

Fig. 228. Here are shown a number of powerful lamps of the type which are used in airport flood lights and beacons.

Fig. 229 shows an excellent layout for permanent flood lights located around the field and remotely controlled by switches in a control room at the hangar. The devices marked "remote controllers" are magnetically operated switches which close the circuits to these large lights, as their current would be too heavy to handle with the push buttons. Note that parkway cable is used to supply high voltage to step-down transformers at each light. This circuit is shown in a "one line" diagram until it reaches the remote control switches, where the two conductors are shown separated.

Parkway cable of this type can be buried under the ground surface 10" or more, and makes a very good system of wiring for airports, where of course no overhead wires should be used.

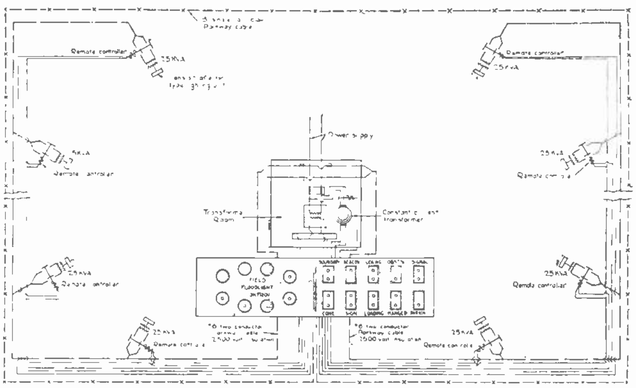


Fig. 229. Wiring diagram for a very practical and efficient airport flood lighting system The lights are fed by individual transformers, and all remotely controlled from one central point.

196. BOUNDARY LIGHTS

Boundary marker lights are used to indicate to the pilot, the location of the edges of the landing field, and are very essential in order to enable him to judge the length of the field and the proper place to approach the ground. These lights are white in color and should be either 25 watt lamps if connected in parallel, or 600 lumen series lamps. They should be spaced from 75 to 125 feet apart for best efficiency, and never more than 300 feet apart. Boundary lights are to be mounted 30 inches above the ground, and the circuits must not have over 5 per cent voltage drop at the farthest points.

Fig. 230 shows three common types of boundary lights. The one in the center is simply a lamp of the proper size enclosed in a weather proof glass globe, and mounted on a special pipe fitting on a 30-inch pipe.

These units on the pipe stems are not very visible in the day time, so it is well to have a circle of whitewashed gravel or crushed rock about 3 ft. in diameter around their bases.

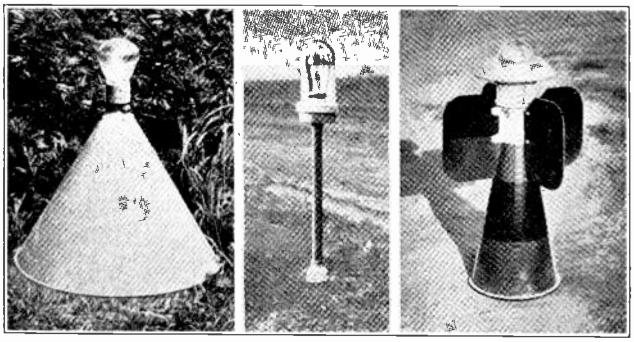


Fig. 230. Several types of boundary lights used for indicating the outline and extent of the landing field at night.

The unit shown at the left in Fig. 230 has a white metal cone base, which makes it very visible. This unit uses a prismatic glass globe which is more efficient than the clear glass, as it directs a stronger beam of the light upward.

Units such as this and also the one on the right in the figure can be merely set on the ground and connected to the circuit by detachable plugs. This makes an added safety feature in case they are struck by a plane, as they will tip over easily without doing so much damage to the plane.

197. APPROACH AND OBSTRUCTION LIGHTS

Approach lights are simply certain boundary lights that are equipped with green globes to indicate good points of approach to the runways of a field. They can also be used to indicate wind direction by turning on only those which are on the proper side of the field to bring a plane in against the wind.

Approach lights should have 50 watt parallel lamps or 1000 lumen series lamps, because their green globes absorb more of the light.

Obstruction lights are red and should be placed on tops of all trees, chimneys, water tanks, power or telephone poles or radio towers which are near to the landing fields. They should also have 50 watt parallel or 1000 lumen series lamps, and 100 watt lamps are recommended in some cases.

We have mentioned several times the possible use of either parallel connected lamps or series lamps for airport lights. Both systems are in use.

The series system has the advantages of lower cost of copper wire and less voltage drop, particularly in the longer circuits such as those to boundary lights or flood lights located on far edges of the field.

The parallel system has the advantages of being somewhat safer due to its lower voltage, using lower cost lamps, and being a somewhat simpler system, as it doesn't require sockets with film cutouts or constant current transformers.

The selection or choice of one system or the other would depend to some extent upon the size or area of the field, and the number of lights to be operated at a distance from the source of current supply.

198. ILLUMINATED WIND DIRECTION INDICATORS

It has already been mentioned that planes should be landed against the wind in order to reduce their landing speed. Wind direction indicators are, therefore, used at airports to show an approaching pilot the direction of the wind. These are very necessary, as his own air speed may make it difficult for him to tell the wind direction accurately unless he can see moving clouds or smoke.

A "wind cone" or tapered cloth sack with an opening in the small end is commonly used for a wind direction indicator. In other cases a large wind vane shaped like an arrow or sometimes like a small plane may be used.

These devices should be mounted on a pole or tower, or on the top of hangars in some conspicuous place. To be effective at night as well as during the day, they should be illuminated from above by one large reflector and light, or better still by four reflectors mounted on 2 ft. brackets as shown in the left view in Fig. 231. These reflectors should have 150 watt lamps in them, and a 60 watt red lamp above the unit to serve as an obstruction light.

In some cases wind cones are lighted from the inside by a 200 watt lamp and reflector pointed in their mouth, and free to revolve with the cone as the wind direction changes.

The right hand view in Fig. 231 shows a "wind tee" shaped like a plane, and lighted by rows of bulbs on its wings and body.

199. "CEILING" PROJECTORS

The "ceiling" projector light is used to determine the "ceiling" height. This term applies to the height of clouds or fog above the landing field. It is quite important to know this "ceiling" height

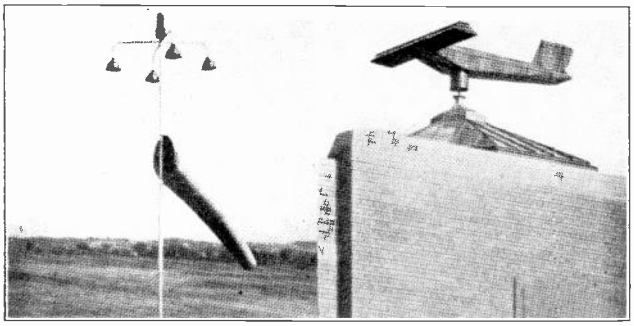


Fig. 231. On the left is shown a wind-cone, with four lights mounted above it, for illuminating the cone at night. On the right is a wind tee made in the shape of a small airplane. This can also be illuminated by rows of lamps on its wings and body.

and be able to report it by radio to aviators approaching from a distance. This gives them an idea of how close they will have to approach the ground in order to see the landing field or its lights.

