WIRING SIMPLIFIED

by

H.P. Richter

BASED ON 1956 CODE

25th EDITION

PRICE 50c

"I WILL STUDY AND GET READY AND SOME DAY MY CHANCE WILL COME"

Abraham Lincoln

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H. P. Richter

Member of
International Association of Electrical Inspectors
American Society of Agricultural Engineers

*All wiring methods shown in this book
are based on the latest (1956)
National Electrical Code*

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PREFACE

This book has been written especially for the man who wants to learn how to install electrical wiring, so that it will be satisfactory to the owner of the building, and will also comply with the National Electrical Code. Then the finished job will be acceptable also to electrical inspectors, power companies, and others having jurisdiction in the matter.

Electrical wiring cannot be learned by skimming through this or any other book for 15 minutes, but careful *study* of this book (plus investigation of such local ordinances as there may be, and observation of local customs), should enable you to wire a house or farm, so that it will be acceptable to everyone concerned. *However, before doing any wiring, learn how to do the job correctly, or hire an electrician who knows how.*

The author hopes this book will also be of considerable value to you in *planning* a wiring job (regardless of who is to do the work), to enable you to write sensible specifications which will lead to your securing the greatest usefulness from electric power. Careful planning will do away with later changes which usually cost twice as much as when included in the original plans.

Finally, I hope the book may be interesting to the man who is just naturally curious, and wants to know how things are done and why—the man who still has in himself something of the spirit of the boy who takes the clock apart just to find out what makes the wheels go around.

Throughout this book I have emphasized the reasons *why* things are done in a particular way. This will help you to understand not only the exact problems discussed, but will also help you to solve other problems as they arise in actual wiring of all kinds.

Suggestions for the improvement of this book (especially from teachers who use it as a text-book) will be greatly appreciated by the author.

H. P. RICHTER

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CHAPTER 1

Underwriters and Codes

Electric power helps us in a thousand ways: it lights our homes, operates our kitchen appliances; it runs motors of every description; it takes drudgery out of many farm chores. All this is done without danger to the user, and so most of us take electric power for granted. Yet electric power can cause fires; it can kill people and destroy property. It does its work *safely* only because in our homes and in industry it is *under control*.

The multitudes of different electrical parts and devices in use today are not made exactly the way thousands of manufacturers think they should be made; they are not installed in any fashion that workmen may wish to install them. They are built to entirely definite minimum *safety* standards, they are installed in a manner which is quite uniform throughout all states, a manner which experience has proved practical and safe.

Underwriters: All this did not just happen that way. Merchants with a reputation to protect will sell only merchandise which is "Approved by Underwriters" because this guarantees that the quality is up to the *minimum* set up by the Underwriters. The Underwriters are a set of Laboratories supported jointly by manufacturers, insurance companies, and other interested parties. Manufacturers submit their products to the Underwriters; they are tested and if they come up to the minimum quality required they are then "Listed by Underwriters" or "Approved by Underwriters." Then the Underwriters regularly test samples secured from factories as well as samples bought in stores, and as long as the merchandise continues to come up to the minimum standards, it stays on the approved list.

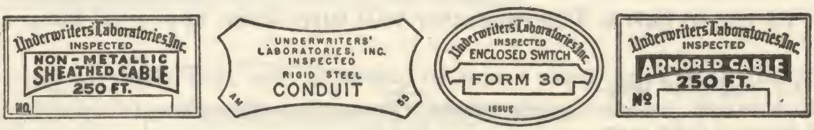


Fig. 1-1. Examples of labels applied on merchandise which is Approved by Underwriters.

Some things (like wire, large switches, fixtures, conduit) have an Underwriters' label similar to that shown in Fig. 1-1 on each coil or piece. Other devices (like receptacles, toggle switches, and similar items) carry the words "Und. Lab. Insp." molded or stamped on each piece. Still other pieces (like sockets, outlet boxes, electric irons, toasters, and similar items) do not carry labels but the nameplate, tag or carton bears the marker of Fig. 1-2, indicating approval. Each piece must be marked in some way so that the electrical inspector in the field, as well as the purchaser, can identify the manufacturer by referring to the Underwriters' book which carries a list of all approved merchandise. The identification is sometimes the manufacturer's name, sometimes only an initial, a number, or other mark.

On lamp cords, a "bracelet" label as shown in Fig. 1-3 is applied every 5 ft. on the cord. If used on an assembled extension cord or appliance cord, this marker merely indicates that the wire used is approved; the devices on the ends of the wire may still be unapproved and possibly unsafe. Such an assembly is approved only if one of the Underwriters' labels shown in Fig. 1-4 is slipped over the cord.

Fig. 1-2. Some approved merchandise is not so marked, but the tag or carton bears one of the markers at left. "UL" means "Underwriters' Laboratories."

Approved—for What? An automobile tire intended for use on a passenger car may be entirely suitable and safe for that purpose, but would be totally unsuitable and unsafe if used on a truck weighing four times as much as the passenger car. So, too, "Approved by Underwriters" guarantees that the merchandise approved is suitable and safe *if used for the purpose for which it was intended.* It does not mean that the merchandise may be used regardless of circumstances; it may be used only for the purpose for which it was designed and only under the circumstances originally intended. It is on this basis that an electrical inspector will sometimes turn down approved merchandise; for example, he will usually refuse to accept approved armored cable if used in a barn on a farm, because the Code does not permit its use in barns. The inspector will turn down approved lamp cord if

Fig. 1-3. Approved lamp-cords bear the bracelet label shown at right, every 5 ft.

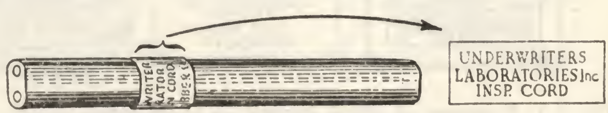


Fig. 1-4. Approved appliance and extension cords bear one of the labels at right, slipped over the cord. If they bear only the label of Fig. 1-3 it indicates that only the wire is approved; the devices on the ends of the cord may not be approved.

used for permanent wiring, because it is approved only for use on portable equipment. Fig. 1-5 shows the result of using it for a purpose for which it was not intended; a serious fire could easily have occurred.

Important: Approval by Underwriters does not mean that two similar pieces of merchandise, both approved, are of the same quality. It merely indicates that both pieces meet the Underwriters' *minimum* requirements. One may just barely meet these requirements, the other far surpass them. For example, of two approved brands of toggle switches, one may average 5,000 "ons" and "offs" at full load before breaking down, the other 25,000. Use your own good judgment in making your choice of several approved brands, as you would in selecting other merchandise.

Codes: Approved electrical parts of high quality, but carelessly or improperly installed, may still be dangerous, both as to shock and fire. For a safe installation, approved devices must be installed as required by the National Electrical Code. The *Code is simply a set of rules which outline

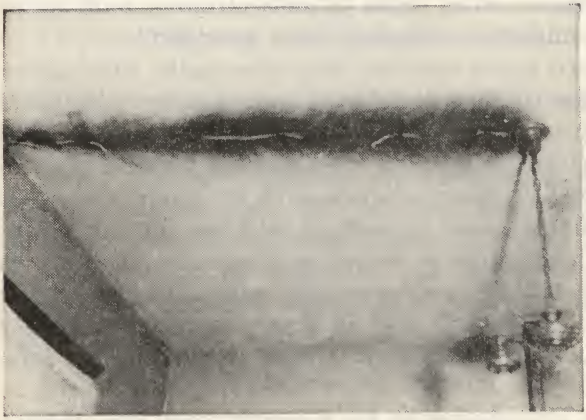


Fig. 1-5. Electrical materials should be used only for the purpose for which they were designed *and approved.* At the left is shown what may happen when approved material is misused. The lamp cord used may have been approved for use on floor lamps or radios, but certainly not for the use shown: permanent extensions. A serious fire might have resulted from such misuse.

the wiring methods that over a period of many years have been found to be safe and sensible. The Code permits many things to be done in several different ways, and all wiring must be done in one of the ways outlined in the Code.

The National Electrical Code is often supplemented by local Codes or ordinances which are never contrary to the National Code, but limit its application. For example, Armored Cable wiring is one method permitted by the National Code, but sometimes prohibited by local Code.

All methods described in this book are in strict accordance with the latest (1956) National Electrical Code. This book covers only the wiring of houses and farm buildings; if here and there the statement appears that some particular thing is "always" required by Code, it means "always so far as the type of wiring described in this book is concerned."

* A copy of the National Electrical Code may be obtained from the National Board of Fire Underwriters, 85 John St., New York 7, N. Y., or 222 W. Adams St., Chicago 6, Ill., or 1014 Merchants Exchange, San Francisco 4, Calif.

are dangerous because stepping on them wears them out, sometimes causing short circuits and fires. It is easy to trip on them, causing accidents. The Code requires a *minimum* of one receptacle outlet for each 12 ft. (or major fraction—10 ft. or more) of circumference of a room. Thus a room 12 by 18 ft. (which has a circumference of 12 + 12 + 18 + 18 or 60 ft.) requires not less than five. This is a *minimum and especially living rooms should have more.

Wire Size: The Code does not permit a wire smaller than No. 14, protected by 15-amp. fuses, in house wiring. There is a rapidly growing trend towards using No. 12, protected by 20-amp. fuses, and in a few localities it is

Fig. 2-1. A typical toggle switch. The "plaster ears" on the ends of the strap are a great convenience in mounting the switch.

Fig. 2-2. A typical duplex receptacle. It has two terminal screws on each side. It is rated at 15 amp.

required as a minimum. The larger wire means brighter lights, less power wasted in heating of wires, fuses that blow less often. Using No. 12 in place of No. 14 adds only a very small percentage to the cost of the installation, and will prove a good investment.

Living Room: Suit yourself about whether to have a fixture in the center of the ceiling. Most homes no longer have them; the owners depend entirely on floor and table lamps for light. If you do depend entirely on lamps, have some receptacles into which they are plugged, controlled by wall switches, so that all lamps can be turned off at one time, as will be explained later. Wall-bracket lights may be used if you like them. They are decorative but have little value for general lighting.

There should be an absolute minimum of *four* receptacle outlets, one for radio or television, one for electric clock, two for floor lamps. Another should be located where it is convenient for vacuum cleaners and other portable appliances. The best way is to follow the Code recommendation; then no point on the wall is more than 6 ft. from an outlet.

* The National Adequate Wiring Program in its "National Standards for Residential Wiring" recommends "convenience outlets so placed that no point along the floor line in any wall space unbroken by a doorway is more than 6 ft. from an outlet in that space. At least one convenience outlet placed in every wall space 3 ft. or more in length at the floor line."

Dining Room: One ceiling outlet for fixture should be provided; let it be controlled by a wall switch. Locate this fixture above the center of the table, rather than in the center of the room. Wall brackets may be provided if you like them. There should be at least two "plug-in" receptacle outlets; be sure to locate them where it is easy to reach them. Too many dining room outlets are hidden behind furniture where it is almost impossible to reach them.

Kitchen: Since the housewife probably spends more time in the kitchen than in any other room, surely the kitchen deserves really adequate wiring. Let it be well lighted, and be provided with lots of receptacle outlets. A fixture in the center of the room must be provided for general lighting; let it be controlled by a wall switch. If there are two doors by which the kitchen can be entered, use a pair of 3-way switches so that the light can be controlled from either door. Unless the kitchen is very small, another light above the sink is necessary, otherwise anybody working at the sink will be standing in his own shadow.

Fixtures installed where it is possible to touch the fixture and also a water faucet should be made of porcelain, not metal. Likewise, if the fixture is controlled by a pull-chain, be sure there is an insulator in the chain. These are safety measures. Should a defect occur in the fixture, metal fixtures make a serious shock possible; porcelain fixtures tend to prevent this.

Install a generous number of plug-in receptacles. Install one where the electric refrigerator is to be placed. Locate at least one from 6 to 10 in. above table level for toasters, irons, electric mixers and similar appliances. A special clock-receptacle located on the wall where an electric clock will later hang, will do away with the nuisance of long cords. Even if you are not buying an electric range right away, it is wise to install a heavy-duty receptacle for it at the time of the original installation. It will cost more later.

Bedrooms: Every bedroom deserves a ceiling light controlled by a wall switch. There should be at least two receptacle outlets, one on each side of the room. One should be easy to get at, for vacuum cleaner, and the other should be near the bed for a reading lamp, an electric heating pad, and so on. Do not overlook lights in the closets; simple single-bulb pull-chain fixtures are suitable because most closets are so small that it is impossible to miss the cord controlling the light. Install the light on the ceiling of the closet, not on a wall. This is a safety measure required by Code. When lights are installed on walls, clothes can be left touching the bulb, and that can lead to fires.

Miscellaneous: Locate a hall light so that it actually lights up the stairs; this reduces the danger of accident. Use 3-way switches so that this light can be turned on and off from either upstairs or down. An outdoor porch light controlled by a switch inside the house is most handy. One of the basement lights should actually light the stairs; control it by a switch at the head of the stairs. By all means provide several receptacle outlets for use of washing machine, workshop, etc. The Code requires an outlet near permanently-installed laundry tubs. A light is usually installed in the garage, controlled from either house or garage.

Lighting Fixtures: The finest light in the world is natural sunlight. At night we use lighting fixtures to provide artificial light in place of it. Spend as much or as little money for them as you please, but make sure that the fixtures you select are good light producers and not mere decorations, or fixtures that ruin your eyesight. Many times one fixture will be much better from a lighting standpoint than another costing twice as much. Let us consider the question briefly: what is good lighting?

It is well known that on the average, 24% of high school students and over 30% of college students, have defective eyesight. Poor lighting has surely caused a large part of this. The advertising slogan "Better Light, Better Sight" sums up the answer. Good lighting is today within the reach of all, for good fixtures are inexpensive, bulbs are cheap, and in most places a 100-watt bulb can be burned more than two hours for a penny.

Good lighting requires not only *enough light,* but also requires *proper distribution of light* throughout the room. Of course, a big bulb gives more light than a small one, but often a small bulb with a well designed fixture, will give better, more useful light than a larger bulb with a poorly designed fixture. A fixture with exposed bulbs that you can see from any part of the room does not produce good lighting. True, such fixtures cost less, but the little extra cost for shaded light fixtures is one of the best investments you can make.

You have found that it is easier to read in the shade of a tree than in direct sunlight, even if there is less light in the shade. In the direct sunlight, the light all comes from one point, the sun; in the shade of a tree it comes from all around. So also when using fixtures with exposed bulbs, the light all comes from one direction, causing sharp shadows and glare, which makes reading or sewing or other fine work impossible without eyestrain. Why? Consider how the eye operates. You know that the pupil of your eye changes in size; if there is much light, it becomes smaller, to reduce the amount of light entering the eye. If there is not much light, the pupil enlarges to admit all the light possible.Watch your own eye in a mirror, with a dim light; see how large the pupil is. Then have someone turn on a bright light; see how small the pupil suddenly becomes.

Now, suppose you are reading under a bright light, from an exposed bulb. Out of the corner of your eye you can see the exposed bulb; it is very bright. The bright light entering your eye causes a message to go from the brain to the muscles controlling the eye: "Too much light—pupil smaller." At the same time, however, you look at the page of the book, and the light may be just right, so there is another message: "Light is right—pupil as is." Subconsciously you also see a corner of the room where the light is poor, and a third message comes along: "Not enough light—pupil bigger."

The result is that different muscles of the eyes fight each other over conflicting messages, and in turn there is straining, sore eyes, and sooner or later defective eyesight. Consider now, light that is too dim; there is not enough light. The eye tries to adapt itself; the pupil tries to become bigger, when it is already as big as it can become. The result is more eyestrain.

Now look at Fig. 2-3 which shows a "shaded" fixture. You cannot see the bulb. The shade itself is semi-transparent so that some of the light filters through. Most of the light, however, hits the reflector, is thrown to the ceiling, then back into the room. A few individual rays have been numbered in

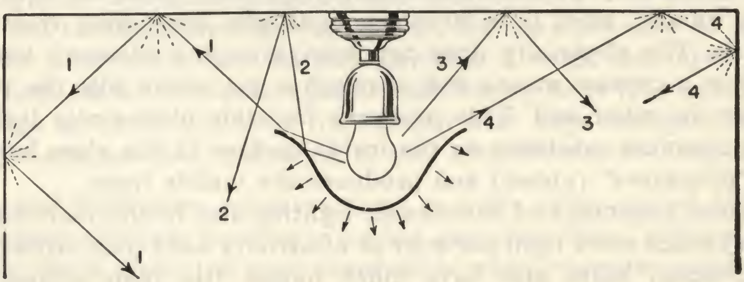


Fig. 2-3. You cannot see the bulb in a shaded light fixture. Light from the bulb is thrown to the ceiling and then reflected throughout the room. It is restful, glareless, diffused light.

the drawing: follow No. 1 from bulb, to reflector, to ceiling, to side wall, out into the room. Follow No. 2, No. 3 and No. 4. The reflectors are designed so that light is distributed evenly throughout the room, and that is the secret of good lighting—a good supply of well distributed (diffused) light. There are no extremely bright spots, no extremely dark spots. The light seems to come from no particular place; it just simply is everywhere, as in the shade of a tree. Conflicting messages no longer go to the muscles of the eyes, which adjust themselves to the general level of the light in the room. That is why your eyes seem more rested after hours of work in a room with well diffused light, than they do after working in a room with perhaps brighter light, but with glare and harsh shadows. The muscles of your legs become tired after continued use in walking; the muscles of your eyes also get tired from too much exercise. Give them a chance with good, well diffused light from fixtures that have *shaded* bulbs.

Larger bulbs are more efficient, give more light *per watt of electricity used* than smaller sizes. Three 60-watt bulbs (total 180 watts) give *10% more* light than five 40-watt bulbs (total 200 watts). One 150-watt bulb gives *twice as much* light as five 25-watt bulbs (125 watts). One 100-watt bulb gives 15% more light than three 40-watt bulbs (120 watts). From these figures it should be plain that a fixture that uses one large bulb will in general provide much better lighting than one using several small bulbs.

There is one important point to remember in connection with all lighting: your ceilings should be of a light color. A white ceiling will reflect most of the light thrown against it. Ivory is not quite as good. Next comes buff and pink. Blue, grey, green, and brown are poor reflectors, and black reflects practically no light at all. A flat finish is better than a glossy finish.

Buy the styles of fixtures that suit your taste and your purse. Always make sure the fixtures you select are electrically good and safe; look for the Underwriters' label on each fixture.

Fluorescent Lighting: This type of lighting, introduced only about 15 years ago, is a very great improvement over other forms of lighting. The bulbs are tubular, from 18 to 60 inches in length, consuming from 15 to 60 watts each. The electricity does not flow through a filament, but instead jumps from a contact at one end, through a gas which fills the tube, to a contact at the other end. This produces *invisible* ultra-violet light which strikes a chemical substance on the inside surface of the glass bulb, which in turn "fluoresces" (glows) and produces the visible light.

The chief advantage of fluorescent lighting lies in the fact that it produces very much more light *per watt of electricity used* than ordinary bulbs. The fluorescent bulbs also have much longer life than ordinary bulbs. Besides the saving in operating cost, this also greatly reduces the heat released in a room; this becomes important if large wattages are used, especially in a relatively small room.

When buying fluorescent fixtures, buy only those which have "high power factor" and only those which use two or four bulbs each. Single bulbs produce a flicker which may be hardly noticeable on direct inspection, but which becomes most annoying and tiring especially in connection with fine work or reading.

Floor and Table Lamps: As in lighting fixtures, make sure your lamps are efficient and produce good illumination. In general, lamps with a single bulb produce more light per watt used than any other type. The reflector style lamp with a special bulb with two filaments gives you a choice of 100, 200, or 300 watts (with a smaller bulb 50, 100, or 150 watts). Part of the light in such lamps is thrown upward against the ceiling, then reflected throughout the room; part of it comes downward through the glass or molded reflector to provide light below the lamp.

