ARTIFICIAL LIGHT AND ITS APPLICATION IN THE HOME

G. W. Barse

Historical Lighting

15—

(architecture)

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PREPARED BY

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FOREWORD

The aim of this book is to present a practical, concise, and reliable treatment of artificial lighting and its application in the home. It is hoped that this textbook, which contains the fundamental concepts and the practical interpretations and applications of light in the home, may satisfy the demands for information on the part of colleges, universities, normal schools, and other places where instruction is centered on training in the various phases of house planning and home economics.

Since the printed sources of home-lighting information have been scattered, difficult to locate, and not especially prepared for this apparent need, the Illuminating Engineering Society undertook the preparation of this book.

Although it is designed primarily as a textbook, it is hoped that, because of its simple, non-technical style, it may prove a suitable source of information to the home keeper herself, who is more and more interested in the best methods of utilizing artificial light in the home.

This book has been prepared by specialists who have devoted either all or a large part of their time and efforts to the development of the art of home lighting, and, accordingly, this compilation includes the underlying fundamentals and practices gained from their researches, observations and experiences.

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ARTIFICIAL LIGHT
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CHAPTER I

LIGHT AND PEOPLE

As man developed he gradually realized that during each twenty-four hour period one of his most important senses, that of vision, became useless. To his probable terror and bewilderment the light faded and things were blotted out into an inky blackness. While this condition lasted, he was able to see little or nothing and became especially aware of the dangers, which, because of their uncertainty, seemed much more formidable than they really were. Because of these lurking dangers and the insecurity of darkness, the pursuits of man were of necessity limited to the daylight hours. The absence of light became a crippling, paralyzing factor and a severe handicap to pride, which was an ever present influence differentiating man from the beasts. It was only the sun each morning which could sufficiently renew his confidence in himself, and quite logically it became his god.

The effort to combat darkness symbolizes one of the first important steps in the progress of the human race. Light from the sun, moon, and stars brought a certain amount of confidence and serenity. On the other hand, light that was reflected in the eyes of wild animals, that from lightning, the aurora borealis was of a different order and probably filled mankind with awe and terror. Evidently light was for the most part a benign god but at least was a whimsical one and rather irregular as the seasons progressed. Distinctly light was not controllable. Distinctly it was not portable. Quite certainly, too, the amount of light which could be placed at a given point was beyond the power of man to control. The bonfire, which primarily provided warmth and protection for the physical being, soon manifested itself as a means of surmounting the overpowering darkness. Before long, human intelligence prompted the removal of a burning brand from the fire, thus somewhat feebly enlarging the range of vision after sunset and lengthening the hours of activity. How long this method was used is more or less conjecture, but selection eventually took place and certain vegetable matter that contained oil and pitch was used, thereby producing a better vehicle for light.

Development of Light Sources.

As time progressed, oil lamps were made out of natural receptacles such as hollowed-out stones, and later a crude wick was found to be valuable in the operation of such a lamp. Gradually, yet slowly, these utensils were fashioned to meet the advancement of civilization, and the plasticity of clay brought a variety of shapes. Bronze, a more permanent and beautiful medium, came into use later. These, refined through decoration, very often were fashioned for multiple wicks, showing always the desire for more and better light. The utility of lamps was then enhanced by suspending them from walls or ceilings or by raising and lowering them on pedestals.

In most countries the hand lamp seemed to be most useful and dates back in use to ancient Egypt, China, Greece, Rome and, at a much later date, again found its place in colonial America.

Beeswax and tallow candles were used throughout the Christian era. In fact, some authorities feel that they were invented by the Phoenicians. Candles have long held a very conspicuous place in the rituals of many religions of the world. Massive brass and bronze candelabra were used for state and religious purposes, sometimes singly and often in pairs, a custom that is practiced even to the present day.

Beautiful craftsmanship developed massive chandeliers, brackets, and tripods for oil and candles. It was not until about the middle of the nineteenth century that camphine (turpentine and alcohol) was used because of the improvement in the light which the burning of this mixture produced. Close on the heels of camphine came kerosene, which still holds a place in lighting in the more remote parts of this country.

Gas, until the advent of the Welsbach mantle, was only a moderate improvement as far as light was concerned. It did, however, eliminate some of the drudgery of filling and cleaning oil lamps. From the use of gas resulted the term "fixture," since the earlier and more generally devised arrangements for this illuminant required a fixed position for its use. The necessary piping created this immobility.

The advent of electricity meant the use of an illuminant that was for the first time safe, clean, portable, and one that promised more comfort than was obtainable from the flickering flame of the oil lamp, tallow candle, or gas jet. The first incandescent lamp to be generally used was developed in 1879 by Thomas A. Edison and produced light equal in amount to that of 16 candles. Since that time this original lamp has been developed into a great number of varieties which have not only interesting and romantic but also almost limitless applications. For example, aviation beacons now guide planes in their flight and make possible the night air mail. Outdoor sports, including football and baseball, are played by the light of the modern incandescent lamps. Vehicular traffic in underground tunnels is made possible. Divers now explore the depths of the sea and are helped in salvaging operations by incandescent lamps designed for under-water service.

Unusual Developments.

It was less than ~~ten~~ 15 years ago that Elihu Thomson and his assistants in his research laboratory bent light around a corner, took it out of the bulb, and put it into a quartz rod which obligingly carried it over several feet of distance without perceptible loss. Not long ago light was "frozen" in Schenectady, New York, put into a thermos bottle containing liquid air, and carried on a train more than 100 miles. When the material involved was warmed, the light trapped in Schenectady escaped in New York City.

Even sources, the radiations of which cannot be seen without special preparation on the part of the man who wants to see them, have been developed. Sources whose radiations go through a steel wall, and which penetrate the internal cavities of the human organism, or which can be bent around corners, have been developed.

In addition to light-source developments, there has also been developed a device which, like the human eye, is sensitive to light. This has been referred to as an "electric eye." However, it is correctly termed the photoelectric tube. Its appearance is not unlike an ordinary lamp bulb, except that its inner surface is silvered like a mirror. In place of a filament it has in its center what might be called a small target, while on part of the inner mirrored bulb surface there is a very thin coating of a metal such as potassium, caesium, or rubidium. Directly opposite the surface covered with the thin metal layer there exists a small opening in the silvered inner surface of the bulb through which the light is admitted. Light, upon entering this cell, is readily detected by instruments connected to the inner surface of the bulb and the center "target," although the entering light must strike the thin metal coating of potassium, caesium, or rubidium to have this action take place. Changes in amounts of light entering the cell produce changes in the amount of current flowing through it. These changes of current, while very small in value, can be amplified, making it, in turn, possible to operate electric switches and other devices.

The applications of this combination are many and varied. Artificial lighting may be turned on automatically at the end of the day and turned off at sunrise. Indoors in offices and schoolrooms artificial lighting may be turned on automatically when the daylight falls below a predetermined value. Automobiles passing through tunnels are automatically counted as each car in passing interrupts a beam of light which is directed at a photoelectric tube. The variation in color of various products can be recorded by the photoelectric tube, inasmuch as the differences in the amounts of reflected light are readily detected. These few application cases are given merely to emphasize further some of the wonders of light, electricity, and man's accomplishments with them.

It is fair to conclude that artificial light has been exceedingly important in permitting man to move indoors and that it has provided certain compensating luxuries for the change in the habits of races. Whether it be for better or worse may be argued, but not the fact that it has played no small part in the creation of the home, the apartment, the office, and the factory. This influence is particularly well illustrated in some recently built structures wherein all windows have been eliminated and all light is obtained from well-designed artificial lighting systems.

Safety.

We find a natural heritage in the fact that light is generally associated with safety. Perhaps one of the most dramatic illustrations is the signal system of railroads, particularly underground railroads such as subways, where trains whiz along at the rate of a mile a minute less than five blocks apart, and the really controlling factor is light signals. It is still more effective than all the punishments ever invented to combat crime. Daylight robberies and attacks are only for the most courageous or the most insane. The time for the typical prowler today and five thousand years ago was during darkness.

Light and Vision.

Relative values of our separate senses in acquiring knowledge give the visual sense first place. It is worthy of note also that a very high percentage of all muscular activity depends upon our ability to see—in other words, three-fourths of our work and play reverts to the eyes for guidance.

Primitive man in being out of doors used his eyes under intensities of illumination ranging from a few thousand to 10,000 foot-candles. Since a foot-candle is the illumination produced by a standard candle 1 foot away from the surface illuminated, it is seen that it requires the equivalent of 10,000 lighted candles, all concentrated into a single candle, 1 foot away from a surface to equal this sunlight intensity of illumination. Man today, however, living indoors, has quite changed the conditions under which he uses his eyes. Unless sunlight is streaming through windows, daylight intensities indoors are usually not more than 50 foot-candles, even though we are within 2 or 3 feet of the windows. Move away from the windows and the intensity of illumination usually falls to 8 or 10 foot-candles, and in many rooms there are plenty of areas where the value would be not more than 1 or 2 foot-candles. Couple this greatly lessened value under which we so often use our eyes with the fact that closer visual tasks over longer periods of time are involved, and we obtain a better appreciation of the desirability of the very best artificial lighting that can be produced. Using the eyes for close visual work under the prevalent conditions of low intensities of illumination has been likened to the driving of an automobile in "low gear." Such driving places undue and unnecessary wear and tear on the mechanism when engaged in for long periods of time. It is not unreasonable to assume that the eyes used in "low gear" would suffer similar impairment.

Poor health, accidents, inferiority complexes, and backwardness in school and in the social world can often be attributed to defective vision—a condition frequently brought about by the employment of the eyes in close work. Good general lighting in combination with properly placed localized lighting minimizes eye strain. Lighting which fails to do this satisfactorily is ineffective and is characterized primarily by the following negative factors:

1. Inadequate amounts of lighting.
2. Glaring lighting.
3. Spotty and excessively uneven lighting.

Proper lighting conditions include adequate amounts of light, shaded light, and properly placed light. Proper lighting accompanied by correct reading posture definitely provides improved seeing. This fact is demonstrable. The average inertia of human beings, however, is such that a single recitation of such simple statements scarcely ever leads the listener to examine his or her home for possible defects.

While the earlier specialists in vision and in lighting, respectively, did not approach the final product, *seeing*, in its fullest sense, we are today building what is termed the "science of seeing." The correction of eye defects with glasses does not go all the way any more than just supplying light with which to see. Furthermore, there are a number of psychophysiological sciences involved in lighting which are just coming to be appreciated. The science of seeing, on the other hand, recognizes the importance of the partnership of light and vision, and the seeing specialist, a product of our day, will eventually provide us with information on the best combination of conditions which will enable us to see most easily, most accurately, most safely, most quickly, and most comfortably. In the final sense he is concerned with the greatest productiveness and with complete conservation of vision and other human resources which are drained through the process of seeing.

Light of the right sort not only conserves vision but lends more to the charm of a home than is generally appreciated. One of the greatest obstacles to its adoption is lack of appreciation of its potentialities. Contrary to a general misconception, satisfactory lighting is not expensive. Furthermore, no one has ever regretted the additional effort which may be involved in planning for the comfort and convenience which it can provide. That we are usually living with inadequate amounts of light has been proved in the laboratory and in the home itself. It is unusual to find people changing to lessened amounts of light after they have lived with properly distributed levels of lighting which insure comfort and freedom from eye strain.

Light, Radiation, and Health.

There has always been a health aspect in lighting. Improper and inadequate lighting impairs eyesight and unnecessarily wastes human resources through eye strain, fatigue, and various disorders. Lighting should be adequate in quantity to enable eyes to see easily, quickly, and comfortably. Humanitarian lighting aims to make the eyes most productive with the least drain upon human beings.

Recently, artificial light has extended its service to mankind by supplying ultraviolet radiation for health along with light for seeing. Summer sunlight is now known to be beneficial to health. The particularly effective radiation, as far as is known at present, is the ultraviolet rays of wave lengths near the short-wave end of the solar spectrum. High-powered sources of ultraviolet radiation have been serving well in professional therapy for many years. These sources emit ultraviolet radiation throughout a great range of wave lengths. The short-wave ultraviolet radiation is harmful to the eyes, causing conjunctivitis or inflammation of the outer membrane. Therefore, in order to make the radiation safe for public use in the maintenance of health, filters had to be developed which absorbed the harmful rays and transmitted the beneficial ones. Ordinary glass accomplishes the former but not the latter.

Safe sources of light and beneficial ultraviolet radiation are now available. Naturally, the early stage of utilization of this artificial sunlight is that of the portable "treatment" sun lamp. Children need sunlight or its artificial equivalent in order to develop properly. Rickets is cured and, better still, prevented. A child with rickets is handicapped by a deficiency in bones, teeth, blood, and muscles. Even after the cure is effected, it is suspected that a handicap lingers for years. Inasmuch as ultraviolet radiation is beneficial or even essential to life processes, it seems probable that it is important to healthy adults.

A natural goal of artificial lighting is to provide all the benefits of summer sunlight. Artificial lighting is now crossing the threshold into dual-purpose lighting. New fixtures and lighting systems are necessary in order to conserve the beneficial ultraviolet while diffusing the light. Many advances have already been made along this line. Researches are determining the threshold dosages of ultraviolet radiation. Time of exposure to ultraviolet radiation is an important factor as well as intensity of this radiation. It is already known that surprisingly small dosages daily will produce beneficial results. In dual-purpose lighting the public must rely upon the knowledge and integrity of the lighting profession. Ultraviolet radiation cannot be seen directly; therefore, too much may be obtained before the harm is discovered or too little may be supplied.

The development of dual-purpose lighting which supplies the beneficence of ultraviolet radiation along with light for seeing is now an established fact. It can be installed so that exposure to it may be as indiscriminate as exposure to sunlight without harmful results. Excessive dosages of safe ultraviolet radiation manifest themselves by sunburn. No other harmful effect is known.

CHAPTER II

FUNDAMENTALS OF LIGHTING

Size of Light Source.

A study of light and shade in nature is most helpful in creating a concept of artificial-lighting fundamentals. The artist appreciates this, for he spends many hours studying nature with brush and crayon. First, the chief sources of light in nature—the sun and the sky—and the varied combinations of light from both, afford us excellent examples of one of the most important phases of lighting—the size of the source from which the lighting is obtained. An overcast sky (sun not visible) illustrates the results obtained when all of the light comes from a very large area. If one were to walk on an open road in a level country on such a day, the shadow of one's self falling on the road would be difficult to detect. Furthermore, the eyes feel comfortable under this condition, and there is little or no desire to wear sun glasses. If indoors the ceiling and walls of a room are illuminated with a lighting fixture in which the lamps are not visible and the fixture itself is opaque, the lighting effect is very similar to that found outdoors on an overcast day. Shadows are exceedingly soft and eye comfort is assured. Reflections from shiny magazine and book paper are so softened that they are neither annoying nor do they appreciably interfere with vision. These parallel cases definitely indicate that the size of the light source is of first importance, if soft and comfortable lighting is to be obtained.

In direct contrast to this condition let us again place ourselves out on the country road on a day with a clear

FIG. 1.—The sun on a clear day, limited in area with respect to the total sky area, contributes 80 per cent or more of the light on the earth's surface. Harsh shadows result and eye comfort is reduced.

FIG. 2.—The overcast sky, extensive in area as a light source, provides great softness of shadow and eye comfort.

Fig. 3.—Illumination provided with unshaded lamp bulbs results in harsh shadows and impaired eye comfort. The size of the principal light source (the unshaded lamp bulbs) is too small.

Fig. 4.—Illumination provided from an extended light source, the ceiling, similarly found out of doors on an overcast day, provides softness of shadow and eye comfort.

blue sky and full sun. This time we find a very harsh, clearly defined shadow of ourselves cast on the road. While this condition may be cheerful, we eventually find it trying on the eyes, and unless the sun is behind us we feel vastly relieved when wearing sun glasses. Under this condition the sun *directly* contributes *four* to *five* times the amount of light on the surface of the earth that the entire sky contributes. The sun occupies but a very small part of the total area of the sky, and the effect of having such a large part of the light coming from a relatively small source results in sharp shadows and may produce an uncomfortable lighting condition. This condition is readily simulated indoors by hanging a single bare lamp from the center of the ceiling in a room. In this case we again find harsh shadows and also an uncomfortably lighted room. White walls and ceiling in a room so lighted assist in softening the effect, but just as the sun out of doors contributed a considerably larger part of the light falling on any object near the earth than the sky did, the sky cannot wipe out the harshness of shadow or the eye discomfort. Similarly, indoors the white walls and ceiling cannot wipe out the harshness of shadow or the eye discomfort. When we try to read print on shiny magazine or book paper under this lighting condition, annoying reflections of the small source of light, the bare lamp, are present unless we orient ourselves and the book to avoid these reflections. Aside from the harshness and eye discomfort found in interiors illuminated with bare lamps, there is always a feeling of garishness.

The importance of the size or extent of light-giving area in an interior cannot be overemphasized. Being tangible it is easily visualized, and inasmuch as it is always apparent, predictions or appraisals of the lighting satisfactoriness may be readily made in a planned or existing room respectively.

Position of Light Source.

Next in order, but still involved with the size of source, we turn our attention to the position of the source of light. The sun when it is directly overhead at noon is in its most favorable position for eye comfort, whereas later in the afternoon its lower position may become extremely annoying. This experience we most markedly feel when we have an afternoon of driving to do "against" the sun. The nearer the horizon or the closer to our line of vision the light source the more trying the lighting condition becomes. Carrying the illustration still further, bright sunlight on a field of snow is most unpleasant, for our eyes no longer receive the protection of our forehead. The brightly lighted snow has considerable extent or area which should assist in providing comfort, but its position (that of being beneath us) plays a large part in making it uncomfortable to view. Another factor in this case is the actual brightness of the snow, for it may be considerably brighter than the sky. Physically, human beings are not constructed for higher values of light from below.

Indoors the position of lighting equipment and the need for controlling the brightnesses of this equipment should be governed by the experiences obtained out of doors. Wall brackets, due to their closeness to our line of vision, should be of low brightness. With the more conventional candle and similar types of brackets, shades should always be used to assure low brightness. We feel more comfortable wearing sun glasses when driving against the sun. Indoors instead of placing these glasses on our eyes, we place them on the brackets, and improvement in effect results.

Lighting Fundamentals Applied.

After considering the extent (area) and positioning of lighted wall and ceiling areas of the room, we next apply these same principles to the lighting equipment itself—ceiling fixtures, wall brackets, and portable lamps. The more extensive the lighted surfaces of lighting fixtures, assuming that these surfaces are of material sufficiently diffusing to conceal the lamp bulbs, the lower will be the brightness of these areas and, due to the more extensive surface, the less harsh are the shadows. The limited surface areas of bare lamps are inadequate for producing comfortable brightnesses and freedom from harsh shadows. In rooms having darker finishes it is extremely important that the light-giving surfaces of the fixtures be low in brightness and as extensive as possible, for while the dark surfaces of the room reflect light, it is difficult to make them bright enough, due to their poor reflecting qualities, to be valuable in affording the "sky-area" effect which is the softening factor. Light-colored linings in portable lamps are of great value both from the point of efficiency of the portable lamp and from that of the lighting results obtained. The bare lamp inside a shade having a dark inner surface provides harsh lighting beneath it, for most of the light is coming from the bulb itself and relatively little from the inner surface of the shade. This condition may be thought of as being similar to the sun without the softening aid of the surrounding sky areas. Lighten the inner surface of the shade and the effect of the softening sky area is added; at the same time a greater amount of light will be given off by the lamp and shade combination.

Overhead lighting equipment may create effects ranging from harsh, non-uniform downward light from small light-source areas to highly diffused, soft, practically shadowless lighting. The latter, due to its high degree of uniformity and shadowless character, is apt to be lifeless, monotonous, and lacking in interest and sparkle, yet its eye-comfort qualities are not to be overlooked. The former, due to its excessive contrasts and harshness, can possess great sparkle and interest, yet when depended upon for visual work has many shortcomings. These opposite attributes of the two extremes definitely point to the desirability of combining modified forms of each of these types of lighting, thereby gaining the advantages of each and at the same time largely eliminating such disadvantages as either possesses when used alone. This can be done in a variety of ways, and it is this latitude in effect that makes it possible to produce individuality in the lighting of various rooms of the home and also in varying the character of entire homes. A central fixture can supply the softening (sky area) effect if it reflects light to the ceiling. Portable lamps containing reflecting bowls can provide this component, and the more usual open-top shades on portable lamps can assist in accomplishing this result. Smaller apparent light-source areas may be a part of the fixture, bracket, or portable lamp to furnish the interest element of the lighting.

Reflection and Reflection Factors.

The ease or difficulty of lighting interiors is in a large measure dependent upon the reflecting qualities of the walls and particularly the ceiling. White paints and wall papers are now obtainable which reflect more than 80 per cent of the light striking them. Rooms finished with such surfaces are easily lighted inasmuch as the backgrounds for lighting devices are so easily made luminous, and hence excessive contrasts are avoided. In such cases a large part of the light striking extremely light surfaces is reflected, making it simple to provide large-area sources of softening light. The use of such whiteness does, however, often introduce coldness and unpleasantness in an interior and is confined largely to bathrooms, kitchens, and basements. It is not difficult to find individuals whose sensibilities are offended by the use of this extreme whiteness, which is therefore rapidly coming into disfavor even in these rooms. Light ivories, buffs, greens, blues, pinks, and warm grays can be obtained which reflect 60 to 70 per cent of the light which strikes them, and slightly darker tones of these colors can be obtained which reflect 50 per cent of the light striking them. This range of values is both practical and economical for wall use, although wall coverings which go as low as 50 per cent will often be found to be too dark to be pleasing.