This information regarding "ceiling" heights can also be transmitted to various other airports along the route, either by telephone or radio, thus keeping the pilot informed of weather conditions at various airports which he may have to use.

For a "ceiling" light a 500-watt, narrow beam projector can be used. If this unit is tilted upward at an angle of 45 degrees with the horizon, then the spot where its beam strikes the under side of clouds or fog will be directly above a spot on the ground, which is the same distance from the light unit as the bright spot on the cloud is above the earth. This can be proven by the fact that the diagonal of a square is at an angle of 45 degrees with either its base or vertical side, and, of course, the base of a square is the same length as its vertical side. See Fig. 232.

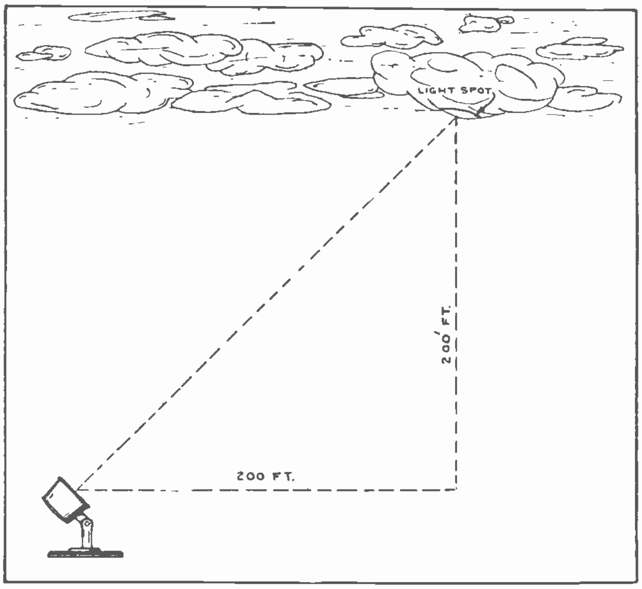


Fig. 232. This diagram illustrates the method of calculating the height of clouds or fog with a ceiling projector.

Other angles can be used, and then with a simple quadrant and pointer set in the same plane as the projected beam, and a definite distance away from the projector; we can by sighting along the pointer toward the point where the beam strikes the clouds, obtain a direct reading of the "ceiling" height.

200. HANGAR AND SHOP LIGHTING

The interior lighting of airport hangars and repair shops is another very important use for electric illumination. In the handling of planes in and out of the hangars, and in making repairs on them, good lighting is a great time saver and promoter of safety.

In the shops where some of the very critical repair and adjustment of engine or plane parts must be made, it is equally important to have efficient illumination. Fig. 233 shows an exterior view of a well-lighted hangar in the upper part of the figure, and an inside view below. Industrial lighting fixtures and principles can be applied to these buildings.

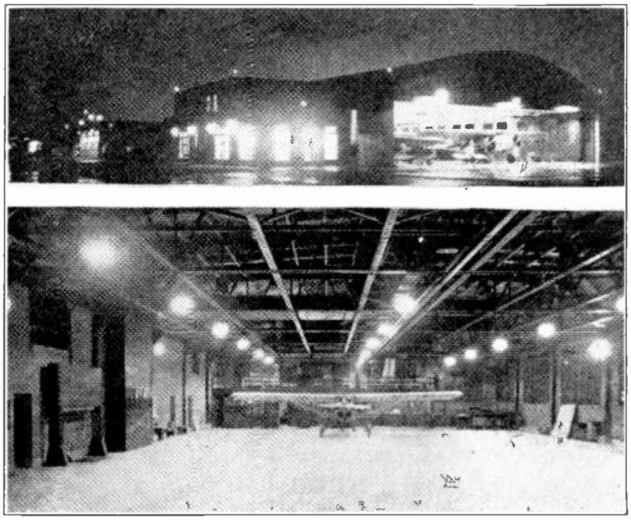


Fig. 233. The top view shows the outside appearance of a well lighted hangar, and below is shown the inside of the hangar and the arrangement of the lighting units.

201. AIRWAY LIGHTING OR ROUTE BEACONS

The Federal Government requires airway beacons approximately every ten miles along principal flying routes. These beacons should consist of projectors at least 24 inches in diameter, using 1000-watt lamps and producing 2,000,000 beam candlepower. These units are kept continually revolving at a speed of six revolutions per minute by a small motor and gear mechanism.

In addition to the revolving beacon there should be two "On Course" lights with 18-inch, 500-watt projectors to indicate to the pilot the direction of the next airport. These course lights can be equipped with a mechanism to keep them continuously flashing the number of that particular beacon in the Morse Code. This also indicates to the pilot the distance he has progressed along the course. These lights can be fitted with amber or red cover glasses, while the rotating beacon uses a white beam.

Fig. 234 shows a typical airway beacon on a tower which is also equipped with a "wind-cone". This particular beacon is located at an intermediate landing field. Where beacons of this type are near to power lines they can obtain the energy for their lights from these lines. In other cases they must be equipped with an independent lighting plant similar to farm lighting plant installations. These beacons and plants have to be maintained and inspected by trained men, as their condition and dependable operation are very important. Imagine yourself in the place of a pilot, and the great comfort you would receive from being able to see at least one beacon ahead at all times along your route. These airway beacons are a great safety factor in night flying.

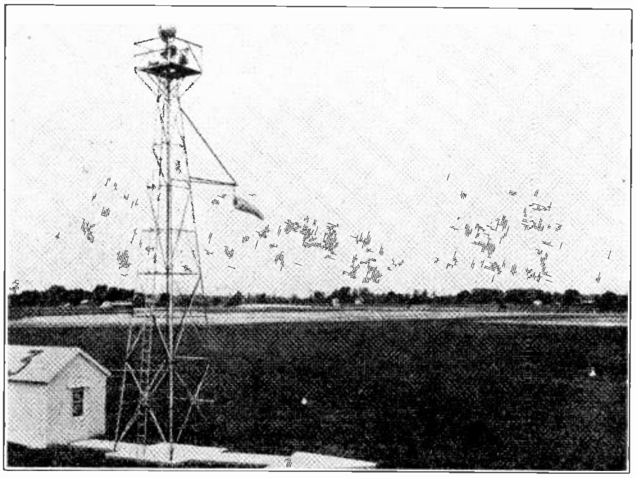


Fig. 234. This photo shows a typical airway beacon mounted on a steel tower, and also provided with a wind-cone for day-light use only.