CHAPTER 3

Measurement of Electricity

Water is measured in gallons, wheat in bushels, meat in pounds. Electricity cannot be poured into a measure or weighed on scales, but rather is something which must be considered as always in motion, and our problem is to measure how much flows at any point, at any given moment, or in total over a period of time.

Amperes: The flow of electricity is measured in amperes, which corresponds to "gallons per minute" in a comparison with water. Note that the term is not amperes *per minute,* or amperes *per hour,* but just plain *amperes.

Volts: Water and air and other substances can be put under pressure; it is common to speak of such pressure in terms of pounds per square inch. Electricity is always under pressure, and that pressure is measured in volts. Any dry cell or flashlight cell, when new, develops a pressure of 1½ volts; one cell of your automobile battery develops 2 volts, the three cells together 6 volts. Most house wiring and farm wiring is at †115 and 230 volts. The voltage at which power is transmitted over high-voltage lines varies from 2,300 volts for short distances, to over 100,000 volts for long distances.

Watts and Kilowatts: Amperes alone or volts alone do not tell us the actual amount of power flowing in a wire, any more than "gallons per minute" tell us much about the work involved in pumping water unless we also know the pressure, or the depth of the well from which it is being pumped, which is almost the same as pressure. Both the amperes and the volts must be considered. The two together tell us how much power is flowing for *Volts* × *Amperes* = ‡*Watts.*

Watts measure power just like horsepower does; as a matter of fact, 746 watts is always equal to 1 hp. A motor that delivers 1 hp. delivers 746 watts, and could just as well be called a 746-watt motor (it *uses* more than 746 watts because some power is wasted as heat and it also takes some power to run the motor even when it is not delivering power). A light bulb that uses 746 watts could just as well be called a 1 hp. bulb.

A watt is a very small amount of power; when speaking of large amounts of power, it is simpler to speak of kilowatts (the Greek word *kilo-* means *thousand*). One kilowatt (abbreviated kw.) is 1,000 watts.

* The absolute measure of quantity of electricity is the "coulomb." When electricity flows at a rate of 1 coulomb per second, we say that 1 ampere flows. Instead of saying that the current is "10 coulombs per second," we say that the current is 10 amperes. However, you can safely forget the word coulomb, because you will probably never meet it again unless you study electrical engineering.

† In most localities today the current in homes is 115- and 230-volt. In other localities it is 120- and 240-volt. In only a very few places is the formerly common 110- and 220-volt current still used.

‡ This formula is always correct with Direct Current, but with Alternating Current it is correct only part of the time. It is correct with lamp bulbs, flatirons and similar things; in commonly used devices it is wrong only with motors, where the watts are a good deal *less* than volts × amperes.

Again note that you must speak of just watts, not watts *per hour* or kilowatts *per hour,* any more than you would say that the engine in your automobile delivers 125 hp. *per hour.*

Since watts = volts × amperes, any wattage may consist of either a low voltage and a high amperage, or a higher voltage and a lower amperage. A bulb which draws 10 amp. from a 6-volt battery consumes 10 × 6 or 60 watts; another bulb which draws ½ amp. from a 120-volt line consumes ½ × 120 or 60 watts. The voltage and amperage differ widely, but the actual power in the two bulbs is the same.

Watt-Hours and Kilowatt-Hours: One watt used for 1 hour is 1 watt-hour. Multiplying the watts used by the number of hours gives you watt-hours. A 60-watt bulb used for 6 hours consumes 60 × 6 or 360 watt-hours. A 1,000-watt flatiron used for 2 hours consumes 1,000 × 2 or 2,000 watt-hours.

A watt-hour is a very small amount of power so it is more common to speak of kilowatt-hours; a kilowatt-hour is 1,000 watt-hours. The flatiron mentioned in the previous paragraph, consuming 2,000 watt-hours in 2 hours, consumes 2 kilowatt-hours, abbreviated kw-hr. Power is measured and paid for by the kilowatt-hour.

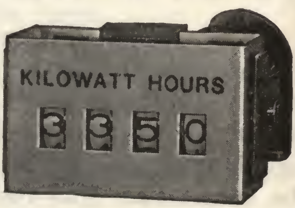


Fig. 3-1. The most modern killowatt-hour meter has dials like the speedometer of an automobile, and is read in the same way.

One kilowatt-hour will operate the average flatiron for an hour, a washing machine for three hours. It will operate a 1-hp. motor for about an hour, or pump about 1,000 gallons of water. It will operate the average radio about 15 hours, a 50-watt bulb 20 hours. It will operate an electric clock for almost a whole month. One kilowatt-hour will do all this, and at average rates, costs less than five cents.

Reading Your Meter: Most meters being installed at the present time show the total kilowatt-hours on a register just like the speedometer of an automobile; see Fig. 3-1. The total is easily read.

Reading an old-style meter is a little harder, but you can learn how in a few minutes. Fig. 3-2 shows the register or dials of the meter. Two of the pointers move in one direction, the others in the opposite direction. Assume it is your meter at the beginning of the month. Simply write down, from left to right, the number that the pointers *have passed.* The total of the meter in Fig. 3-2 is 1,642 kw-hr.

The next picture, Fig. 3-3, shows the same meter a month later. One of the pointers points directly to the 7. Before writing down 7, look at the pointer on the dial to the right; it has not quite reached the "0." Therefore the pointer which seems to point directly to 7 has not actually reached the 7, so write down a 6 instead, making the total reading 1,969 kw-hr. (If the last pointer were just past the "0," the total would be 1,970.) The difference between the two readings, or 327, represents the number of kilowatt-hours used during the month.

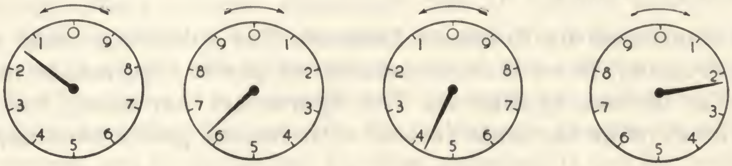


Fig. 3-2. In reading the ordinary meter, write down the number the pointer has passed.

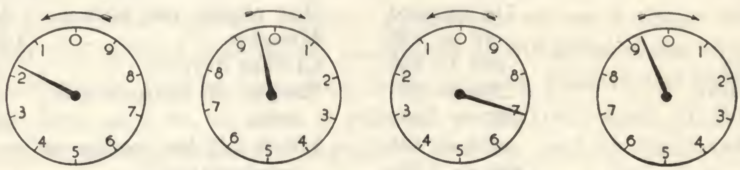


Fig. 3-3. The meter shown in Fig. 3-2, but now a month later.

Power Rates: The rate charged for electric power averages considerably under 5¢ per kilowatt-hour throughout the United States, but varies greatly in different parts of the country. For home and farm use it is seldom as high as 10¢ and sometimes as low as 1¢. Almost always there is a step rate so that the more electricity you use per month, the lower the average cost per kw-hr. A typical rate structure is as follows:

First 60 kw-hr. used per month	6¢ per kw-hr.
Next 40 kw-hr. used per month	3¢ per kw-hr.
All over 100 kw-hr. used per month	2¢ per kw-hr.

Your bill for the 327 kw-hr. used in the example of the previous paragraph is figured this way:

60 kw-hr. at 6¢	$3.60
40 kw-hr. at 3¢	1.20
227 kw-hr. at 2¢	4.54
327 kw-hr.	Total $9.34
Average per kw-hr., approximately	$ .028

Operating Cost Per Hour: To find out how much it costs to operate any electrical device for one hour, simply multiply the watts the device consumes, by the rate in cents per kw-hr. and point off five places; this gives the cost in dollars per hour. For a 60-watt bulb at 5¢ per kw-hr., the figures are: 60 × 5 = 300; pointing off five places makes 0.003 or 3/10 cent per hour. For any 600-watt appliance at 4¢ per kw-hr., the figures are: 600 × 4 = 2,400; pointing off five decimals makes 0.024, not quite 2½¢ per hour.

To determine how long any device may be used to consume one kw-hr., simply divide 1,000 by the wattage of the device. For example, a 40-watt bulb may be used $\frac{1,000}{40}$ or 25 hours. A 600-watt appliance may be used $\frac{1,000}{600}$ or 1.666 hours or 1 hour 40 min. An electric clock uses about 2 watts and will run 500 hours while consuming 1 kw-hr.

Watts Consumed by Common Devices: The following table should at times prove handy, to estimate the amount of power required, or the operating cost for various appliances. The figures are not exact, for different manufacturers make the same devices with various power consumptions.

	Watts
Bulbs	7½ upward
Radio	40 to 100
Television	200 to 400
Refrigerator	200 to 275
Flatiron	660 to 1,000
Percolator	500 to 660
Toaster	600 to 1,000
Roaster	1,000 to 1,650
Fans	25 to 100
Sewing Machine	50 to 75
Heating Pad	10 to 35
Sunlamps	350 to 600
Clocks	1 to 3
Vacuum Cleaner	150 to 350
Kitchen Mixers	150 to 250
Portable heaters	600 to 1,500
Christmas tree lights, per string	30 to 100
Hot plates, per burner	500 to 1,000
Mangles	1,200 to 1,500
Clothes dryer	up to 4,000
Ranges, all burners and oven	up to 14,000
1/6 & 1/5 hp. motors as on refrigerators	275
1/4 hp. motors as on washing machines, pumps	325
1/3 hp. motors	375
1/2 hp. motors	600
3/4 hp. motors	775
1 hp. motors	1,000
5 hp. motors	4,500
Water Heaters (tank type)	1,500 to 3,000

D.C. and A.C.: On a battery, one terminal is *always* + (positive), the other is *always* — (negative). Any current where each wire is *always* of the same "polarity," either positive or negative, is known as direct current or D.C. Current from a battery is always Direct Current.

The current used in practically all city homes, and in every "high line" in the county, is known as Alternating Current or A.C. because each wire changes or alternates continually from positive to negative to positive to negative and so on. The change from positive to negative and back again to positive is known as a "cycle." Usually this takes place 60 times every second, and such current is then known as 60-cycle current. Sixty times every second each wire is positive, and 60 times every second it is negative, and 120 times every second there is no current at all in the wire. The voltage is never constant but is always gradually changing from zero to a maximum of usually about 162 ½ volts, but averaging 115 volts, and such current is then known as 115-volt current. You may well ask the question: if there is no current in the wire 120 times every second, why do not lights flicker? They do not flicker because the filament in the bulb does not cool off fast enough. Very small bulbs used on 25-cycle current (where there is no current in the wire 50 times every second) do have an annoying flicker.

Single- and 3-Phase Current: The current described in the previous paragraph is single-phase current. Remember that if 115-volt 60-cycle current flows in a pair of wires, 120 times every second the wires are dead, there being no voltage at all; 120 times every second, the voltage is about 162½ volts; at all other times it is somewhere in between, but averaging 115 volts. It is therefore anything but steady; the voltage is always changing. The changes however are so rapid that for most purposes it can be considered a steady 115-volt current.

Imagine now three separate electric generators all on a single shaft, so arranged that the voltage reaches its maximum at different times in each of the three generators: first in one, then in the second, then in the third, then again in the first, and so on. Run a pair of wires from each of the three generators. The three generators together then are said to deliver 3-phase current (although the current from any one generator is still single-phase). In actual practice, the three generators become a single generator with three windings; the three pairs of wires become three wires.

A 3-cylinder engine will deliver steadier power than a single-cylinder engine; so also 3-phase current will deliver steadier power than single-phase current (provided the device that consumes the current is one designed to operate in fact with 3-phase power). The most ordinary use of 3-phase power is in operating electric motors; single-phase motors are seldom practical in sizes larger than 7½ hp. A 3-phase motor of any given horsepower is considerably smaller and simpler in construction than the same horsepower in the single-phase type, and costs less.

Three-phase power is common in cities in factories and similar establishments where there are many motors. It is seldom found on farms, for to provide it requires 3-wire instead of 2-wire transmission lines; each farm with 3-phase power requires three transformers instead of one. Do not be misled into thinking that because there are three wires in the service entrance, the result must be 3-phase power. On farms and in homes, almost always three wires mean *single*-phase 3-wire service. (Three-phase current may be supplied with either three or four wires.) If however, you are fortunate enough to have 3-phase power available, by all means use 3-phase motors

CHAPTER 4

Wire Sizes and Types

Electricity flows over wires. It flows much more easily over some materials than others; copper is the best material for ordinary purposes. If iron wire were used, it would have to be about 10 times as big as copper wire.

Copper wire sizes are indicated by number. No. 14 is the most ordinary; it is not quite as big as the lead in an ordinary pencil. Nos. 12, 10, 8, and so on are larger than No. 14; Nos. 16, 18, 20 and so on are progressively smaller. No. 14 is the smallest size permitted for ordinary house wiring, and No. 2 is the heaviest usually used in residential and farm wiring. Still heavier sizes are Nos. 1, 0, 00, 000, and 0000, the No. 0000 being almost half an inch in diameter. See Fig. 4-1. No. 16 and No. 18 are used mostly in flexible cords and the still finer sizes are used mostly in the manufacture of electrical appliances such as motors.

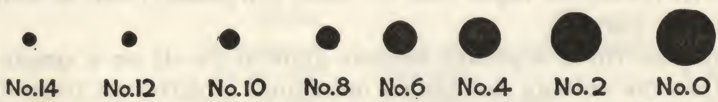


Fig. 4-1. Actual diameters of different sizes of copper wire, without the insulation.

Why Wire Size Is Important: Wire of the correct size must be used, this being necessary for two reasons: carrying capacity and voltage drop.

When current flows through wire, it creates a certain amount of heat. The greater the amperage flowing, the greater the heat. (Doubling the amperes without changing the wire size increases the amount of heat *four* times.) This heat is entirely wasted; therefore to avoid wasted power, we must use a wire size which limits the waste to a reasonable figure. Moreover, if the amperage is allowed to become too great, the wire may become so hot that it will damage the insulation or even to cause a fire. The Code is not particularly concerned with wasted power, but is chiefly concerned with safety; therefore it sets the maximum amperage that various sizes and types of wires are allowed to carry, the amperages being as follows:

Wire Size	Rubber-covered Wire		Weatherproof wire
	In cable, or conduit	Knob-and-tube work	
14	15 amps.	20 amps.	30 amps.
12	20	25	40
10	30	40	55
8	40	55	70
6	55	80	100
4	70	105	130
2	95	140	175
0	125	195	235

Note: The Code differentiates between wires in cable or conduit, and open wires which dissipate heat more readily and accordingly may carry more amperes.

The Code also recognizes several additional types of rubber-covered wire which have greater capacities than shown at left, but since these are specialized types little used in house wiring, they will not be shown here.

Type T plastic insulated wires have the same carrying capacity as rubber-covered wires.

If forcing too many amperes through a wire caused only a certain amount of wasted power, we might look upon it as a mere nuisance and loss. However, it also causes *voltage drop.* Actual voltage is lost in the wire so that the voltage across two wires is lower at the end than at the starting point. For example, if you connect two voltmeters into a circuit, as in Fig. 4-2, one at the main switch, one across a 1 hp. motor at a distance, you will find that the voltage at the motor is lower than at the main switch. The meter across the main switch will usually read 115 volts. If No. 14 wire is used to the motor, the voltage across the motor terminals will be about 114½ volts with 10 ft. of wire, but only about 103½ volts with 200 ft. of wire. The difference is lost in the wire and is known as voltage drop. Voltage drop is wasted power, but there is one other very important consideration: appliances work very inefficiently on voltages lower than the voltage for which they were designed. At 90% of rated voltage, a motor produces only 81% of normal power; a light bulb produces only 70% of its normal light.

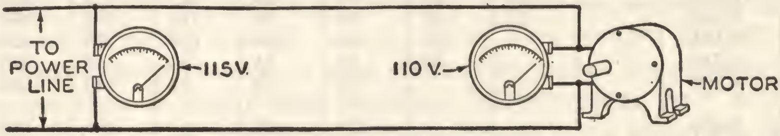


Fig. 4-2. This illustrates "voltage drop." The voltage at the motor is lower than the voltage at the starting point.

Selecting Right Size Wire: The Code permits nothing smaller than No. 14 for ordinary wiring. It is better to consider No. 12 the smallest, this being required in some places by local ordinance. If you need wire heavier than the minimum permitted, it is a fairly complicated matter to *figure* the right size, but a simple matter to look it up in tables.

First determine the amperage to be carried by the wire. To help in arriving at the correct figure if motors are involved, use the following table:

Motor	115 v.	230 v.	Motor	115 v.	230 v.
¼ hp.	5 amp.	2½ amp.	1½ hp.	15 amp.	7½ amp.
⅓ hp.	6 amp.	3 amp.	2 hp.	20 amp.	10 amp.
½ hp.	7 amp.	3½ amp.	3 hp.	28 amp.	14 amp.
¾ hp.	10 amp.	5 amp.	5 hp.	46 amp.	23 amp.
1 hp.	12 amp.	6 amp.			

On page 22 appear two tables, one for 115 volts, the other for 230 volts; use the one that corresponds to the voltage of the circuit in question. All distances shown are *one-way* distances; to operate a device 300 ft. away requires 600 ft. of wire, but look for the figure 300 in the table. The distances under each wire size are the distances that size wire will carry the different

TABLE OF WIRE SIZES FOR 115 VOLTS

Amperes	Watts at 115 volts	No. 14	No. 12	No. 10	No. 8	No. 6	No. 4	No. 2	No. 0	No. 00
1	115	450	700	1,100	1,800	2,800	4,500	7,000		
2	230	225	350	550	900	1,400	2,200	3,500		
3	345	150	240	350	600	900	1,500	2,300	3 /50	
4	460	110	175	275	450	700	1,100	1,750	2,750	3,500
5	575	90	140	220	360	560	880	1,400	2,250	2,800
10	1,150	45	70	110	180	280	450	700	1,100	1,400
15	1,725	30	45	70	120	180	300	475	750	950
20	2,300	*22*	35	55	90	140	225	350	550	700
25	2,875	*18*	*28*	45	70	110	180	280	450	560
30	3,450	*15*	*25*	35	60	90	150	235	340	470
35	4,025		*20*	*30*	50	80	125	200	320	400
40	4,600		*17*	*27*	45	70	110	175	280	350
45	5,175			*25*	*40*	60	100	155	250	310
50	5,750			*22*	*35*	55	90	140	225	280
60	6,900				*30*	45	75	120	185	240
70	8,050				*25*	*40*	65	100	160	200
80	9,200					*35*	55	85	140	180
90	10,350					*30*	*50*	75	125	160
100	11,500					*28*	*45*	*70*	115	140

TABLE OF WIRE SIZES FOR 230 VOLTS (OR 3-WIRE 115/230 VOLTS)

Amperes	Watts at 230 volts	No. 14	No. 12	No. 10	No. 8	No. 6	No. 4	No. 2	No. 0	No. 00
1	230	900	1,400	2,200	3,600	5,600	9,000			
2	460	450	700	1,100	1,800	2,800	4,500	7,000		
3	690	300	480	700	1,200	1,800	3,000	4,600	7,500	
4	920	220	350	550	900	1,400	2,200	3,500	5,500	7,000
5	1,150	180	280	440	720	1,020	1,750	2,800	4,500	5,600
10	2,300	90	140	220	360	560	900	1,400	2,200	2,800
15	3,450	60	90	140	240	360	600	950	1,500	1,900
20	4,600	*45*	70	110	180	280	450	700	1,100	1,400
25	5,750	*35*	*55*	90	140	220	360	560	900	1,100
30	6,900	*30*	*50*	70	120	180	300	470	680	940
35	8,050		*40*	*60*	110	160	250	400	640	800
40	9,200		*35*	*55*	90	140	220	350	560	700
45	10,350			*50*	*80*	120	200	310	500	620
50	11,500			*45*	*70*	110	180	280	450	560
60	13,800				*60*	90	150	240	370	480
70	16,100				*50*	*80*	130	200	320	400
80	18,400					*70*	110	170	280	360
90	20,700					*60*	*100*	150	250	320
100	23,000					*55*	*90*	*140*	230	280

In both tables above, figures represent ONE-WAY distances, not the length of wire back and forth. Distances shown in *italics* indicate that for the amperage in the same line in column at left, only weatherproof wire may be used. In all other cases either Type R or Type T or weatherproof wire may be used.