Paneled walls of oak, walnut, mahogany, and other woods, which are finished in the usual rich, dark manner, are very poor reflectors of light, and accordingly rooms paneled with these woods are more difficult to light comfortably than lighter-walled rooms. If, however, the ceilings of such rooms are left light in color, the problem is simplified, for much of the light for illuminating the room can be first directed against the ceiling to obtain extensive light-source area. When, however, the ceiling is beamed and the wood or plaster surfaces of the ceiling are dark, which is so often the case, the softening effect of light coming from the ceiling and walls cannot be economically created, and from the decorative point of view it is not usually desirable. The principal amounts of useful light will then have to come directly from the fixtures and lamps. Since the lighting equipment receives so little assistance from walls and ceiling in rooms of this character, the shades, reflectors, and other apparent light-giving surfaces of the fixtures should be lower in brightness and more extensive in area than similar parts for rooms finished in the more usual light-colored walls and ceiling. Shades on portable lamps should also be denser than those used in lighter-colored rooms, for the lighter shades and particularly the lightest shades create undesirable contrasts with the backgrounds (the dark wall areas) against which they are viewed.

Quantity of Light versus Glare.

If in planning interiors the foregoing principles are incorporated, the lighting will be usually free from that

Reflection Factors

The proportion of light reflected by walls and ceilings of various colors, that is, their reflection factors, has an important bearing on both the natural and the artificial lighting. The proportion reflected will depend somewhat upon the

# of Colored Surfaces

color of the incident light. The figures here given show what proportion of the light of tungsten-filament incandescent lamps these painted surfaces reflect. The reflection factor of any colored surface can be approximated by comparing it with these samples.

No. 17
Buff Stone and Pale Azure
39%

No. 18
Buff
64%

No. 19
Buff Stone
41%

No. 20
Tan
35%

No. 21
Cocoanut Brown
19%

No. 22
Satin Green
56%

No. 23
Bright Sage and Ivory Tan
48%

No. 24
Bright Sage
41%

No. 25
Forest Green
20%

No. 26
Olive Green
21%

No. 27
Pale Azure and White
55%

No. 28
Pale Azure
40%

No. 29
Sky Blue
37%

No. 30
Shell Pink
54%

No. 31
Pink
52%

No. 32
Cardinal Red
20%

S1712 S31 534

demon of lighting—glare. We have, however, still one more factor to consider—amounts of light. Artificial lighting has long had the stigma of "too much light" associated with it. This is most unfortunate, for both physiologically and economically too much light is difficult to attain, but it is, however, so easy to produce glare that practically every case of so-called "too much light" is really a case of glare.

When 23 out of every 100 persons under twenty years of age have defective vision; when 39 out of every 100 under thirty years of age have defective vision; when 48 out of every 100 under forty years of age and when 82 out of every 100 under sixty years of age have defective vision, it is not unreasonable to assume that there must be something wrong with much of our artificial lighting. True, we have imposed tremendously greater tasks on our eyes with each step ahead in our civilized world, but that should warn us to provide better and better lighting to compensate for the gradually increasing eye work. Every function of vision which has ever been tested has always shown improvement with increasing amounts of light, whether it be speed of reading, accuracy of vision, sharpness of vision, or any one of the many phases of vision. These researches definitely point to the desirability of using intensities of illumination considerably higher than those commonly now in use.

While it is difficult to assign fixed values of illumination intensities for the various rooms of the home, due to the wide variety of decorative schemes which may be created, suitable equipment for the many services involved provides a means of obtaining satisfactory illumination intensities in the majority of cases. Inasmuch as lamp sizes and fixtures, portable lamps, and their various uses are so closely connected, it is best to consider these elements together. Since Chapter VIII discusses these elements in a correlated way, the sizes of lamps (bulbs) are not discussed in detail in this chapter.

CHAPTER III

CHARACTERISTICS OF INCANDESCENT LAMPS

Incandescence.

A material becomes incandescent when it is heated to a high temperature. A piece of metal held in a forge until it is glowing is an incandescent light source of very elementary form. The hotter a given metal the more light it emits. The glow from this metal after it is withdrawn from the fire will furnish light as long as the metal remains sufficiently hot.

Heat is produced when an electric current flows through a wire, and it is possible to heat the wire to the point of incandescence in this way thereby producing light. As long as the current continues to flow, heat and light will be produced. For example, if a piece of fine copper wire were connected between the terminals of an ordinary dry cell and the length of the connecting wire gradually shortened, the wire would begin to glow. If the wire were shortened still more or the number of cells increased, thereby increasing the voltage, the glow would become brighter. If this process were continued, the wire would burn and eventually be destroyed, for even metals will burn when heated to high temperatures in the presence of oxygen. For this reason, the filaments of incandescent lamps are operated always either in a vacuum or in an inert gas. In general, as the temperature of an incandescent solid increases, the amount of light it gives increases, and the color of the light grows whiter.

So-called "white" light is made up of all of the wave lengths of the visible spectrum in approximately the proportions found in sunlight or daylight. The characteristic color of any particular light is determined by the proportions of different colors of light (wave lengths) present in its composition. Blue light is made up largely of short wave lengths, and red light contains a predominance of long wave lengths. Incandescent lamps produce a greater amount of radiant energy at the longer wave lengths toward the red end of the spectrum than at the shorter wave lengths toward the violet end. With higher filament temperatures the energy distribution is more even, and the light, therefore, is "whiter." Daylight, however, is by no means constant in color value, ranging from clear blue sky through cloud light, to noon sunlight, and on to late afternoon sunlight. The present method of obtaining artificial daylight is by filtering out the excess red light of the incandescent lamps with blue glass. Such lamps approximate the color of late afternoon sunlight and are an approach to daylight.

Efficiency.

The relation between light output and the energy used is known as the efficiency of the lamp and is expressed in lumens per watt. (When one lumen of light falls on one square foot of area, an illumination of one foot-candle is produced on the surface.)

The efficiency of a lamp increases with the temperature. Therefore, it is desirable to operate the filament at as high a temperature as possible without melting it. The filament, however, vaporizes at temperatures below the melting point, and the lower the temperature the lower the rate of vaporization. The filament becomes thinner as its surface evaporates until it finally burns out. Thus, the higher the temperature the shorter the life of the filament, so the operating temperature must be considerably below the melting point in order to gain a reasonable length of life for the filament.

The selection of a suitable material for filaments was one of the first difficulties which faced the early lamp makers. Edison, like other experimenters, tried hundreds of materials before he found a practical method of carbonization which enabled him to produce the carbon filament used in his first successful incandescent lamp (1879). The very high melting point of carbon recommended it for filament use. The efficiency of the early carbon lamp was 1.4 lumens per watt.

The development of the osmium and tantalum lamps marked the first successful attempt to use a metal filament. These could be operated at higher temperatures than the carbon lamp and were, therefore, more efficient. The efficiency of the tantalum lamp in 1906 was approximately 5 lumens per watt.

In 1907 tungsten lamps were commercially introduced. Tungsten is particularly suitable for incandescent lamp filaments because it has a very high melting point—more than 3000°C.—and does not vaporize so fast as carbon. Hence, tungsten filaments can be operated at much higher temperatures than carbon lamps and at, therefore, greater efficiencies. Each of the steps ahead in these developments resulted in a higher efficiency as evidenced by the fact that the drawn-tungsten wire lamps of 1913 operated at an efficiency of practically 10 lumens per watt or nearly seven times the light per unit of energy that was derived from the first incandescent lamp of 1879.

Vacuum and Gas-filled Lamps.

If the air in the lamp bulb were not removed, the oxygen present would combine chemically with the hot tungsten filament, producing a white smoke and burning out the filament immediately. The presence of white powder in a lamp is an indication that some air has leaked into the bulb, usually through a crack in the glass.

By filling the bulb with an inert gas which will not combine chemically with the hot filament, the rate at which the filament material vaporizes may be retarded and the efficiency of the lamp increased, since the filament may be operated at a higher temperature without shortening its life. The higher operating temperature of the gas-filled lamps provides a light more nearly white.

Today most incandescent lamps of 40 watts or more are gas filled. In these lamps, the gas, when heated by the filament, rises to the upper part of the bulb where it becomes cooled. It then descends, the cycle being repeated, so that the gas circulates in the bulb as long as the lamp is lighted. In rising, the gas carries with it the particles of tungsten which are evaporating from the filament and deposits these particles on whatever part of the bulb is uppermost. This results in the blackening, due to filament evaporation, being confined to one area, thus cutting off less of the light than in the vacuum lamp where the blackening is more evenly distributed over the entire inside of the bulb.

Shapes and Sizes of Bulbs.

The various shapes and sizes of lamp bulbs are indicated by a letter and a number. The letter identifies

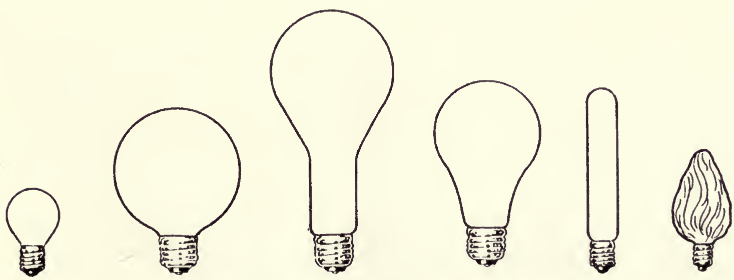


Fig. 5.—Lamp bulb shapes and their designations.

the shape of the bulb and the number shows its diameter in eighths of an inch. The A-21 bulb, for example, is the A shape and is $^{21}/_{8}$ or $2\frac{5}{8}$ inches in diameter.

The lamps generally used in home lighting are of the A shape and are frosted on the inside. Bulbs of the A shape may be obtained in sizes from 15 to 100 watts;

G (round), F (flame shaped), and T (tubular) bulbs are used for various decorative applications.

Bases.

The bases of the usual lamps used in home lighting may be grouped as medium, intermediate, and candelabra screw bases. The candelabra and the intermediate bases are used generally for small decorative lamps, while the medium screw base is used on lamps for general lighting. The mogul screw base is used on lamps over 200 watts in size. Some of the indirect-lighting floor lamps employ the mogul-type base.

Fig. 6.—Lamp bases (actual size). 1. Medium screw base. 2. Intermediate screw base. 3. Candelabra screw base. 4. Miniature screw base.

A fifth type of base, the miniature screw, is used only on the low-voltage lamps for flashlights and series-burning lamps for Christmas-tree strings.

Frosting.

Frosted lamps are preferable to clear lamps, as the frosting assists in shielding the eyes from the intense brightness of the filament itself. The resulting illumination is softened and the shadows cast by the fixture parts—shade, frames, etc.—are less marked. The inside frosting, used today in most lamps for general lighting, absorbs but a small amount of light, less than 1 per cent. This very small loss is more than compensated for by the improved lighting obtained.

Daylight Lamps.

The "daylight" lamp has a bulb of greenish-blue glass which screens out some of the excess red and yellow rays in the light emitted by the filament, making the resulting light which passes through the bulb a practical and economic daylight approximation.

Life.

A lamp may be designed for any average life desired, but long life is obtained at a sacrifice of efficiency. Two major items in the cost of light are the cost of energy and the cost of lamp renewals. Long-lived lamps, being relatively inefficient, will make the energy cost high for a given amount of light but will reduce the lamp renewal cost during a given period. Short-lived lamps, while reducing the energy cost, will increase the lamp renewal cost. Theoretically, therefore, the most economical life is where the sum of these two costs, for a given amount of light, is a minimum.

All lamps are designed for a certain average life, depending upon the uses to which they will be put. The standard general lighting lamps in the A bulb are rated at 1,000 hours' average life; the decorative G-bulb lamps at 750 hours, and the F-bulb, 1 amp. at 600 hours.

It should not be expected that every lamp will burn exactly its rated life, for lamps are like people—some will live longer than others. The average of any considerable number of lamps, however, produces results close to the rated life.

Voltage.

Lamps are designed to give the best performance at specific voltages, such as 110, 115, or 120 volts. The voltage for any community may be determined from the lighting company. Everyone knows that the performance of an automobile tire is affected by inflation above or below normal pressure. Incorrect voltage acts similarly on incandescent lamps. A 110-volt lamp burned on a 115-volt circuit produces more light and is brighter than when it is burned on a 110-volt circuit, but only about 58 per cent of the normal life of the lamp is obtained. *Vice versa,* a 120-volt lamp used on a 115-volt circuit will burn longer—about 60 per cent—but only about 86 per cent of its normal light or brightness will be produced. Longer life can be obtained only at the cost of poor economy. Lamps should be burned always at their rated voltage and, therefore, should be selected with the same voltage rating as the circuit on which they are to operate.

Carbon Lamps.

The so-called 16-candlepower carbon lamp consumes slightly more than 60 watts of energy but it provides only one-third the light produced by one of the modern gas-filled tungsten-filament 60-watt lamps. Judging from the great number of carbon lamps in use today, the low efficiency of the carbon lamp is not universally appreciated. The amount of energy wasted in burning a carbon lamp 1,000 hours—the average life of the modern gas-filled lamp—equals in cost one dozen modern gas-filled tungsten-filament lamps. It is not uncommon to find people appraising the quality of incandescent lamps only in terms of the number of years that a lamp has continued to burn. Light, rather than electricity or lamps, is really the commodity being purchased. The modern gas-filled tungsten-filament lamp affords the greatest amount of light for a given expenditure.

Summary.

An incandescent lamp is essentially a filament of some material that is able to withstand high temperatures without too rapid vaporization. It gives light by virtue of its being heated to incandescence by the passage of

TABLE I.—PRINCIPAL APPLICATIONS OF LAMPS USED IN RESIDENCE LIGHTING
(Shapes and Finishes as of August 14, 1931)

Watts	Bulb	Base	Finish	Application
15	A-17	Medium	Inside frosted	Decorative lamps and wall brackets
25	A-19	Medium	Inside frosted or ivory	Decorative wall brackets and wall pockets
25	A-19	Medium	Flame tint, ivory or old rose	Decorative lighting effects
40	A-19	Medium	Inside frosted or ivory	Ceiling fixtures, wall brackets, and portable lamps
40	A-19	Medium	Flame tint, ivory or old rose	Decorative lighting effects
60	A-21	Medium	Inside frosted	Ceiling fixtures, utility brackets, and portable lamps
100	A-23	Medium	Inside frosted	Ceiling fixtures and portable lamps
150	PS-25	Medium	Inside frosted	Enclosing globes and semi-indirect ceiling fixtures
200	PS-30	Medium	Inside frosted	Indirect ceiling fixtures and lamps
300	PS-35	Medium	Inside frosted	Indirect ceiling fixtures and lamps
60	A-21	Medium	Daylight	Bathrooms, laundries, kitchens, and sewing rooms (for local applications)
100	A-23	Medium	Daylight	Bathrooms, laundries, kitchen, and sewing-room ceiling fixtures
150	PS-25	Medium	Daylight	Bathrooms, laundries, kitchen, and sewing room ceiling fixtures
5	S-6	Candelabra	Clear	Light ornaments and pilot lights
10	S-11	Intermediate	White, flame tint, and colored	Decorative lamps, light ornaments, and coves
15	G-16½	Intermediate or candelabra	White or flame tint	Decorative wall brackets and lamps
15	F-10	Intermediate or candelabra	White or flame tint	Decorative wall brackets and lamps
25	F-15	Medium	Flame tint or white	Decorative wall brackets and lamps
25	G-18½	Medium	Flame tint or white	Decorative wall brackets and lamps
25	G-25	Medium	Flame tint or white	Decorative fixtures and wall brackets
40	G-25	Medium	Flame tint or white	Decorative fixtures and wall brackets
25	T-6½	Intermediate	Clear	Modernistic wall brackets, special fixtures, and coves

an electric current through it. To prevent the filament from oxidizing or burning up, it is operated either in a vacuum or in an atmosphere of inert gas. In a vacuum, the filament suffers by reason of the absence of a pressure to assist counteracting the tendency to vaporize. This difficulty is overcome in the gas-filled lamps by the use of an inert gas in the bulb which permits operating the filament at a higher temperature with a less rapid rate of vaporization.

CHAPTER IV

LIGHT AND COLOR

Spectral Composition of Light.

Light is the master painter and sculptor, for light colors and models everything. Obviously, without light our eyes would be of no value, and the presence and shape of objects would have to be detected largely by touch; color would not exist, for without light all things are black. It is light which possesses the color and not the objects. Nature reveals the fact that sunlight, which we may call a "white light," is a "mixture" of a great many colored lights when she exhibits her marvelous display—the rainbow. The raindrops in the air reflect the light of the sun back to us during this phenomenon and while doing this they also break the white light into its component parts, and we readily see these parts as red, orange, yellow, green, blue, and violet lights strung in bands of color. These colors are called spectral colors. The rainbow provides us with conclusive proof that white light is made up of all the spectral colors.

Without some optical device such as the raindrop, prism, or finely ruled lines on glass (a grating) it is doubtful if we would be permitted to see the color composition of light. Our eyes are not analytical. They see only the summed-up effect of light mixtures. They do not in themselves break these mixtures into their component parts.

When we view an object, we usually see this object by the light which is reflected from it to our eyes. If the surface viewed is painted white, practically all of the light striking it is reflected. If it is painted medium gray, one-half of the light may be absorbed by the surface, and the remaining one-half reflected. When we view a surface painted black, as much as 90 per cent or more of the light striking it may be absorbed, leaving only a small amount to be reflected to the eye. Surfaces painted white, medium gray, and black, placed alongside of each other and illuminated with the same amount of light, appear white, medium gray, and black, respectively, because they absorb different amounts of light.

The entire absence of light or the condition of no light is perfect black. A room with tight-fitting, opaque curtains becomes black the moment the light with which it is illuminated is extinguished. All surfaces absorb some light; even the very lightest surfaces exhibit this characteristic.

White light or any given composition of colored light can be considered as a mixture in which very definite amounts of each of the spectral colors involved are present. Change the amount of any of the "ingredients" in such mixtures and the color of the resulting light will be changed. For example, we can consider white light as a mixture in which practically equal amounts of each color are present; reduce the amount of blue present but slightly, and the white light becomes yellowish; reduce the red component but slightly, and the white light becomes bluish; reduce the green slightly, and the resulting light will be purplish. On the other hand, if all colors present are reduced equally in amount, the color of resulting light is not changed. A neutral gray (a gray which exhibits no colorfulness) is gray and not colored, because it absorbs equally all the colors in white light which strikes it.

Pigments.

Surfaces which appear colored under white light possess in themselves the ability to absorb some colors and reflect others. The pigment on the surface can be thought of as having "likes" and "dislikes," and furthermore, except for fading, a given pigment or a mixture of pigments will always exhibit the same likes and dislikes. In the case of a surface which appears red under white light, the surface likes (absorbs) the blue, green, and yellow components of the white light striking it, but it does not like red, it "rejects" (reflects) the red component of the white light to our eyes, and the sensation is exactly the same as though red light were entering the eye from a primary light source.

In viewing a card which appears blue, the pigment absorbs the red, yellow, and green components of the white light, and only the blue is left to be reflected, and accordingly only blue is reflected to our eyes. Green pigment absorbs all colors but green; yellow pigment absorbs all colors but yellow; and so on. Actually few pigments possess the ability completely to absorb all colors but one. The red pigment readily absorbs all the colors but red. It does not, usually, completely absorb orange; hence there will be some orange reflected with the red. The green pigment may completely reflect green light, but it does not completely absorb blue and yellow, and accordingly both blue and yellow will be partly reflected with the green. If a considerable amount of blue is reflected with the green, the result is a bluish green; whereas if considerable yellow is reflected with the green, the result is a yellowish green. From this it is seen that the purity of color reflected depends upon the ability of the pigment to absorb color. When all colors but one are absorbed, very high purity of the color reflected may result.

Pigment Mixtures.

The colors resulting from the mixing of pigments involve the same physical processes as just discussed. A mixture of yellow and blue pigments produces green. The yellow pigment is one that does not absorb everything but yellow. In fact it also reflects green. The blue pigment will, of course, reflect blue, but inasmuch as the yellow pigment with which it is mixed absorbs practically all the blue, there will be little or no blue reflected. Therefore, the blue used reflects green, and inasmuch as the yellow pigment reflects green, they both reflect green. Thus far we have only green reflected. The yellow pigment of the mixture reflects yellow, but the blue does not; hence the blue will suppress the yellow. Finally, we see that green is the only color which is reflected in common by both elements of the mixture, and the surface so coated appears green. Colors resulting from mixtures of pigments always take on their apparent colors in accordance with the principles just described.

Colored Light.

Thus far we have dealt with light reflected from surfaces coated with some form of pigmentation. A discussion of color would not be complete without dealing with mixtures of lights of various colors directly from light sources. Colored light may be produced by interposing a "colored" transmitting medium (dyed fabric or gelatin and colored glass) between the light source and the surface to be illuminated. These materials possess the ability to absorb light of certain colors and to transmit others. The color or colors transmitted produce a definite color to the transmitted light. For example, a so-called "red" piece of silk or gelatin may have any color of light fall upon it but only red light will be freely transmitted through it. Accordingly when white light, which is composed of all the spectral colors, falls on the silk or gelatin, it will freely transmit only the red component of the white light, and the resulting transmitted light is red. Due to the vast numbers of dyes and their mixtures it is possible to obtain a vast variety of colored lights in this manner. Colored glass also occupies an important position in this field, although the variety of available colors is more limited. Pigments on glass are also used to produce colored light, although their use is limited chiefly to incandescent-lamp bulb coatings placed either on the outside or on the inside of the bulbs. In this case light striking the small pigment particles is altered in color by absorption. Only a very small part of the resulting light actually passes through the pigment particles, for most of it is reflected from the surface of the pigment particles; and inasmuch as there are spaces between the particles, the emerging light after striking the pigment particles escapes through these minute spaces.