202. AIRPLANE LIGHTS

It may seem rather surprising to talk of lights on airplanes, as probably a great many people don't even realize that planes carry lights. Government regulations require, however, that every plane which flies between sunset and sunrise must be equipped with flying lights, to indicate its position and direction of flight to other pilots.

These lights consist of small automobile-type lamps of 18 or 21 candlepower, mounted in stream-lined pyralin shells. These are mounted on the tip of each wing, and one on the top of the tail or rudder. The left wing light must be red and the right one green, while the tail-light shows clear white. Government specifications can be obtained governing the proper angles between these lights. Airplanes also require lights on the control-board in the pilot's compartment. These lights are usually equipped with a small rheostat so they can be adjusted to just the right brilliancy to show the instruments, and in this manner avoid glare in the pilot's eyes and enable him to see better in the darkness ahead.

Many of the larger planes, or planes intended for night flying, are equipped with powerful landing lights for use in landing on unlighted fields. These units use a lamp with a concentrated filament which requires about 35 amperes. They are, therefore, kept switched off when the plane is flying, and turned on only when needed for use in making a landing. Otherwise they would place a very heavy drain on the battery.

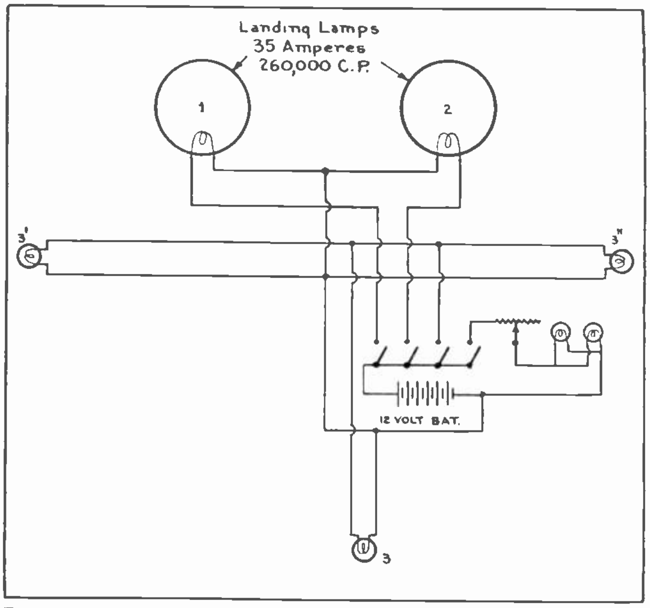


Fig. 235. Simple wiring diagram for lights on an airplane. Trace this circuit and note which lights each of the switches control.

Ordinary flying lights and landing lights can be supplied from a light-weight battery carried aboard the plane. Fig. 235 shows a wiring diagram for the commonly used lights on a plane, and Fig. 236 shows the mounting of wing tip and rudder lights, as well as landing lights. The upper part of this figure shows the tail-light mounted on top of the plane rudder, in its stream-lined shell. You will note that the front end of this shell is painted black while the rear end, or more sharply tapered end, is clear and allows the light to escape in this direction. The lower left view shows a wing tip

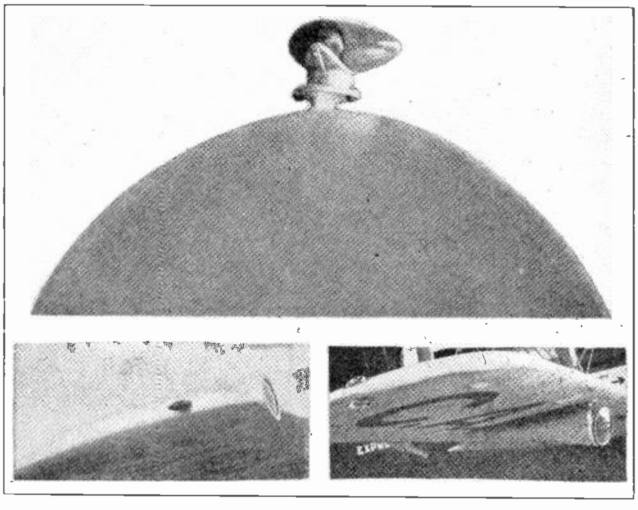


Fig. 236. The top view shows a tail-light mounted on the rudder of an airplane. The two views below show two methods of mounting wing tip lights and landing lights.

light for the right wing, and also a landing light which is built in, or stream-lined, with the forward edge of the wing. The lower right view shows a different form of mounting for the wing light, and also for the landing light, which in this case is hung underneath the wing in a stream-lined shell.

This stream lining is exceedingly important, and every device of an electrical nature or otherwise, that is attached to the outer surface of any airplane, should be stream-lined to prevent air resistance to the forward motion of the plane. The greater part of this resistance occurs at the trailing ends or edges of such devices where violent whirling eddy currents are set up in the air, causing a sort of vacuum at these ends or edges; so you will notice that all of these devices taper most toward their rear ends. This is a very good point to keep in mind when installing any equipment on airplanes.

Fig. 237 shows the interior lighting of a large cabin-type passenger plane. Many of these planes carry lighting of this nature, which not only makes them very attractive in appearance but makes it possible for passengers flying at night to read, play cards, or otherwise occupy their time.

Where large numbers of lights are used in this manner the plane is usually equipped with a wind-driven generator mounted on the outside of the fuselage, or between the wings, in a stream-lined casing and driven by a small wind propeller.

From the foregoing material on aviation lighting, we can see that this is developing into a tremendous field for trained electrical men who have a good knowledge of the principles of electric wiring and testing, as well as the fundamentals of illumination.

It will be well for every student to keep on the alert for opportunities in this field, and not to overlook the possibility of being the first in his home town to suggest that they provide a well-lighted airport for the general good of the town; and possibly get the job of laying out and installing the equipment yourself.

Fig. 237. The insides of large cabin-type planes are often lighted to give many of the same comforts and conveniences as a Pullman coach.

MERCURY VAPOR LAMPS

A special type of lighting unit, which has become very popular and generally used in industrial plants and large machine-shops, is the Mercury Vapor Lamp.

Its particular advantage lies in the yellow-green color of the light it produces. This light is particularly good for certain machine-shop operations, and the handling and assembling of small bright metal parts, as well as in textile mills.

Lamps of this type are not intended for commercial or home lighting, but only for such special applications as mentioned, and where its peculiar color is not objectionable. Ordinary Mazda lamps produce a light which, as before mentioned, is largely white in color, but also contains a considerable percentage of violet and red rays. These rays are somewhat tiring to the eyes in certain classes of work.

The Mercury Vapor lamp produces light with a predominance of yellow and green rays and a small percentage of violet and blue. In light of this color small objects, such as screws, pins, bolts, nuts, etc., stand out very sharply. Therefore, the use of this type of lighting unit increases production speed and improves quality in machine shops, with less eye-strain for employees. Large automobile manufacturing plants have installed many thousands of these units.