Each figure indicates the maximum distance in feet each size wire will carry the amperage in the left column, with 2% voltage drop. If you wish to permit 4% drop, double the distances shown. If you wish to permit 5% drop, multiply all distances by 2½.

amperages (or wattages) in the left-hand column, with the customary 2% voltage drop. For example, in the 115-volt table, to determine how far No. 8 wire will carry 20 amp., follow the 20-amp. line until you come to the No. 8 column, and there is the answer: 90 ft. If 4% drop is to be allowed, double the distances shown. Where a distance appears in *italics*, it indicates that only weatherproof wire may be used, for the amperage involved is greater than the carrying capacity of rubber-covered wire.

Compare the 115-volt and 230-volt tables; you will see that any given size wire will carry the same amperage *twice* as far on 230 volts as on 115 volts, with the same percentage of voltage drop; it will carry the same wattage *four* times as far.

Overhead Wiring: When wire is run overhead out of doors, it must be big enough to carry the amperage involved without excessive voltage drop; it must also be strong enough to support its own weight. Sometimes it is called upon to carry a heavy ice load. This often makes it necessary to use a wire larger than is electrically required. Requirements vary in different localities, but R. E. A. specifications usually call for a minimum of No. 10 and that to be used only for spans not over 50 ft., and No. 8 or heavier for spans over 50 ft. long. If distances are greater than 150 ft. usually an extra pole is used.

If the wire is installed on a hot summer's day, remember the wire will shrink a couple of inches per 100 ft. during cold winter weather; leave considerable slack, otherwise the shrinkage of the wires in winter may pull the insulators off your buildings.

Kinds of Insulation: Bare, uninsulated wire may be used for electrical purposes in only a few cases which will be explained later. In almost all cases, the wire must be insulated. The insulation on wires in common use for indoor wiring is usually rubber (natural or synthetic), sometimes plastic.

Fig. 4-3. Weatherproof wire may be used only outdoors. There is no rubber in its insulation.

Weatherproof Wire: The insulation on weatherproof wire is sufficient only for its intended purpose: outdoor use. The Code prohibits it entirely for all indoor wiring. The ordinary kind is shown in Fig. 4-3, which shows its construction: three braids of cotton, thoroughly saturated with weatherproofing and light-resistant compounds. Usually there is an application of mica flakes over the outside, to do away with a tacky finish. On another kind of weatherproof wire the insulation consists of a single jacket of neoprene or similar insulation.

Type R Rubber-Covered Wire: While many kinds of wire use rubber for insulation, only one particular kind is commonly known as "rubber-covered wire", and that is the common wire used for indoor wiring. The Code calls it Type R. Its construction is shown in Fig. 4-4; it consists of a copper conductor, usually tinned to make the rubber insulation strip off easily and cleanly, and to make soldering easier. Next comes a layer of rubber the thickness of which depends on the size of the wire. Over all comes a cotton

Fig. 4-4. Rubber-covered wire is usually used only indoors. If it is No. 6 or larger, the conductor is stranded and there are two cotton braids, as shown in the lower picture.

braid, saturated with a compound that is moisture-resistant and fire-retardant; if set on fire by a blow torch, the flame will go out when the torch is removed. Finally comes a layer of wax to make the wire slick and clean. If the wire is to be some color other than black, a layer of paint comes under the wax. The purpose of color will be explained in a later chapter. The rubber in Type R wire may be either natural rubber or synthetic, so long as the compound is vulcanizable.

Rubber-covered wire in sizes No. 6 or heavier is stranded, that is, the copper conductor consists of a number of small strands of copper wire twisted together; this makes the wire more flexible. Two cotton braids are also used for greater mechanical protection of the insulation.

Rubber-covered wire is usually used only indoors. It is not prohibited out of doors, but it is better to use weatherproof wire, which lasts longer, and in larger sizes costs less than the rubber-covered. Indoors rubber-covered wire may be used supported on insulators, or run through pipe known as conduit, or in the form of cables.

Type T Wire: The Type R rubber-covered wire is gradually being replaced by Type T wire. The insulation on Type T wire is what is known as thermoplastic type. It consists of a single heavy layer of plastic, without the outer layer of cotton used on Type R. The insulation comes in many colors. The finished wire is clean, small in diameter, and the insulation strips easily. It may be used wherever Type R may be used.

Cables: Type R or Type T wires are often assembled into cables, such as nonmetallic sheathed cable or armored cable. These will be described in detail later. When a cable contains two No. 14 wires, it is known as 14-2 (fourteen-two) cable; if it has three No. 12 wires, it is known as 12-3, and so on. If a cable contains two wires, one is always white, one black; if it contains three wires, one is white, one black and the third red.

Nonmetallic Sheathed Cable: This material, known by such trade names as Romex, Cresflex, Loomwire, etc., is shown in Fig. 4-5, and consists of two or more Type R or Type T wires; over each wire is a paper braid, and over all is a spiral wrapping of paper. The wires are then enclosed in an overall outer braid of cotton, which is treated with moisture-resistant and fire-retardant compounds. The spaces that would otherwise be empty are filled with a jute or similar cord. An entirely different construction designed especially for farm use is described in Chap. 17.

Nonmetallic sheathed cable may not be used out of doors. It is the most common cable in use for farm wiring. It is relatively easy to install, is neat in appearance and less expensive than other styles of cable.

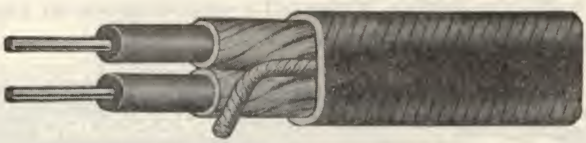


Fig. 4-5. Nonmetallic Sheathed Cable consists of two or three individual wires, assembled into a cable. It may be used only indoors. Code Type NM is shown. Type NMC is shown in Chap. 17.

Armored Cable: This style of cable, which is known by such trade names as BX, Flexsteel, etc., is shown in Fig. 4-6. The individual wires are Type R or Type T, with an overwrap of tough paper between the wires and the outer spiral wrapping of steel armor. Armored cable may be used only indoors.

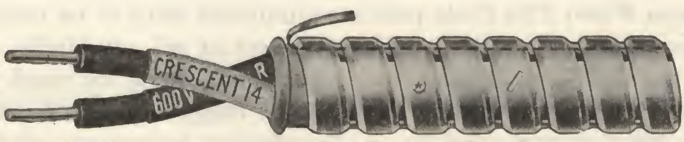


Fig. 4-6. Armored Cable consists of two or three individual wires, assembled into a cable, protected by flexible steel armor. It may be used only indoors.

Underground Wires: See Chapter 17.

Lamp Cords: Flexible cords to connect appliances and other devices to outlets are known as lamp cords. Each wire consists of many strands of fine wire for flexibility. Over the copper is a wrapping of cotton to prevent the insulation from sticking to the copper. The more common types will be described here.

Underwriters' Type SP (formerly POSJ) is the most common cord used for radios, floor lamps and similar devices. As shown in Fig. 4-7, it consists of copper wires imbedded in solid rubber. It is tough, durable and available in an assortment of colors. A similar cord with plastic insulation is known as Type SPT (formerly POT).

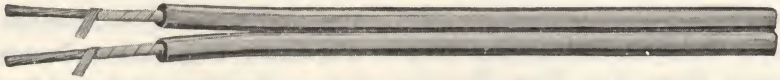


Fig. 4-7. In Type SP, the wires are imbedded in rubber. The cord is durable, attractive.

A really tough and knock-about cord is Underwriters' Type S shown in Fig. 4-8. Each wire is rubber-insulated; the two wires are then bundled into a round assembly, the empty spaces being filled with jute or paper twine to make it round. Over all comes a layer of tough, high-grade rubber. Type SJ is similar except that the outer layer of rubber is thinner.

For flatirons and other devices delivering considerable heat, a special cord is required known as "heater cord." The most common type is Type HPD and Fig. 4-9 shows its construction. A layer of asbestos is applied over each wire before twisting. Over all comes a layer of rayon or cotton; the cotton is by far the more durable.

Fig. 4-8. Types S and SJ cords are designed for severest use.

Fig. 4-9. Type HPD cord is used on flatirons, toasters, etc.

Aluminum Wire: The Code permits aluminum wire to be used, but there are many problems involved in using it. First of all, aluminum wire is not as good a conductor as copper, so larger wires must be used. A rule-of-thumb is to use No. 6 aluminum in place of No. 8 copper, No. 4 aluminum in place of No. 6 copper, and so on. Connecting aluminum wire to copper or brass terminals does not result in a satisfactory connection; neither can aluminum be soldered. The only satisfactory method of joining aluminum is to use special connectors designed for the purpose, together with a special chemical paste, according to the instructions coming with the material. Aluminum wire is used mostly on "high-lines", and in the form of weatherproof wire; in both cases there are relatively long spans with few connections to make.

Removing Insulation: Before a wire can be attached to a switch or other device, or spliced to another wire, the insulation must be removed. There is a right way and a wrong way to do this. Do not cut it off sharply, as shown in A of Fig. 4-10; there is too much danger of nicking the copper wire, leading to breaks later. If the wire is to be attached to a terminal, hold your knife at an angle as shown in B of Fig. 4-10. If the wire is to be spliced to another wire, hold the knife as in sharpening a pencil, as shown in C in the same picture.

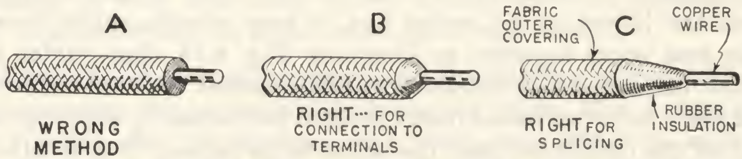


Fig. 4-10. Wrong and right methods of removing insulation from wires.

Whether the wire is to be attached to a terminal or is to be later soldered, you absolutely *must* remove all traces of insulation from the copper conductor. Some kinds of wire have a tinned copper conductor which makes it easy to strip the insulation off cleanly. Other kinds, such as weatherproof, require considerable scraping to clean the conductor. Always make sure the conductor is absolutely clean.

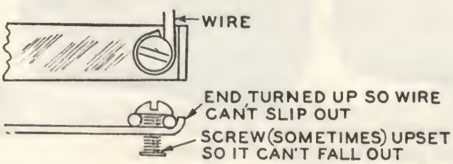


Fig. 4-11. Common terminal for small wires. The end is turned up to keep the wire in place.

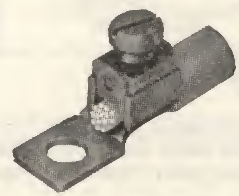


Fig. 4-13. Solderless terminals of this type are used with heavy sizes of wire.

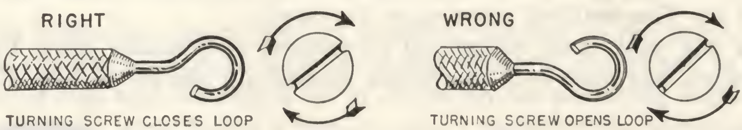


Fig. 4-12. Always insert the loop on a wire so that tightening the screw closes the loop.

Terminals: Terminals to which wires are connected are of two types. If the wire is No. 8 or lighter, usually the common screw terminal shown in Fig. 4-11 is used. Bend the end of the wire into a loop, insert it under the head of the terminal screw so that, as the screw is tightened, it tends to close the loop. Figure 4-12 shows the right and wrong ways. If the wire is No. 6 or heavier, only terminals or connectors similar to that shown in Fig. 4-13 are permitted. The straight end of the wire is inserted into the connector; when the screw is driven down tightly, an entirely secure and electrically good joint is made. Regardless of the type terminal involved, *be sure the insulation on the wire comes up close to the terminal.*

Splices: The spliced wire must be as good a conductor as an unbroken piece, which requires proper soldering, or using approved solderless connectors. The insulation on the splice must be as good as on a continuous piece of wire, which requires proper taping.

When there is no mechanical strain on the joint, as, for example, when two wires are joined in an outlet box, a very simple splice is sufficient. Twist the two wires together as shown in Fig. 4-14, then solder and tape. If you wish, use solderless connectors of the general type shown in Fig. 4-15. One type has a threaded metal insert molded permanently into the insulating shell; screw the connector onto the wires to be joined. If one wire is much smaller than the others, let it project a bit beyond the others. The other type has a removable metal insert. Slip the insert over the wires to be joined, tighten the set-screw, then screw the insulating shell over the joint. If you remove the right amount of insulation from each wire, the insulating shell of either type connector will fully cover all bare wire, and no taping is then necessary.

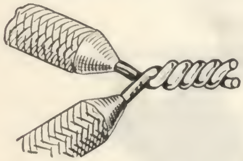


Fig. 4-14. If there is no strain on the wires, merely twist them, solder, tape.

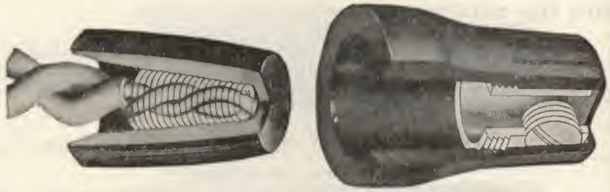


Fig. 4-15. Solderless connectors save a great deal of time, as compared with soldering. No taping is necessary.

For wires that are too large to be joined using the insulating connectors just discussed, you can use heavy-duty metal connectors of the style shown in Fig. 4-16. The finished joint must be taped.

Often one wire must be tapped to another continuous wire. For larger sizes of wire, use split-bolt solderless connectors shown in Fig. 4-17. Tape after making the connection. If the wires are to be soldered, use the method shown in Fig. 4-18 if the wire is solid. If the wires are stranded, it is better to first separate the strands of the main wire into two parts; push the tap

Fig. 4-16. For heavier wires, use metal connectors. They must be taped.

Fig. 4-17. Heavy sizes of wires are hard to tap and solder properly, especially in awkward locations such as at the top of a pole. Heavy-duty split-bolt solderless connectors of the type shown at the right simplify the problem.

wire through the opening, wrap half of it in one direction, half in the other, all as shown in Fig. 4-19. Solder and tape to complete the job.

If two pieces are to be spliced *and there is strain on the splice*, there is one additional requirement: the spliced wire must be as strong as a continuous piece of wire. The steps shown in Fig. 4-20 will show you how to proceed. The finished joint must be soldered and taped.

Soldering: The first requirement of good soldering is that both the wire and the soldering copper must be absolutely clean. Use a non-acid flux; rosin is suitable for the purpose and rosin-core solder in wire form is

Fig. 4-18. Tapping one wire to another is simple as the picture at the left shows.

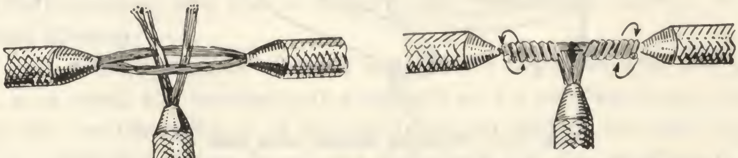


Fig. 4-19. If the wires are stranded, the construction shown above is better than that of Fig. 4-18.

Fig. 4-20. When there is strain on the wire, splice as in picture above.

handy. In soldering, apply the hot soldering copper to the joint, until the wire itself is hot enough to melt the solder when it is touched to the wire, as shown in Fig. 4-21. Having a bit of solder on the soldering copper as it is held against the wire, forms a liquid contact between the soldering copper

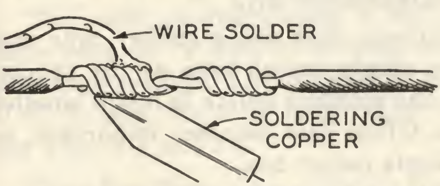


Fig. 4-21. In soldering, do not drop hot solder on cold wire. Heat the wire until it is hot enough to melt solder.

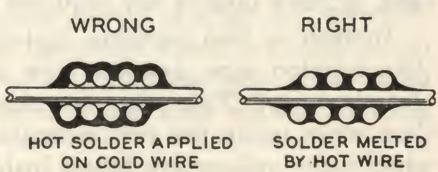


Fig. 4-22. Hot solder applied to cold wire will lie on the surface. Solder melted by hot wire fills all spaces, makes a good joint.

and the wire, leading to a more rapid heating of the wire than if the bare copper were used. If the soldering copper is at the right heat, the wire will quickly heat sufficiently for good soldering; if the soldering copper is too cool, the wire will heat slowly because the heat will flow from the splice into the wire under the insulation, leading to a poor joint and possibly damaged insulation.

If the soldering operation is properly done, solder will flow down into every little open space in the splice, making a good electrical joint. See Fig. 4-22 for the difference between poor and good soldering.

A solder dipper shown in Fig. 4-23 is convenient for many kinds of soldering. The solder is kept at the right temperature with a blowtorch.

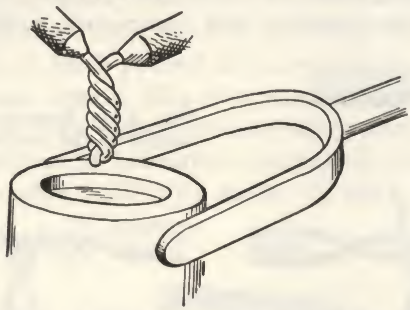


Fig. 4-23. A solder dipper saves time.

Taping: Every soldered joint must be properly taped. Two kinds of tape are used. Rubber tape, also known as splicing compound, replaces the insulation; friction tape replaces the outer protective braid on the wire. Rubber tape is a very high grade of unvulcanized rubber which, under slight pressure, vulcanizes to other rubber. Wrap a couple of layers of this rubber tape tightly around a pencil, one on top of the other, then cut through them. You will find one thick solid layer; the several thin layers have vulcanized together. In applying the tape on a splice, start it on the tapered end of the rubber insulation of the wire, wrap toward the other end, then back and forth until the layer of rubber is as thick as the original insulation. Keep the tape stretched tight at all times. Follow with a layer or two of friction tape. Rubber tape is not required on weatherproof wire.

Instead of two separate taping operations, first using rubber tape and then friction tape, you can now use one single scotch tape of the special electrical type. This takes less time and the finished splice is much smaller than when using the two separate tapes. Often this becomes important, as when many splices are found inside a single outlet box.

CHAPTER 5

Fuses and Circuit Breakers

The Code has established a maximum amperage which is considered safe for any particular kind and size of wire. This maximum is shown in the Table in Chap. 4. If more than the permissible maximum amperage is allowed to flow, the temperature of the wire goes up, and the insulation may be damaged. If the overload is great enough, there is danger of fire.

Overcurrent Devices: The amperage in any wire is limited to the maximum permitted, by using what the Code calls an overcurrent device. Two types are in common use: fuses and circuit breakers, both rated in amperes. Any overcurrent device you use must have a rating in amperes, not greater than the carrying capacity in amperes of the wire which it protects. For example, No. 12 wire has a carrying capacity of 20 amp., therefore the fuse or the circuit-breaker you use to protect the wire must have a rating not greater than 20 amp.

When two different sizes of wire are joined together (as, for example, when No. 8 is used for mechanical strength in an overhead run, joined to No. 14 for the inside wiring of the building to which the wire runs) the overcurrent protection must be of the right size for the *smaller* of the two wires. Of course a size correct for the *larger* wire may be used at the starting point, provided another one of the proper size for the *smaller* wire is used where the wire size is reduced.

Fuses: A fuse is nothing more or less than a short piece of metal, of a kind and size which experiment has shown will melt when more than a predetermined number of amperes flows through it. This metal link is enclosed in a convenient housing, to prevent hot melted metal from spattering if the fuse blows, and to permit easy replacement. A fuse rated at 15 amp. will carry 15 amp. continuously. When more than 15 amp. flow through it, the wire inside the fuse melts (the fuse "blows"), which is the same as opening a switch or cutting the wire.