Colored-light Mixtures.

After the consideration of a single light source with a given color medium for producing colored light, we may consider the lighting of surfaces with several light sources, each equipped with a different color medium, to produce a vast variety of desired colors of the surface so illuminated. This variety of color can be obtained from *three light sources* and *three properly chosen* color media. The light sources used, however, must illuminate the same given surface. The colors used are red, green, and blue, and they are called the additive primaries. When used to illuminate a white surface, various quantitative mixtures of red and blue light can produce an extensive series of purples, ranging from reddish purple through mid-purple to a blue-purple. Mixtures of red and green produce yellows, ranging from pinkish yellow to greenish yellow. Some of the colors produced in this series are known as the ambers. Mixtures of blue and green produce a series of colors ranging from blue-green up to mixtures which are difficult to name as either blue or green on through to green-blue. In each case the various colors of a series are produced by using varying proportions of the two colors. A large amount of blue with a small amount of red produces a bluish purple, while a large amount of red with a lesser amount of blue produces a reddish purple.

While it is not particularly practicable to produce white light with mixtures of red, green, and blue lights, the proper proportions of these three primaries used together do produce white light.

Additive and Subtractive Primaries.

It should be noted that these three primary colors (red, green, blue) are not the same primary colors used by the artist in dealing with pigments. The pigment primaries are usually named red, yellow, and blue. If, however, the artist had to produce all of his work from three pigment colors, it would be found that the pigment primaries would be more accurately described as a reddish purple, yellow, and blue-green. While it may appear that these two differing sets of primaries present an inconsistent situation, nothing could be further from the truth. There is the closest of relationships between the two. We do, however, have to bear in mind that for a surface to be colored with the "light" primaries, one or more of these primaries must fall upon a white surface to produce the possible range of colors with these primaries, while all the colors in white light must fall on a pigment-covered surface in order that the surface may select out of the entire assortment the color it always absorbs and in turn reflect that color or those colors which it always reflects. Colors of the first set are always added either in space or at the surface to be colored; while with the second set (the pigments), white light—a composition of all the colors—must fall on these pigments in order that subtraction may take place. As previously stated, the "light" primaries (red, green, blue) are termed the additive primaries, and the "pigment" primaries

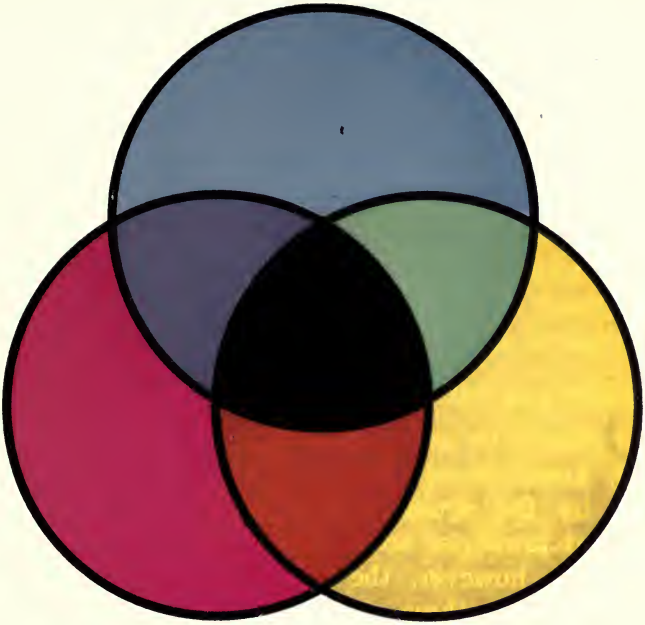


Fig. 7.—The subtractive method of mixing colors. The result obtained when mixing pigments.

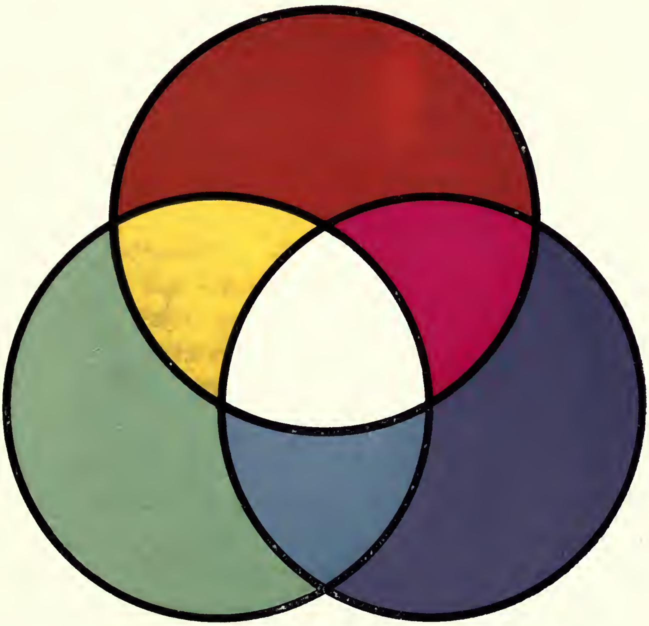


Fig. 8.—The additive method of mixing colors. The result obtained when mixing colored lights.

(reddish purple, yellow, blue-green) are termed the subtractive primaries. When the action which is taking place on the surface illuminated (namely, the addition of colored light to produce the color and the subtraction of lights of certain colors at the surface to produce a resultant color), the significance of the terms "additive" and "subtractive" primaries becomes obvious.

Table II.—Additive and Subtractive Primary Combinations

Additive Primary Combinations (Light Mixtures)	Subtractive Primary Combinations (Pigment Mixtures)
Red + blue = reddish purple	Reddish purple + yellow = red
Green + red = yellow	Yellow + blue-green = green
Blue + green = blue-green	Blue-green + reddish purple = blue

The close relationship between the two sets of primaries is verified when we allow red and blue light to fall on a white surface, for this pair produces reddish purple, one of the pigment primaries. Again, when we allow green and red light to fall on a white surface, yellow light results, another one of the three pigment primaries. Last allow blue and green light to fall on a white surface, and a blue-green results, the third of the pigment primaries. Furthermore, any two of the pigment primaries may be mixed together in proper amounts to produce one of the light primaries. Reddish purple and yellow pigments mixed produce red, one of the additive primaries. Yellow and blue-green pigments mixed produce green, another of the light primaries; while blue-green and reddish purple pigments mixed can produce blue, the third of the light primaries. These relationships are readily demonstrated with the proper choice of pigments and light filters. In checking these combinations it becomes apparent that it is all readily understood with the exception of the addition of the red and green light which produce yellow light. In this case yellow need not be present in either the red or the green light used to produce the sensation of yellow light. Actually the yellow sensation is produced when the eye is stimulated by red and green light. This method of producing a yellow may be thought of as a synthetic one, for pure yellow light entering the eye also creates the sensation of yellow.

Apparent Color Changes.

Some of the peculiarities and attributes of color are invaluable in making an intelligent use of it. For example, colors appear less colorful when viewed under high illumination or at high brightnesses. The artist will paint a deep-red object which is illuminated by direct sunlight of high intensity, orange-red instead of red, because the high-intensity illumination on the deep-red object robs this object of its deep colorfulness. View this same object in the shade, and it will take on its full colorfulness.

The extent of a given area of color plays an important role in apparent color. Researches indicate that larger areas of a given color appear more colorful than smaller areas.

Time of exposure apparently has much to do with how colorful a color appears. The longer one views a color the less colorful it appears to be. An hour or more spent in a red-illuminated photographic dark room provides excellent proof of this.

When two colors are placed close together—for example, when red and green are juxtaposed—they appear accentuated in color and deeper in hue. These same two colors separated appear, however, very much the same as though they were viewed separately. Surrounding a relatively small area of a given color by another color often produces very striking changes in the color of the smaller area. A black pattern on a red ground may appear blue green; a white surrounded by green will appear brighter and of a pinkish tint.

Table III.—Some Apparent Color Changes Produced by Contrast

I Color of Smaller Area Viewed Alone	II Color of Surrounding Smaller Area	III Apparent Color of Smaller Area when Surrounded by Color in Column II
Light green	Red	Dark green
	Green	Brownish yellow
	Blue	Yellow-green
Light blue	Red	Dark blue
	Green	Purple
	Blue	Brownish gray
Light red	Red	Reddish brown
	Green	Bright red
	Blue	Orange

These effects are obtained only when the proper colors are chosen and proper brightness of the colors employed.

Symbolism of Color.

Association, usage, sensation, all contribute toward a more or less universal "language of color."[1]

Red is associated with danger and blood. It is characteristically a stimulant or excitant.

Yellow or orange is often significant of light and warmth due to the association of this color with the

[1] Luckiesh, M., "Language of Color," Dodd, Mead & Company, Inc. Luckiesh, M., "Light and Color in Advertising and Merchandising," D. Van Nostrand Company.

sun or with sunlight. Yellow and orange are mildly stimulative and are described as warm colors.

Green is the most conspicuous garb of nature and thus represents life. It is particularly associated with freshness and newness of springtime, and from analogy there have arisen many uses of green symbolizing youth, immaturity, etc. Green is most generally characterized as a neutral color, perhaps due to continued adaptation to large areas of this color in nature. Nature's greens are darker or deeper in shade than is commonly realized. Certain greens can be very disagreeable.

Blue, due to its earliest association with the sky or heaven, took on a divine significance. The darker blue found toward nightfall, a time of quietude, has undoubtedly bestowed on this color the attribute of sedateness. Blue may be serene, cold, sedate, or depressing, depending upon its tint and hue.

Purple of a hue resulting from mixtures of approximately equal parts of red and blue lights has long been a color of state. We know that it was one of the most costly colors in early history, and this may account for its use as a regal color.

White is the logical color for symbolizing purity, innocence, chastity, etc. The purity of freshly fallen snow brings this to mind again and again. It produces the extreme of contrast when used with black. It is, however, coming into some disrepute for interiors, for it is harsh.

Alack is the antithesis of white, and its association with gloom and darkness renders it a fitting symbol for woe and fear. As it provides an environment for evil deeds, it is emblematic of crime.

Gray is the color of age because the hair of the aged is hoary gray. This association also results in a signification of ripened judgment and maturity. White is enlivening; black is gloomy; and gray is intermediate, sad. Colors and their combinations may be agreeable, cheerful, stimulating, neutral, tranquilizing, depressing, warm, cold stern, stately, weak, or impressive. These are factors which should always be borne in mind whenever color schemes are being evolved.

Use of Colored Light.

In using colored light for illuminating interiors and objects contained therein, it must be remembered that distortion of the color of areas and objects so illuminated is likely to occur. Sometimes the resulting distortion or change of color is a sought-for effect, whereas in other cases it may be so disastrous that entire color schemes must be discarded or the lighting scheme abandoned. An exact prediction of the appearance of a color under lights of various colors cannot be made without an exact knowledge of the reflecting characteristics of the surface illuminated and of the spectral composition of the light used. If, however, we consider the use of colored light that would be commercially termed medium, red, yellow, green, or blue, the changes in the appearance of colored fabrics, wall surfaces, and colored objects illuminated by these lamps can be approximately stated. A number of these predictions are indicated in Table IV.

In recent years a marked advance in the use of color in the home has taken place. This is evidenced in hangings, colorfully painted furniture, dishes, and even in kitchenware. This prompts the question as to what we may do with colored light in the home. In fact discussions of the possibilities of lighting given rooms with colored light have appeared from time to time. With the emotive power of colored light in mind, it would seem that rooms might be fitted with lighting systems which would bathe an entire room in red, green, or blue light or resulting mixtures of these colors, thereby creating a room which could be changed from one of warmth to one of coolness, or one which would stimulate or depress, and so on. Theater auditoriums employ such systems of lighting, and inasmuch as we go to the theater to be entertained and spend but a short time in them, such systems of lighting are extremely valuable and appropriate. On the other hand, but

Table IV.—Resulting Effects of Colored Light on the Appearance of Objects

Appearance of Object under White Light	Color of Light Illuminating Object					
	Red	Orange	Yellow	Green	Blue	Purple
Black	Red black	Orange black	Yellow black	Green black	Blue black	Purple black
White	Red	Orange	Yellow	Green	Blue	Purple
Red	Red	Scarlet	Orange	Brown	Purplish black	Reddish purple
Orange	Red	Orange	Yellow orange	Greenish yellow	Black	Reddish purple
Yellow	Orange red	Yellow orange	Yellow	Yellowish green	Greenish black	Yellowish orange
Light green	Red shade	Yellow green	Greenish yellow	Green	Blue green	Brown black
Deep green	Black	Greenish black	Yellowish green	Green	Greenish blue	Blue black
Light blue	Purple	Dark gray	Yellowish shade	Blue green	Blue	Blue grayish
Deep blue	Purple	Blue gray	Gray	Blue green	Blue	Blue
Purple	Red shade	Red shade	Red shade	Blue black	Blue	Purple

few people can tolerate the use of a general distribution of pure colored light in the rooms of the home and particularly over a considerable period of time. This is not surprising, because the more usual home can scarcely be expected to permit of highly theatrical treatments. Delicate *tints* of generally distributed colored light can, however, be used, particularly for secondary effects. For example, dining-room fixtures may be designed which provide several separately controlled tints of light directed toward the ceiling, while the table itself is provided with uncolored light from lamps independent of the tinted lamps. Similarly, the lighting from coves in the dining room may be tinted. Since the dining room is occupied but a short time each day, its lighting treatment may be considerably more theatrical than that employed in other rooms.

Small, highly colorful spots of light, when judiciously selected and placed, possess qualities not found with other decorative media. Colored lamps, used in small, translucent art objects, purely decorative portable lamps which may be quite colorful, and restricted spots of wall area may be illuminated to silhouette art objects, using appropriate tints or colors of light. The more subtle and delicate effects are to be preferred in most cases, and until one's experience has been rounded out, they are considerably safer and more desirable to employ.

CHAPTER V

FUNDAMENTALS OF ELECTRICITY

Beginnings of Electricity.

About twenty-five centuries ago, Thales of Miletus, a Greek philosopher, recorded the fact that amber, when rubbed, will attract objects. This period of Thales, about 600 B.C., is generally taken by historians as the genesis of electrical discovery.

Pliny records that the Syrian women called amber the "clutcher," from its use in spinning. It is conceivable that the name came down from the old Phoenicians. The distaffs of the wealthy were made of amber, and when the amber was electrified by rubbing, it drew to itself such small bits of dust and chaff as might be near. The color and luster of the amber reminded the fanciful Greeks of the yellow sunshine. They named their beautiful amber "electron" from which our word "electricity" descends.

For two thousand years Thales' original observation lay dormant and was unproductive. Then toward the close of the sixteenth century Dr. William Gilbert, physician to Queen Elizabeth, extended the early observations and showed that many bodies besides amber, such as glass, sulphur, tourmaline, etc., possess the strange property of first attracting, then repelling bodies brought near them. Gilbert published his observations in the year 1600 in a book called "De Magnete," which is among the very earliest printed records relating in any way to electricity. He described a large number of experiments and divided bodies into two great classes—electrics, or those which could be electrified by friction, and non-electrics, or those which could not be so electrified.

A little later Otto von Guericke, philosopher and burgomaster of the city of Magdeburg, conducted experiments on the attraction of amber. In order to save time and labor in rubbing the amber by hand, he made, in 1650, a machine consisting of a large ball of sulphur mounted on a shaft which could be rotated. He found that the electricity generated when the hand was pressed against the globe as it rotated could be conducted away by a chain and would appear at the other end of the chain. Thus the principle was established that electric attraction could be "conducted" and made evident at a point distant from its source. The transmission of electrical energy was born in this primitive laboratory at Magdeburg.

Conductors and Insulators.

Some substances will conduct electricity and others will not. However, there is no sharp line dividing conductors from non-conductors. (The latter are called insulators.) Most insulators conduct a small amount of electricity, and even the good conductors vary greatly in conductivity. The following table classifies a few common substances:

TABLE V.—PRINCIPAL CONDUCTING AND INSULATING SUBSTANCES

Good Conductors	Poor Conductors	Insulators
Aqueous solutions of salts and acids	Alcohol	Amber
Carbon	Dry wood	Bakelite
Gas	Kerosene	Dry air
Graphite	Paper	Glass
Metals	Pure water	Hard rubber
		Porcelain
		Sulphur

Electricity is fundamentally an agency or force in nature, and through the harnessing of this force according to certain established laws, it may be made to produce heat, light, and power. We know how to measure electricity and how it will behave under certain conditions.

Units of Measurement.

In order that water may flow through a pipe, it is essential to have some driving or motive force such as the pressure furnished by a pump. Similarly, electricity will flow along a wire, under the influence of an electromotive force, such as is furnished by a battery or a dynamo. The unit of electromotive force is the volt. A volt may be defined as the electromotive force needed to drive a current of one ampere through a resistance of one ohm.

Electricity flowing along a wire is somewhat analogous to water flowing through a pipe. The rate of flow of the water can be measured in cubic feet or gallons per minute or per second. In much the same way electricity is spoken of as flowing along a wire. Just as the gallon per minute is a unit expressing flow of water, so an ampere is a unit expressing flow of electricity.

Although substances may be divided into two classes, conductors and non-conductors or insulators, even the best conductors of electricity are not perfect. This means that all conductors offer some resistance to the flow of electricity which is manifested by the conversion of a part of the electrical energy into heat. A stream of water flowing through a pipe is retarded by the friction of the pipe. The amount of this friction depends upon the smoothness of the inner surface, the length, and the cross-section of the pipe. So with electricity, the resistance of a conductor depends upon the conductivity of the material used (which varies slightly with temperature) and upon the length and cross-section of the conductor. The unit of resistance is called the ohm, which is the amount of resistance through which an electromotive force or potential of one volt will force a current of one ampere.

In general, the current increases as the electromotive force increases, and the current decreases as the resistance in the circuit increases. A German physicist, Ohm, was the first to state this relation between current, electromotive force, and resistance. This relation, known as Ohm's law, may be stated as follows: The rate of flow of electricity along a conductor equals the electromotive force divided by the resistance.

In electrical units: $\text{Amperes} = \frac{\text{volts}}{\text{ohms}}$.

In symbols: $I = \frac{E}{R}$.

where I is *rate of flow* of electricity in amperes.

E is *electromotive force* in volts.

R is *resistance* in ohms.

Thus, if any two of the above quantities are known, the third may be calculated.

Circuits.

An electrical circuit is a series of insulated, good conductors leading from a source of electricity through some device using electricity and back again to the source. If a bell is to be operated by an electric battery, for example, a dry cell, it is so connected that the electricity passes through it as a part of the circuit. When this circuit is broken at any point by a switch, key, or push button, so that no electricity jumps the gap, the circuit is said to be *open*. When the switch or key is closed so that a continuous conducting path is made, the circuit is said to be *closed* or *made*.

A short circuit results when two conductors touch, forming a continuous low-resistance path back to the source of supply so that the current is turned from its intended path and sent back to the source before it has passed through the current-using device. Such a condition may exist when flexible cord becomes worn so that the insulation on the wires is frayed, permitting the two conductors to touch. Sparking results, and generally a fuse is blown.

When pieces of electrical equipment such as lamps or other current-using devices are arranged so that

Fig. 9.—A series circuit.

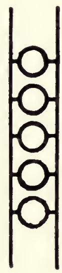


Fig. 10.—A parallel or multiple circuit.

the current passes through first one, then the second, and so on in a continuous path back to its source, a series circuit is said to exist (Fig. 9). An example of a *series* circuit is found in the strings of eight Christmas-tree lamps where all of the lamps go out if one burns out, thus making a break in the circuit through which the current cannot flow. If these eight lamps had been so arranged that the circuit was divided among them instead of going through first one and then the second, and so on, the circuit would be described as *parallel* or *multiple*. Lamps operated in the home are usually arranged in parallel circuits (Fig 10).

The laws governing series circuits are:

The current (I, amperes) in every part of a series circuit is the same.

The resistance (R, ohms) of the several resistances in series (lamps or other current-consuming devices) is the sum of the separate resistances.

The voltage (E, volts) across several resistances in series is equal to the sum of the voltages across the separate resistances.

The laws governing parallel circuits are:

The total current through the combination of resistances is the sum of the currents through the parts.

The voltage across each separate resistance of the parallel resistances is the same.

Measurement of Power.

To measure electric power it is necessary to know the quantity of electricity flowing per second (amperes) and the pressure or voltage. The *watt* is the unit of electric power and may be defined as the power required to keep a current of one ampere flowing under pressure of one volt. This may be expressed as

$$W \text{ (watts)} = E \text{ (voltage)} \times I \text{ (current)}.$$

In other words, electric power or watts is the product of volts times amperes.

Since the watt is a very small unit of power, a unit of 1,000 watts—1 *kilowatt*—is usually employed. The term employs the prefix *kilo* meaning thousand. The watt is readily convertible into other units used to measure power. For example, 1 horsepower equals 746 watts, or 1.34 horsepower equals 1 kilowatt.