203. MERCURY VAPOR TUBES

The source of light in a Mercury Vapor lamp is a long glass tube, approximately an inch in diameter and 50 inches long, in which there is sealed a small quantity of mercury. This tube is suspended at a slight angle so the mercury runs down to the lower end, at which there is a bulb equipped with a metal electrode sealed into the glass and in contact with this pool of mercury.

Fig. 238 shows a view of a complete unit with the tube mounted in its trough-shaped reflector. The lamp mechanism, which will be explained later, is in the metal housing above the reflector. The upper end of the tube has two bulb-like horns or extensions on the glass, with a metal electrode sealed into each one. Wires from each end of the tube connect to proper coils in the lamp mechanism and from this to the supply line. Most of the air has been exhausted from the tubes of these lights, leaving them to operate in a vacuum. When they are cold most of the mercury may be condensed and run to the pool at the lower end of the tube, so it is necessary to use a spark or impulse of rather high voltage through the tube first to vaporize a small amount of the mercury.

We should understand that a high voltage spark will pass through a much greater distance in an ordinary vacuum than through open air, so by applying about 2000 volts from an induction coil in the lamp mechanism, we can start an arc through the tube.

As soon as a little mercury vapor is built up it forms of soft green arc or light throughout the full length of the tube. Thus the name Mercury Vapor Arc.

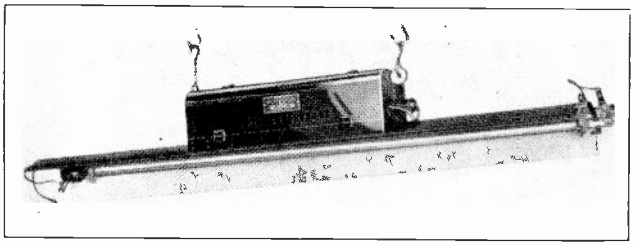


Fig. 238. This view shows a complete mercury vapor lamp. Note the mounting of the tube under the long reflector, and the manner in which the lamp is hung at a slight angle.

As long as the lamp is operated this arc continues to agitate the surface of the mercury pool and create sufficient vapor to keep it going. After the vapor forms and the arc is established, the resistance of the lamp tube is low enough so the arc can be maintained with from 70 to 100 volts, and about 3.8 amperes on the common sized lamp. The total wattage rating of the lamp is about 450 watts, part of which is used up in the resistors and coils. The voltage from the lamp coils is about 120 to 130 volts, but not all of this is applied to the tube.

The source of light from these units, being spread over such a long tube, distributes the light softly and evenly with very little glare and shadow effects, which is one of their decided advantages.

The average life of the tubes is two years or more if they are properly cared for, but they should be very carefully handled as it is easy to crack them and allow air to leak in if the tubes are strained, or if they are bumped and cracked. For this reason they are protected by long metal bars running under the length of the tube and attached to the ends of the reflector.

204. LAMP MECHANISM

Fig. 239 shows a top view of the lamp mechanism and coils. This consists of a pair of resistance units at the left end, and next to these are the coils of an auto transformer which raises the line voltage, and has taps brought out to terminals to obtain the proper voltage adjustment for the operation of the tube. The pair of coils at the right of the center are those of an induction coil which generates the high voltage for the starting spark to ignite the tube

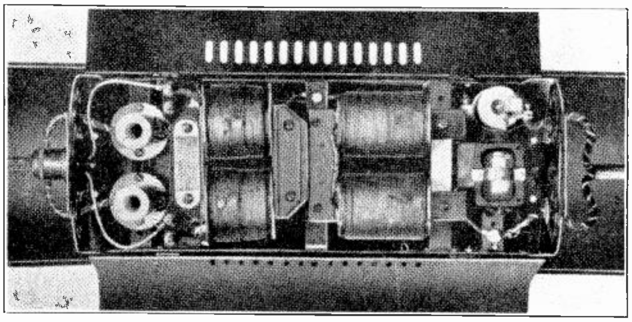


Fig. 239. Above is shown the mechanism and coils of a mercury vapor lamp. Also note the mercury shifter switch at the extreme right end.

or start the lamp. Just to the right of these coils is a small mercury switch in a glass tube. This switch is mounted on a pivot so when the coils are energized and the ends of their cores become magnetized they attract a small iron plate on the mercury switch, tilting it up and causing a "V" shaped depression in the glass to separate the pool of mercury and break the circuit.

When this circuit is broken and the flux around the induction coils is allowed to collapse, it induces a high voltage of about 2000 volts in these coils. There is also an added resistance unit just above this tilting or "shifter" switch in this view.

205. LAMP CIRCUIT AND OPERATION

Fig. 240 shows a simplified wiring diagram for an A. C. mercury vapor light. Examine this diagram carefully and note the connections and circuits through the various coils and the tube.

We know that alternating current is constantly reversing in direction, but let's assume for the moment that the current is entering at the lower line wire as shown by the small arrows. We can trace this flow of current through the lower half of the auto transformer—A.T., then through both windings of the induction coil—I.C., through the mercury switch—M.S., and protective resistance—R3; then back to the upper line wire.

This flow of current energizes the induction coils and magnetizes their cores. This magnetism attracts the metal plate or armature on the mercury switch, causing it to tilt and break the circuit we have just traced.

When this current stops and the flux around the induction coils collapses, it induces the high voltage previously mentioned, and this is applied to the ends of the lamp tube as shown by the dotted arrows.

We also find that this high voltage is applied across the two terminals at the lower end of the tube. One of these wires we know is connected to the electrode in contact with the mercury, and the other one is connected to a thin metal band which is clamped around the stem of the tube, and also attaches to a strip of metal foil which is pasted to the under side of the bulb.

The high voltage across these two points sets up a capacity charge through the glass to the mercury, exciting the surface of the mercury and emitting the first mercury vapor. As soon as this vapor is started, the high voltage across the ends of the tube establishes the arc. After the arc is started the line current will flow alternately through resistance R1 and R2, and into the two horns or electrodes at the upper end of the tube, as shown by the large arrows, down through the tube and back through both windings of the induction coil, to the center tap of the auto transformer. From here it returns to either line wire, according to the polarity of the A.C. line at that instant.

The auto transformer A.T. serves to increase the voltage of the tube slightly above the 110 volts on the line.

You will note that the current flows through the tube in only one direction, so we find that this tube also acts as a rectifier as well as a source of light. In other words, current can flow from the metal electrodes at the top of the tube, into the mercury vapor, but it cannot flow from the vapor back into these electrodes, because of the high resistance film built up at their surfaces the instant the reverse current attempts to flow. This principle will be more fully explained in a later section.