The most ordinary fuse is the plug type shown in Fig. 5-1, which is made only in ratings of 30 amp. and less. Cartridge fuses are made in all amperage ratings. Those rated at 30 amp. or less are 2 in. long; those rated 31 to 60 amp. are 3 in. long; those rated at 61 to 100 amp. are 5⅞ in. long. See Figs. 5-2 and 5-3.

Time-Lag Fuses: An ordinary fuse carries its rated amperage indefinitely, but blows very quickly if twice that amperage flows through it. For that reason fuses often blow when a motor is started, because a motor which draws only 6 amp. *while running* may draw as much as 30 amp. for a few seconds *while starting*. On the other hand, wire which can safely carry 15 amp. continuously (and which might be damaged or even cause a fire if 30 amp. flowed continuously) will not be damaged in the least, or cause a fire, if 30 amp. flow for a few seconds. For this reason another type fuse was developed, known as the "time-lag" type. It is commonly called a Fusetron. It blows just as quickly as an ordinary fuse on a small continuous overload, or on a short circuit, but *it will carry a big overload safely* for a fraction of a minute. This type of fuse is rapidly becoming popular, especially where motors are used. It prevents needless blowing of fuses and does away with many service calls. It looks like an ordinary fuse, but is made differently inside.

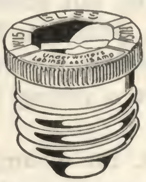


Fig. 5-1. Plug fuses are not made in ratings over 30 amp.

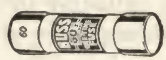


Fig. 5-2. Cartridge fuses rated 60 amp. or less are of the ferrule type shown.

Fig. 5-3. Cartridge fuses rated more than 60 amp. have knife-blade terminals shown.

Non-Tamperable Fuses: Since all ratings of ordinary plug fuses are interchangeable, nothing prevents one from using, for example, a 25-or 30-amp. fuse to protect a No. 14 wire, which has a carrying capacity of only 15 amp. This is unsafe. For that reason there was developed a non-tamperable fuse, which is shown in Fig. 5-4; it consists of two parts: an adapter, and the fuse proper. The Code calls this a "Type S" fuse; it is commonly called a Fustat.

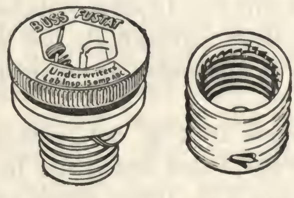


Fig. 5-4. A typical Type-S non-tamperable fuse, and its adapter. Once an adapter has been screwed into a fuse-holder, it cannot be removed. This prevents use of fuses larger than originally intended.

Once an adapter of any given size, say 15-amp., has been inserted in a fuse-holder, only fuses of that size or smaller can be used—a safety measure. The adapter once inserted, cannot be removed. The National Code recommends but does not require this type of fuse; some local Codes do require it.

Circuit-Breakers: More and more circuit-breakers are being used in place of fuses. A circuit-breaker looks something like a toggle switch, with a handle that lets it be used just like a switch to turn power on and off. See Fig. 5-5 which shows a single unit, also an assembly of eight breakers. Inside each unit is a fairly simple mechanism which in case of overload, trips the circuit-breaker and disconnects the load. There is nothing to replace, just reset it like turning on a switch.

A circuit-breaker has a definite time lag, just like the time-lag fuse. It will carry its rated load indefinitely, a small overload for a considerable time, and trip quickly on a large overload. Nevertheless it will carry temporary large overloads long enough to permit motors to start.

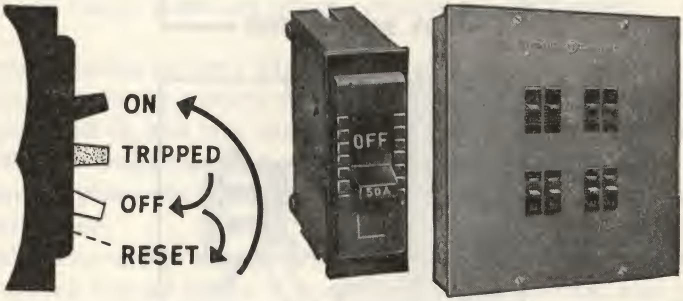


Fig. 5-5. A single circuit-breaker, together with an assembly of eight in one cabinet. When breaker trips, reset as shown in picture above.

When a Fuse Blows: What is to be done when a fuse blows? Most people will say: install a new fuse. Correct, but first find out *why* the fuse blew. Fuses are the safety valves of electrical installations. To use substitutes, or fuses that are too large for the size of the wire involved, is either ignorance or stupidity. Don't do it, any more than you would drive an automobile without brakes. See Fig. 5-6.

When a fuse blows, or a circuit-breaker trips, it is for one of two reasons. Either something connected to the circuit is defective thus drawing an excessive number of amperes, or there are too many things connected at the same time, thus overloading the circuit.

If a fuse blows quickly every time a particular appliance is plugged in, especially if it makes no difference whether it is plugged in downstairs or upstairs on a different circuit, the appliance is probably defective. Usually the defect is in the cord. If the appliance has a removable cord, try a different cord; if the cord is permanently attached, only careful inspection will locate the defect. Be suspicious of badly twisted and badly worn cords.

If the fuse blows when a motor (as on a washing machine) is turned on, remember that a motor which consumes only 5 amp. while running, may draw up to 30 amp. for a few seconds while starting. That may be the reason for the fuse blowing. Substituting a time-lag fuse for an ordinary fuse may solve the problem. If however the fuse continues to blow, suspect the motor. Check the cord. Check to see that the motor bearings have oil. Perhaps the belt is too tight, or the machine that the motor drives lacks oil, increasing the load on the motor, increasing the amperes beyond the safe point.

capacity, each circuit at 115 volts has a capacity of 15 × 115 or 1,725 watts. Since 7,380 watts in total must be carried and each circuit can carry 1,725 watts, the number of circuits is 7,380 divided by 1,725 or 4.2 circuits. There can't be a fraction of a circuit so the answer is four circuits as a minimum requirement. If the fraction had been greater than half, the answer would be five circuits.

If the house is wired with No. 12 wire, which has 20 amp. carrying capacity, each circuit at 115 volts has a capacity of 20 × 115 or 2,300 watts. A total of 7,380 watts divided by 2,300 watts results in 3.2 circuits, meaning three circuits in practice.

Note that receptacle outlets for floor lamps, clocks and similar usage *may* be connected to these lighting circuits. Receptacles for kitchen appliances however *may not* be connected to the lighting circuits, as will be explained later.

The number of circuits determined as outlined above is the *minimum* permitted by Code, for lighting purposes. In most cases more than the minimum number should be installed to make an installation which is more adequate, more flexible, which provides for future additional loads, and involves less voltage drop and wasted power. Although the Code does not require it, it *recommends* one circuit for every 500 sq. ft. of space. For the 2,460 sq. ft. house, five circuits would be required—and five lighting circuits are by no means too many for a house of this size, whether the wiring be No. 14 or No. 12.

Receptacle Circuit: In addition to the lighting circuits, the Code requires one special circuit to which no lighting outlets may be connected. The circuit is to serve only receptacle outlets in kitchen, pantry, breakfast room, dining room and laundry. It *must* be wired with No. 12 or larger wire, and may then be provided with 20-amp. overcurrent protection. The circuit has a capacity of 2,300 watts which is by no means too much, considering that electric irons, toasters and so on usually require full 1,000 watts each. As a matter of fact, a modern home needs *two* special appliance circuits: one for kitchen appliances, one for basement appliances.

Special Circuits: Heavy appliances such as ranges, water heaters, clothes dryers, and so on, require individual circuits. See Chap. 14.

CHAPTER 6

ABC of Wiring

Before you can actually wire a building, you must first learn how switches, receptacles, sockets and other devices are connected to each other with wire, to make a complete electrical system.

Grounded Wire: In residential and farm wiring, one of the wires is always grounded, that is, connected to a water pipe or driven ground rod. It is most important that you remember the following four points:

1. The grounded wire is *always* white in color.
2. The grounded wire must run direct to every 115-volt device to be operated (*never* to a device operating only at 230 volts).
3. The grounded wire is *never* fused.
4. The grounded wire is *never* switched or interrupted in any other way.

The grounded white wire is known as the neutral wire.

With one exception (which will be discussed later), white wire may never be used except as a grounded wire. Other wires are usually black but may be some other color, but not white (with the one exception just mentioned).

One black wire and one white wire must run to every 115-volt electrical device *other than a switch.* Examine a socket or similar device carefully and you will find that one of its two terminals for wire is a natural brass color, the other is a white color, usually nickel-plated or tinned. The *white* wire must *always* run to the *white* terminal. In the case of sockets, the white terminal in turn is always connected to the screw shell and never to the center contact of the socket. Switches for controlling lights, etc., never have white terminals.

Wiring Diagrams: Two wires must run from the starting point to each outlet whether it serves a bulb, motor, or any other electrical device. Imagine, if you wish, that the current flows out over the black wire to the device, through the device, and back to the starting point over the white wire. We will call the starting point the SOURCE, and use a bulb to indi-

Fig. 6-1. This symbol indicates a bulb in all diagrams.

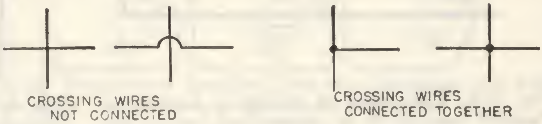


Fig. 6-2. This method will be used in all diagrams to indicate whether crossing wires are connected to each other or not.

cate the device to be operated. We will use the symbol of Fig. 6-1 instead of a picture of a bulb. Note also the method shown in Fig. 6-2 to indicate whether crossing wires are connected to each other or not. In all diagrams the white wire will be indicated by a light line like this ———; black wire, which is usually known as the "hot" wire, by a heavy line like this ———; and the black wire between a switch and the outlet which it controls by a heavy broken line like this — — —.

The simplest possible diagram is that of Fig. 6-3: a bulb which is always on, with no way of turning it off. Such a circuit is of little value, so let us add a switch. This is very simply done; all we have to do is to make the *black* wire detour to a switch as shown in Fig. 6-4. An open porcelain-base

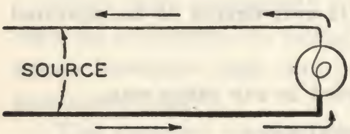


Fig. 6-3. The simplest circuit: a bulb always on.

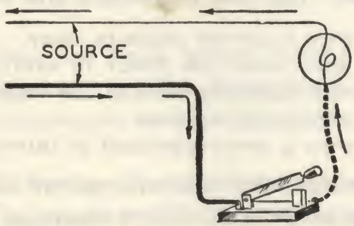


Fig. 6-4. The circuit of Fig. 6-3, plus an open switch.

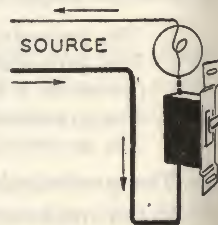


Fig. 6-5. A toggle switch substituted for the open switch in Fig. 6-4.

switch is shown so that you can see how it operates; opening the switch is the same as cutting a wire. Fig. 6-5 shows the same circuit but with a flush toggle switch which serves the same purpose but is far neater, handier, and safer because there is no exposed mechanism and because of other differences in construction.

If several bulbs are to be used, do not make the mistake of wiring them "in series," as the wiring shown in Fig. 6-6 is known, which is impractical except for very special purposes. For example, if one bulb burns out, all go out (as in the "series" type of Christmas tree lights).

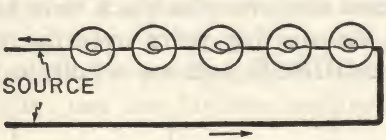


Fig. 6-6. This style of wiring is known as "series" wiring; it is impractical except for very special purposes.

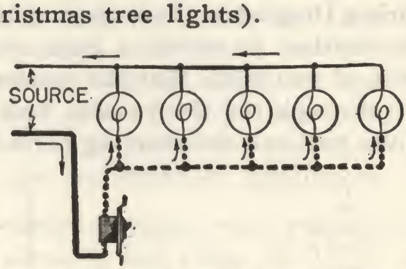


Fig. 6-7. This style of wiring is known as "parallel" wiring; it is used for all ordinary purposes.

Wire them "in parallel," as the scheme shown in Fig. 6-7 is known. The white wire goes to each bulb, from the first bulb to the second and the third and so on; the black wire also runs to each bulb in similar fashion. Each bulb will still light even if one or more of the others is removed. The switch shown cuts off the current to all the bulbs at the same time. The wiring is most simple: white wire from SOURCE to each socket or outlet:

black wire from SOURCE to the switch, and from the switch another black wire to each of the sockets. This is the way a fixture with 5 sockets is wired.

If each bulb is to be controlled by a separate switch, use the diagram of Fig. 6-8. The white wire always runs from SOURCE to each bulb, the black wire from SOURCE to each switch; from each switch a black wire runs to the bulb which it is to control. Trace the current in over the black wire through each switch separately, along the black wire to the bulb, and back from bulb to the SOURCE. Trace it carefully and you will find that each bulb can be separately controlled.

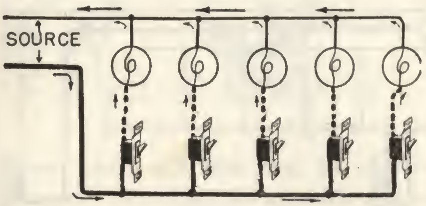


Fig. 6-8. The same diagram shown in Fig. 6-7, but each bulb is now controlled by a separate switch. Note that the white wire runs directly from SOURCE to each bulb.

Wiring Receptacle Outlets: The wiring of plug-in receptacle outlets is most simple. If there is only one receptacle, run the white wire from SOURCE to one side of receptacle, the black to the other, as in Fig. 6-9. If there are several receptacles, run the white wire to one side of the first receptacle, from there to the second, and so on; do the same with the black. See Fig. 6-10; study this picture carefully and you will see that it is the same as the diagram of Fig. 6-7, except that receptacles have been substituted for bulbs, and the switch omitted. In better homes you often see a group of receptacle outlets controlled by a wall switch, so that all the floor lamps, radios, etc., can be turned off with one switch. In that case, connect as shown in Fig. 6-10, but install a switch in the black wire.

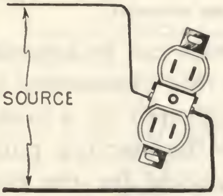


Fig. 6-9. The wiring of receptacles is most simple.

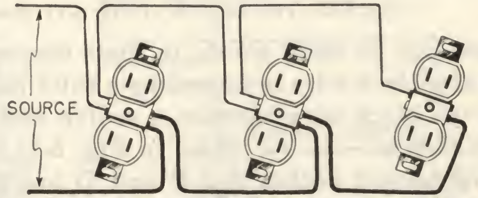


Fig. 6-10. Receptacles usually have two terminals on each side, to make it easy to run wires from one to the next.

Wiring Outlets Controlled by Pull-Chain: Since the pull-chain mechanism is part of the socket, an outlet that is to be controlled only by pull-chain is wired exactly like a receptacle outlet. Simply substitute the pull-chain socket for the receptacle in either Fig. 6-9 or 6-10.

Combining Several Diagrams: When several groups of outlets are to be wired, the two separate wires from each group can be run back to a common starting point, where the wires enter the house, as is shown in Fig. 6-11 where the diagrams of Figs. 6-5, 6-7, and 6-8 have been combined into one. This would require a very considerable amount of material, and the wires would be much longer than necessary. It is much simpler to merely wire the first group, then to run wires from the first group to the second, and from the second to the third, as is shown in Fig. 6-12, which shows the same three groups but using less material.

The *white* wire may be extended at any point whatever to the next outlet. The black wire likewise may be extended at any point, provided only that it can be traced all the way back to the SOURCE without interruption

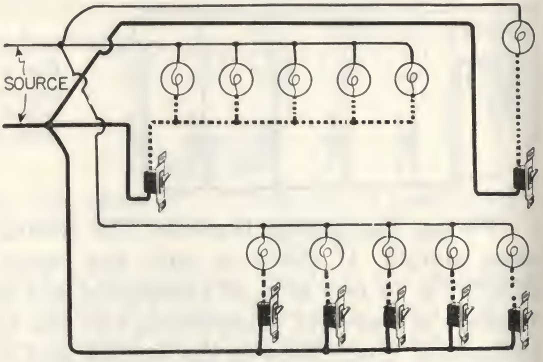


Fig. 6-11. The outlets of Figs. 6-5, 6-7 and 6-8 have been combined into a single group of outlets, in other words here form one circuit. It still uses a great deal of material; to reduce the amount required, the circuit can be rearranged as the next picture shows.

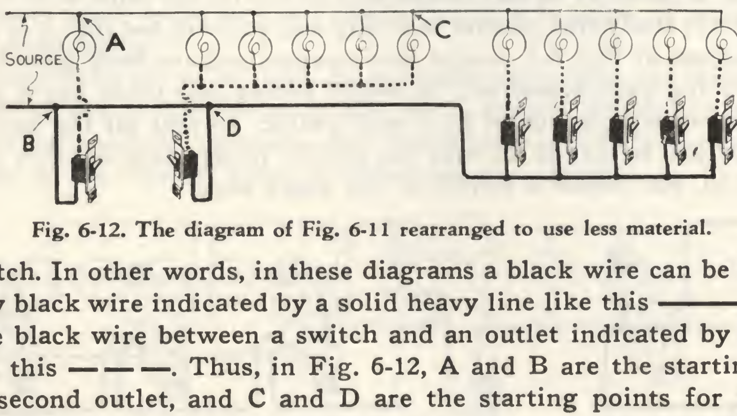


Fig. 6-12. The diagram of Fig. 6-11 rearranged to use less material.

by a switch. In other words, in these diagrams a black wire can be extended from any black wire indicated by a solid heavy line like this ———, but not from the black wire between a switch and an outlet indicated by a broken line like this — — —. Thus, in Fig. 6-12, A and B are the starting points for the second outlet, and C and D are the starting points for the third group of lights.

3-Way Switches: The switch used for controlling a light from one point is known as a "single-pole" switch. Very often it is most convenient to be able to turn a light on or off from two different places, as for example, a hall light from upstairs and downstairs, or a garage light from house and garage, or a yard-light from house and barn. For this purpose, switches known as the "3-way" type are used. Despite their name, they will not control a light from three different places, but only two. Such switches have three different terminals for wires, and their internal construction is similar to that shown in Fig. 6-13. In one position of the handle, terminal A is connected inside the switch to terminal B; in the other position of the handle, terminal A is connected to terminal C. Different manufacturers make their 3-way switches in different ways, so that the "common" terminal A is some-

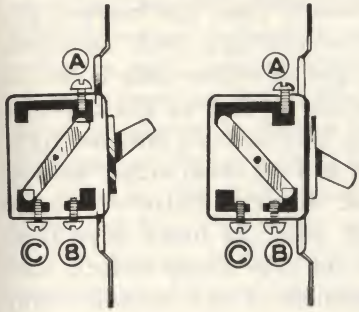


Fig. 6-13. This shows what happens inside a 3-way switch when the handle is thrown from one position to another. The current enters by terminal A, leaves by either B or C depending on the position of the handle.

times alone on one end of the switch, sometimes alone on one side. *The common terminal is usually identified by being of a darker color than the others, which are natural brass.*

Study the diagram of Fig. 6-14, in which the handles of both switches

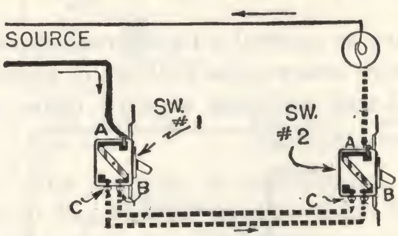


Fig. 6-14. A light controlled by two 3-way switches. With both handles down, the light is out.

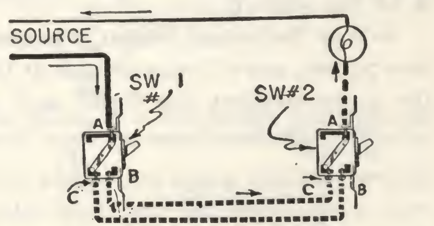


Fig. 6-15. With the handles of both switches up, the light is still out. Trace the current along the arrows.