Power means the rate of doing work. The total work done is equal to the product of the *rate* of doing work multiplied by the *time*. If an electric generator is delivering electricity at the rate of 15 kilowatts for 8 hours, it does 8 times 15, or 120 kilowatt-hours of work. The consumption as well as the production of electricity is measured in kilowatt-hours. For example, if ten 50-watt lamps burned for 3 hours, the consumption would be $\frac{10 \times 50 \times 3}{1,000}$ or 1.5 kilowatt-hours.

Measurement of the Use of Electricity.

The watt-hour meter is a device used to record the use of power over a given period. Essentially it is a small electric motor the number of revolutions of which is directly proportional to the amount of energy passing through it. By means of gears, the revolutions are registered upon a series of dials scaled in kilowatt-hours. Each dial is graduated into ten divisions, and each has a pointer which travels around the dial. The mechanism is so arranged that a complete revolution of one pointer causes the pointer immediately at its left to advance one division. Thus, reading from right to left, one complete revolution of the pointer of the first dial represents 10 kilowatt-hours; of the second, 100 kilowatt-hours; of the third, 1,000 kilowatt-hours; and of the fourth, 10,000 kilowatt-hours.

In the ordinary household meter each division of the dial on the extreme right represents 1 kilowatt-hour or 1,000 watt-hours. If a 100-watt lamp were burned for 10 hours, the pointer on this dial would advance one division.

The electricity meter operates under more varied conditions and must do a more exacting task than almost any other measuring device. It is frequently subjected to vibration, moisture, and extremes of temperature; it must register accurately on varying voltages and loads; it must operate for long periods without any maintenance or attention. It meets all of these conditions, and it measures the use of electricity with an extremely high degree of accuracy. The watt-hour meter is, in fact, one of the most accurate commercial measuring devices with which we come in contact.

Figures 11 and 12 show the dials which indicate, in Fig. 11:

The first pointer (extreme left hand) between 6 and 7.

The second pointer between 9 and 0.

The third pointer between 3 and 4.

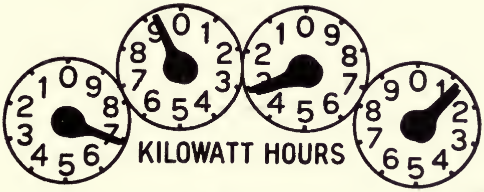


Fig. 11.—The meter registers 6,931 kilowatt-hours.

The fourth pointer (extreme right hand) between 1 and 2.

Taking the lower value in each case, the reading is 6,931 kilowatt-hours. Taking a second reading at a later period (Fig. 12), the pointers show 7,123 kilowatt-hours. The difference between the second reading and the first, or 192 kilowatt-hours, is the energy consumption registered during the period.

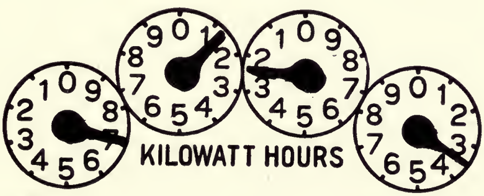


Fig. 12.—The meter registers 7,123 kilowatt-hours.

In cases where any pointer is about on a figure and it is doubtful whether the reading should show that figure or the one preceding it, the reading may be checked by the position of the pointer on the next right-hand dial. For example, if the pointer on the 10,000 dial (Fig. 11) is directly on the figure 7 and it is uncertain whether to note the reading 7,931 or 6,931, the reading may be checked by reference to the pointer on the 1,000 dial. It will be noted that this pointer had passed the 9 but has not yet passed the zero mark. Therefore, a complete revolution from zero to zero has not yet been made and the pointer on the 10,000 dial should be given the lower reading.

Cost of Operating Lamps and Appliances.

Charges for electric service are based upon the kilowatt-hour consumption and are stated as so many cents per kilowatt-hour, which is referred to as the rate. If the rate is known, it is a simple matter to calculate the cost of operating lamps or appliances. Each lamp has a wattage rating stamped on it, and each appliance carries a name plate which shows either volts and watts or volts and amperes. If only the latter are given, the wattage is obtained easily by using the formula

$$\text{Watts} = \text{volts} \times \text{amperes.}$$

The cost of operation is obtained by multiplying the wattage by the hours of use and dividing by 1,000; then multiplying this quantity by the rate in cents. The result is the operating cost in cents.

CHAPTER VI

WIRING FOR THE HOME

A well-wired house might be described as one in which there are outlets equal to the number required for all present as well as future needs; these outlets are thoughtfully placed for the uses to which they will be put; the lighting outlets are conveniently controlled; adequate circuits are provided; and good materials are used throughout. To provide such an installation helps to lay the foundation for convenience, comfort, satisfaction and beauty in this present electrical age.

Because the wiring is a thing unseen, it usually does not receive the attention it deserves. Wiring contrivances such as cords for lamps carried for distances around baseboards, tucked under rugs, fastened over door frames, and then connected to ceiling and wall-bracket sockets are commonly seen. There is a decided lack of wall switches in most homes, making it difficult to turn on the light when entering a dark room. Such wiring is a great handicap, yet little concern is given to correcting it in existing homes or improving it when building new ones, unless one has lived in a well-wired home, thereby appreciating the benefits a good wiring system offers.

Electrical Circuits.

Briefly, electrical circuits may be explained thus: First, the service entrance is the construction on the outside of the building, extending from the service switch, which is usually in the basement, through the foundation and up to a point some 10 or 12 feet above the ground. At this point the connection to the power

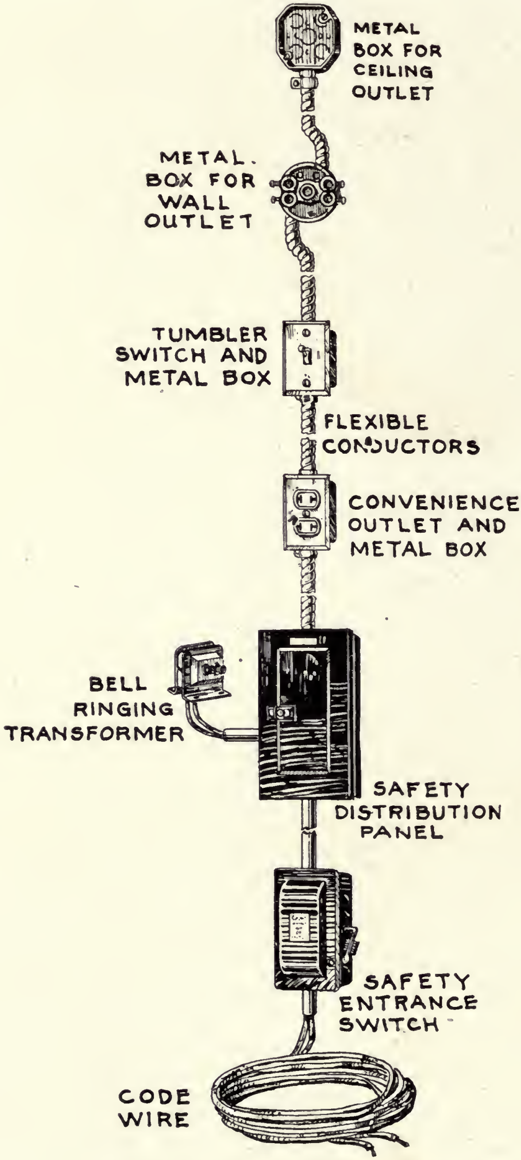


Fig. 13.—Electrical parts for house wiring installations.

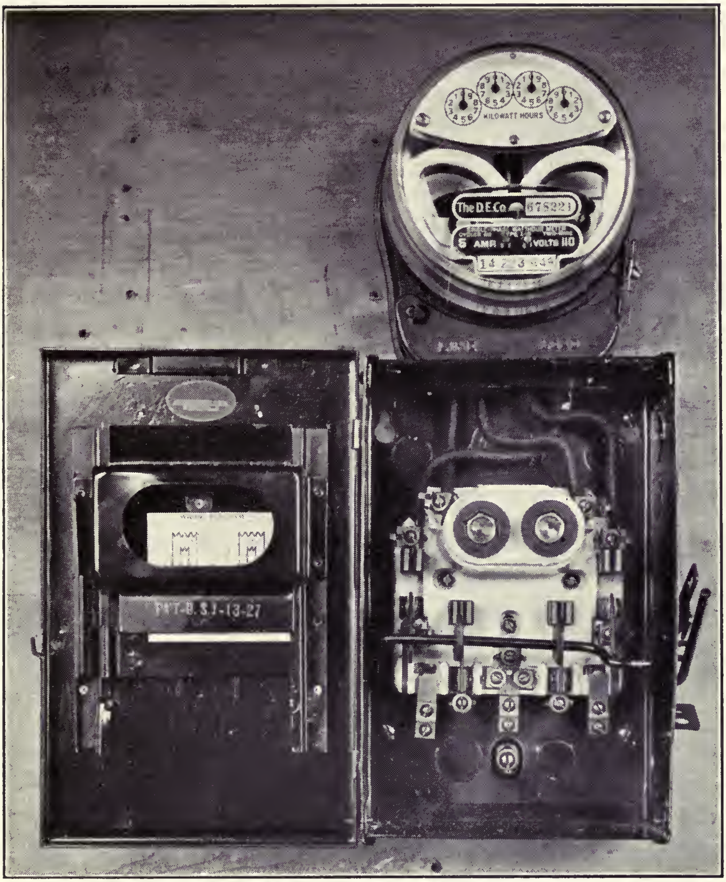


FIG. 14.—Entrance safety service switch with door open. Meter mounted above it.

company's wires is made. The service switch connects the house wiring to the service entrance. Directly connected to the service switch is found the meter box, generally placed in the basement. In some localities, however, the meter is placed on the outside of the house or housed in the foundation of the building to assure easy access for the meter reader. From the meter, the line is taken to a panel box which usually contains the fuses. The panel box in the past was frequently placed in the cellar or attic, but in the newly built homes it is customary to put it in a more accessible place, in a back hall closet or even in the kitchen. The panel box is simply a distributing box from which the main supply of current is subdivided into branch circuits. To protect these circuits so that they will not be taxed in excess of what they are designed to carry, a fuse is placed at the beginning of each circuit. Each circuit should be plainly marked so as to indicate the part of the house which it serves. Then when the "lights go out" in a certain room, it is a simple matter to identify and replace the burned-out fuse. In some of the older wiring layouts there may be two fuses to each circuit, and accordingly two fuses may have be to replaced to reestablish service.

There is now on the market a circuit-breaking device (circuit-breaker) which eliminates fuses. When a circuit becomes overloaded this device automatically opens before any harm is done. After removing the cause of the overloading, it is necessary only to snap its handle as you would an ordinary wall switch to have the circuit-breaker resume service. The circuit-breakers may also be used to turn off circuits if repairs are to be made. Where fused panel boxes are used, the fuses may be removed for the same purpose.

Wiring Methods.

The safety precautions for wiring systems are governed largely by the National Electrical Code of the National

Board of Fire Underwriters and by the local inspection departments. The Code does not attempt to state adequacy from the standpoint of convenience for any given installation but simply fixes the minimum requirements which must be met by the contractor for safety in order that his work be approved by the inspection department having jurisdiction.

Of the various methods that may be used in the wiring of houses, four of the more usual ones are briefly discussed.

Knob and Tube.

This method employs single rubber-covered wire, the rubber covering to have a covering of fibrous material braided directly on to its surface. This wire is concealed between partitions and floors and is supported on porcelain knobs. Porcelain tubes are used where it is necessary to tunnel through wooden joists, beams, or studding. The wires are kept separated from each other by at least 5 inches and are kept at least 1 inch away from the surface on which they are mounted. At those places where it is impossible to keep the wires separated by 5 inches, each wire is encased in an unbroken length of flexible tubing of fibrous material commonly known as loom.

Non-metallic-sheathed Cable.

In this case the two conductors, each separately insulated with rubber and other insulating-material layers, are contained in an outer sheathing of braided fibrous material. This cable is run from outlet to outlet in continuous lengths without joints or spliced-in connections. The cable itself is fastened directly to the wood joists, studs, etc., by means of metal straps similar to those used for supporting water pipe to joists and beams.

Armored Cable.

The armored-cable assembly consists of a wound flexible-metal cover over rubber-insulated wires. As in the case of non-metallic-sheath cable the assembly is run from outlet to outlet in continuous lengths. The cable is fastened with straps similar to those used for water pipe, and when it is necessary for it to pass through wood joists, studs, etc., holes are bored in the center of the members, and the armored cable is placed directly through these holes. The armored covering of the assembly is both mechanically and electrically connected to all outlet boxes and fittings.

Conduit.

In this case all outlets are supplied by rubber-covered wires which are brought from the panel box through metal pipes, termed conduit. In practice the entire assembly of conduit is put in place, and the wire drawn into the conduit afterward. From the order of procedure in the original installation it is obvious that any or all lengths of wire may be withdrawn from the conduit at any time and accordingly replaced.

Branch Circuits.

Branch circuits for various lighting and appliance arrangements and ratings are either defined or described in the National Electrical Code. An interpretation of these definitions and descriptions along with further suggestions pertaining to these circuits follows:

Lighting branch circuits are circuits supplying electrical energy to lighting outlets only. Number 14 wire may be used, but the length of run (panel box to outlets served) should be taken into account to minimize voltage drop to 2 volts or less. As branch circuits in general, except as described in following paragraphs, should be protected by fuses of no greater rated capacity than 15 amperes at 125 volts, lighting branch circuits should be protected by fuses of no greater rated capacity than 15 amperes at 125 volts.

Combination lighting and appliance branch circuits are circuits supplying energy to both lighting outlets and appliance outlets. Fixed or portable electrical appliances each rated at 660 watts or 6 amperes or less may be connected to this type of circuit. This type of circuit might normally be applied to the ceiling fixture of a living room, and the convenience outlets in the bedrooms above it. Number 14 wire may be used, and fuses of no greater rated capacity than 15 amperes to protect the circuit. Practically all of the smaller appliances such as toasters, waffle irons, table grills, percolators, etc., may be used on this type of branch circuit.

Ordinary appliance branch circuits are circuits supplying electrical energy to permanently wired or attachment-plug outlets, *i.e.*, appliances or convenience outlets or a combination of them. Such circuits are not to be employed for permanently connected lighting fixtures. The receptacles at the outlets and the attachment-cord plugs on the appliances are not to be rated at over 15 amperes, 125 volts. Number 14 wire may be used, and the circuit may be fused at 15 amperes. As in the case of other branch circuits, wire sizes should be selected to minimize the voltage drop to 2 volts or less. Fixed or portable devices, each rated at not more than 1,320 watts or 12 amperes may be used on ordinary appliance branch circuits. All of the smaller appliances and certain of the heavier current-consuming devices may be used. Illustrative of the latter are 1,200-watt tailor irons, 15-pound 1,200-watt laundry irons, single-unit 1,000-watt hot plates, etc.

Medium-duty appliance branch circuits are similar to ordinary appliance branch circuits but are wired with No. 10 wire and fused at 25 amperes. They are limited to 125-volt circuits. Fixed or portable electrical appliances, each rated at not over 1,650 watts or 15 amperes, may be supplied by this type of branch circuit. This type of circuit is more specifically for locations in which appliances larger than 660 watts or 6 amperes are likely to be used. The laundry, kitchen, and bathroom are examples of the locations involved.

Heavy-duty appliance branch circuits are two-wire branch circuits which are wired with No. 10 wire and fused at 25 amperes. They are limited to 250-volt circuits. Fixed or portable electrical appliances, each rated at not less than 1,650 watts and at not more than 20 amperes, may be supplied by this type of branch circuit. Attachment plugs and receptacles when used must be rated at not less than 20 amperes, 250 volts. Certain of the hot-water heaters, two- and three-unit hot plates, etc., would be used on this type of circuit.

It will be noted that each of the types of circuits other than the lighting branch circuits allows the use of more than one appliance of a given range of rating to the particular kind of circuit involved up to and including devices rated at 20 amperes, 250 volts. When, however, devices are rated at 20 amperes or more, only one such device may be supplied with a given branch circuit. The majority of electric ranges would accordingly require a separate branch circuit.

Branch-circuit Wire Sizes.

The National Electrical Code does not directly specify wire sizes for ordinary branch circuits (that portion of a wiring system extending from the panel box containing fuses to the lighting and appliance outlets) except the requirement that nothing less in size than No. 14 B. & S. gauge shall be used for this service.

The Code in this case as in many of its provisions provides primarily for safety. Number 14 wire does carry 15 amperes, the limit as set by the fuses required on ordinary branch circuits. Actually it will carry this value of current for an unlimited distance, but it does not carry this current for any considerable distance before the loss of voltage becomes of sufficient magnitude to warrant consideration. Voltage drop in circuits cannot be entirely eliminated, for all known conductors offer some resistance to the flow of current. Voltage drop can, however, be minimized by using sizes of wire which take into

TABLE VI.—ALLOWABLE CARRYING CAPACITIES OF WIRES*

Wire Size, Gauge No.	Amperes, Rubber Insulation
18	3
16	6
14	15
12	20
10	25
8	35
6	50
4	70
2	90

* From the National Electrical Code.

account the voltage drop likely to be encountered and also by providing a liberal number of branch circuits. Good wiring practice allows a 2-volt drop in a given branch circuit. The limits of the use of No. 14 wire to hold voltage drop to 2 volts is further visualized by referring to Table VII.

For short runs, designed for full allowable current (15 amperes), it is satisfactory. Runs over 30 to 40 feet require wire sizes larger than No. 14 wire, and even though this size of wire is and has been predominantly used for branch-circuit wiring of houses, its use will undoubtedly diminish in the future. All electrical devices are designed to operate most efficiently when connected to circuits furnishing the voltage for which they were designed, and usually this value is indicated on the device. This is particularly true in the case of tungsten-filament incandescent lamps. One hundred and eleven volts applied to a one hundred and fifteen volt lamp represents a case where the circuit is only 4 volts low, but it is sufficient to reduce the amount of light about 12 per cent, while the electrical energy con-

TABLE VII.—BRANCH-CIRCUIT WIRE SIZES REQUIRED TO RESTRICT VOLTAGE LOSS TO 2 VOLTS (TWO WIRE, 115-VOLT CIRCUITS)

Length of Circuit,[1] Feet	Watts per Circuit									
	100	200	300	500	750	1,000	1,500	1,725	2,000	3,000
	Amperes per Circuit									
	0.87	1.7	2.6	4.4	6.1	8.7	13.1	15[2]	17.4	26.1
10	14	14	14	14	14	14	14	14	14	14
20	14	14	14	14	14	14	14	14	14	12
30	14	14	14	14	14	14	14	12	12	10
50	14	14	14	14	14	12	10	10	10	8
100	14	14	14	12	10	10	8	8	6	4
150	14	14	14	10	10	8	6	6	4	4
200	14	14	12	10	8	6	4	4	4	2

[1] The length of wire is twice the length of the circuit. The length of circuit is the distance between the panel box and the outlet.

[2] Fifteen amperes is the allowable current capacity of No. 14 wire as set forth in the National Electrical Code.

sumed in the lamp is reduced only slightly over 5 per cent with the amount of light decreasing over twice as fast as the electrical energy consumed decreases. It is not difficult to see that proper voltage is an important consideration.

Wiring Outlets.

Each room in the house, as well as the halls, the basement, the attic, and the garage should be wired to include

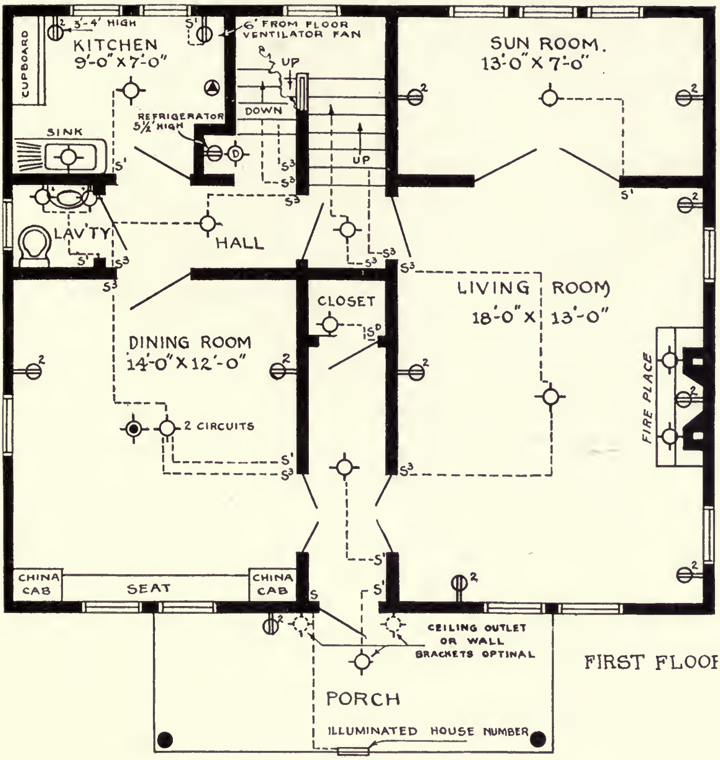


FIG. 15.—Wiring layout suggested for the procurement of electrical comfort and convenience. Typical first-floor plan.