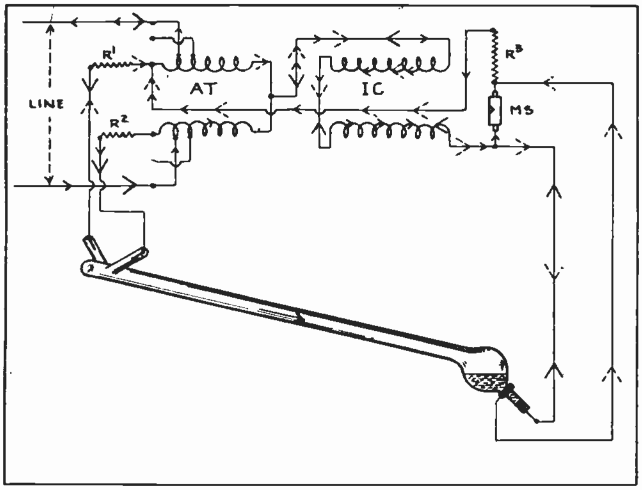


Fig. 240. Wiring diagram of a mercury vapor lamp, showing the various circuits traced through the tube and coils.

These mercury vapor lights are also made to operate on direct current, and those for D.C. operation have no transformer, but merely the pair of induction coils and mercury switch in addition to the tube; so their circuit is much simpler than the one we have just traced.

206. INSTALLATION

When installing lighting units of this type they should be suspended by two pieces of chain or strong rope, and hung with the tube at the proper angle; or otherwise they will not operate satisfactorily. This angle can easily be determined by leveling the tops of the hooks provided with the unit, as these hooks are made in uneven lengths to obtain the proper slope for the tube. The upper end of the reflector should be about 8 inches higher than the lower end when the mounting is finished.

The next step is to insert the shifter switch in its mounting and connect its terminals to the binding post provided. This shifter when mounted, should rotate freely, and it should not be possible for it to slip to either side far enough so that the metal armature can touch either of the iron cores of the induction coils. Next, the tube should be unpacked and washed clean before mounting. Remember to handle these tubes very carefully to avoid cracking them. To test new tubes before placing them in the lamp, or for testing old tubes that are thought to be defective, the condition of the vacuum can be determined by the sound of the mercury in the tube when it is allowed to run slowly from one end to the other. Tilt the tube up so the mercury runs slowly down to the opposite end, and if it produces sharp-sounding metallic clicks like shot rolling in the tube, this indicates that the vacuum is good. If the mercury slides to the bottom end of the tube without producing these clicks it is an indication that the tube has leaked air and the vacuum is destroyed.

The end with the two horns should be at the higher end of the reflector. Place the tube in the holding clamps and tighten them securely, but not too tight, or the glass may be cracked when heated. It should be possible to rotate the tube with the fingers after the clamps have been fastened. Be sure that the single negative terminal points straight down from the black bulb. Observe the mercury to see that it covers the metal contact which is sealed in the glass at this terminal. If these lamps are operated without sufficient mercury in the bottom end the tube may be ruined.

After the tube is installed, it is a very simple matter to connect its terminals to the wires provided on the lamp unit and reflector.

207. OPERATING VOLTAGE

The tubes are rather critical as to their operating voltage, and if the line voltage is considerably lower than normal because of voltage drop, the lamps may not start promptly. In this case, when they are turned on the mercury switch may keep operating and clicking repeatedly, without starting the lamp. When this happens the voltage at the line terminals should be tested with a volt meter, and if it is found too low the connections can be shifted to the inner taps shown on the auto transformer coils. This will enable the transformer to raise the voltage on the tube.

These terminals are usually marked for the different voltages, so it is easy to tell where to connect the line wires. When these lamps are connected on circuits from 95 to 125 volts, wires not smaller than No. 12 should be used, and each circuit for a single lamp should be fused for 15 amperes.

For each additional lamp placed on any branch circuit, the fuse should be increased by 10 amperes per lamp.

208. CARE AND MAINTENANCE

If mercury vapor lamps are installed in cold rooms they may be somewhat slow in starting and also give less than normal candlepower. In such cases it may also be necessary to change the line connections to apply higher voltage to the tube; or even to increase the line voltage somewhat.

The resistance units used with these lamps occasionally burn out but they can be very easily replaced, as they are screwed into standard sockets on the unit, the same as a lamp or plug fuse would be.

In maintaining a group of these lamps it is very important to keep the tubes clean by washing them occasionally with soap and water, and also to keep the negative terminal and starting band free from dust and dirt. An accumulation of dirt around the starting band will often allow the high voltage starting current to flash over at this terminal and cause the lamp to fail to start.

If a lamp fails to start after several operations of the shifter switch it should be turned off until the trouble is located, so that this switch will not be damaged by continuous operation. Failure to start is usually due to one of the following causes: low line voltage, very cold tube, blown fuses, burned out resistance unit, stuck or broken shifter switch, loose connection, cracked tube, or dirt accumulated at the starting band on the negative terminal. Checking each of these items systematically will usually locate the trouble.

The transformer or induction coils can easily be tested for open circuits, shorts, or grounds, as explained in previous sections.

Be very careful not to connect an A.C. lamp on a D.C. circuit, or a 60 cycle A. C. lamp on a 25 cycle circuit.

Extra tubes and resistance units can be obtained from the lamp manufacturers and kept on hand for convenient and prompt repairs.

The extensive use of this type of lamp in manufacturing plants will make this material very valuable for any maintenance electrician to know, and have on hand for future reference.

HOME LIGHTING

With all the vast number of homes in this country that are wired for electricity, there are still hundreds of thousands of old houses to be wired, as well as the many thousands of new ones that are built yearly.

Another very important fact to consider, from the standpoint of opportunities for the trained electrical man, is that actually a majority of the homes that have been wired a few years do not have efficient or adequate lighting. This is partly because the old style fixtures installed years ago were not made very efficient, and partly because it used to be the opinion that home-lighting fixtures should be chosen for beauty and appearance, rather than for lighting efficiency.

This idea is out-of-date, and the most important essential in modern home-lighting is first to see that the wiring and fixtures are planned and chosen to give adequate light of the right quality; and second, to give proper attention to the appearance and artistic features.

We should keep well in mind that good fixtures are now made to provide ample and proper lighting, as well as pleasing appearance and decorative effects.

Properly designed lighting is one of the greatest comforts and conveniences that any home owner can enjoy, and in building new homes or remodeling old ones, the lighting should be considered equally as important as many pieces of the furniture, and as one of the most important features of the decorations.

Home lighting does not require any elaborate calculations, but the illumination for practically any room can be easily planned by application of the simple fundamentals of illumination, and the general rules on the following pages. Furthermore, the great number of homes which really require improved lighting and more modern fixtures, offer splendid opportunities right in his own neighborhood, to practically every graduate who wishes to take advantage of them.

209. LIVING ROOM LIGHTING

The living room is, of course, one of the most important rooms to have well lighted, as in the average home this room is the one in which the members of the family spend much of their time, and also one that we wish to have most attractive when guests are present.

Proper lighting units for the living room are the ceiling shower or cluster, wall bracket lights, and portable floor or table lamps. The ceiling fixtures are often called chandeliers or by the more modern name **Luminaire.** No one of these types of lights is alone sufficient for a well-lighted living room, but two or all three of them should be combined to obtain the varied or complete lighting effects desirable.