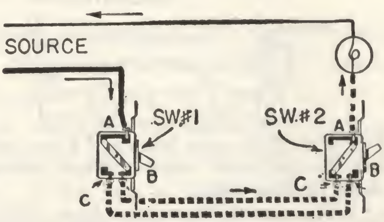


Fig. 6-16. With one handle up, the other down, the light is now on. Trace the current along the arrows.

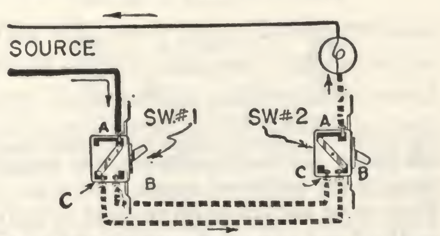


Fig. 6-17. Both handles are now the opposite of Fig. 6-16, but the light is still on. Either switch controls it.

are down. The current can be traced from SOURCE over the black wire through switch No. 1 through terminal A, out through terminal B, and up to terminal C of switch No. 2, but there it stops. The light is out.

Next see Fig. 6-15 where the handles of both switches are up. The current can be traced from SOURCE over the black wire through switch No. 1

through terminal A, as before, but this time out through terminal C, and from there up to terminal B of switch No. 2. There it stops and the light is out.

Now examine the diagrams of Fig. 6-16 and 6-17, in both of which the handle of one switch is up, the other down. In each case, the current can be traced from SOURCE over the black wire, through both switches, through the bulb, and back to SOURCE. The light in either case is on. In the case of either Fig. 6-16 or 6-17, throwing either switch to the opposite position changes the diagram back to either Fig. 6-14 or 6-15, and the light is out. In other words, the light can be turned on and off from either switch.

The wiring is simple, as these diagrams show. Run the white wire from SOURCE as usual to the light to be controlled. Run the black wire from SOURCE to the common or marked terminal of the *first* 3-way switch. Run a black wire from the common or marked terminal of the *second* 3-way switch to the light. That leaves two unused terminals on each switch; run two black wires from the terminals of the first switch, to the two terminals of the second switch. It makes no difference whether you run a wire from B of the first switch to C of the second as shown, or from B of the first to B of the second.

4-Way Switches: When it is necessary to control a light from more than two points, use a 3-way switch at the point nearest the SOURCE, another at the point nearest the light, and use 4-way switches at each other point.

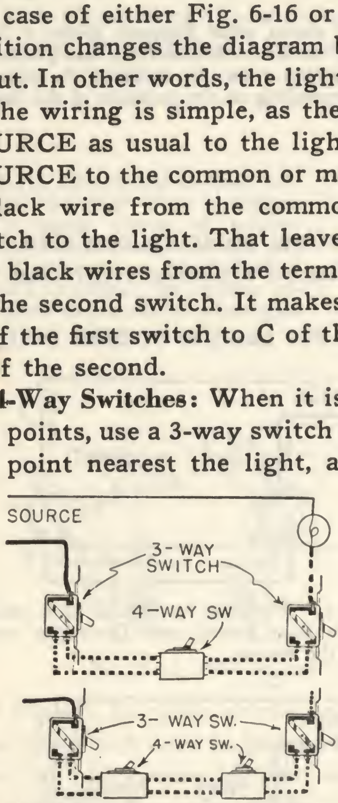


Fig. 6-18. To control a light from more than two places, use 3-way switches at two points, 4-way at the additional points.

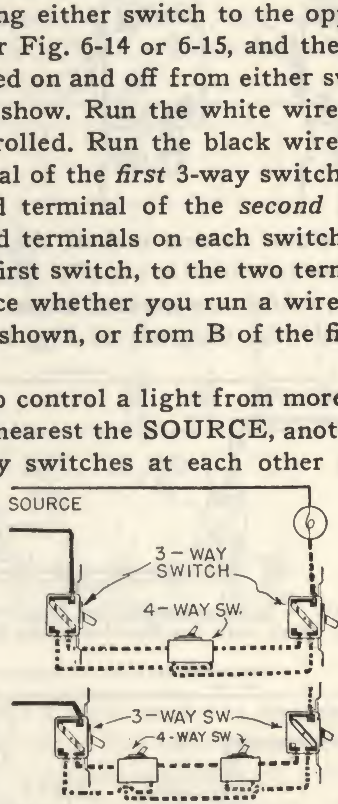


Fig. 6-19. With some brands of 4-way switches, use the diagrams shown above, instead of those in Fig. 6-18.

Four-way switches have four terminals for wires, and there are two different methods of internal construction, so that the wiring diagram may be one of two different types. See Fig. 6-18, which you will recognize as the same as Fig. 6-14 except that a 4-way switch has been added between the two 3-way switches. This shows the usual diagram but with some brands it is necessary to wire as shown in Fig. 6-19. You will have to proceed by trial and error until you hit the right combination; no harm can be done by wrong connections, except that the hook-up will not work. If two 4-way switches are required, wire as shown in the lower part of the same pictures.

Pilot Lights: When a switch controls a light that can't be seen from the switch, the light is often left turned on when it should be turned off. Install a pilot light (a small, low-wattage bulb) near the switch, so that both lights are turned on and off at the same time. The pilot light then serves as a reminder that the other light (which can't be seen from the switch) is on. Pilot lights are commonly used in connection with basement and attic lights in homes, with hay-mow lights in barns, and similar locations. Their wiring is very simple as Fig. 6-20 shows. First consider the diagram, disregarding the wires shown in dotted lines, as well as the pilot light itself. It is then the same as Fig. 6-5. Add the wires shown in dotted lines and it becomes the same as the diagram of Fig. 6-7 except that there are only two bulbs instead of five. The white wire runs to both bulbs; the black wire from the SOURCE runs to the switch as usual; the black wire from switch runs to both bulbs, and the diagram is finished.

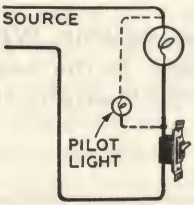


Fig. 6-20. The basic circuit of a pilot light.

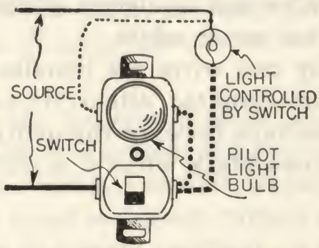


Fig. 6-21. The wiring scheme of a combination pilot light and switch. Another brand might be wired somewhat differently.

For this purpose, a combination switch and pilot light similar to that shown in Fig. 6-21 is usually used; the pilot bulb and the switch are combined in one device. The diagram shown in connection with this picture is correct only for one brand; exact diagrams usually come with each piece of merchandise.

Other Diagrams and Combinations: You will have little difficulty making a diagram for any desired combination of outlets and switches, whether single-pole, 3-way or 4-way, if you will bear in mind the principles covered in this chapter. To make any diagram, first locate each outlet where desired and run the white wire (light line like this ———) from SOURCE to every outlet. Then run a black wire (heavy line like this ———) from SOURCE to each outlet that is not to be controlled by a switch. Next run black wire (heavy broken line like this — — —) from each outlet which is to be controlled by a switch, to the switch which is to control it; if 3-way or 4-way switches are involved, run additional ones between the switches which are to control the outlet. Finally, from each switch run black wire (heavy line like this ———) back to SOURCE. You may have to rearrange some of the wires when you have finished, to reduce the amount of wire used, but this will not affect the proper operation of the hook-up.

CHAPTER 7

The Service Entrance

The service entrance consists of all the wiring from the point where the service drop (the Power Company's wires) ends, to the point inside the house where the branch circuits begin. Thus it will include the insulators on the outside of the house, the cable (or conduit with wires) running down the side of the house and on into the house, the meter, the service switch and branch-circuit fuses (or circuit-breakers) and the ground connection. This chapter will discuss the design and installation of the service entrance in a city home; installations on farms are somewhat different and will be discussed in a separate chapter.

2-Wire or 3-Wire Service Entrance: One of the wires in the service entrance is grounded, as was explained in the previous chapter. It is called the neutral wire and is always white. The other wires are black or some other color, but never white.

When only two wires are installed, only 115 volts are available. When three wires are installed, either 115 or 230 volts are available. In the 3-wire system, the voltage between the neutral and either black "hot" wire is 115; between the two black wires it is 230. See Fig. 7-1.

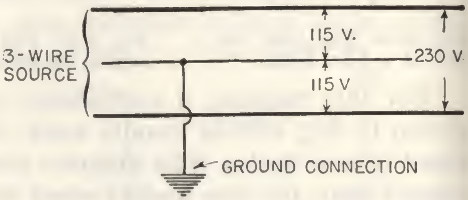


Fig. 7-1. Using only three wires, two different voltages are available. Use the lower voltage or 115 volts for low-wattage devices, the high voltage or 230 volts for high-wattage devices such as large motors, water heaters, ranges.

Not much over 25 years ago electric power was used mostly for lights and a very few small appliances. Everything operated at 115 volts, the total amperage required was small, and a 2-wire 115-volt service was entirely suitable. Today electric power is used for many things not even thought of 25 years ago; 230-volt appliances like ranges, water heaters, clothes dryers are common. As a result, 3-wire services providing both 115- and 230-volt power are absolutely necessary. Even if in a particular home no 230-volt appliances were to be used, the 3-wire service has other advantages that cannot be discussed here for lack of space.

As a practical matter, use a 3-wire service in every case except possibly a small summer cottage. Even there you may some day wish to install an electric water heater or a range and will then have to replace the 2-wire service with one of the 3-wire type.

Size of Service Entrance Wires: If the house has one or two circuits, the Code permits No. 8 wire to be used. Every house of consequence will have more than two circuits, and the Code minimum then becomes No. 6 wire. Do note that this is a *minimum*. Is No. 6 large enough for the house you are discussing? The service entrance wires must be big enough to carry not only the average load, but rather the maximum number of amperes that are ever going to be required at any given moment. No. 6 wire with 55 amp. capacity can handle 55×230 or 12,650 watts. Household electric ranges come as large as 14,000 watts; water heaters require up to 4,500 watts; clothes dryers require up to 4,000 watts. The ordinary electric flatiron used to consume about 600 watts; today the 1,000-watt type is more ordinary. More and more electric motors are being used, and motors may consume up to 25 or 30 amp. for a few seconds while starting.

Is No. 6 wire heavy enough for the service in the average house? Maybe when the house is first built, yes. In a few years, probably no. It is wise to use larger wire, preferably No. 2 with 95 amp. capacity, or even No. 0 with 125 amp. capacity.

Switch or Circuit-Breaker: Inside the house you must provide a means of disconnecting all the wiring from the power line, and you must also provide overcurrent protection for all the wiring. You have a choice of circuit-breakers, or a switch with fuses. The trend is rapidly toward circuit-breakers because of the great convenience of merely resetting in case of overload, as well as their advantage of automatically providing time-lag features which permit them to carry temporary overloads. The next paragraphs will discuss the proper selection of either type of protection.

Selecting the Service Switch: If fused equipment is to be used, a switch must be provided so that the entire building can be disconnected from the power line. In almost all cases the branch-circuit fuses are in the same cabinet with the main switch. Switches come only in standard ratings of 30-, 60-, 100- and 200-amp. The Code prohibits the 30-amp. switch when more than two circuits are involved, so we can dismiss that size.

The 60-amp. switch with No. 6 wire is still the most popular size (even if it is often too small). You would use 60-amp. main fuses with it even if the No. 6 wire has only 55 amp. capacity, for the Code permits the next larger standard size fuse to be used when the theoretically correct fuse is a non-standard size like the 55-amp. Assuming that you will use the 60-amp. switch, how many branch-circuit fuses will you need? You will need one for each 115-volt circuit (one for each black wire, never one in the neutral). You will need two for every 230-volt circuit (one for each black wire; there is no neutral in a 230-volt circuit).

A very popular switch is shown in Fig. 7-2, popularly known as a range combination. It contains no "switch" in the sense of one operated by moving a handle, but the two main fuses are mounted on a convenient removable block of insulating material. When this block is pulled out of the switch, everything is disconnected, everything is dead, no live parts are exposed. The fuses are replaced while the block is in your hand. In addition, the switch contains four plug fuses for four 115-volt branch circuits. It also contains a second removable block holding another pair of cartridge fuses for the range, or any other 230-volt circuit. Usually too it contains a pair of unfused 230-volt terminals for a water heater. Run wires from these terminals to a small separate fused switch and then to the water heater, as explained in Chap. 14.

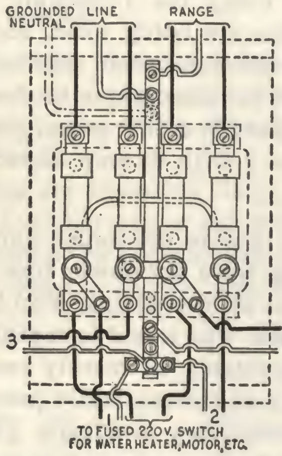


Fig. 7-2. The popular "range combination" switch. Besides main fuses it has fuses for four 115-volt circuits, and one 230-volt circuit. Wiring diagram at right.

Fig. 7-3. A larger switch. Besides main fuses it has plug fuses for twelve 115-volt circuits, and cartridge fuses for two 230-volt circuits.

The switch described is suitable when there are not over four 115-volt circuits (three for lighting, one for appliances). Similar switches are available with 6 or 8 plug fuses, and it is entirely wise to use such larger switches, even if you do not have as many circuits as fuses; a spare fuse or two for future circuits is most desirable.

Better yet, use a similar 100-amp. switch shown in Fig. 7-3. This has 100-amp. main fuses on a removable block, two pairs of 60-amp. cartridge fuses (on two removable blocks) for two 230-volt circuits, and twelve plug fuses for twelve 115-volt circuits. A modern home deserves such a switch.

A word of explanation regarding all switches and fuses may be in order. The 100-amp. fuse holders accommodate fuses rated from 65 to 100-amp.; use the rating matching the size of wire used. Likewise the 60-amp. fuse holders accommodate fuses from 35 to 60-amp.; again use the rating matching the wire used. Plug fuse holders accept any fuse up to 30 amp.; use a rating to match the wire. Also remember that while the plug fuses are provided primarily for 115-volt circuits, two of them can be used to protect a 230-volt circuit; you will then have two less 115-volt circuits.

A service switch for a 3-wire service is known as a "3-pole solid neutral" switch. There are only two blades or poles in the switch proper; the third is merely a connection block or strip to which all the neutral wires entering the switch are connected. Remember that the neutral is never switched or fused.

Circuit-Breakers: When a circuit-breaker is used in place of a fuse, it will trip and disconnect the load in case of overload. To restore the service, merely reset the handle. You can also use the circuit breaker as a switch, to disconnect the load at any time.

When circuit-breakers are used, the Code does not require a main switch, main fuses, or a main breaker provided the entire load can be disconnected by not over six movements of the hand. Each 230-volt circuit requires a double-pole (2-pole) breaker; each 115-volt circuit requires a single-pole breaker. Fig. 5-5 showed a typical assembly with 8 single-pole breakers. However, two single-pole breakers can be combined by a mechanical tie-bar on the handles to become one double-pole breaker for a 230-volt circuit. Also, two separate single-pole breakers each protecting a 115-volt circuit can be mechanically tied together so that both can be operated by a single handle, although each one still protects its own circuit. In this way the combination illustrated, although it has eight individual breakers, can have the handles tied together mechanically so that all the breakers can be operated as if there were only four breakers. In other words, you can have up to 12 individual breakers, tied together to be operated by six movements, and be within the Code requirement of not needing a main switch, main fuses, or main breaker ahead of the combination. The 12 breakers could serve twelve 115-volt circuits, or one 230-volt and ten 115-volt, or two 230-volt and eight 115-volt, and so on. Each breaker on the panel is one pole; it requires two poles for each 230-volt circuit and one pole for each 115-volt circuit.

The circuit-breaker assemblies are constructed with a basic framework of bus-bars within the cabinet. The individual breakers are plugged into the mechanism as required; they are available in 15-, 20-, 30-, 40- and 50-amp. ratings to match the carrying capacity of standard sizes of wire. The assemblies are available in surface type as well as flush type.

Location of Switch or Circuit Breakers: The Code requires that this equipment be located as close as practicable to the point where the wires enter the house. In other words, the service wires must not run 10 or 20 ft. inside the house before reaching this equipment. So, decide where to put your switch or breakers before deciding where the wires are to enter the house.

The heaviest loads in a house, the loads that will consume the largest amperages, are located in kitchen and basement. Therefore, locate the service equipment where the circuits using large wires (to range, clothes dryers, and similar equipment) will be as short as possible. A spot in the basement more or less under the kitchen is desirable, if the service wires can be brought into that location directly from outside. Many prefer to locate the equipment in kitchen or pantry, where it is convenient for replacement of fuses or resetting of circuit-breakers.

Location of Meter: The outdoor type of meter is used in nearly every case today. The meter itself is weatherproof and in turn is plugged into a weatherproof socket, both of which are shown in Fig. 7-4. The socket is

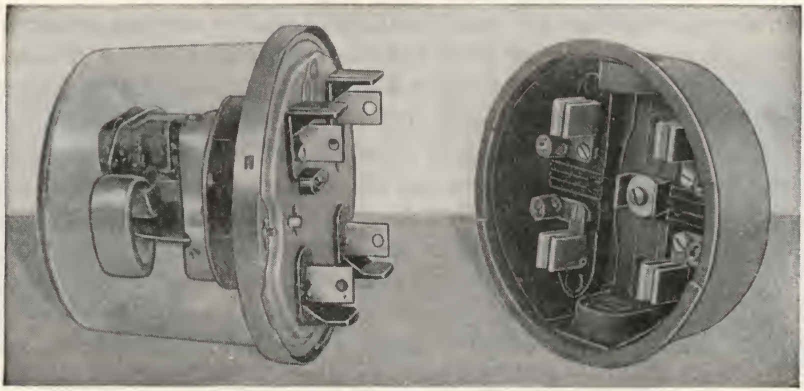


Fig. 7-4. A typical outdoor weatherproof kilowatt-hour meter and its socket.

usually supplied by the Power Company, but installed by the contractor, usually about 5 ft. above the ground. In the case of indoor equipment, the meter is installed on a substantial board near the service equipment.

Installation of Service Entrance: Up to now we have discussed the major parts that make up the service entrance, and how to select the right kind and size. All these parts must now be installed. Figure 7-5 shows a typical entrance. We will have to install insulators on the outside of the building, and the Power Company will run their wires up to that point. We must provide wires from the end of the Power Company's wires, down to the meter socket, and then on into the house to the main switch or the circuit breakers. We can use special cable for the purpose, or run wires through conduit. After installing the switch or circuit breakers, we must properly ground the installation. Then we are ready to wire the branch circuits.