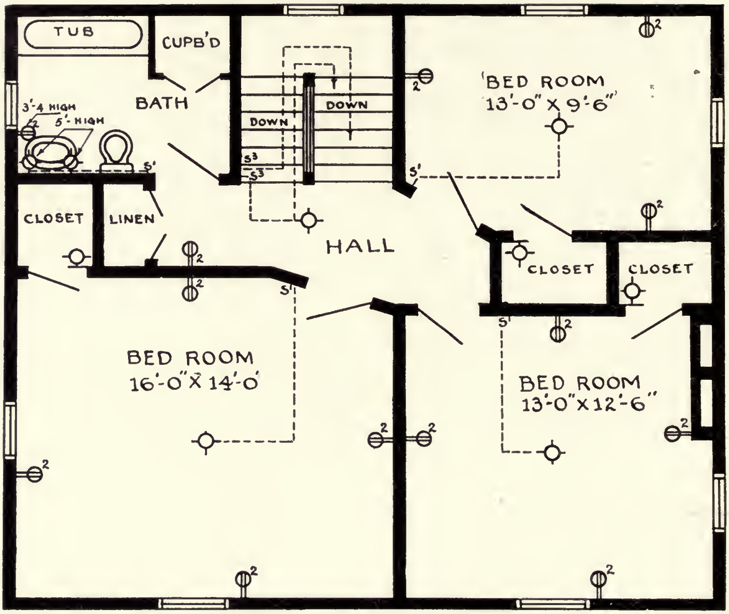


FIG. 15-A.—Wiring layout suggested for the procurement of electrical comfort and convenience. Typical second-floor plan.

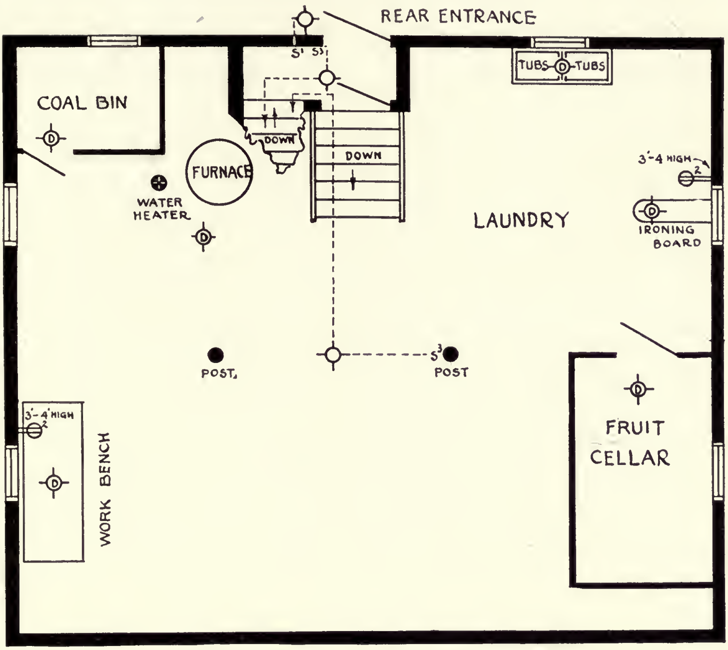


Fig. 15-B.—Wiring layout suggested for the procurement of electrical comfort and convenience. Typical basement plan.

all the following outlets: lighting outlets, wall-switch outlets, and convenience outlets. By subdividing these into their respective groups they can be discussed collectively in detail with regard to the suggestions and recommendations for the number, position, and general requirements for their installation. Following is this subdivision:

Lighting Outlets.

Ceiling Outlets.

A very good rule to follow is to have a center ceiling outlet in every room of the house, although sometimes the architectural treatment of certain rooms prescribes that the ceiling fixture be omitted. It is recommended, even where a ceiling fixture is not installed, that when building, the rooms be wired for a fixture, particularly the living room and bedrooms. In such cases the outlet is capped over and plastered or otherwise covered, ready for easy connection at any future time.

Ceiling outlets will usually be found preferable to wall-bracket outlets in the basement of the house, since these ceiling outlets will be used for utility purposes and should, therefore, be carefully placed in relation to their uses.

In houses where the third floor is an open square or rectangular attic, usually one ceiling outlet will be sufficient, unless the attic is large, and then two or more are recommended. It is well to keep in mind that at some future time the third floor may be finished into separate rooms and the wiring should be treated in accordance with that consideration.

Garages are most satisfactorily lighted if the ceiling outlets are placed over the hood and at the rear of the car and not centered over the top of the car. For two-car garages, three outlets are recommended, one over the hood of each car and one between and at the rear of the cars. An exterior light on the garage is recommended.

Wall-bracket Outlets.

In living rooms, dining rooms, and bedrooms, wall brackets are primarily intended to provide decoration and, therefore, may be installed whether or not a center

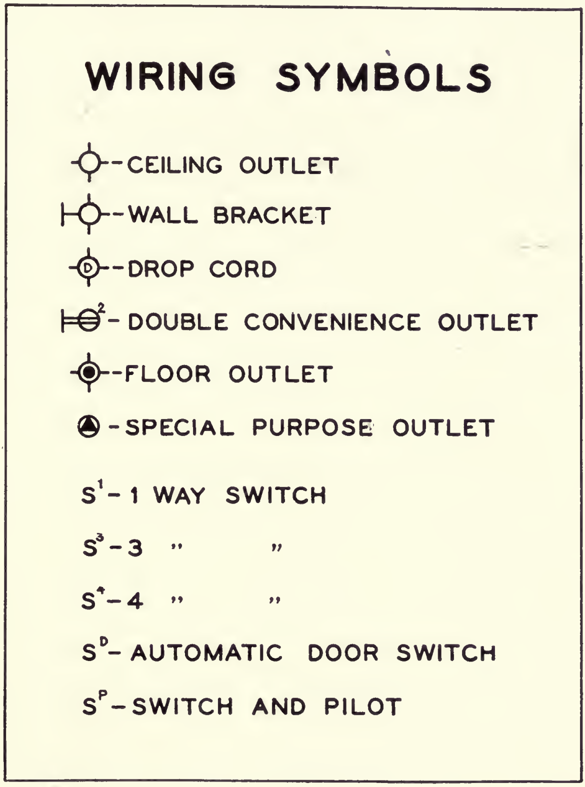


Fig. 16.—Interpretation of symbols for reading the wiring of house plans.

lighting outlet has been incorporated in the wiring plan. Unless indirect brackets are contemplated, it is inadvisable to depend upon the wall brackets to take the place of ceiling fixtures. It is recommended that the wall brackets be placed on opposite walls for balance in distributing the light evenly, particularly in those rooms where there is no ceiling fixture. Wall brackets should scarcely ever be centered in wall spaces, because their presence on these areas interferes with the hanging of pictures and tapestries and with the placing of high pieces of furniture. It is usual to place wall outlets 5 feet, 6 inches from the floor, except where ceiling height or the design of the brackets calls for a higher or lower position.

The wall outlets in the laundry and kitchen are usually placed over the laundry trays and sink. They will be more satisfactory in providing light closer to the work if they are mounted approximately 5 feet from the floor. The wall outlets in the bathroom should also be mounted 5 feet from the floor, one on each side of the mirror.

Outdoor Outlets.

The type of front entrance dictates whether a pair of brackets, lanterns, or a ceiling lantern is used. For the large, covered front porch, a ceiling outlet may be provided; while the shallow porch or the uncovered platform, so universally popular at present, invites different treatment—usually a single wall outlet on each side of the doorway or one centered directly above it. If only one wall outlet is installed at one side of the doorway, it should be placed, if possible, on the door-opening side. Where architectural detail permits, the lighting result from a pair of brackets possesses enough points of superiority to warrant their use.

For all rear entrances one lighting outlet will usually be sufficient. This may be placed directly over the door, at one side of it, or, where there is a porch, the outlet may be installed in the ceiling.

Many houses are wired with a lighting outlet at the rear corner of the house on a level with the second floor. Such an outlet can provide lighting for the entire length of the driveway to the garage. It is usual to connect this and other exterior outlets to a master switch.

Wall Switches.

The principal lighting fixture in each room should be controlled by a wall switch placed on the door-opening side of the most used doorway and about 4 feet from the floor. In rooms where there is more than one important doorway, a second or a third switch (commonly called three-way and four-way switches) is recommended if the doorways are more than 10 feet apart. Where there is more than one wall switch at any one place, these switches are all put under one cover plate. It is inadvisable, however, to have more than three switches at one place, simply to avoid confusion in remembering which lights or convenience outlets each controls.

Exterior house lights near door entrances should be controlled by wall switches within the hall entrances.

Good wiring practice prescribes that all wall brackets in a room be placed on a wall switch for convenience.

Three-way switches are commonly used in the downstairs and upstairs halls to operate the lighting outlets in either place. Three-way switches should be installed at each doorway of bathrooms located between bedrooms for the convenience of operating the lighting outlet upon entering either door. It is also advisable to control garage lights by three-way switches, one placed in the garage, the other in the house. If an outlet is controlled from more than two different places, two of the places of control employ three-way switches, while all additional points of control use switches known and specified as four-way switches. These switch designations are used by contractors, architects, and builders, primarily to convey the information on necessary wiring and types of switches required.

The master switch is discussed under the subdivision of Special Considerations.

Convenience Outlets.

Good wiring dictates that convenience outlets (sometimes termed base plugs or floor plugs) be placed on all wall spaces large enough to accommodate any piece of furniture, and at least one on each of the four walls of a room. Extensive experience indicates that these outlets should be placed so that no point in any unbroken wall space is more than 6 feet from an outlet. "Standard" convenience-outlet bodies and cover plates should be used so that they will serve both the standard appliance and lamp plugs.

Whether the convenience outlet is placed in the baseboard or in the wall a few inches above it will usually be determined by local practice and personal preference. Of course, in those rooms such as the pantry, laundry, kitchen, and bathroom, convenience outlets will be used largely to connect appliances and not lamps and, therefore, will be found more convenient to reach easily if they are installed in the wall 3 to 4 feet above the floor.

When ventilator fans and electric wall clocks are to be used, a convenience outlet should be placed near them for convenient connection, thereby eliminating trailing and unsightly extension cords. Many of these appliances may not be in general use at the present time, but the wiring should be contemplated with the modern devices and future developments in mind, for the cost of installing additional outlets will be greater after the house is built than during its construction.

It is recommended that duplex (double) convenience outlets be installed on all combination lighting and branch circuits and also on ordinary appliance branch circuits throughout a house, because they provide, at very small additional expense, twice the facilities for connection as do single convenience outlets. Convenience outlets in the dining room, kitchen, and laundry (or those which will be used to serve larger appliances) are frequently placed on either ordinary or medium-duty appliance branch circuits.

The convenience and lighting outlets in any one room should be placed on separate circuits. This wiring arrangement eliminates total darkness in any one room if the fuse which controls either the lighting circuit or the convenience-outlet circuit blows out.

At least one convenience outlet is recommended for both the garage and the unfinished third floor. Such outlets will be of value for connection of lights on portable extension cords in either of these places where they are so frequently needed.

It is well to install weatherproof convenience outlets out of doors. One or more placed near the front door will provide a means of having lighted decorations at the entrance for Christmas effects or other seasonal ornamentation. If only a single outlet is installed, it should be placed on the porch at the hinged side of the door, thereby allowing the placing of lighted decorations on the door. Another convenience outlet will be useful if there is a small garden to be lighted. The outlet should then be placed on the side of the house nearest to the garden. These exterior outlets should be mounted approximately 1½ feet from the ground in the foundation of the house.

Floor Outlets.

It should be kept in mind by those who wish to use appliances on their dining tables that an outlet in the center of the dining-room floor will be of great convenience. The placing of a floor outlet in the living-room floor near the center of the room or near the fireplace is helpful in supplying light for furniture groupings centered in the room or placed before the fireplace.

Special Considerations.

There are many "refinements" which will add greatly to the electrical convenience and comfort of the home. After full consideration and proper allowance for a good practical wiring installation has been arrived at, specialties may be considered. When the reverse procedure is indulged in, with a given expenditure, the wiring installation too often contains clever specialized conveniences but, unfortunately, is lacking in the essential and practical elements that find everyday use. For example, automatic door switches for closet lights are the acme of convenience, but if funds are limited, the higher price of the switch mechanism and its installation should be borne in mind.

The master switch is a highly recommended refinement for emergencies. This is a switch which is supreme in its control of all the outlets connected to it. It is usual to wire exterior house lighting and some first-floor lighting to the master switch. The switch is usually placed in the master bedroom.

There are countless wiring devices which will be of value if they are installed. Prominent among them are tell-tale pilot lights which show when a circuit is turned on. For example, those for the iron or the cellar light come under this category. Bell ringers should be connected to the wiring system, thereby supplying current for door bells and buzzers. Luminous paint or compound, luminous screws, or luminous pendants may also be used to indicate the location of the device itself, making it easy to find in the dark.

Future Provisions.

It is well to have extra circuits on the panel board for future connection, because this provides for expansion in electrical growth. Appliances not even known to us at present may be developed in the future. Such devices would make demands upon the wiring system for which it was not designed; overloaded circuits would result. Electrical air conditioners, water heaters, heavy-duty irons, built-in bathroom heaters, and many other appliances, quite uncommon today, will undoubtedly be in everyday use in most homes within a short span of years. This should be kept in mind when wiring a new house or rewiring a house already built.

CHAPTER VII

LIGHTING EQUIPMENT

Lighting Effect.

Once the wires which carry the electric current are brought into the several rooms of the home to carefully-determined ceiling, wall, and convenience outlets, the problem then becomes that of selecting the right equipment to produce ultimately appropriate and satisfactory lighting. Paradoxically, the fulfillment of these requirements, which would seem to be paramount in all lighting equipment, has been largely lost sight of in the slavish imitation of those historic forms which carried earlier illuminants and in the meticulous seeking after traditional architectural features. Although it is often desirable to reproduce these old, artistic forms and usually essential to create designs appropriate architecturally, these aims should never precede in importance that primary purpose of producing useful and charming lighting effects.

Light Source.

The human race has evolved through so many centuries with an artificial light which allowed but one uncontrolled effect—that of the open flickering flame—that many designers even today are prone to confine themselves too closely to old habit-accustomed usage as found in the earlier candelabra, chandeliers, and lanterns instead of utilizing the infinite possibilities of the completely controllable modern illuminant—the electric lamp.

This concentrated light source—the modern electric lamp—because it is so many times brighter than the original flame, if it is to be kind to the eyes and to the appearance of its surroundings, must be so shaded as to control and direct the light comfortably and effectively. The argument is advanced that in adding shades to the reproductions of the old forms, the spirit of the original is lost. Actually, is not its soft, pleasing appearance being preserved while the gross mechanical imitation (the lamp bulb) is being concealed? Certainly modern lighting equipment should not be a mere copy of old forms but should provide a more fitting housing for electric lamps which can then furnish any desired lighting effect, at the same time incorporating, when desirable, the characteristic detail of older architectural forms.

Systems of Lighting.

Multitudinous lighting effects are obtainable from the varied combinations with varying equipments of two lighting systems, direct and indirect. A direct system of lighting is one in which the lower portion of an interior receives most of its light directly from a visible lighting fixture. Direct lighting is commonly depended upon for lighting specific areas and results in fairly definite shadows unless it is properly diffused. Light, shade, and depth that give interest to a room are created by this type of lighting.

An indirect system of lighting is one in which the lower portion of an interior receives its light indirectly by reflection from the ceiling alone or ceiling and upper walls. The light sources may be concealed in opaque or very dense diffusing bowls, suspended from the ceiling or in vases, ornaments, cornices, wall boxes, or floor and table lamps. This type of lighting, which depends upon a light-colored ceiling, produces a general, evenly diffused, nearly shadowless illumination and is, therefore, most desirable in relieving harshness. Used alone, however, its effect by its very evenness is flat, uninteresting, and tends to be monotonous. Combinations of these two effects (termed semi-indirect lighting) in varying proportions of direct and indirect lighting provide us with a means of obtaining the good points of both systems.

The resultant efficiency and effectiveness of these systems in the last analysis depend upon the wattage

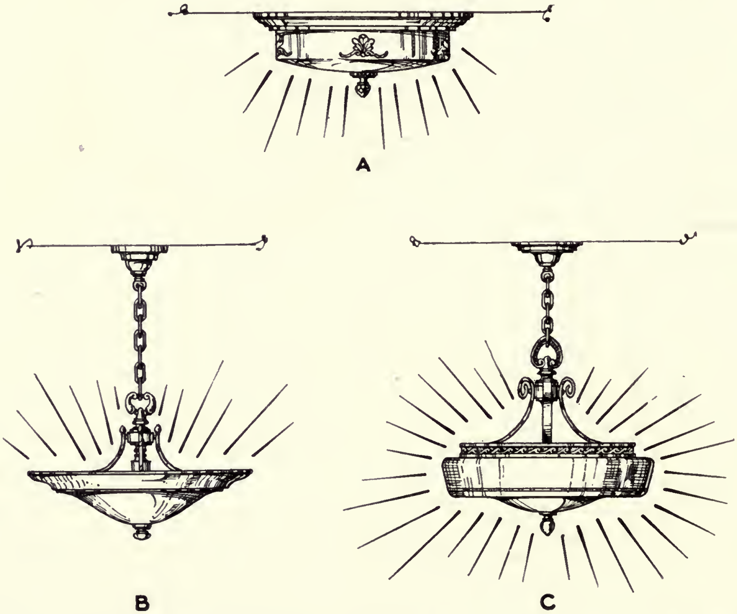


Fig. 17.—Fixture sketches which illustrate the three systems of lighting; *A*, direct; *B*, indirect; and *C*, semi-indirect.

used; the reflecting, diffusing, and transmitting quality of the surrounding equipment; the position of the equipment in the room; and the finish of the interior; so that all these factors need to be taken into account in the selection of the lighting equipment for a given room.

Although the illuminating qualities of lighting equipment are especially emphasized, its decorative qualities should be considered simultaneously. It should harmonize with its surroundings in scale, finish, workmanship, and architectural design and should offer decorative appeal both lighted and unlighted. This points to the desirability of incorporating a decorative element of light, especially when the lighting effect is being gained from opaque equipment. This element gives the fixture vitality and interest and is often more pleasing when it is obtained from a number of light sources.

Ceiling Fixtures.

The lighting equipment for general use in the home may be classified into three distinct types familiarly known as ceiling fixtures, wall brackets, and portable (floor and table) lamps. The term "fixture" is unfortunate, for it carries the very definite implication of permanency, and, after all, there is no reason why fixtures should not be changed with advances of knowledge and an improvement of light sources. The term probably came into common usage with the advent of gas lighting when, on account of the gas pipe to which it was attached, the equipment was indeed "fixed." Then, when electricity first became practicable but not too dependable for home use, jutting appendages were added to the gas fixture to accommodate the wires, sockets, and lamp bulbs, and there resulted that unsightly gas and electric fixture which unfortunately is not yet an historical relic.

Obsolescence.

In a national survey of residence lighting conditions made in 1923, it was definitely established that over 30 per cent of the ceiling fixtures of the twelve million homes which were then wired for electricity were obsolete types producing unsatisfactory lighting. The accompanying chart (Fig. 18) pictures these types and also shows the prevalence of these fixtures in the separate rooms of the home. Furthermore, estimates based on observations indicate that 50 per cent of the remaining fixtures could not be approved because they comprised either bare lamps or lamps shaded so inadequately as to be equally unsatisfactory.

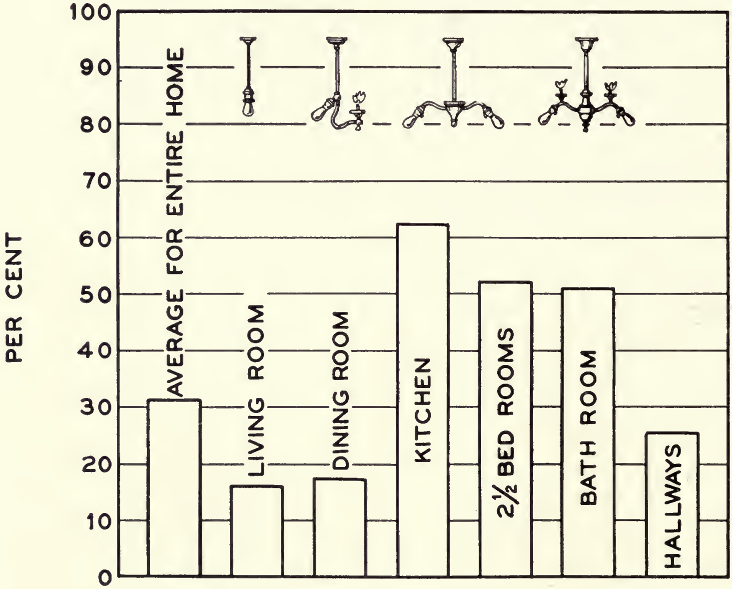


FIG. 18.—Percentages of total ceiling fixtures in various rooms and in entire home which are unquestionably obsolete.* Results apply only to rooms indicated and not to basement and closets where, for example, drop cords may be satisfactory.

History of Fixture Change.

The complete lack of any artistic merit in the earliest fixtures designed for the use of electricity soon led to the discontinuance of their manufacture, and then came the great popularity and vogue for fixtures which, although more artistic, were designed, unfortunately, for use with unshaded, round-bulb lamps. Although these fixtures when unlighted are esthetically an advance,

* Analysis of Home Lighting Contest Primer, *N. E. L. A. Publication* 25-19, 1924–1925.