210. CHOICE OF CEILING, WALL, OR PORTABLE UNITS

The ceiling fixture is, of course, the most essential and useful of these units, and for the average sized living room it should consist of four or more lamps of 40 watts each or larger, and they should be equipped with glass shades to soften the light and prevent glare.

Fig. 241. This photo shows a living room lighted only by the ceiling fixture. There is plenty of light in the center of the room, but you will note the room appears very plain.

The purpose of the ceiling fixture is to provide general light throughout the room, and it should provide sufficient light to give the room a bright and cheerful appearance.

Ceiling fixtures should, of course, be chosen of a design and color to harmonize with the room furnishings and decorations, and they can be hung either quite close to the ceiling in low rooms, or suspended down farther in higher rooms.

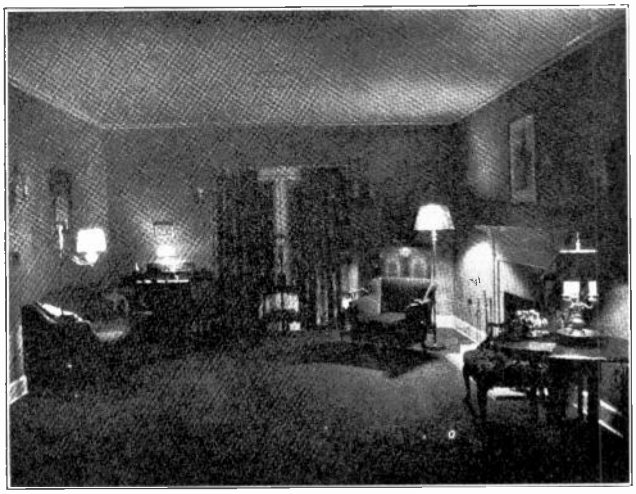


Fig. 242. The same living room as shown above lighted only with portable lamps. This condition would be very good for reading directly under these lamps.

Usually they will shed a more even light on the ceiling if they are down from 18 to 30 inches from it. The bottom of the fixture should be at least 6 ft. 6 in. or more from the floor; and preferably 7 ft. or more, even if it is necessary to use a very short fixture close to the ceiling.

Fig. 241 shows a living room lighted by a ceiling fixture only, and while the room is fairly well lighted, the general appearance is plain and drab and the light is centered too much above and below the fixture.

Portable floor and bridge lamps, as well as table lamps, are very good for local spots of light and for reading in a chair directly beneath them without lighting the rest of the room. They also add a great deal to the decorative appearance, with their local spots of light and their colored shades.

There is in many homes, however, a wrong tendency, to depend on portable lamps almost entirely for living room light. Portable lamps are not intended for this, and do not give sufficient general illumination for many occasions.

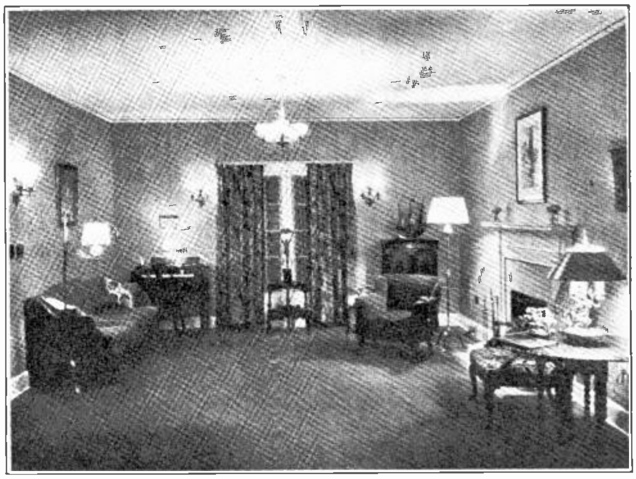


Fig. 243. Here we have the same room lighted by the ceiling unit, wall lights, and portable lamps. Compare carefully the different effects in the three photographs on this page.

Fig. 242 shows a room using only the portable lamps, and while the effect is restful and fine for a quiet evening alone with a book, it would not do at all for a room full of company, with card games or social gatherings.

Floor lamps with open tops, and in some cases extra lamps and reflectors to direct light to the ceiling, are very useful and beautiful in their effects.

Fig. 243 shows a room well lighted by the ceiling luminaire and portable lamps, and with the walls "livened up" by wall bracket lights. A combination of lighting units of this kind provides wonderful possibilities and comfort, by the use of all or certain ones of the lights at proper times.

Novelty table lamps, concealed cove lights, and artificial electric windows, can also be added to produce beautiful effects and increased attractiveness of the living room. Some of these are shown in Fig. 244.

Sun parlors or porches should also be well equipped with outlets for floor and table lamps; and ceiling fixtures of a type that give a soft light are desirable.

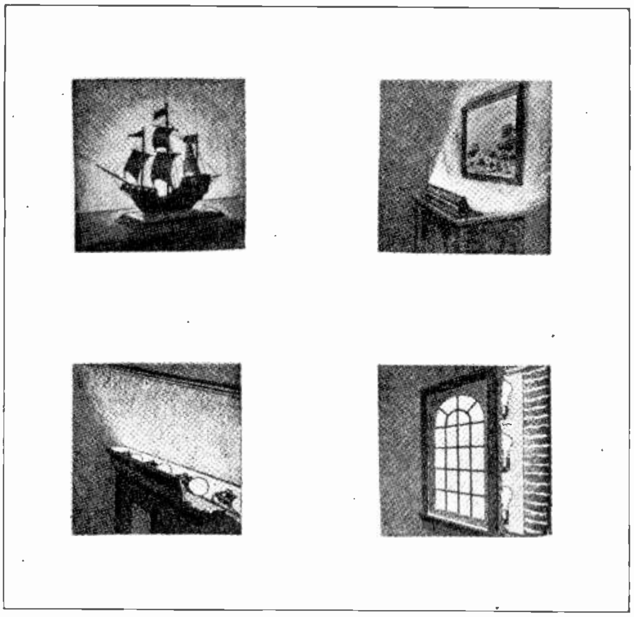


Fig. 244. These four views illustrate some of the effects obtainable with lights placed behind decorative objects, concealed coves, and artificial windows.

211. DINING ROOM FIXTURES

In the dining room we should have a flood of soft white light on the table, and sufficient light on the walls and ceiling to prevent them from appearing dark and depressing. There should also be a reasonable amount of light on the faces of the diners. Here we can use a good-looking ceiling fixture with four or more shaded lamps of about 50 watts each or larger. This fixture should be hung low enough to center its light well on the table, and yet not low enough to shed too much light in the eyes of persons seated at the table. About 30″ to 36″ above the table is generally a good height.

Buffet lights add to the appearance, and provide part of the extra light needed for the walls. A very well-lighted dining room is shown in Fig. 245.

Beautiful effects in dining room lighting can also be obtained with a semi-indirect ceiling fixture and wall lights of the types shown in Fig. 246.