Service Insulators: The incoming wires are anchored on the building on service insulators, as high as possible. The Code requires a clearance of 10 ft. above sidewalks, 18 ft. above driveways. In most localities racks of the type shown in Fig. 7-6 are used. Select a type with the insulators at

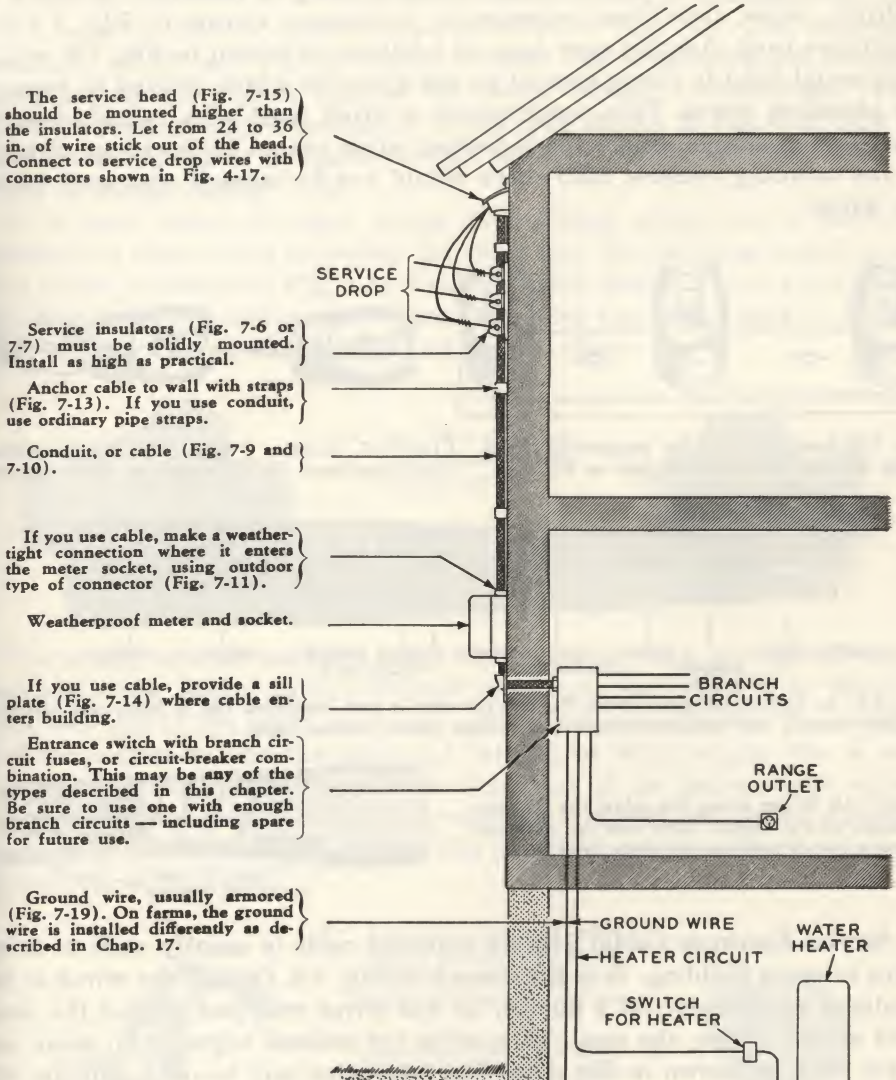


Fig. 7-5. A bird's-eye view of a typical service entrance.

least 6 in. apart; in many localities 8 in. spacing is required. In place of multiple racks, individual screw-point insulators, shown in Fig. 7-7 are sometimes used. Another new type of insulator is shown in Fig. 7-8, which has a metal band to clamp around an upright pipe which is used to support the incoming wires. This construction is often used with ranchhouses or other low buildings, where the incoming wires cannot be anchored directly on the building because then there would not be enough clearance below the wires.

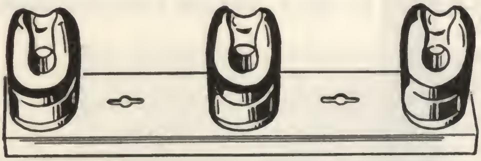


Fig. 7-6. Insulator rack for supporting three wires. Be sure to anchor rigidly to building.

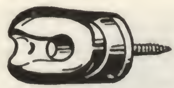


Fig. 7-7. Screw-point insulator.

Fig. 7-8. This insulator clamps to pipe support.

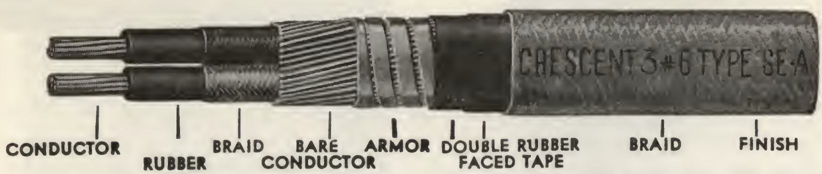
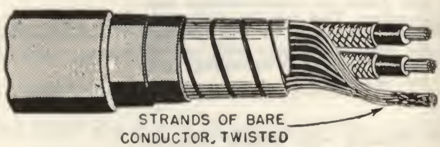


Fig. 7-9. In service entrance cable the neutral wire is not insulated, but is bare, and wrapped spirally around the insulated wires. The picture shows 3-wire cable.

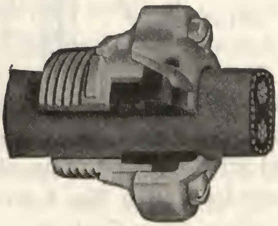
Fig. 7-10. When using the cable, the separate strands of the neutral bare wire are gathered into a bunch making one large wire.



Service Entrance Cable: Service entrance cable is usually used to bring wires into the building. It is illustrated in Fig. 7-9. One of the wires is not insulated and consists of a number of fine wires wrapped around the insulated wires. In use, the small bare wires are twisted together to make one larger wire, as shown in Fig. 7-10. The bare wire may be used only for the grounded neutral. Over the neutral wire there is a flat spiral steel armor, for mechanical protection. In some localities cable is used which does not have this steel tape; both types are approved by Underwriters. Over all comes a fabric braid or outer protective layer. This usually has a painted finish which in turn may be painted to match the building. Use cable with No. 8 wires for a 30-amp. switch; with No. 6 wires for a 60-amp. switch; with No. 2 wires for a 100-amp. switch.

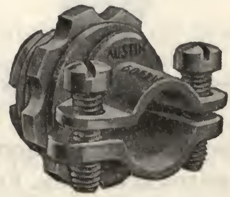
Wherever the cable enters a switch cabinet or a meter socket, it must be securely anchored with a connector. Out-of-doors a weatherproof connector must be used; a common type is shown in Fig. 7-11. The connector consists of a body and a heavy block of rubber, and a clamping nut or cover which presses the rubber against the cable, making a water-tight joint. Indoors a less expensive connector of the type shown in Fig. 7-12 may be used instead. Cable is anchored to the building with straps, one type of which is shown in Fig. 7-13.

At a point where the cable enters the building, steps must be taken to prevent rain water from following the cable into the building. Install a sill plate which is shown in Fig. 7-14, over the cable where it enters the building. Weatherproof compound is furnished with the plate; pack it tightly in all openings between the cable and the sill plate.



← Fig. 7-11. A watertight connector for outdoor use.

Fig. 7-12. An ordinary connector for indoor use. →



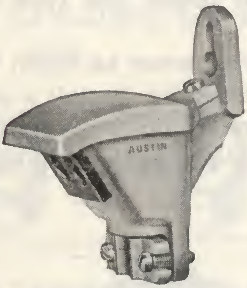
To install service entrance cable, cut a length long enough to reach from the meter socket to the topmost insulator, plus about 3 ft. Remove about two feet of the outer braid and spiral steel tape. Unwind the uninsulated wires from around the cable and twist them into a single wire as was shown in Fig. 7-10. Then install a service head of the general type shown in Fig. 7-15, letting the individual wires of the stripped end project through the holes in the service head. The service head is to prevent rain from entering the top of the cable.

← Fig. 7-13. Entrance cable should be anchored to the building every 2 ft. Use straps of the type shown.

Fig. 7-14. Use a sill plate packed with sealing compound, where cable enters building. It keeps water out. →

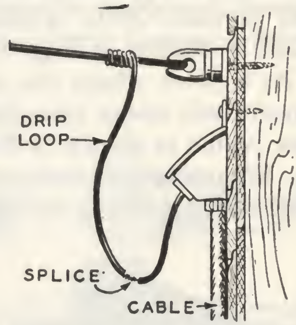
Anchor the service head on the building at least 6 in. above the topmost insulator, so that after the connection has been made to the Power Company's wires, rain will tend to flow away from the service head rather than into it. Sometimes it is not possible to locate the service head above the insulators, in which case be sure to provide drip loops as shown in Fig. 7-16, again to keep rain out of the cable. In connecting the ends of the wires in the cable to the Power Company's wires, solderless connectors of the type that were shown in Fig. 4-16 or 4-17 are often used.

Anchor the bottom end of the cable to the meter socket, and connect the three wires to the terminals in the socket, all as shown in Fig. 7-17, which also shows the next length of cable running to the inside of the building.

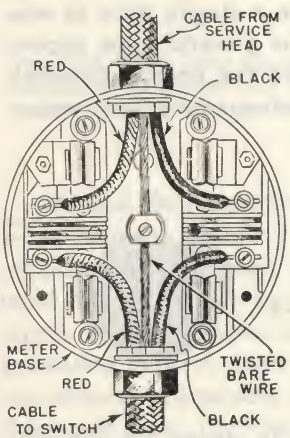


← Fig. 7-15. The service head prevents rain from entering the cable at the cut end. The style shown is for cable.

Fig. 7-16. If insulators are higher than service head, provide drip loop. Splice at bottom of loop. →



Service Entrance with Conduit: Instead of service entrance cable, separate Type R or Type T wire inside conduit may be used. The neutral wire is always white; in some localities bare, uninsulated wire is used. The other two wires are black. For 3-wire service, use ¾-in. conduit with No. 8 wires; 1-in. with No. 6 wires; 1¼-in. with No. 4 or No. 2 wires. The Code permits two insulated No. 4 and one bare No. 4 in 1-in. conduit in a service run if it is not over 50 ft. long and does not have more than the equivalent of two quarter-bends in it.



← Fig. 7-17. How wires are connected to the meter base or socket. The bare, uninsulated wire is always connected to the neutral center contact of the socket.

Fig. 7-18. When entrance wires run through conduit, use entrance cap of this type, and special entrance ell with removable cover, at the bottom. →

Conduit is steel pipe which looks like water pipe, but is different in several important respects. Cut pieces as long as required, thread them, and ream them in the manner outlined in Chap. 11. Attach a service head at the top, similar to that shown in Fig. 7-18 and threaded to fit directly on the conduit. At the point where the conduit is to enter the house, use an entrance ell, one type of which is shown in Fig. 7-18. This has a removable cover which makes it possible to help the wires around the sharp bend while pulling them into the conduit.

The conduit must be securely anchored to the service switch, both to make a good mechanical joint, and to provide a good ground between the switch cabinet and the conduit for grounding purposes. Use a locknut and bushing as outlined in Chap. 11.

After the conduit itself is completely installed, pull the wires into it. For the relatively short lengths involved, the wires can usually be pushed in at the top and down to the meter socket; from there, other lengths are pushed through to the inside of the house. If the conduit is quite long or has bends in it, use fish wire; a length of galvanized clothes line or similar wire will serve the purpose. Push the fish wire into the conduit, attach the electrical wires to it, and pull them in.

Connections at Switch or Circuit Breaker: The switch or circuit breaker has two heavy terminals to which the two incoming "hot" wires are connected. It also has a neutral bar or strap, with one large connector, and a number of smaller terminals. Connect the incoming white neutral wire to the heavy connector on the ground strap; the smaller terminals on the strap are for the neutrals of the individual 115-volt branch circuits, and the ground wire.

Grounding: Every installation of the type covered by this book must be grounded. This is done by running a wire from the incoming neutral wire (from the point where it attaches to the neutral strap in the service switch) to the underground water system which is always in good contact with the earth. The cabinet of the service switch becomes automatically grounded because the neutral wire is attached to it through the neutral strap, which is not insulated from the cabinet. The armor of armored cable, or the conduit of a conduit system, are also automatically grounded because they are also attached to the service switch. The technical reasons for grounding are fairly complicated, but a *good, carefully installed ground connection is absolutely necessary if the completed installation is to be safe.*

Ground Wire: There is no objection to using insulated wire, but bare, uninsulated wire is usually used for the ground, either No. 8 or No. 6.

Fig. 7-19. Armored ground wire. The wire is not insulated.

If No. 8 is used, it must be protected by running through conduit or armor; a common type is shown in Fig. 7-19. If No. 6 is used it does not need to be protected by conduit or armor, but must be attached to the surface over which it runs, staples being used for the purpose. Some inspectors require even No. 6 to be protected by conduit or armor. In any event, keep the ground wire as short as possible.

The ground wire is attached to the water pipe by means of a ground clamp, of which several types are shown in Fig. 7-20. Galvanized iron clamps should be used only with galvanized pipe grounds. That at A is used in connection with armored ground wire of the type shown in Fig. 7-19; the copper wire is fastened under the large terminal screw, and the armor is secured by the clamp provided for the purpose. That at B is similar but larger to accommodate conduit which is sometimes used as protection for the ground wire.

Fig. 7-20. Typical ground clamps for connecting ground wire to water pipe.

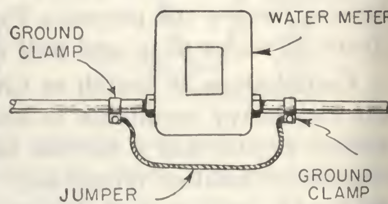


Fig. 7-21. Install a jumper around the water meter.

Water Meters: A jumper should be installed around the water meter as shown in Fig. 7-21. Use two ground clamps and a piece of wire the same size as used for the ground. This prevents the ground from being made ineffective if the water meter is removed; some water meters also have insulating joints.

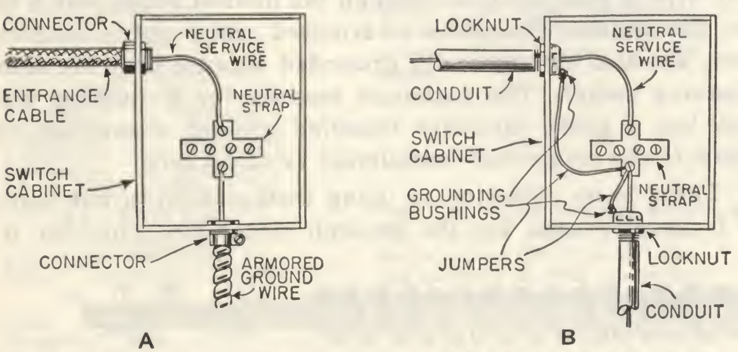


Fig. 7-22. Typical grounding connection, at left when cable is used, at right when conduit is used. Only the white wire is shown.

Fig. 7-23. A grounding bushing.

Grounding Connections at Service Switch: If armored ground wire is used attach it to the switch by means of a connector similar to that shown in Fig. 7-12, but smaller. If conduit is used attach it by means of locknut and bushing. The ground wire proper is connected to the neutral bar of the service switch—the same neutral bar or strap to which the incoming neutral wire is attached.

When service entrance cable is used to bring the incoming wires into the building, the grounding is most simple, as A of Fig. 7-22 shows. Only the white wires are shown in this diagram.

When conduit is used to bring the incoming wires into the building, the Code requires that a grounding bushing (shown in Fig. 7-23) be used instead of the ordinary bushing which is usually used. This grounding bushing has a clamp into which it is necessary to fasten a short piece of wire the same size as the ground wire; the other end goes to the neutral bar or strap. If conduit is used to protect the ground wire, a grounding bushing is also used on that, again with a jumper to the neutral bar of the switch. B of Fig. 7-21 shows the construction.

Artificial Grounds: If there is no underground city water system in the house being wired, a good ground becomes a problem. Proper method of installation is discussed in Chap. 17 concerning farm wiring.

CHAPTER 8

Four Wiring Systems

In residential and farm wiring, four different systems are in common use. They are: (1) Nonmetallic sheathed cable, (2) Armored cable, (3) Knob-and-tube, (4) Conduit.

Which System to Use? Separate chapters will cover the details of each system. Local codes sometimes prohibit one or more of these systems. In general, nonmetallic sheathed cable is the most common, especially on farms. Where there is a city water system for grounding purposes, armored cable is more common. In larger cities cable is often prohibited for *new* buildings, and conduit required instead. The knob-and-tube system is almost unknown in some parts of the country but is extensively used in other parts. Follow local custom. If you are not sure, consult your Power Company, the electrical inspector, or the Project Supervisor in the case of R. E. A. jobs.

Many things are done in the same way regardless of which system is used, and these will be explained in this chapter. *Study them well, for they are the foundation for all systems and will not be repeated later.*

All explanations will be for "new work," or the wiring of a building while it is being built. The basic principles for "old work," or the wiring of a building after it is built, will be covered in a later chapter. There is little difference except that "old work" has more problems of carpentry. Study "new work" well in order to better understand "old work."

Outlet and Switch Boxes: It is not practical to use switches and receptacles fastened to the wall without further protection. Joints and splices in wire and cable, if not given special protection are dangerous. Therefore the Code requires that every switch, every outlet, every joint in wire or cable must be housed in a steel box. Every fixture must be mounted on a box. The boxes are known as switch boxes or outlet boxes, depending on their particular shape and purpose. Most boxes are of metal with a galvanized finish and these may be used anywhere. Those with a black enamel finish are little used today and may be used only indoors. R. E. A. requires galvanized finish.

Nonmetallic Boxes: Boxes made of bakelite, porcelain or other insulating materials are becoming quite common, especially for farm use. They may be used only with nonmetallic cable or knob-and-tube wiring. See Chap. 17.

Switch Boxes: Every switch and receptacle must be housed in a box; the most common is the type shown in Fig. 8-1. Note the small holes used to nail the box to the studding. There are also mounting brackets on each end so that the box can be mounted on wooden or similar supports. There are two "ears" with tapped holes for screws to hold switches and similar devices mounted in the boxes. The Code requires that such boxes must have a depth of at least 1½ in.; the deeper ones (from 2¼ to 2¾ in. in depth) are handier and more generally used.

A switch box is usually considered the handiest type of box for mounting fixtures of the wall bracket type. Locate one at each point where a wall bracket is to be used.

Each box holds one switch, receptacle or similar device. When two or more switches are to be mounted side by side, two or more boxes can be changed into one "2-gang" or larger box by simply throwing away one side of each box and fastening the boxes together, as Fig. 8-2 shows.

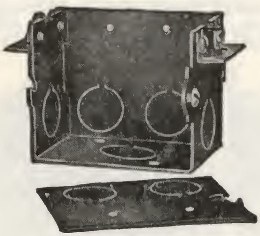


Fig. 8-1. A typical switch box, used to house switches, receptacles, etc. The sides are removable.

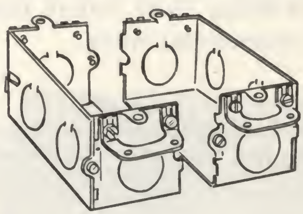


Fig. 8-2. Two single boxes are easily changed into one larger "two-gang" box. Still larger boxes of 3 or 4 or more gangs are made the same way.

Knockouts: Wires and cables must be brought into the box. For this purpose, "knockouts" are provided; these are sections of metal sufficiently loosened so that they can easily be removed to form openings. These sections are knocked out by placing a screwdriver at the proper point and striking it a stiff blow. In many cases "pry-outs" are provided—these are knockouts, each with a narrow slot punched into it. Place a screwdriver into the slot, twist out the pry-out.

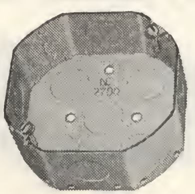


Fig. 8-3. The common octagonal box.

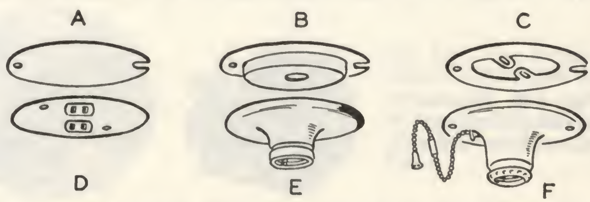


Fig. 8-4. Every outlet box must be covered. Above are shown the more common covers.

Outlet Boxes: Fig. 8-3 shows the most common outlet box. It is octagonal in shape and comes in two sizes: 4 and 3¼ in. The larger box is the more common, being much handier because it is more roomy, which permits more wires to be used, does away with cramping, and in general speeds up the work. All boxes are required by Code to be at least 1½ in. deep if used for "new work."

Outlet boxes must always be covered. A great many different covers are available and common ones are shown in Fig. 8-4. At A is shown a blank cover used when a box is merely used to hold a splice or tap. At B is shown a drop cord cover; the opening for the drop cord is fitted with a smooth bushing to eliminate sharp edges. At C is shown a spider cover used to mount surface-type switches. At D is shown a cover with a duplex receptacle. At E is shown a keyless receptacle for a bulb and at F a similar one with a pull-chain. Many other styles are available.