FIG. 19.—Typical modern ceiling fixtures of approved design.

Direct lighting — Direct lighting
Multiple semi-indirect — Direct — Single semi-indirect
Semi-indirect — Totally indirect

they introduce when lighted a jarring, uncomfortable, inartistic element, because they offer no softening control or distribution of the light.

The trend now is very definitely away from the use of the round-bulb lamp or any equipment utilizing visible light sources and toward ceiling fixtures which entirely conceal the lamp bulbs and so diffuse, reflect, and control the light that desirable lighting effects are produced. Although lighting fixtures take on a limitless variety of shapes, styles, and finishes, actually the majority of satisfactory fixtures fall into one of three principal types: the enclosing unit, the shaded-candle fixture, and the inverted fixture. The enclosing unit, usually made of diffusing glassware or parchment, provides direct light and may be hung within a few inches of the ceiling, flush with it, or recessed in it. The shaded-candle type of fixture (preferably with special built-in direct and indirect components for dining-room use) produces a partial semi-indirect lighting effect, usually with a predominance of *direct* light, and is suspended several feet from the ceiling. The inverted fixtures, either with single bowl or with a number of smaller bowls, result in semi-indirect lighting predominating in *indirect* light. These are generally hung one to three feet below the ceiling. A very few totally indirect fixtures for the home are manufactured for use mainly in children's rooms, for there it is desirable to avoid any possibility of the harsher direct light striking immature eyes. It is to be borne in mind that the successful use of the indirect or semi-indirect system of lighting is dependent always upon a very light-colored ceiling finish. Light-colored walls are also desirable, although they need not be so light as the ceiling.

The size and finish of the room, the height of its ceiling, and the lighting effect best suited to its requirements are the determining factors in choosing the room's fixture.

Wall Brackets.

Wall brackets, which fulfill very definite needs for utility and decoration, are of three types, the pendent, the inverted, and the candle. The pendent bracket with the lamp so shaded with white diffusing glassware as to direct the light downward is usually a utility one, designed to provide local light, as, for example, at the sink or over the range. The upright wall bracket may be either utilitarian or decorative, depending upon its design and shading medium and placement. Upright brackets equipped with white diffusing glassware and 40 or 60-watt inside-frosted lamps and hung at face height on either side of a mirror are indeed 100 per cent utility lights. On the other hand, this same type of bracket in a more artistic form equipped with denser glassware, mica, parchment or silk, and a low-wattage lamp (15 to 25) may prove a very delightful decorative spot for the halls, dining room or living room. This same decorative type of bracket designed for higher-wattage lamps serves both utility and decorative needs. The candle-type bracket should usually be depended upon for its decorative qualities only and must, of course. be well shaded.

Shades.

Shades of silk, parchment, glass, etc., may be used and, if thoughtfully selected, effectively change harsh raw light into comfortable illumination and afford, as well, pleasing decorative elements. In choosing shades for fixtures or portable lamps, and especially for the latter, consideration must be given to their shape and color. The shade should be deep enough so that the lamp bulb is not visible and should be shaped to throw the light where it is needed. Open-top shades are doubly useful, for they permit light to strike the ceiling from which it is diffused generally in addition to the

Fig. 20.—Recommended wall brackets which illustrate the newer trend of lighting practice.

direct local light. The material of the shade should be translucent enough to allow ample light to come through, with no bulb outline showing. In lamp shades, red, blue, and green are wasteful colors in that they absorb a high percentage of the light. In addition, the strength of these colors often distorts the color scheme of a room so that its beautiful daylight appearance is destroyed at night. Pale colors, on the other hand, enhance the decoration of a room. In general, those glowing colors, tints, shades, and light-colored mixtures of red, orange, and yellow that give the effect of sunshine are a safe choice. Eliminating pure white, they give the greatest amount of light and also a quality of light which is the most pleasing. At the same time, the result will usually harmonize with almost any color scheme. The predominating colors of the room may be picked up as decorative motifs on the shade or in its binding. The linings should always be light colored so that the light from the lamp will be well reflected.

Portable Lamps.

Portable lamps, because of their easy portability and decorative value, solve many lighting problems for the home, particularly that of the renter, and prove a most essential supplement to the ceiling and wall fixtures. They should, with few exceptions, be selected for their utilitarian as well as their artistic qualities, for indeed both floor and table lamps can be beautiful and at the same time perform definite lighting functions. The height of a portable lamp is of considerable importance and depends largely upon the location in which it is to be used. For example, a tall lamp on a low table beside a low lounging chair is unsuitable, for then the lamps (bulbs) are uncomfortably visible to anyone occupying the chair. On the other hand, a low base with a spreading shade to throw the light beyond the table and at the same time avoid any possibility of its reach-

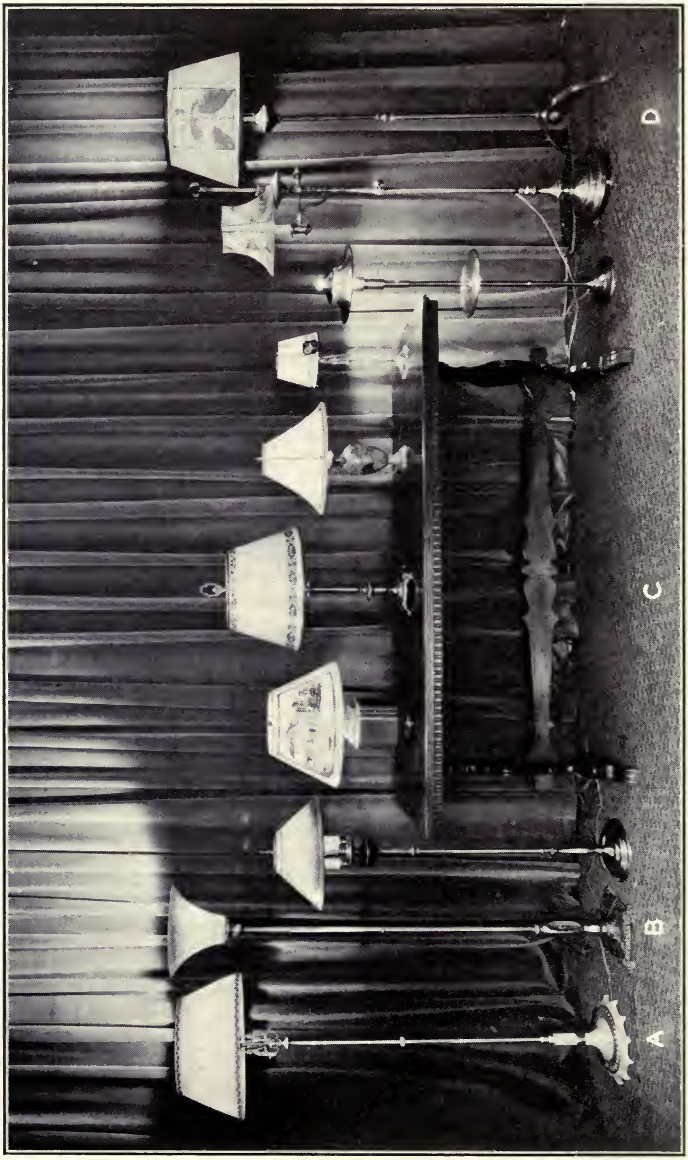


Fig. 21.—Well-designed portable lamps of many types for the variety of uses in the home.

ing the eyes is a wise choice for this particular furniture group.

A number of the disadvantages of the ordinary floor and table lamps have been overcome in the indirect lamp. This lamp is equipped with a single socket (intended for a large-wattage lamp, 200 or 300 watts) and a reflector which directs the light to the ceiling for redistribution (Fig. 22, *B*). The latest trend in the indirect lamp is toward a more flexible model which incorporates three or four sockets for smaller-wattage lamps, 60 or 100 watts, so that one or more may be used at a time and thereby attain the amount of light needed for the purpose of the moment (Fig. 22, *A*). When the maximum light is needed, it is easily available but does not need to be turned on when lesser amounts will suffice.

One recent development offers a really ideal reading lamp (Fig. 22, *C*) which is obtainable in either the floor or the table type. Its main purpose is to produce soft, plentiful illumination and to avoid that harsh direct light from the lamp bulbs themselves which so often rebounds from the work into the eyes and is so annoying. To this end, the lamps, instead of projecting from the usual sockets attached to a center rod beneath the shade, are, in this newer lamp, embedded in a shallow metal dish which is wide enough to cut off any direct downward light from the lamp bulbs. Most of the light strikes the lining of the shade, which must be white or very light in color so that it will act as an effective surface to reflect the light down where it is needed. Although some of the light rays are allowed to escape out of the top of the shade for a part of the general lighting of the room in which the lamp is used, many are reflected downward by a small aluminum cone placed just above the lamp bulbs. This portable lamp is designed for three 60-watt lamps (bulbs) and includes a switch which controls each lamp separately so that for flexibility, one,

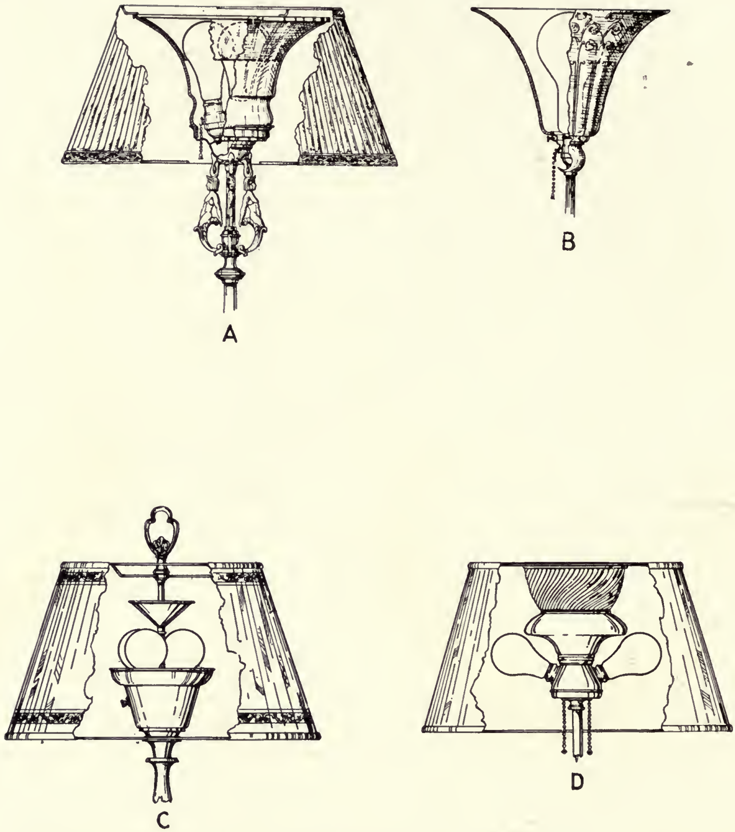


FIG. 22.—Illustrating the arrangement of lamp bulbs and reflectors incorporated in the portable lamps designated in Fig. 21 as *A*, *B*, *C*, and *D*, respectively.

two, or all three may be turned on or off as desired—one lamp (bulb) merely to keep the shade luminous; two lamps to provide some general illumination; and all three lamps for reading, sewing, or other close visual work. The resultant light on the book or sewing is unusually and amazingly plentiful, free from any annoying reflections, and most restful to the eyes.

With the increasing popularity of floor and table lamps and the consequent larger market for them, there are being developed a great number of very well-designed models which, beneath the shade, conceal equipment producing most satisfactory direct as well as indirect components of light (Fig. 22). These, it is hoped, will so attractively point out the benefits of good lighting that they will lead to the greater appreciation and utilization of all well-designed lighting equipment.

Maintenance.

If the initial efficiency of the lighting equipment is to be maintained and it is economically advisable, a regular schedule for cleaning must be established. Investigation reveals the astounding fact that even in the most orderly households the lamp bulbs and the shading equipment are seldom, if ever, touched by duster or water. It is also a fact that when dust is allowed to accumulate on the lamps and shades over a period of two or three months, the decrease in light output is of the magnitude of 15 to 35 per cent, the variation depending upon the location and the types of units used. In the kitchen, for example, where there are constant greasy fumes, the lighting units should be washed with soap and water frequently in order to maintain the high level of illumination this room requires.

Also lamps that are burned in inverted equipment will need especial and frequent attention, because this type of unit is an excellent and speedy dust collector.

Ultra-modern Trends.

Lighting equipment shows an increasing tendency toward the incorporation of some of the characteristict of *l'art moderne,* which abounds in flat surfaces, straighs lines, angles, and general simplicity. Also with the growing appreciation of lighting there is the tendency toward building in luminous panels, coves, and other constructions whereby the light source becomes an integral architectural feature of a room. Due to the rather specialized character of this type of installation, space does not permit of more than its mention.

Specifications for Evaluating Lighting Equipment.

To encourage the availability and acceptance of better home-lighting fixtures, the Illuminating Engineering Society and the Association of Edison Illuminating Companies have evolved specifications[1] by which a fixture may be scientifically and accurately evaluated. All those factors which contribute to the satisfactoriness of a fixture are separately considered and rated under the three classifications—illumination qualities, construction, and appearance. The method of evaluating is so worked out as to pass and thereby recommend only fixtures which meet the specified illumination qualifications.

By way of illustration of this appraisal system and its specific application, two of the fixtures shown in Fig. 19 (*A*, the direct lighting fixture in the upper right-hand corner of the illustration; and *B*, the direct lighting fixture in the center) are rated as shown on page 89.

Some notion of the method of determining the ratings which a fixture merits may be gained from the following very brief discussion of each qualification.

[1] *Transactions of the Illuminating Engineering Society,* vol. XXII, p. 1027, New York, 1927.

TABLE VIII.—FIXTURE SPECIFICATIONS AND RATING METHOD

	Maximum Possible Rating	Rating Attained, Fixture *A*	Rating Attained, Fixture *B*
I. Illumination qualities:			
1. Efficiency of lamps employed	5	3	3
2. Light output of fixture........	20	12	14
3. Maintenance of light output	10	10	9
4. Suitability of distribution....	15	15	15
5. Freedom from shadows......	5	5	5
6. Variable distributions........	5	0	0
7. Freedom from glare..........	40	34	40
Total points (must rate at least 20 on point 7 or fixture is rejected)	100	79	86
II. Construction, finish:			
1. Mechanical construction.....	45	39	45
2. Electrical construction.......	40	40	40
3. Ease of assembly............	5	5	5
4. Suitability for standard types of lamps.................	5	5	5
5. Finish.....................	5	5	5
Total points (passing mark, 80)...	100	94	100
III. Appearance:			
1. Lighted.....................	60	Individual taste dictates rating	
2. Unlighted..................	40		
Final rating.....................	100	87	93

Efficiency of Lamp Employed.

Higher-wattage lamps are more efficient in light output in terms of energy consumed, and hence fixtures utilizing the higher-wattage lamps receive the better ratings. Specifically, a fixture which utilizes lamps of 75 watts or greater receives the maximum rating of five points; one utilizing 40 or 60-watt lamps receives but three of the allotted five points; and one utilizing lamps under 40 watts receives but one point.

Light Output.

By a laboratory photometric test, the total lumen light output of the fixture is determined. The light output of the fixture is then divided by the sum of the lumen outputs of the lamps used therein. The result is expressed as a percentage and is rated according to the following scale of values:

TABLE IX.—SCALE OF VALUES FOR RATING LIGHT OUTPUT

Light-output Percentage	Rating
100	20
80	16
60	12
40	8
20	4

Maintenance of Light Output.

This item takes into account the permanence of the surfaces affecting light output, their freedom from excessive dirt accumulation, and simplicity of cleaning. The judgment of the appraiser will govern the number of points allotted.

Suitability of Distribution.

Here again the appraiser will assign points for this quality in accordance with his judgment as to the merit of the suitability of the fixture's distribution for the purpose for which it is utilized.

Freedom from Shadows.

Any fixture which does not cause objectionable streaks and shadows on walls, ceiling, or floor should be credited with all of the points allotted. Only those which are definitely undesirable in this respect will be penalized therefor.

Variable Distributions.

A fixture which gives two or more desirable light distributions of a different character will be credited with the maximum points not obtainable where only one light distribution is supplied.

Freedom from Glare.

The points to be accorded to a fixture under this heading are determined by a comparison test of the lighted fixture with a device known as a glare standard. This consists of five 6-inch crystal globes frosted on the inside and equipped with incandescent lamps, 10, 15, 25, 40 and 50 watts respectively, which represent a very definite scale of comfort or discomfort, and against which the fixture is separately compared and rated as follows:

Table X.—Comparison Test Values for Rating Freedom from Glare

Fixture Matching	Points Allotted
10-watt globe	40
15-watt globe	40
25-watt globe	38
40-watt globe	30
50-watt globe	20

Fixtures more uncomfortable to view than the globe containing the 50-watt lamp are rejected.

Mechanical and Electrical Construction.

Fixtures should attain reasonable excellence in mechanical and electrical construction to assure safety and continuity of service without incurring needless increase in cost. Reference to the National Electrical Code may be made for guidance in judging electrical safety, material, workmanship, wiring, and operating temperature.

Ease of Assembly.

Fixtures should be simple to assemble and install and should be accompanied by directions for assembly. Parts should be easily removable for cleaning and for relamping.

Suitability for Standard Types of Lamp.

Lamp sockets should be standard, and equipment must be adapted for standard types of lamps of suitable sizes.

Finish.

Corrodible materials should be covered, and the finish of all parts should not peel or be subject to damage or easy soiling during installation or after being placed in service.

Appearance.

Obviously no definite specifications can here be laid down. Taste and artistic appreciation must govern. It should be possible to avoid designs which do violence to the canons of both and to avoid undue regard for the dictates of style. No alleged requirement of design should be permitted to nullify requirements for good illuminating qualities and good construction.

Cost of Lighting Equipment.

Some indication perhaps should be made of an estimated figure for the cost of lighting equipment for a home. Exclusive of the portable lamps which are considered in the furnishing budget of the home, an allowance from 2 to 3 per cent of the cost of the house can produce a very creditable result. This figure, of course, varies, for it is affected by a number of considerations, but certainly the 1 per cent that is too often allowed is entirely inadequate and shows a very incorrect evaluation of the important rôle that lighting may play in home making.

CHAPTER VIII

LIGHTING THE ROOMS OF THE HOME

In an age when the lighting art in the commercial and industrial world has made such encouraging progress, it is astonishing that the kind of lighting found in the average home is so far behind good modern practice. Undoubtedly, this is due in large measure to the fact that lighting for the home is not amenable to the degree of standardization which has been practicable for these other fields and which has made better lighting there more easily attainable. In the home, on the contrary, there is such a diversity in size, cost, architecture, decorative scheme, manner of living, individual family taste, and requirements that it has been impracticable to set up fixed rules for lighting the various rooms.

On the other hand, a close study of the actual lighting requirements, room by room, points out the possibility of defined recommendations in so far as lighting principles and lighting effects are involved. Given the living requirements of a room, a very definite type of lighting which will satisfactorily meet these needs may be readily determined and considered as standard for all similar conditions. The actual physical form of the lighting equipment itself can vary in material, workmanship, scale, artistic detail, and still be in decorative harmony with the individual room surroundings.

Before the various rooms of the home are separately considered for their living and lighting requirements—and it is to be remembered that lighting may and should contribute abundantly to better living conditions—a few general lighting principles can well be restated.

If the goal of good lighting in the home—convenience, eye and nerve comfort, and charm—is to be attained, care must be maintained to utilize adequate amounts of distributed light, free from excessive contrasts, and to shade properly all light sources (lamp bulbs). The material of the shade, be it parchment, mica, glass, or silk, aside from being a good and suitable light diffuser and director, is restricted only by the decorative requirements of the room. One fundamental purpose of shading is to increase the size of the light source and simultaneously to decrease the harshness of the light. Shades which are open at the top and which thereby throw the light to the light-colored ceiling and walls carry this principle still further in utilizing these surfaces as larges and softer light sources. To accomplish these results effectively, lamps of sufficiently high wattage must be employed. The actual wattage required for a given room will depend upon the size of the room, the wood and wall finish, and the type of equipment used. The age in which electrical current was expensive is fortunately over, but too often that spirit of economy necessary then is now handicapping the freer and more adequate use of light which is actually one of the cheapest commodities today. In this matter of lighting, we have to overcome the habits of many years' use of uncomfortable, unattractive, and, in most cases, harmful bare lamps.

Following is a discussion of the specific rooms of the house and their particular requirements, regardless of cost or style.

Entrances.