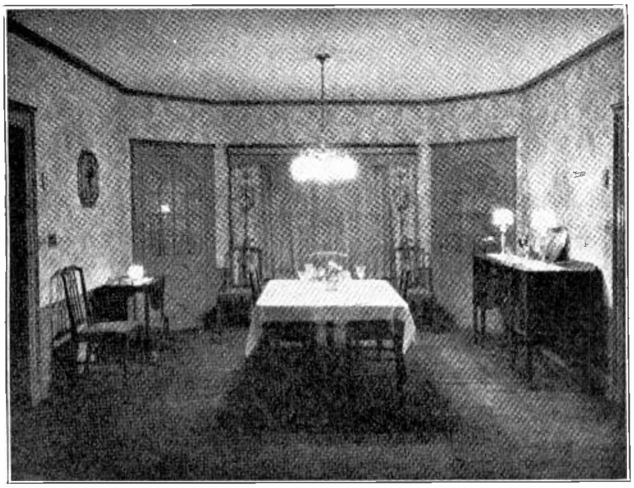


Fig. 245. The above dining room photo shows the manner in which the light should be principally centered on the table, and yet should light the walls and ceiling sufficiently to prevent a dark appearance in the room.

Semi-indirect ceiling luminaires of this type shed soft white light on the table to make the dishes, food, and silverware show up to excellent advantage; and they also direct sufficient light on the ceiling to give a cheerful and well-lighted appearance to the room.

The inverted bowl wall lights of the type shown in Fig. 246, add the small fountains, or touches of light on the walls, which just complete the perfect appearance of this room.

Fig. 247 shows a number of very excellent modern fixtures which are both efficient and beautiful in appearance. These units deliver a sufficient quantity of well diffused light, and add to the comfort, appearance, and actual value of a home enough to be worth many times their cost.

The semi-indirect unit in the upper right corner of Fig. 247 is typically a dining room fixture, and the one in the center of the top row is particularly good for use in low living rooms. The others are very excellent living room fixtures.

Fig. 248 shows several styles of fixtures that are particularly good for dining room lighting.

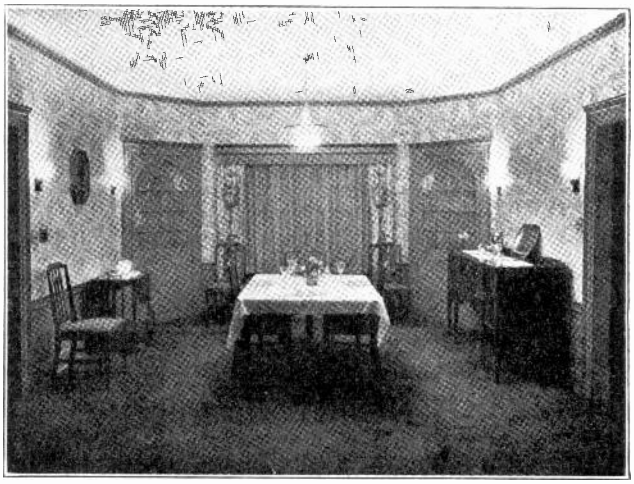


Fig. 246. A combination of a semi-indirect ceiling fixture with shaded wall lights of the type shown, produces a very beautiful lighting effect.

212. BEDROOM LIGHTING

Bedrooms should also be well lighted with soft light that is not tiring to the eyes of one lying in bed. Ceiling units of the types shown in Fig. 249 and mounted close to the ceiling are very good.

It is very important to have sufficient light at dressing tables and on mirrors; and wall bracket lights or attachable brackets for clamping on each side of the mirrors should be provided.

Portable lamps on small tables by the beds, or clamp lights to mount on the heads of beds are ideal for reading lights.

Plenty of convenience outlets should be provided around the walls of bedrooms, for the attachment plugs of portable lamps, curling irons, fans, etc.

A switch controlling one of the lights in the room should be located near enough to the bed to be within easy reach of a person either in bed or right at its edge.

The clamp lights on the head of the bed will accomplish this, or in some cases a small light is mounted under the bed with a switch at the head of the bed. These lights will shed sufficient light on the floor to enable one to move about the room easily, and yet they do not throw light in the faces of other sleepers. Fig. 249-A shows a well lighted bedrcom.

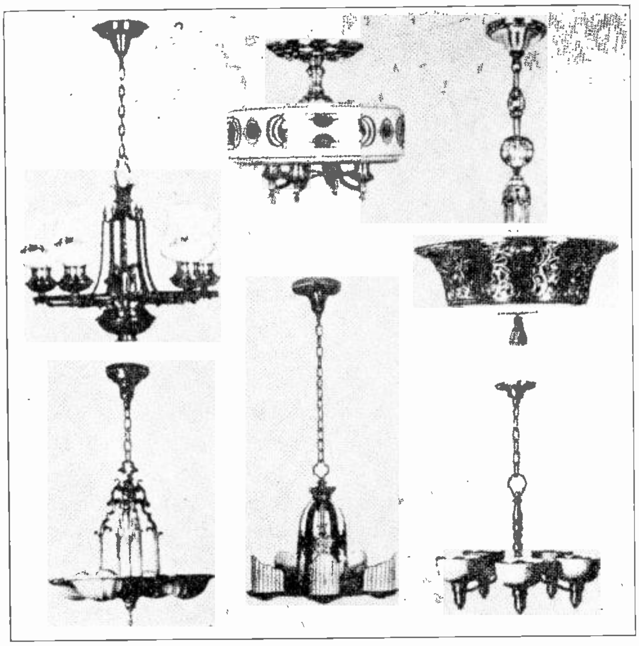


Fig. 247. Several very efficient and popular types of dining room and living room fixtures.

213. KITCHEN UNITS

The kitchen is one of the simplest rooms in a house to properly illuminate, and yet it should always receive careful attention, because it is the one in which the housewife spends a great deal of her time.

A low hanging fixture should never be used in a kitchen, but instead a short unit which is high up and close to the ceiling should be used. It should be of the enclosed type with a dense white glass bowl, and equipped with a 100-watt lamp.

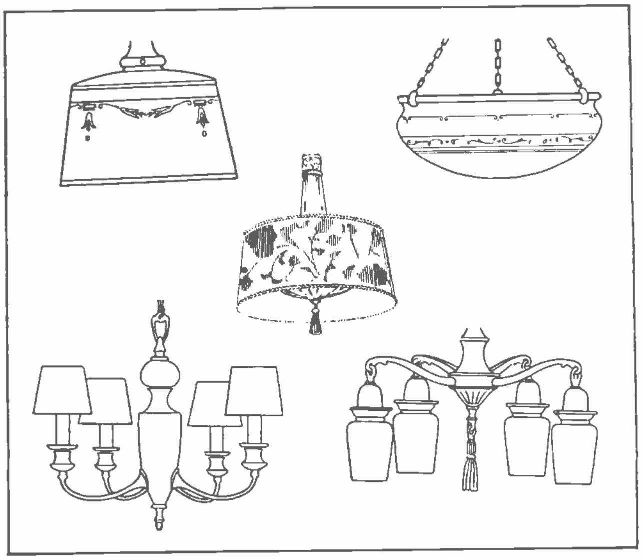


Fig. 248. Units of the above type are very appropriate for dining room lighting.