Other Outlet Boxes: Boxes 4 in. square are sometimes used, having the advantage of being more roomy than the octagonal variety. They are used mostly for commercial work.

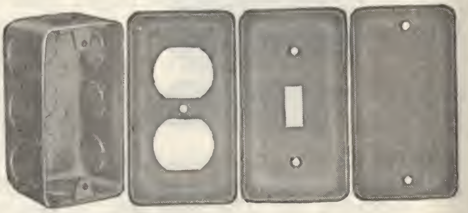


Fig. 8-5. The box at right is known as a "utility box" or "handy box." Use it for permanently exposed wiring on the surface, as in basements, garages, etc. Neither the box nor the covers have sharp corners.

If an ordinary switch box is mounted on the surface of a wall, as in a garage or barn, the sharp corners on both the box and plate are quite a nuisance. In such locations use a box with rounded corners, known as a "utility-box" or "handy-box." This box is shown in Fig. 8-5 with suitable covers for switches and receptacles.

Connectors: When cable of any style is used for wiring, the Code requires that it be securely fastened to each box where it enters the box. There are many kinds of connectors for this purpose; an assortment of them is shown in Fig. 8-6. The connector at A is used for ordinary purposes, that at

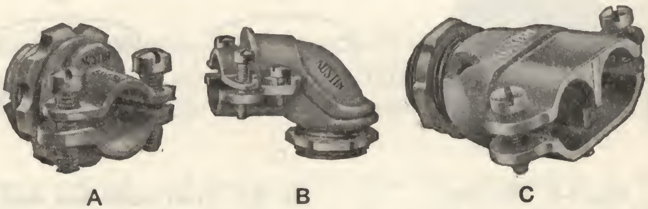


Fig. 8-6. Connectors used in anchoring cable to boxes.

B for a sharp 90° turn and that at C when two pieces of cable must enter the same knockout. The connector is first fastened to the cable, then slipped through the knockout, and the locknut then driven home solidly on the inside. See Figs. 8-7 and 8-8.

Some boxes have built-in clamps that securely hold the cable entering the box, so that separate connectors don't have to be used. Typical boxes of this kind are shown in Fig. 8-9.

Fig. 8-7. The connector is first attached to the cable by means of a set screw.

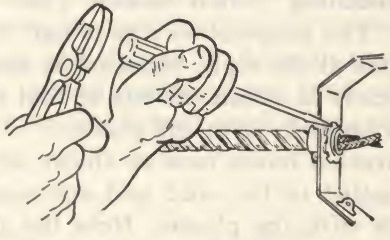


Fig. 8-8. The connector is anchored to box by means of locknut inside the box.

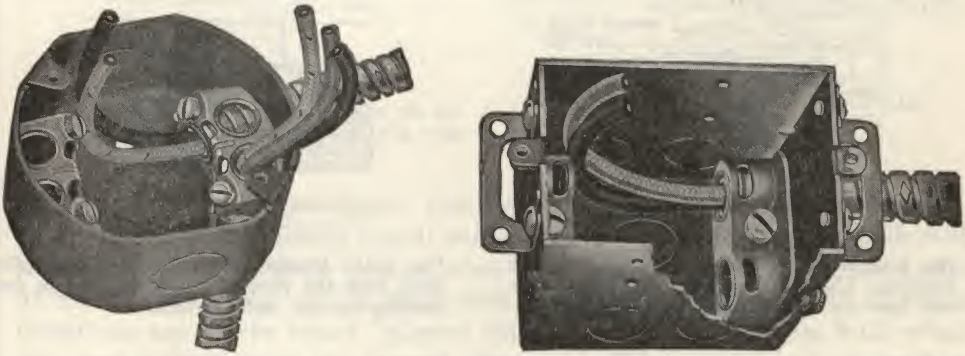
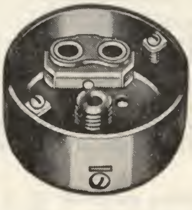


Fig. 8-9. When using boxes of the type shown above, separate connectors are not used. The boxes have clamps to hold the cable.

Round Boxes: Instead of using boxes which are octagonal or square, round boxes may be used instead, if preferred. A typical one is shown in Fig. 8-10. Such boxes nearly always have cable clamps because connectors

Fig. 8-10. Round boxes are preferred by some, especially in old work or the wiring of buildings after they are completed.



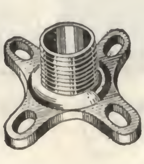


Fig. 8-11. The fixture stud shown is mounted in the bottom of the box by means of stove bolts. The stud later supports the fixture.

(or locknuts and bushings for conduit) cannot be used on a rounded surface but only in the flat bottom.

Fixture Studs: A fixture stud is shown in Fig. 8-11. Mount one in the bottom of the box with stove bolts, if a fixture is later to be installed on that particular box. This is unnecessary if a hanger described a little later is used to support the box. Some styles of boxes, as for example the one shown in Fig. 8-10, have a fixture stud as a permanent part of the box.

Mounting Switch Boxes: There are many ways of mounting a switch box. The simplest way is to nail it to one of the studs, if there happens to be one at the right location, as shown in Fig. 8-12. The important point to watch is to mount the box so that after plastering, the front edge of the box will be flush with the plaster.

Bracket boxes used as shown in Fig. 8-13 are much handier. The bracket is nailed to the stud and automatically brings the front edge of the box flush with the plaster. Note the trough which supports the ends of those laths which end at the box. Projections on the bracket hold the plaster.

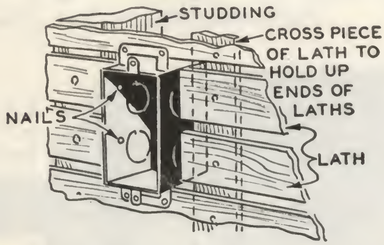


Fig. 8-12. Switch boxes may be nailed to the studding. Use care so that the front edge will later be flush with the plaster.

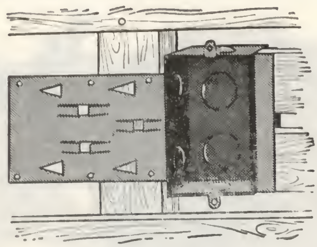


Fig. 8-13. Bracket boxes are automatically flush with the plaster. Note the trough for holding up the ends of lath.

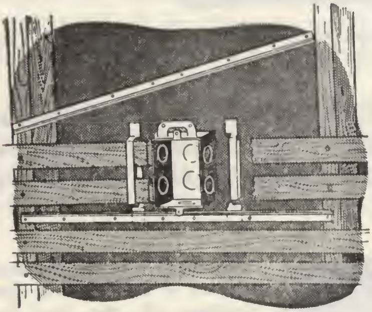


Fig. 8-14. Metal mounting strips permit one or more boxes to be mounted between studs.

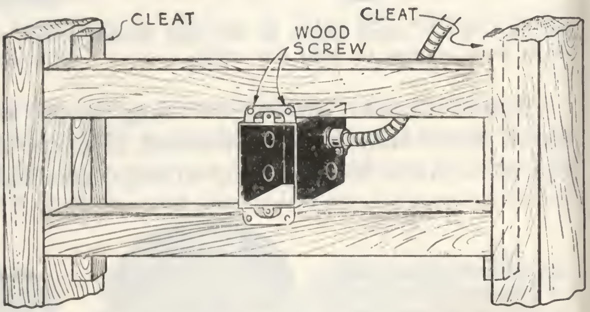


Fig. 8-15. Wooden strips may also be used to support boxes, if the strips are at least ⅞th in. thick.

If the box is to be mounted between studs, mounting straps are necessary. The ready-made steel straps shown in Fig. 8-14 are handy and accommodate not only a single box but a 2-, 3-, 4- or 5-gang box as well. Strips of wood may be used as shown in Fig. 8-15; the Code requires them to be at least ⅞-in. thick and rigidly mounted.

Mounting Outlet Boxes: The simplest way of mounting an outlet box is to use an offset hanger of the type shown in Fig. 8-16. If a plain hanger is used which does not have the fixture stud shown in the picture, fasten the outlet box to it by means of stove bolts. More usually, a hanger with the fixture stud is used. To attach a box, remove the center knockout in the bottom, slip the fixture stud into this opening, and tighten the locknut over the fixture stud, inside the box. The hanger is then nailed to the joists of the building, and later a fixture is mounted on the fixture stud, all as shown in Fig. 8-17.

Fig. 8-16. An offset bar hanger.

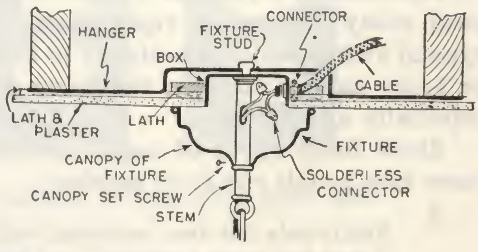


Fig. 8-17. The fixture is supported on the fixture stud. The stem of the fixture fits the stud.

Hangers come in two types: shallow and deep. Use the shallow type for all wiring except conduit; it will bring the front edge of the box flush with the plaster. Use the deep variety when wiring with conduit. The front edge of the box will then not be flush with the plaster, but below it; therefore install on top of the box a "plaster ring" cover, shown in Fig. 8-18, which will then be flush with the plaster. Plaster rings are available only for 4 in. octagonal or square boxes. The opening in the ring however is the same as that of a 3¼ in. box so 3¼ in. covers must be used with it. Instead of a hanger, a wooden mounting board may be used. It must be at least ⅞-in. thick and is installed as shown in the two views of Fig. 8-19.

Fig. 8-18. A plaster ring, used with conduit wiring.

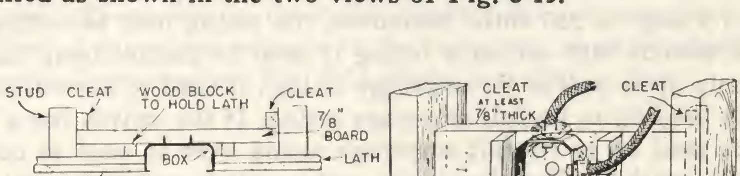


Fig. 8-19. Wooden mounting strips may also be used for supporting outlet boxes. The strips must be at least ⅞th in. thick.

Wiring at Boxes: Regardless of the particular system used, let from 6 to 8 in. of wire stick out at each box. Any extra length can easily be cut off, but if the wires are too short it is impossible to do good work.

Location of Switch Boxes: Boxes for switches should be located near doors, so that they can be easily found as the door is opened; consider which way the door is to swing. The right height is about 48 in. above floor level. Switch boxes for receptacle outlets are usually located a few inches above the baseboard. Don't locate them in the middle of a long wall, for then they are frequently hidden behind a davenport or other large piece of furniture. It is much more sensible to locate them near a door or near the end of a wall where it is easy to get at them, not only for floor lamps and radios but also for vacuum cleaner.

Selection of Switches: The old-fashioned push-button switch is seldom used today except for replacements in old installations. Use the toggle type of switch which was shown in Fig. 2-1. You will have a choice of brown or ivory colored handle; the ivory is fast growing in popularity as it is especially attractive.

Since three types of toggle switches are in common use, you should learn how to tell one from another.

Single-pole has two terminals, and the words ON, OFF on handle.
3-way has three terminals, and plain handle without ON, OFF.
4-way has four terminals, and plain handle without ON, OFF.

Mercury Switches: Ordinary switches make a distinct sharp noise when they are turned on and off. This noise may bother sick people, wake the baby and certainly does annoy everybody. A special type of switch which looks just like an ordinary switch (but operating on the mercury-contact principle) is absolutely silent in operation. It costs more, but discriminating people are willing to spend the difference to secure complete absence of noise.

T Rating: The usual toggle switch is given a double rating by the Underwriters, so that it can be used either up to 10 amp. at 115 volts, or up to 5 amp. at 230 volts. Moreover, the rating may be ordinary or "T" type. A switch with ordinary rating if used to control lamp bulbs may be used only up to *half* of its amperage rating; if used to control other devices may be used up to its full amperage rating. If the switch has a T rating, it may be used up to its *full* amperage rating even if used to control bulbs. The type with the T rating is the better switch, and is the only type permitted by the R. E. A. for farm use. T-rated switches cost so very little extra that they should be used generally. All approved switches have the words "Und. Lab. Insp." stamped on the metal strap. The ones with ordinary rating are marked "10 A 125 V-5 A 250 V," while those with the T rating have the letter T after the rating so that it reads "10 A 125 V-5 A 250 V-T."

Wall Plates: Typical plates are shown in Fig. 8-20; they are available in plastic, brass, glass and other materials. The plastic is by far the most popular type today, and comes in a choice of brown or ivory color, the latter being especially attractive. Use the kind you like best.

For two or more switches or similar devices used side by side, use a 2-gang or larger plate of the type shown in the same picture. It is hard to find 3-gang and larger plates in dealers' stocks, especially in odd combinations, but there is available a type of *single-gang* bakelite plate so made

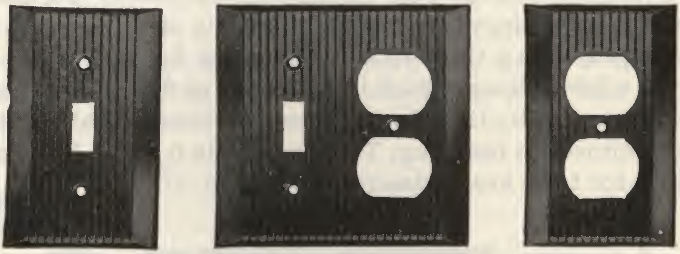


Fig. 8-20. Every switch and receptacle must be covered with a switch plate.

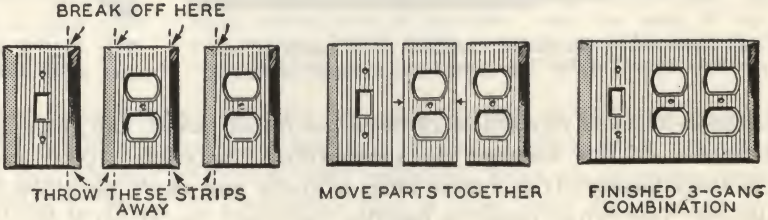


Fig. 8-21. A style of plate which makes it possible to make 2-gang or larger plates in any desired combination, out of single plates.

that a strip can be easily broken off either side. Two separate plates, each with one strip broken off, are exactly the right size to make a 2-gang plate. Plates of any number of gangs can be made in the same way, in any desired combination no matter how unusual. Fig. 8-21 shows how this is done.

CHAPTER 9

Nonmetallic Sheathed Cable

Nonmetallic sheathed cable costs less than other kinds of cable in common use, is light in weight and very simple to install; no special tools are needed. That makes it very popular. The Code recommends it for all locations where an especially good ground connection is *not* found. That makes it the only type of cable used for farms, although its use is quite general for other locations, too. It may be used only indoors. It is quite simple in construction as Fig. 9-1 shows. It consists of two (or three) Type R or T wires, each wire wrapped with a thick spiral paper tape for additional protection. Over all comes a fabric braid which is saturated with moisture-resistant and fire-retardant compounds; it will not support a flame. Finally comes a layer of wax for cleanliness in handling. The Code calls it Type NM cable. (Type NMC, required for farm use, is described in Chap. 17.)

Fig. 9-1. Code Type NM nonmetallic sheathed cable contains two or three Type R or Type T wires. The outer braid is easily removed.

Fig. 9-2. A cable ripper saves time.

Only a jack-knife is needed to remove the outer cover. Cut a slit parallel with the wires; do not damage the insulation. The cable ripper shown in Fig. 9-2 is very handy; it is faster than a knife and can't possibly damage the insulation. The outer cover is usually removed for about 8 in.

Installation: Do not bend cable sharply or you may damage the outer fabric cover. The Code says that all bends must be gradual so that, if continued in the form of a complete circle, the circle would be at least 10 times the diameter of the cable. Cable must always run in continuous lengths from box to box—no splices except inside boxes.

Cable must be fastened to the surface over which it runs every 4½ ft., also within 12 in. of every box. Straps of the general type shown in Fig. 9-3 are used for the purpose. *Do not use staples of any kind because you will damage the cable by hitting staples too hard.*

If the cable when the job is finished will be concealed, rather than exposed, there are no restrictions as to how it is to run. It may follow the side of a stud or joist, anchored as above outlined, or at right angles to such timbers through bored holes.

If the finished wiring is exposed (as, for example, in basements), see to it that the cable is protected against later mechanical injury. The easiest way is to run it along the side of a stud or joist. If run at right angles to such timbers (unless the cable runs through bored holes) a running-board must first be installed as shown in Fig. 9-4. The Code is not specific as to the size of this running-board but the so-called "1 by 2" is fine for the purpose. The cable may never be run across free space, must follow the surface of the building except when mounted on running-boards. In unfinished basements, it may be run through bored holes through the centers of joists (cables No. 8-3 or 6-2 or heavier may be mounted directly on the bottoms of joists without a running-board.) In accessible attics, cable may run at an angle to joists if protected by guard strips at least as high as the cable, as shown in Fig. 9-5; a running-board costs less and takes less time to install.

Fig. 9-3. Support cable at least once every 4½ ft. Use straps shown.

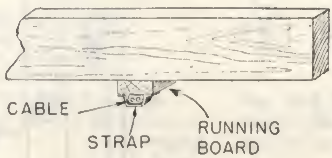


Fig. 9-4. Exposed cable running across timbers must be protected by a running board, which prevents damage.

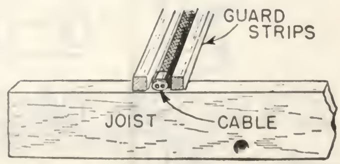


Fig. 9-5. In attics, guard strips may be used. If run through bored holes, the cable needs no further protection.

Plan the Installation: Before you can do any actual wiring, you must make a plan. Decide upon the location of each outlet, each switch. Be generous in the number of outlets and switches; plan an *adequate* installation as described in Chap. 2; remember that it costs very much more to add an outlet later, than it does to include it in the original job.

Which Outlets on Which Circuit? Your first idea may be to put all the outlets of your basement on one circuit, all the outlets of the first floor on the next circuit, those of the second floor on still another circuit, etc. If you do that and a fuse blows, what happens? An entire floor will be dark. Put different parts of any floor on two different circuits; then at least part of each floor will still be lighted even if the rest of that floor is dark.

After you have decided which outlets are to go on each circuit, draw a diagram of each circuit; show how the cable is to run from one outlet to the next, from outlet to switches, and so on. A typical diagram of this kind is shown in Fig. 9-6 which shows 8 outlets, plus 3 single-pole switches and a pair of 3-way switches. The outlets have been labeled A, B, C, D, E, F, G, and H. Switches have all been labeled S, that controlling outlet B being indicated as S-B, that controlling outlet G as S-G, that for outlet H as S-H, and the two 3-way switches controlling outlet F as S-F-1 and S-F-2.

This diagram still does not tell you how to connect up the wires inside the cable, so that all the parts will work properly. Draw a second diagram and forget that *cable* is being used; show the wires separately just as if they were open wires. Fig. 9-7 shows the same outlets as Fig. 9-6, and each outlet has been labeled the same as in Fig. 9-6. Note that the same scheme has been used as in Chap. 6: a light line like this ——— for a white wire, a heavy line like this ——— for a black wire (or other color, but not white), and a heavy broken line like this — — — for the black wire (or other color, but not white) between a switch and the outlet it controls.

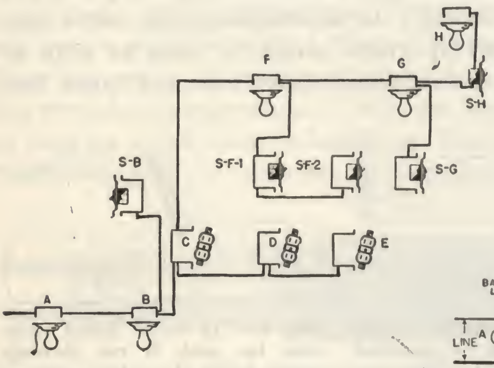


Fig. 9-6. Before proceeding to do any wiring, make a rough layout showing where each outlet is to be located, and how cable is to run from box to box.