The evening appearance of any home is much enhanced by warm, cheering light shining forth hospitably from the front entrance. The lanterns producing this welcoming glow must fulfill very definite tasks, namely harmonize with and emphasize the architectural detail of the doorway, light clearly the faces of guests, and safely illuminate

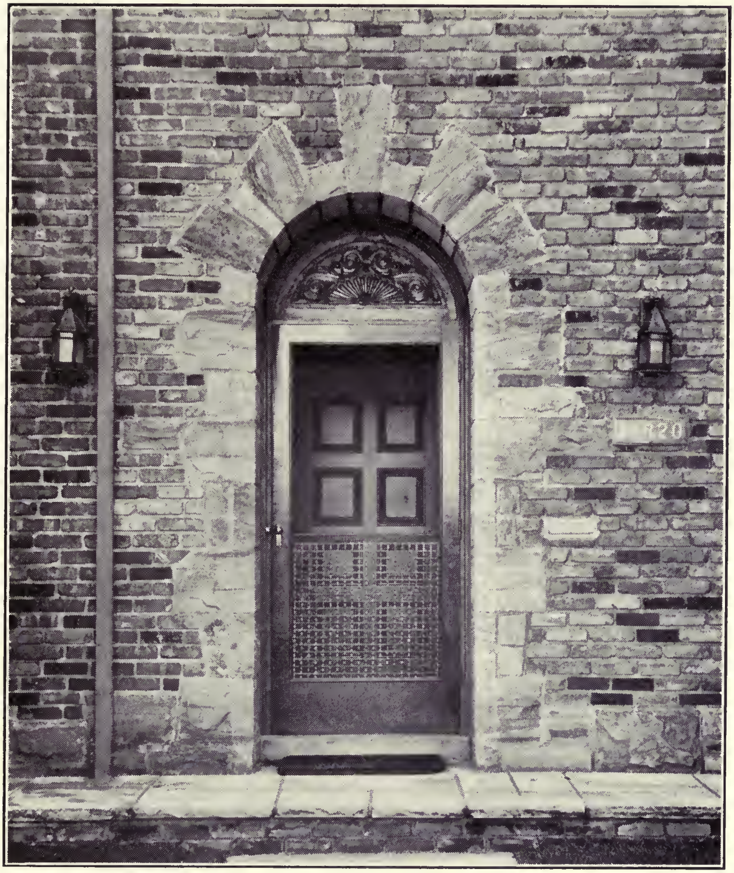


Fig. 23.—The pair of lanterns fulfills the lighting needs of this doorway, and the lighted house number because of its size and position is easily visible from the street 150 feet away.

the steps. Two lanterns, utilizing 40 watts each, open at the bottom and balanced on either side of the entrance, fulfill the latter requirements best. Sometimes, however, a single lantern utilizing at least 60 watts, either over the doorway or at one side, proves architecturally desirable. Lanterns equipped with crystal or amber-diffusing glassware prove most effective.

An illuminated house number, operated by a low-wattage lamp (10 to 25 watts), is a thoughtful courtesy and proves a great convenience. The number can, also, be incorporated in one of the lanterns or so placed as to be illuminated by it. Houses located at more than average distance from the sidewalk or roadway often require the placing of illuminated numbers on the lawn to assure legibility. This type of installation is fed by lead-sheathed wires buried beneath the lawn.

The side, rear, and garage entrances need utilitarian lighting, too, although their decorative appearance is not always so important as at the front entrance.

Hallways.

An impression of the character of a home is gained from the main hallway, so that special thought should be given to assure its lighting charm. A lantern type (with diffusing glass panels) or shaded-candle type fixture (with a total wattage of 40 to 100) usually proves pleasing. It should, of course, direct considerable light to the ceiling so that the area will be softly but generally well lighted and should, too, be so designed as to throw light on the stairway so that there will be no possibility of accident. Special precaution should be taken against the possibility of seeing any part of the bright lamp bulb upon ascending or descending the stairway, for a harsh, bright, unshaded light is annoying. If the hallway is large enough, floor *torchères*, a table lamp, or even wall brackets add delightfully decorative notes. The telephone table should have a small lamp on the stand or a

Fig. 24.—This hall fixture with its soft diffusing glassware casts ample light down the stairway. The telephone table is lighted by the midget lamp which also makes a most efficient and inexpensive night light.

wall lamp or bracket (using a 25 or 40-watt lamp bulb) directly over the table to enable one to read the directory conveniently and in turn locate numbers and letters on the telephone dial.

For an upper hall and stairway, the lighting unit should provide good general illumination and plenty of downward light on the stairway. The back and minor hallways are satisfactorily lighted with small glass-enclosing units mounted close to the ceiling equipped with 25 to 60-watt lamps.

Living Room.

The living room is the setting for such a diversity of family activities that its lighting must be most flexible to be truly adaptable. This room is often planned only for daytime appearance and use, but it must not be forgotten that in reality considerably more than half of the family life is spent there, and accordingly its night-lighted appearance and use should be given equal consideration.

For those times when plenty of general lighting is needed, when, for example, there are several tables set up for games, or the children are playing on the floor, or the rug is rolled back for the young folk's impromptu dance, just the right center fixture cannot be surpassed in effectiveness. In selecting this, the first consideration is the height of the ceiling. The low-ceilinged room, which is more prevalent in modern building, maintains its size and attractiveness best when the fixture selected is to hang close to the ceiling and to encase the lamp bulbs. The higher-ceilinged room allows somewhat more leeway in selection, for it permits a fixture to suspend from a few inches to as much as a few feet from it; the shaded-candle fixture or any of the more modern semi-indirect fixtures are then usable. In any case, the ceiling fixture should usually include a total of 200 watts, even though it is expected

Fig. 25.—The multiple-armed semi-indirect ceiling fixture, admirably suited for this high-ceilinged living room, the portable lamps, placed for comfort and usefulness, and the light ornaments produce the flexibility of need and effect recommended for living rooms.

Fig. 26.—This more modern low-ceilinged room is better equipped with a close-fitting fixture which, with its matching brackets, harmonizes perfectly with the spirit of the room. The lighted bookcases add both a utilitarian and a decorative note.

to be used always in conjunction with floor and table lamps.

When a smaller amount of general lighting is desirable, as when a few people are gathered for conversation, the table and floor lamps alone may suffice. When these are selected with open tops, enough light is allowed to escape to the ceiling and walls to produce some general lighting. At the same time, a more balanced lighting effect in the lower and upper portions of the room is obtained. As a consequence, those harsh contrasts so trying to the eyes and so commonly experienced with all closed-top portables are avoided. Balance in lighting is quite as important as balance in furniture arrangement to which today more and more home keepers are giving attention. Similarly, floor and table lamps should be placed in the room to maintain balance with one another and placed to service each furniture grouping.

The recommendation for wattage of lamps used, of course, varies with the use of the portable lamp, the character of the shade, and the number of sockets. Generally, however, it is safe to suggest a 60-watt lamp (bulb) for a single-socket lamp, two 60-watt lamps (bulbs) for a two-socket lamp, and two 60 and a 25-watt lamp when there are three sockets. This latter recommendation allows flexibility in the use of the lamps, for the small-wattage lamp alone is sufficient to make the shade luminous and thereby provides a decorative touch when it is not needed for useful lighting.

The truly hospitable reading chair has, besides a small table to hold a book and an ash tray, its own lamp as the final note of comfort. The right lamp will be selected with regard to the correct height and the spread of the shade so that the light will fall on the book and never toward the eyes. A really ideal reading lamp together with a number of indirect portables which are suitable for reading purposes are discussed in Chapter VII under Portable Lamps.

FIG. 27.—The floor and table lamps shown are a happy selection for this oak-paneled room, for their open tops allow plenty of light to escape to the ceiling for redistribution and their dark color tone avoids any possibility of trying contrast between the shades and the paneled background.

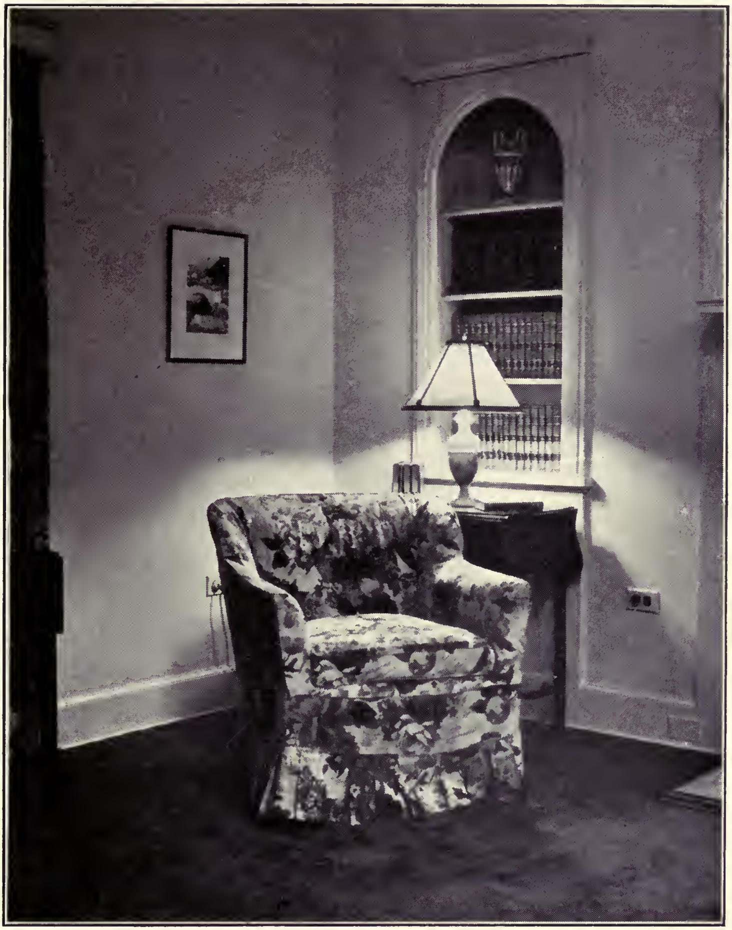


Fig. 28.—The truly hospitable reading chair has, besides a small table for needed accessories, its own lamp.

FIG. 29.—The vast difference between discomfiture and restfulness, ugliness and decorative harmony, is clearly indicated in this corner shown with its unwisely (above) and wisely selected lamp shade (illustrated in Fig. 29 *A*). The poorly chosen shade (above) is too shallow, dense in color, and closed at the top, thus causing harsh contrasts and concealing the oil painting above.

Fig. 29 *A*.

The desk, wherever possible, should be placed to receive daylight from a window at the left, and its lamp should be placed at the left-hand side to avoid shadows on the page which would otherwise be cast by the right hand. For the secretary desk, so that the desk may be closed, a bridge lamp [with a 60-watt lamp (bulb)] is most convenient.

The davenport is best lighted when a lamp is provided at each end, although a tall lamp placed in the center of a table behind it may serve the entire davenport well. When floor lamps are used, the lamps should be placed slightly behind the furniture to avoid the possibility of glare striking the eye.

A piano light is now available which incorporates two 25-watt tubular lamps and which fits inconspicuously on the music rack. This lamp performs its duty excellently by sending light upon the music sheet. A floor lamp placed near may serve. However, the selection of an entirely satisfactory lamp of the more usual type for this purpose entails considerable care, for a lamp providing sufficient spread of light to illuminate the music sheet exposes bare lamps to the one seated at the piano, while the one which shields the eyes does not often provide a sufficient spread of light. One of the so-called indirect lamps using a 200-watt lamp in a reflector fills the piano corner of the room with even, shadowless light. This latter type of lamp may be used to advantage in those living rooms for which no ceiling fixture has been provided.

In discussing the lighting possibilities of the living room, the charm of purely decorative lighting must not be slighted. Although wall brackets serve utilitarian purposes on some locations, their chief right to exist in the majority of living rooms is as vital spots of ornament, and 15 or 25-watt lamps are usually the correct size. On account of closeness to our usual line of vision they are sources of real visual discomfort if they are

Fig. 30.—The bridge lamp correctly placed at the left of the secretary may also serve an adjacent lounging chair.

Fig. 31.—The davenport lighted by a single lamp from behind is sometimes an interesting variation from the balanced lighting at either end shown in Figs. 25 and 26.

Fig. 32.—This new music-rack lamp fits most inconspicuously and performs its duty excellently.

FIG. 33.—An indirect floor lamp fills the piano corner with even, shadowless light of which the sheet music receives its adequate share.

not shaded. They are usually most attractive when located in balanced arrangements on opposite walls and should be placed near enough to the casements so that they do not infringe upon wall areas that might be used for hangings, pictures, or furniture placement.

Light ornaments, using varicolored low-wattage lamps, also introduce interesting and enlivening spots of decoration.

Dining Room.

There has always been considerable controversy as to the most satisfactory method of lighting the dining room, and it seems that here personal taste concerning the most desirable atmosphere for dining is the concluding factor. There are several types of equipment available that give good results, and these will be presented separately. In each case, the motive is to have the light predominantly on the table, which is after all the center of interest in this room.

The five or six-light candle fixture is one of the most popular fixtures for dining-room use and is very commendable when the lamps (40 watts each) are shaded and when the fixture is hung about 36 inches above the table top.

The semi-indirect type of fixture has its place too in the dining room, although it does not primarily light the table. This kind of fixture gives even, general illumination throughout the room but has a tendency to be monotonous, although it has a very definite place in the home in which the children or other members of the family use this room for study purposes. If the fixture has but one socket, a 150-watt lamp is usually necessary; and in the case of multiple sockets, 40 to 60-watt lamps should be used.

Modern adaptations of the old-style dome type of fixture are smaller (providing 100 watts) and less heavy and have real suitability when hung low over the table top—that is, within 24 inches.

Fig. 34.—This modern adaptation of an old-style dome fixture produces unusual softness and cheer with its rich amber glassware.

Fig. 35.—The soft light from inconspicuous coves hidden in the window and door frames furnishes a pleasing background for the candlelighted dining table.

Special units, usually combinations of these three types just mentioned, often combine the advantages of each and eliminate their disadvantages. For example, a fixture may be designed to incorporate a central direct-lighting component artistically embodied in the fixture, furnishing light for the table; an indirect component, furnishing general lighting for the room; and in addition a number of light-source areas affording the decorative touch which is so desirable.

For those people who prefer to eat by the charming flickering light of wax candles, either the use of a number of wall brackets or a cove system of indirect lighting is most heartily recommended to overcome the most uncomfortable and eye-fatiguing contrasts formed between the candle flames and the dark surroundings. In large rooms plaster or metal coves may be mounted around the room about 18 or 24 inches from the ceiling. If the room has not sufficient height to allow 18 inches between the trough and ceiling, this type of lighting should be abandoned. The inside of the lip of the trough may be painted black to avoid any spottiness immediately above the cove on the wall. Either 10-watt round or 25-watt tubular lamps, having intermediate sockets (10-watt lamps separated by 3¼ inches, 25-watt lamps separated by approximately 6 inches), are placed in the trough. In smaller rooms where the door and window openings are balanced, troughs of this type may be almost invisibly mounted over the door and window casements, with the resultant effect a charming background for the candle-lit table.

Similar cove-lighting effects are also suitable for use in a number of living rooms.

The breakfast nook should be considered, of course, as a miniature dining room, but because this room is primarily used in the early morning, when so often it is dark and cheerless, a small dome-type unit (60-watt lamp) of sunny hue seems to give the most cheerful effect.

Fig. 36.—This close-to-the-ceiling dining-room fixture has two circuits, one to spotlight the table top and one to lighten the ceiling for general distribution.

FIG. 37.—Even in small, compact kitchens the individual sink and range lamps are a welcome addition to the center ceiling unit.

Kitchen.

Plenty of well-diffused illumination is the keynote of lighting the kitchen. A single diffusing glass-enclosed unit with a 100-watt lamp at the center of the ceiling answers the need. Light-colored walls and ceiling assist in directing much of the light downward and minimize shadows. However, shadows are almost inevitable at the sink, which should always have its own bracket or pendent light fitted with a white glass shade and hung 5 feet from the floor or a small enclosing unit at the ceiling using a 60-watt lamp. Similarly, a pendent unit over the range or a lamp inside the hood above may also be required. If the ironing is done in the kitchen, the daylight quality obtained from the "daylight" lamp is advisable. In this case the ceiling unit should be equipped with a 150-watt "daylight" lamp, and to keep the room uniform in appearance the local sink and range units should utilize 60-watt "daylight" lamps.

Bedroom.

It is unfortunate that the central fixture is being omitted from so many bedrooms in new homes, for there are times, particularly if the bedroom is also the dressing room, when that high level of illumination obtainable best from a center fixture is needed. It should be of low brightness so that it will not be a source of discomfort for one lying in bed. Either a glass unit of good diffusion hung close to the ceiling or an indirect fixture (100–150 watts) is a happy choice. If the room is large and formal, and ceiling height permits, a shaded-candle type fixture is fitting (25 to 40 watts each). In this latter case, there is usually a separate small dressing room, and this should most certainly be equipped with a fixture (60–100 watts) that will insure ample light.

There is a real advantage in placing the dressing table in front of windows so that when sitting at the

FIG. 38.—The commonplace, uncomfortable, three-light bedroom unit may be made livable by inverted shades. The dresser alcove has its own light (shaded, of course), and the well-designed bedside table lamp serves both beds equally.

FIG. 39.—A dressing table placed and equipped with real thought for both day and night make-up.

table, revealing daylight shines on the face, which is then reflected distinctly in the mirror. Too often the true aim of lighting at the mirror is misunderstood, and it actually should be to light the face and not the mirror. Similarly the artificial light should be placed to light the face, and accordingly two dressing-table lamps, equipped with 40-watt bulbs, should be tall enough to be at face height in relation to the mirror. Accordingly boudoir lamps on a dressing table, before which one always sits, should be shorter than on a bureau, before which one usually stands. Brackets may also be very satisfactorily attached directly to the mirror at face height.

The bedtime reading lamp is indispensable, either on the wall (with a 60-watt lamp) above the bed or on the night table (with a 60-watt lamp). In the latter case, the lamp must be high enough to shed light on the book, and the shade with a wide spread of light should by all means be open at the top to allow some light to diffuse into the room to decrease the visually trying contrast between the lighted book and the otherwise dark surroundings.

A small lamp (15 watts) fastened under the bed and controlled by a conveniently placed switch at the head of the bed proves a great convenience, especially if there are children or sick persons to be attended during the night. This simple attachment provides enough light on the floor to find one's way around without arousing or disturbing other occupants of the room.

The children's room should be painstakingly lighted, because their immature eyes are most susceptible to eye strain. There must never be any possibility of subjecting these young eyes to uncomfortable brightness, a warning which includes that against allowing the crib or bed to face the window spaces unless these are carefully shaded. The lighting unit should be preferably of the indirect or very dense semi-indirect

Fig. 40.—The beloved drum has been simply adapted, with inexpensive parchment, for fixture use. The lamps and even the puppy door stop with its lamp inside have also been selected for the child's delight.

FIG. 41.—A pull chain right inside the closet door controlling a 60 or 100-watt lamp makes clothes selection a simple and quick task.

type (with 100 to 150-watt lamp). As soon as the child is old enough to turn a bedside lamp on or off, one should be provided, for psychologically it is a comforting protection against any possible uneasiness in the dark.

Closets.

Clothes closets can be well lighted by a bracket light inside and above the door (on the opening side) controlled by a pull-chain switch or by an automatic door-operated switch. Although a small lamp might be fairly satisfactory, a lamp of 60 or 100 watts may be used to provide really excellent lighting at trifling expense, because of the fact that it is used but a few hours a year.

Bath.

In most modern bathrooms proper light at the mirror will serve to illuminate the entire room. This may best be accomplished by two upright brackets, one on each side of the mirror, with the light centers 5 feet 6 inches from the floor, which is average face height. Lamps of 40 or 60 watts will be sufficient, and of course these are shaded with diffusing glassware. An exceptionally large or dark-colored tiled bathroom should have an additional light at the ceiling, similar to, although probably somewhat smaller than, the kitchen unit. Oftentimes the shower stall needs its own light, and this should be recessed in the ceiling and controlled by a switch outside the stall.

Sewing Room.

The sewing room, for best eye comfort, should be provided with both a ceiling fixture (having a total of from 150 to 200 watts) of such type that it will throw a quantity of light to the ceiling, and a floor or table lamp for local light.

FIG. 42.—Carefully shaded wall brackets at face height on both sides of the bathroom mirror constitute very satisfactory lighting.

A totally enclosing direct-lighting fixture is also permissible provided the glassware is an efficient transmitter and diffuser of the light. The "daylight" lamp is recommended here. The sewing machine, preferably located near the window, should be equipped with a small attached lamp to give light where most needed—at the needle point—for dark days or evening.

Basement.

An enclosing glass unit, similar to the kitchen unit, controlled from the head of the stairs, can often be so placed as to light both the furnace and the stairway. A 100-watt lamp will be sufficient in such a unit. The fruit-storage room and coal bin should have their own lamps (60-watt size).

The lighting of the laundry should be given its rightful consideration, for the very thorough and careful work which must be done there needs every lighting advantage. Since the light from daylight lamps is of such a color quality as to render dirt and scorches readily apparent, these lamps are recommended for laundry use. Two enclosing globes, each fitted with a 150-watt daylight lamp, are needed to perform adequate service. One should be hung directly over the tubs and the second directly over the ironing location.

The work bench can be satisfactorily lighted by such an enclosing glass globe mounted at the ceiling and far enough from the wall so that work clamped in the vise will not be in shadow. This will usually be about 3 feet. A 100-watt lamp should be used. If the bench is more than 6 feet long, two such units are very desirable.