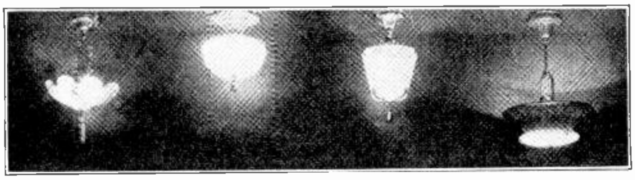


Fig. 249. Several types of bed room fixtures which are mounted close to the ceiling and produce soft, well-diffused light.

Such a unit will provide well diffused light of good intensity throughout the ordinary kitchen. In addition to this overhead unit, it is usually well to have a wall bracket light with a white glass shade mounted over the sink, and possibly one over the range. Fig. 250 shows how cheerful a kitchen can be made with proper lighting and light colored walls and ceiling.

Fig. 249-A. This photo shows a well lighted bedroom, using the dome light in the ceiling and portable lights on the dresser and table.

The left view in Fig. 251 shows more clearly, the shape of the kitchen unit and wall light and on the right is shown a very good unit of the porcelain enameled, metal dome type, to be used in the laundry room in basements.

Lighting units of this type are so low in cost compared to their value in the home, that it is often

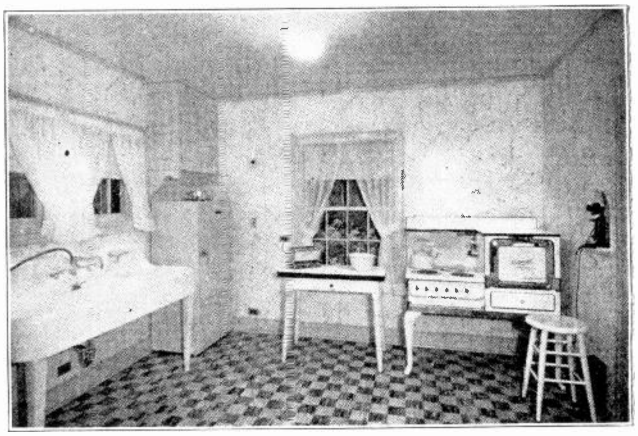


Fig. 250. A well lighted kitchen, such as shown above, is one of the greatest conveniences in any home.

very easy to sell the home owner modern kitchen and laundry lighting equipment and get the job of replacing his old ones with the new.

Clothes closets should be equipped with a wall bracket light over the door, and enough to one side so if a pull-cord switch is used the cord will not hang directly in the doorway. A wall switch at the door or just inside may also be used.

Fig. 251. At the left is shown the arrangement of ceiling unit and wall bracket light for kitchen. On the right a very efficient type of reflector for laundry rooms and basement lighting.

214. BATH ROOM LIGHTS

Bath rooms should have two wall bracket lights above the wash stand, one on each side of the mirror. Another above the mirror is also very convenient for general light in the room and for combing one's hair. Bath room lights can be controlled by key sockets or pull chain sockets on the bracket lights at the mirror or by wall switches for lights out of reach. If chain sockets are used on non-polarized wiring systems, insulator links should be put in the chains to reduce chances of persons obtaining shocks by touching the chain when one hand is on a faucet.

The mirror lights should be low enough to well illuminate one's face and the under side of the chin for shaving, and should use 50-watt inside frosted bulbs.

Large dark colored bath rooms may also require a ceiling light.

215. PORCHES, ATTICS, BASEMENTS, AND GARAGES

Porches and entrances can be made safer and much better appearing at night, by the use of ceiling lights of lantern design on the porch, or bracket lights of suitable weather proof type at each side of doors.

Attics and basements should be lighted with drop-cord lights or other low cost units, and in sufficient number to enable one to work conveniently in any part of them. Where basements are used for childrens' play rooms ceiling fixtures similar to kitchen units can be used, and controlled by pull-cords or wall switches.

Garages should not be forgotten, and the light should be controlled by three-way switches both from the house and garage as previously explained. One or more attachment plug receptacles should also be provided, to permit the use of portable trouble lights or vacuum cleaners around the car. Fig. 252 shows a number of the various types and sizes of Mazda lamps commonly used in home lighting.

In wiring any home for lights remember to install plenty of convenience outlets in all rooms, and three-way or four-way switches where they will add to the convenience in controlling the lights.

216. QUALITY WORK PAYS

Always recommend lighting equipment that will be a permanent satisfaction to your customer as well as a credit to yourself. The home owner's pride in the appearance of his home, and his concern for the comfort, convenience and safety of his wife and children, are points that should not be forgotten in selling good lighting.

In completing this simplified practical material on illumination you can readily see that it is one of the greatest fields of opportunity for profitable and interesting work that the electrical industry offers to the trained man. We are certain that whether you choose to specialize in this line of work, either as an employee of a contractor or fixture dealer, or in business for yourself, you will find the material covered in this section of great value to you. No matter what line of electrical work you may follow, a practical knowledge of these principles of good illumination will prove handy to you many times in the coming years.

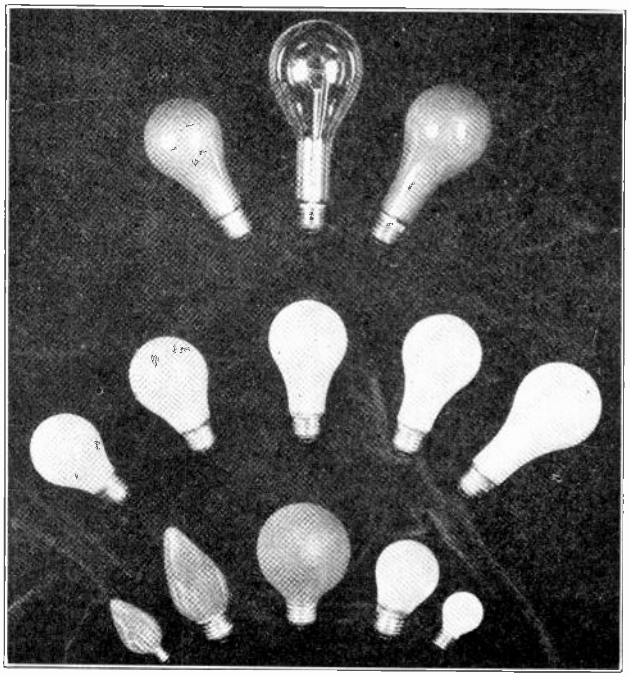


Fig. 252. Above are shown a number of modern Mazda lamps of the types commonly used in home lighting.