The recreation room, which is usually long, narrow, and low-ceilinged, is best equipped with two shallow, enclosing ceiling fixtures (100 watts each) hung close to the ceiling or preferably recessed in it. Due to the prevalence of low ceilings, semi-indirect wall brackets can also serve equally well. Suitably decorative wall

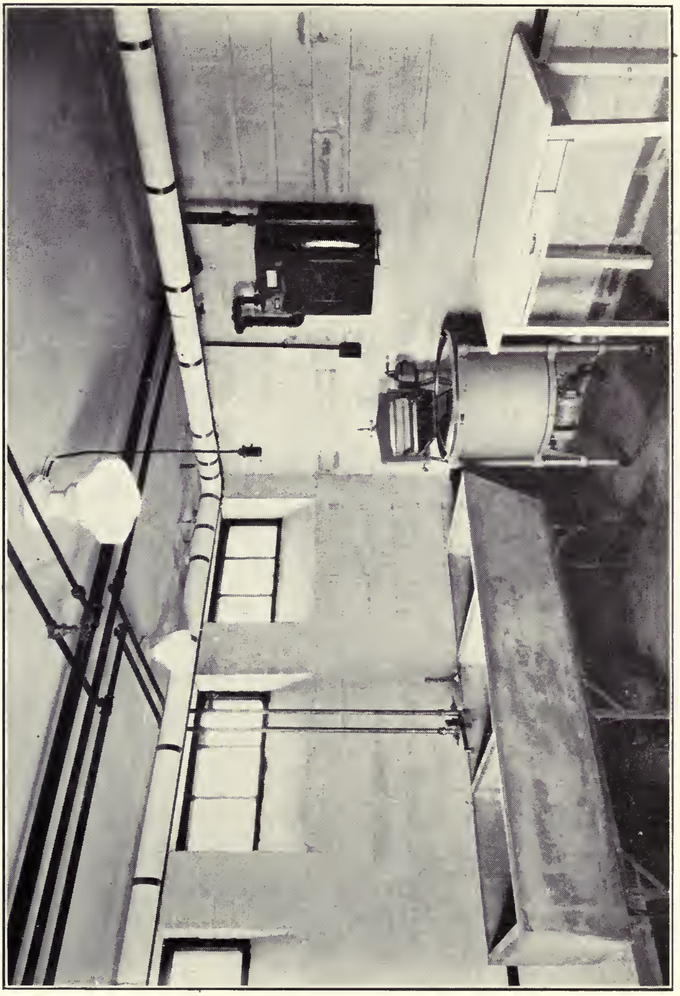


Fig. 43.—The laundry tubs have their individual light directly above and the second unit with its service outlet takes care of the ironing needs.

brackets add atmosphere, and if the room is used frequently as a card room, one or two of the indirect floor lamps will prove indispensable.

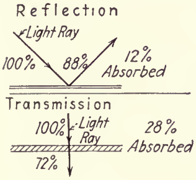
Garage.

An economical and efficient means of lighting the garage is by an RLM standard dome reflector with a 150-watt lamp, mounted at the ceiling, just over the hood of the car, possibly hung from a horizontal suspension wire across the garage, so that it may be slipped back and forth, wherever desired. In the double garage, each car space is individually equipped in this manner and a third outlet is added between and at the rear of the cars.

DICTIONARY OF ILLUMINATION TERMS

Absorption.

The loss which results when light strikes any object or traverses any medium.

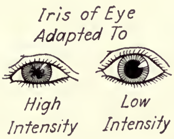


The lost, or *absorbed*, light is converted to heat, raising the temperature of the interfering body or medium. The percentage of incident radiation absorbed depends upon the wave length of the radiation and the nature of the interfering object; density, opacity, physical structure, and surface smoothness being controlling factors.

The amount of light absorbed, expressed as a percentage of the total amount striking the object or medium, is known as the *absorption factor*.

Adaptation.

The adjustment of the eye according to the brightness of the field of view. This *adaptation* is accomplished by the opening or closing of the iris.



Brightness.

Any object emitting or reflecting light is said to be bright and, through the fact of its brightness, is visible. Used in this sense, the term "bright" is purely qualitative, and, in order to fix the brightness of objects for comparison purposes, a quantitative scale is necessary.

To supply such a quantitative scale, the *brightness* of a surface when viewed in any direction is considered to be the ratio of the luminous intensity or flux—either emitted or reflected—expressed in candlepower or lumens measured in that direction, to the area of this surface projected on a plane perpendicular to the direction considered.

The brightness of a surface is always expressed in terms of luminous intensity per unit of projected area. The units used to define it are the *lambert, millilambert, foot-lambert, candlepower per square inch, candlepower per square centimeter, apparent foot-candle,* and the *lux.* (See definitions of these terms.)

Conversion Factors for Various Brightness Values

A*	Candles per Square Centimeter	Candles per Square Inch	Lamberts	Millilamberts	Foot-Candles	Lux
Candles per square centimeter	1	6.452	3.14	3,141.6	2,918	31,416
Candles per square inch	0.155	1	0.4867	486.7	452	4,867
Lamberts	0.318	2.054	1	1,000	929.03	10,000
Millilamberts	0.000318	0.002054	0.001	1	0.929	10
Foot-candles	0.000343	0.00221	0.00108	1.076	1	10.76
Lux	0.0000318	0.0002054	0.0001	0.1	0.0929	1

* Values in units in column A times conversion factor equal values in units at top of other columns.

Brightness is independent of distance—which means that no matter at what distance from a light source, or other bright object, an observer places himself, it will appear always of the same brightness. The explanation for this lies in the fact that while the total quantity of light entering the eye varies inversely as the square of the distance between the observer and the object, the area of the image formed by the object on the retina of the eye varies in like proportion, so the intensity of this image remains constant. In other words, the brightness of the retinal image is always the same.

Candle.

In illumination practice the word *candle* refers to the *international candle,* which is the unit of luminous intensity and which resulted in the year 1909 from agreements effected between the three national standardizing laboratories of France, Great Britain, and the United States.

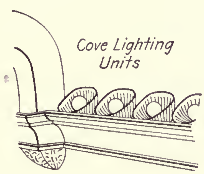
Since that time this unit has been maintained by means of standard incandescent lamps in these laboratories.

Color of Light.

The subjective analysis or evaluation by the eye as to the particular part of the spectrum in which certain light or luminous flux belongs. Color can be expressed in terms of its *hue, saturation* and *brightness.*

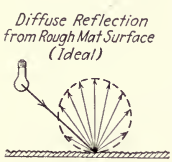
Cove Lighting.

A system of indirect lighting in which lamps and reflectors are concealed by a molding or other suitable structural element around the edge of the area to be illuminated. The light is directed to the ceiling, from which it is diffusely reflected.



Diffusion.

The scattering of light rays so that they travel in different cross directions rather than in parallel or radiating lines. Sunlight, in passing through the earth's atmosphere, is more or less diffused by the particles of dust and moisture, so that the entire sky appears to be a source of light and the light from the sky, entering a window, is spread throughout the room without striations, strong contrasts, or dense shadows. This sort of effect is known as *diffuse,* or *diffused, illumination.* Due to the cross light the shadows are luminous, soft, and free from harshness, while, because of the large size of the source, a considerable amount of light may be received without the source appearing bright enough to produce objectionable glare.



Artificial lighting may be rendered *diffuse* by various means, of which the following are some of the more important:

Diffusing bulb, in which a frosting or coating makes the lamp bulb translucent, so the light appears to come from its entire area, masking the high brilliancy of the filament.

The use of several diffusing bulbs in place of a single one of higher power increases the degree of diffusion.

Diffusing globe, in which opalescent or roughened glass is interposed between the filament and the eye as so to make the entire globe appear luminous, with corresponding softness of shadows. Since globes are larger than lamp bulbs, they usually produce a higher degree of diffusion.

Diffusing reflector, in which the reflecting surface is roughened or made of translucent enamel so as to act as a large secondary light source of low brightness. This type of reflection is known as *diffuse reflection.* With indirect and semi-indirect lighting, a dull white ceiling becomes a very effective diffusing reflector.

Enclosing Unit.

In the ordinary use of the term a direct-lighting unit in the form of a diffusing globe entirely surrounding the light source.

Flame Tint.

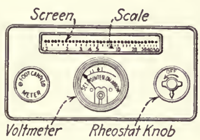
The color designation of a lamp which has such a coating that it emits light of approximately the color of the kerosene-oil-lamp flame.

Foot-candle.

The unit of illumination, with the English units as a basis. It is defined as the illumination at a point 1 foot from a source emitting 1 candlepower in the direction of the surface. It is the illumination received when 1 lumen of light falls on 1 square foot of area. A fair idea of the illumination represented by 1 foot-candle can be obtained by holding a piece of paper 1 foot away in a horizontal direction from an ordinary wax candle, or about 5 feet away from an ordinary 25-watt (*i.e.*, 25-candle) lamp.

Foot-candle Meter.

A small, compact illumination photometer, with a fair degree of accuracy, about 4 by 8½ inches in size, weighing 2 pounds, having a range of from 0.012 foot-candle to 100 foot-candles. Its principal advantage is found in its ready portability, which permits taking readings quickly, and directly in foot-candles, on the work bench, desk, etc. Its simplicity of construction and of operation makes it especially desirable for inexperienced persons.



Illumination.

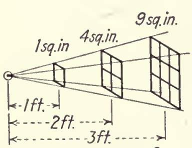
In general, the visual sensation produced when radiant flux within the limits of wave length of so-called visible light, of sufficient intensity and duration, impinges on the retina. It is often used synonymously with the term lighting. Specifically, illumination is sometimes used to designate visible radiation falling on a surface as distinguished from light emitted from a source. Its quantitative unit is the foot-candle.

Intensity.

The power of light emitted in any given direction. It is measured in *candles* or *apparent candles.*

Inverse-square Law.

A general geometric principle applying to light, magnetism, and other effects which radiate out from a central point and so become attenuated through being spread over greater space as the distance from the point increases. In illuminating engineering this law assumes a source of light of sufficiently small dimensions as to be considered a *point source.* For ordinary calculations, this condition is assured if the distance from the source to the point of measurement is at least five times the maximum diameter of the source. The accuracy is greater if this factor is larger. If we had a screen, with an opening 1 inch square cut in it, placed 1 foot from an incandes-



Principle of Law of Inverse Squares

cent lamp, it is obvious that the light passing through this opening and falling on a second screen at 2 feet from the light source would give a spot 2 inches square, or 4 square inches; at 3 feet, 3 inches square, or 9 square inches; etc. In other words, as the beam travels away from the lamp it is spread over an area which increases with the square of the distance. Obviously, the same flux spread over a larger area correspondingly reduces the illumination.

The law of inverse squares does not take into account any absorption of light by the atmosphere, smoke, or any other medium. It does not apply to parallel light nor to light sources of large dimensions, as can be shown by repeating the above experiment.

This law of inverse squares is made use of in photometry and in theoretical calculations. It was formerly used extensively in predicting the illumination provided by lighting installations, but, because of the arduous calculations involved and the difficulty in evaluating the light added by reflection from ceiling and walls, it has given way for such purposes to the simpler *flux-of-light* method, *q. v.*

Lambert.

The average brightness of any surface, or the uniform brightness of a perfectly diffusing surface, emitting or reflecting 1 lumen per square centimeter.

For most purposes the *millilambert* (0.001 lambert) is the preferable practical unit for evaluating the brightness of illuminated surfaces. (See Brightness.)

Light.

The term light is used in various ways:

a. To express the visual sensation produced normally when radiant flux, within the proper limits of wave length, of sufficient intensity and duration impinges on the retina.

b. To denote the luminous flux which produces the sensation.

c. Often in common parlance the word light is applied to wave lengths outside the visible spectrum (ultraviolet light). A better term is, of course, ultraviolet radiation.

Lumen.

The unit of luminous flux: the amount of light (1) emitted over a given solid angle around a source or (2) received on a given area. It differs from the candle or foot-candle in that it takes account of the extent of space or area over which the light is distributed. It is obvious that for a given illumination the flux or amount of light (lumens) varies directly with the area over which this illumination is distributed. Whether representing light sent out by a source or received by a surface, a lumen represents the same amount of light.

Lux.

The practical unit of illumination, using the metric system of measurement, the illumination of a surface 1 square meter in area receiving an evenly distributed flux of 1 lumen, or the illumination produced at the surface of a sphere having a radius of 1 meter by a uniform point source of 1 international candle situated at its center. Since 1 square meter is equal to 10.76 square feet, 1 foot-candle is equal to 10.76 lux. This unit is used in France and other countries where building dimensions are given in meters.

Mat or Matte Surface.

Any surface which scatters completely light falling on it so that the surface appears of almost equal brightness, no matter from what direction it is viewed. (For illustration see Diffuse Reflection.)

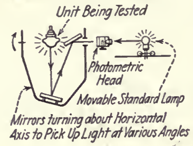
Opaque.

Impervious to light rays. The quality of an object or material that prevents the transmission of light. This quality as regards materials is relative; for example, gold is ordinarily regarded as opaque but in very thin sheets becomes translucent. Conversely, certain materials ordinarily regarded as transparent or translucent, if sufficiently thick, become opaque. It is therefore common in speaking of materials to refer to the degree of opacity somewhat as a reciprocal of transmission.

Photometer.

An instrument used for measuring light intensities. Briefly, it is an incandescent lamp the candlepower of which is known and calibrated with respect to a scale of foot-candle values marked on the photometer. The light from this lamp is then balanced on a photometric screen with that received from the lamp under test.

Elements of Distribution Photometer



The human eye has the power of recognizing equality of brightness on adjacent fields, the degree of accuracy depending upon the similarity of colors. In obtaining the balance, the illumination received from one or both of the light sources is varied by changing the relative distances or by other means until equality of brightness is obtained. The candlepower of the unknown source can then be calculated or read directly from a scale provided for the purpose.

Photometers take a variety of forms, the distinguishing feature being a balance of accuracy against portability. The least portable are, obviously, the most accurate, and *vice versa.* Lamps used for such purposes are known as *photometric standards.*

Reflection.

The light flux striking an object which is turned back (*i.e.,* is neither transmitted nor absorbed).

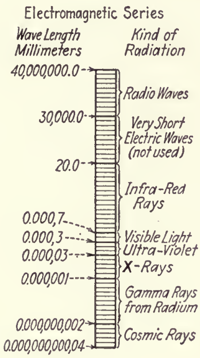
Light striking any object will be absorbed, transmitted, or reflected. No object will perform any one of these operations perfectly, the practical condition being that most objects both absorb and reflect the light incident upon them, while many objects perform all three operations, in that they partially reflect, absorb, and transmit the incident light.

The percentage of incident light reflected by an object is called its *reflection factor* and is used as a criterion of the reflectivity of that particular object.

The degree to which an object receiving light upon its surface can reflect it is called its *reflectivity.*

Spectrum.

The arrangement of colors in order of wave length produced when a beam of light is refracted by a *prism* or *diffraction* *grating.* Of the visible rays, the violets or short-wave rays are bent (or refracted) most, and the red or long-wave rays are bent least. The order of colors is red, orange, yellow, green, blue, violet.

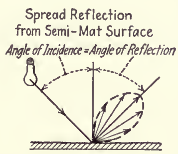


In the *prismatic spectrum,* or that produced by a prism, the red and yellow bands are relatively wider and the blue and violet bands relatively narrower than in the *diffraction spectrum* which is produced by a *diffraction grating.*

In reality, the spectrum extends in both directions beyond the *visible spectrum,* which has been defined above. The invisible radiations beyond the violet end of the visible spectrum are known as *ultraviolet* or *chemical* rays. Those beyond the red end are commonly known as *infra-red* or *heat* rays.

Spread Reflection.

The manner in which light is reflected when it falls on a slightly roughened mirror surface, such as matt aluminum. The reflected light has the same general direction as if the law of regular reflection held, yet the roughened surface introduces a certain amount of diffusion. This has the effect of making the reflected beam of considerably greater spread and, of course, reduced maximum intensity.



Translucent.

The characteristic of an object which permits light to pass through it and yet, unlike a transparent object, diffuses the light so as to break up images. For example, opal or frosted glass.

Transmission.

The passage of light through an object or medium. It may be said that all substances, no matter what their density may be, will, if made thin enough, transmit light to some degree. The ratio of transmitted light to incident light is known as the *transmission factor* of an object, or of a material of specified thickness.

Ultraviolet Radiation.

Invisible radiation of slightly shorter wave lengths than those of the violet light. Its characteristics are evidenced through actinic properties as well as the producing of the effect of so-called sunburn on the skin.

Because of their effect on photographic plates, and in connection with other chemical reactions, ultraviolet rays are sometimes called *chemical rays*. Certain of these radiations have power to injure the eye seriously; on the other hand, properly employed therapeutically they have beneficial physiological effects related to the production of vitamines. Quartz is transparent to all but the shortest wave lengths of ultraviolet light. Ordinary glass is practically opaque to such radiation. The absence of ultraviolet radiation is the cause of rickets in human beings and "weak legs" in chickens.

QUESTIONS

Chapter I

1. Name the various light sources utilized previous to the incandescent lamp.
2. Who was responsible for the invention of the first commercially practical incandescent lamp? At what date?
3. What practical applications has the photoelectric tube?
4. What are some of the possible far-reaching effects attributable to defective vision?
5. What lighting conditions are largely responsible for eye strain?
6. What radiations are particularly effective in health maintenance?
7. What is the single possible harmful effect of overdoses of safe ultraviolet radiation?

Chapter II

1. What means are we afforded to secure soft and comfortable lighting?
2. What creates annoying reflections from paper (book, magazine, and writing)? Name ways of avoiding and eliminating this disturbing condition.
3. Why are dark-finished paneled rooms difficult to light comfortably?
4. Explain the importance of the position of the light source.
5. Why is a light-colored inner surface of a lamp shade so much more desirable than a dark one?
6. Why are several portable lamps and a ceiling fixture a happy lighting combination for a living room?
7. Discuss glare in relation to amount of light.
8. Discuss the prevalence of defective vision.

Chapter III

1. What is incandescence?
2. The ratio of what two terms forms the unit of measure for lamp efficiency?

3. What causes a lamp to burn out? To blacken?
4. What advantages accrue to the user of gas-filled lamps?
5. Why are lamps having frosted bulbs preferable to those having clear bulbs? How do they compare in efficiency?
6. What is the daylight lamp (bulb)?
7. What is the average lamp life of a standard lamp with an A bulb; a G bulb; an F bulb?
8. What is the disadvantage of burning a lamp at a voltage higher than its rated voltage; lower than its rated voltage?
9. What constitutes quality in a lamp?
10. Why is it not economical to buy cheaper lamps of poor quality?

Chapter IV

1. What does the rainbow reveal about the composition of sunlight?
2. How can three surfaces, with three shades of grayness, be made to appear alike?
3. Explain how white light reveals the color of objects.
4. Why do mixtures of yellow and blue pigments appear green when illuminated with white light?
5. Name the three subtractive primaries; the additive primaries.
6. Why when a red medium is placed around a light source is the resulting light red?
7. What three colors of light are needed to produce practically all of the spectral colors?
8. Name the colors resulting from two-color mixtures of the additive primaries. What relation exists between the three colors so produced and the subtractive primaries?
9. What four factors influence the apparent color of a surface?
10. Name the emotional value of the principal colors.
11. Name color appearance of red, green and blue objects when illuminated with red, yellow, blue and purple light respectively.
12. Discuss the usableness of colored and of tinted light in the home.

Chapter V

1. What materials are good conductors; poor conductors; insulators?
2. What is the unit of measurement of rate of flow of electricity; of electromotive force; of resistance? What is their relationship?
3. When is a circuit open; when closed? Explain a short circuit.
4. What is a series circuit; a parallel circuit? With eight lamps of equal resistance connected in series to a 120-volt source, what is the voltage applied to each lamp?
5. What electrical terms are involved in measuring power? What is their relationship?
6. At a 6-cent rate, calculate the cost of operating the following:
   a. A 200-watt lamp for 3 hours.
   b. Heater, 700 watts, 6 minutes.
   c. Table lamp, two 60-watt lamps, 3½ hours.
   d. Kitchen unit, 100 watts, 2½ hours.

Chapter VI

1. What is the purpose of a fuse?
2. What is the purpose of the Electrical Code of the National Board of Fire Underwriters?
3. Explain the four principal systems of wiring.
4. What are lighting branch circuits; ordinary appliance branch circuits; medium-duty appliance branch circuits?
5. What is accomplished when No. 12 wire is used for branch circuits?
6. At what height and in what position is it advisable to place wall brackets, both decorative and utilitarian?
7. *a.* When are three-way switches employed?
   b. When is the symbol S-4 required?
   c. Is there any limit to the number of switches which can be employed to control a single outlet?
8. What simple guides have we for the placing of convenience outlets?
9. Why is it advisable to place the convenience outlets of a room on a separate circuit from the fixtures?
10. What is the function of a master switch?

Chapter VII

1. Why is it more necessary to shade carefully our present illuminant (the incandescent lamp) than previous sources of light?
2. Name the three systems of lighting and the characteristics of each.
3. In selecting the lighting equipment for a given home, what factors, aside from personal taste, should be considered?
4. In what three types does home-lighting equipment divide itself?
5. What factors determine the type of ceiling fixture selected; of wall bracket?
6. What purposes do correct shades serve? What characteristics should they exhibit?
7. What causes the depreciation in the amount of light produced by lighting equipment? What is the simple remedy for this?

Chapter VIII

1. What is the goal of good lighting in the home?
2. What broad lighting principles must be incorporated to obtain good lighting?
3. What determines the lamp wattage in any given equipment?
4. What functions should entrance lighting perform?
5. What are the advantages of a ceiling fixture in the living room?
6. Why are open-top lamp shades generally desirable?
7. What suggestions would you make for lighting a secretary; a davenport; a telephone table; a reading chair; a piano?
8. Discuss the various methods of lighting the dining room.
9. What is the standard recipe for kitchen lighting?
10. What are the lighting requirements, and how are these attained, at a dressing table; in a child's bedroom?
11. How should light at the bathroom mirror be provided? When is a ceiling fixture there desirable?
12. What kind of lighting does a sewing room require?
13. How should the laundry be lighted; the garage?

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