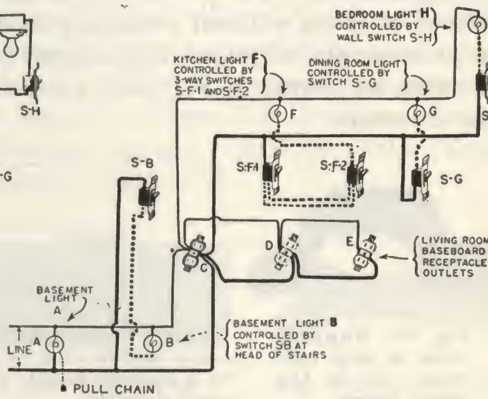


Fig. 9-7. The same outlets shown in Fig. 9-6, but now showing how the wires inside the cable are connected. In due course of time, you will be able to get along without the plans.

In the diagram of Fig. 9-7 you will see that outlet A (if you disregard the cable that runs on to B) is the same as the outlet shown in Fig. 6-3 in Chap. 6, and no detailed explanation is necessary. However, Fig. 9-8 shows the appearance of this outlet completely installed with an outlet box. You have followed the principles you learned in Chap. 6. You have run the white wire from SOURCE to the outlet; you have run the black wire from SOURCE to the outlet.

To better understand the wiring of each additional outlet, consider the cable that runs to it *from the previous outlet,* as the SOURCE for the new outlet. For example, the cable that runs from outlet A to outlet B becomes the SOURCE for outlet B.

In Fig. 9-9, outlet B (if you disregard the cable running on to C) is the same as that in Fig. 6-5, so a detailed explanation may seem entirely unnecessary. However, according to everything you have learned up to this point, and as shown in Fig. 9-7, *both* wires from outlet B to switch S-B should be *black,* and the 2-wire cable that you are going to use contains one black and one white wire. How then can you comply with the Code? The Code in Sec. 2006b makes an exception to the general rule; when wiring with cable (whether nonmetallic or armored) it permits a white wire to be used **where** a black wire *should* be used—but *only* in a switch loop, that is, the **cable** running from an outlet to a switch. It is easy to make the right **connections** if you remember that each fixture *must* have one white and one black **wire**

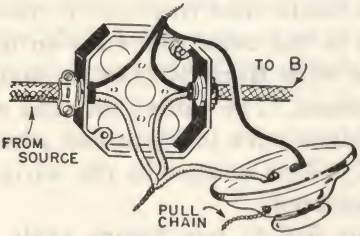


Fig. 9-8. Outlet A of Figs. 9-6 and 9-7, completely installed. The wiring is the same as was shown in Fig. 6-3.

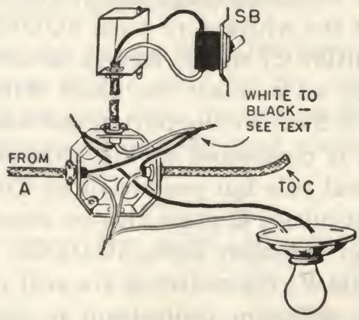


Fig. 9-9. Outlet B of Figs. 9-6 and 9-7: an important diagram. It shows how to connect white wire in cable to switch.

connected to it, and if you observe the following simple steps:

1. At the switch, connect the two wires of the cable to the switch.
2. At the outlet, connect the white wire from SOURCE to the fixture, as usual.
3. At the outlet, connect the *black* wire from SOURCE, to the *white* wire of **the** cable that runs to switch; this is contrary to the general rule, but permitted **by** the Code's exception. This is the only case where a white wire may be connected to a black wire.
4. Connect the black wire of the cable that runs to the switch, to the **fixture as** usual.
5. The two wires running on to the next outlet are connected to the two **incoming** wires (from SOURCE) in the outlet box—black to black, and white to **white**.

When outlet B is properly installed according to these simple rules, it will be connected as shown in Fig. 9-9, which complies with Code **Sec. 2006b**.

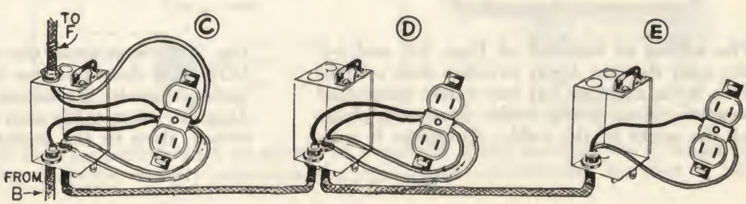


Fig. 9-10. Receptacle outlets are easy to connect, as this diagram shows.

Outlets C, D, and E are very simply wired as shown in Fig. 9-10. Receptacles have double terminal screws so that the two wires from two different pieces of cable can easily be attached as shown. In the case of C, it is necessary to connect three different wires to the receptacle, so connect two of them under one terminal screw.

Outlet F in Fig. 9-7 (if you disregard the cable running on to the next outlet G) is the same as Fig. 6-14 in Chap. 6. Run 2-wire cable from the outlet to the first 3-way switch S-F-1, and 3-wire cable from there to the second 3-way switch S-F-2. Again we meet the problem of the proper colors of wire. Remembering the steps outlined in connection with outlet B, simply connect the white wire from SOURCE (which in this case is the white wire from outlet C) to the fixture as usual. The other wire on the fixture *must* be black, so connect the black wire of the cable that runs on to the first switch S-F-1. At the outlet, the white wire in the cable that runs on to the switch, is connected to the incoming black wire from SOURCE, contrary to general rule but permitted by Code exception. The cable that runs on to the next outlet G must also be connected; black wire to black and white to white, of the cable from SOURCE (from C). This completes the wiring of the outlet F; the switches are still to be connected.

Two different cables end in the box for S-F-1: one 2-wire cable, one 3-wire cable, five wires altogether. Two of them are white; splice them together so that there will then be a continuous white wire from F to S-F-1 to S-F-2, where you connect it to the common or marked terminal of that switch. Connect the black wire in the cable between F and S-F-1 to the

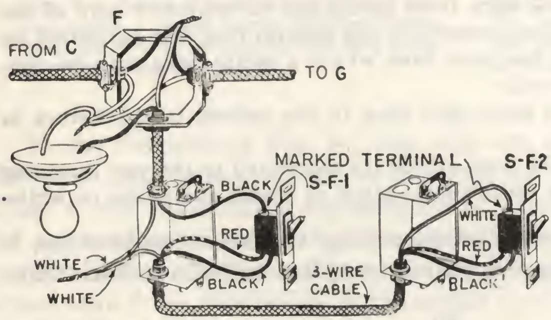


Fig. 9-11. The wiring of outlet F of Figs. 9-6 and 9-7 is shown here, with the two 3-way switches that control the outlet. This is the diagram for any outlet controlled by 3-way switches, when using cable. Study carefully the colors of the wires in the cable. Compare it with Fig. 6-14.

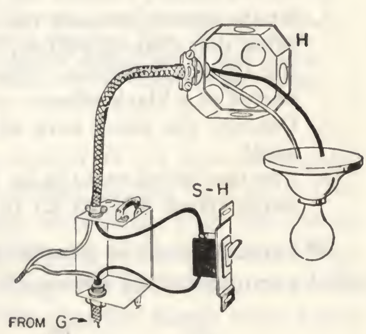


Fig. 9-12. Sometimes the cable from SOURCE does not run first to the outlet, then to the switch. Use this diagram when cable runs first to the switch, then to the outlet.

common or marked terminal of the first switch S-F-1. That leaves two unconnected wires in the cable from S-F-1 and S-F-2: the red and the black. Connect them to the remaining terminals of each switch; it does not matter which color goes to which terminal on the switch. That finishes the wiring which is shown in Fig. 9-11.

Outlet G is exactly the same as outlet B; wire it in the same way.

Feed Through Switch Box: In all the outlets wired so far, the cable ran first to the outlet box and fixture, then on to the switch. When you come to outlet H of Fig. 9-7, you will see that the cable runs first to the switch box S-H and then on to outlet H. This combination is even simpler to wire than the others, for there is no problem with the colors of the wire, as you can see from Fig. 9-12, which pictures this outlet completely wired.

Outlets Beyond H: Additional outlets can *not* be installed beyond H by simply attaching the black and white wires of the cable for the new outlet, to the black and white wires in outlet H, because then the new outlet would be turned on and off by switch S-H. However, an additional outlet can be

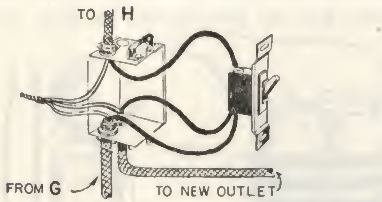


Fig. 9-13. One method of adding an outlet beyond an existing outlet.

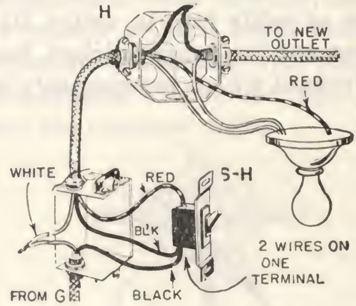


Fig. 9-14. Another method of adding an outlet beyond an existing outlet.

added by tapping in at the switch S-H; splice the wires of the cable for the new outlet, to the incoming cable from G, as shown in Fig. 9-13. Another way is to run 3-wire cable from S-H to H; splice the two wires in the cable for the new outlet, to black and white in H, as shown in Fig. 9-14.

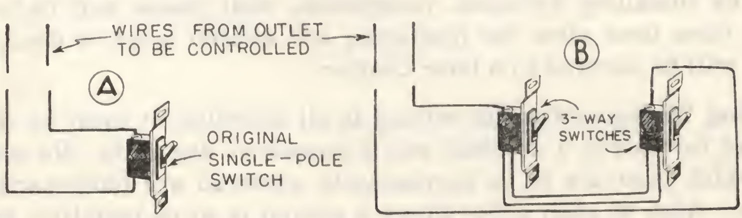


Fig. 9-15. It is a simple matter to substitute a pair of 3-way switches for a single-pole switch, in any wiring diagram. Simply substitute the right-hand combination for that at left.

A cable to any additional outlet can be spliced to any existing cable in any outlet box by splicing white to white, black to black, *if each wire can be traced all the way back to SOURCE without interruption by a switch.*

Substituting 3-Way Switches for Single Pole: It is a very simple matter to substitute a pair of 3-way switches for a single-pole switch, in any wiring diagram. Study Fig. 9-15—the starting point is an outlet already wired with two wires ready for a switch. If a single-pole switch is to be used, connect it to the two ends of the wires as at A. If a pair of 3-way switches is to be used, substitute the combination of B.

If you want to add a switch to a diagram which shows an outlet permanently connected, without a switch, cut the black wire. That gives you two ends of black wire to which the switch connects, or two ends to which you will splice the 2-wire cable which runs to the switch.

Junction Boxes: Sometimes it is necessary to make a T connection in cable, when there is a long run and no convenient outlet from which to start the T branch. In that case, use an outlet box, run the three (or more) ends of cable into it, splice all black wires, all white; cover with a blank cover, and the job is finished. See Fig. 9-16. Such junction boxes must always be located *where permanently accessible.*

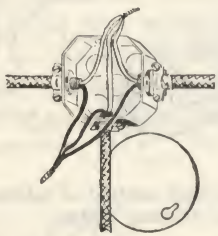


Fig. 9-16. A junction box contains only the splices of several lengths of cable.

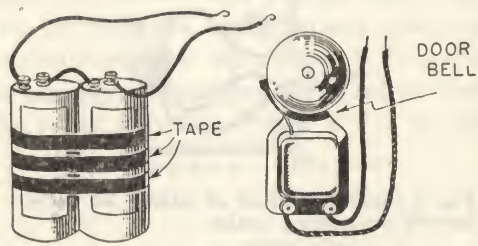


Fig. 9-17. To test the finished wiring, all you need is a doorbell and a couple of dry cells.

Completing the Wiring: Since at the moment we are studying the wiring of a building *while it is being built,* we can't at this stage finish the wiring by installing switches, receptacles, wall plates and fixtures. This work is done later after the plastering and similar work is done, and how to do it will be covered in a later chapter.

Testing Wiring: After the wiring is all installed, it must be tested. All you need for this is a doorbell and a couple of dry cells. Be sure all the wires which later are to be permanently soldered are temporarily twisted together. Also, at each point where a switch is to be installed, have all of those wires to which a switch is later to be connected, touch each other, just as if the switch were there and in the ON position. Do not, however, twist them together too securely, for then the ends of the wires will be badly bent and twisted and it will be hard to connect the switches later.

When you have done all this, connect two dry cells in series as shown in Fig. 9-17, leaving a hook on the end of each wire. Hook these ends of wires across the wires of the cable where they attach to the fuse cabinet (or circuit breaker). You will then have 3-volt current in your line, where you later will have 115-volt current. Touch the doorbell across each pair of wires at the various outlet boxes where a fixture or a receptacle outlet is later to be connected; if the wiring is o.k. the bell will ring. If the outlet in question is controlled by a switch, the bell should stop ringing when the two wires, where the switch is later to be connected, are separated. If everything checks, the wiring is properly done and you are ready to install switches, receptacles and fixtures as outlined in a later chapter.

Cable with Ground Wire: In a few localities a special type of nonmetallic sheathed cable is used. In addition to the usual wires it contains another bare, uninsulated wire. Thus 14-2 cable of this type has two insulated wires plus one bare wire. If this type of cable is required in your locality, use it in the usual way but connect the bare wire solidly to each metal box. It may be clamped under the locknut of the connector, or if boxes with clamps are used, under one of the screws holding the clamps. If you use this type of cable, test as described in the next chapter for armored cable.

CHAPTER 10

Armored Cable

Armored cable is quite simple in construction as Fig. 10-1 shows. The wires are the ordinary Type R or Type T; they are wrapped in a spiral layer of tough kraft paper. The galvanized steel armor is strong and tough but quite flexible. Armored cable may be used only in permanently dry loca-

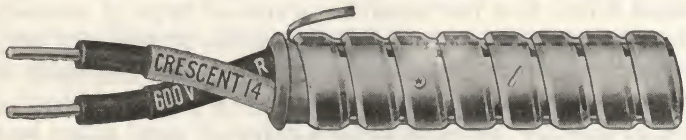


Fig. 10-1. Armored cable consists of two or three Type R or Type T wires, protected by a layer of tough paper and flexible galvanized steel armor.

Fig. 10-2. Staple for cable.

tions; it can't be used outdoors. Like nonmetallic sheathed cable, it must be supported every 4½ ft. and also within 12 in. of every box. It may be fastened with straps similar to those used with nonmetallic cable, but staples shown in Fig. 10-2 are more frequently used; drive them home with a hammer. The armor of the cable prevents damage. Avoid sharp bends in cable; the Code says that the bends must be such that, if completed into the form of a complete circle, the circle would be at least 10 times the diameter of the cable.

Cutting Cable: Use a hacksaw and hold it in the position shown in Fig. 10-3. Note that the blade must be almost at right angles to the strip of

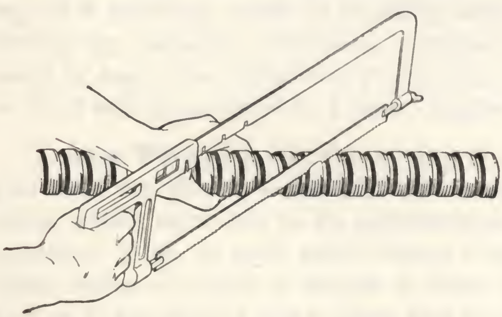


Fig. 10-3. Note the proper angle of the blade in sawing armored cable. Be careful not to damage the wires.

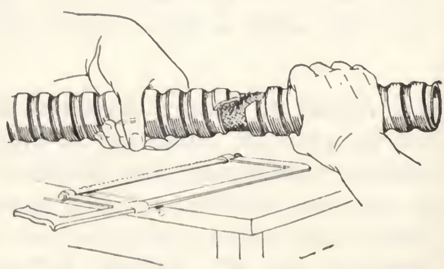


Fig. 10-4. A twist will remove the cut end of the armor. Let about 8 in. of wire stick out beyond the armor.

armor, rather than to the cable itself. Be very careful so that the saw goes only through the armor and does not touch the insulation of the wires. This is not too easy and if you have not had experience, make some practice cuts on odd pieces of cable before proceeding to do wiring. Usually bending the cable at the point where it is to be cut is helpful in sawing. Actually it is difficult to saw completely through only a single turn of armor, but usually if the center part of the strip is sawed completely through and the edges partly through, a sharp bend will break the armor. A sharp twist on the two pieces of armor as shown in Fig. 10-4 will remove the short end. The cut should be made about 8 in. from the end of the piece, so that you will have plenty of wire in the box for connections.

Bushings: Cut a length of cable, examine the cut end of the armor; you will find sharp jagged edges on the armor, pointing inward toward the wire. These teeth tend to puncture the insulation of the wire and cause short circuits and grounds. The Code requires that a bushing of tough fiber must

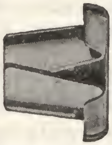


Fig. 10-5. Always use a fiber anti-short bushing shown at left, at the end of the cable, between wires and the armor. It provides protection against the sharp edges of the armor, which might puncture a wire and cause a ground, or a short-circuit.

be inserted at the end of the cable, between the steel armor and the wires. Such bushings are supplied with the cable and Fig. 10-5 shows one of them.

At first you may find it hard to insert the bushing because there is so little room under the armor; the paper wrapped around the wires is in the way. So, you must make room for the bushing. First unwrap the paper a few turns *under* the armor, then give it a sharp yank and it will tear off *under* the armor, all as shown in Figs. 10-6 and 10-7. Then insert the bushing, as

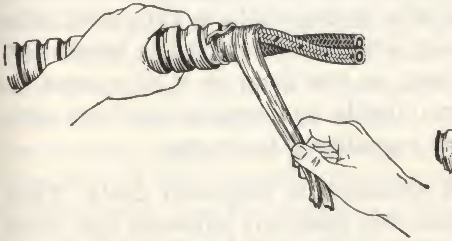


Fig. 10-6. In removing paper, first unwrap a few turns inside the armor.

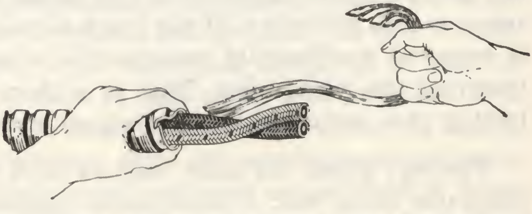


Fig. 10-7. A sharp yank tears off the paper *inside* armor, makes room for the bushing.

shown in Fig. 10-8. Figure 10-9 shows a cross-section of a piece of cable with the bushing properly inserted.

Connectors: Immediately after inserting the bushing, install a connector on the cable as was shown in Chap. 8 in the steps of Figs. 8-7 and 8-8 (unless you are using boxes with cable clamps, which make the use of connectors unnecessary). The connectors used with *armored* cable are almost the same as those used with *nonmetallic* sheathed cable except that they must be what is known as the visible type. At the end which goes inside the box, there are "peep-holes" through which the red color of the bushing can be seen; this allows the inspector to see that the bushings have been used. If you do not use the bushings, your job will not be passed by the inspector.

Fig. 10-8. Insert the bushing between wires and armor.

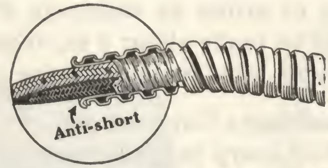


Fig. 10-9. A properly-installed bushing.

Using the Cable: After you have prepared the ends of the cable with bushings and connectors, install the cable in the same way as described for nonmetallic sheathed cable in the previous chapter. The problems concerning correct colors of wire are exactly the same as with nonmetallic sheathed cable. As with nonmetallic cable, splices are not permitted; the cable must be in one piece from box to box. If a splice is necessary, make it in a junction box as shown in Fig. 9-16.

Be specially careful in anchoring the connectors to outlet and switch boxes. The connector must be tightly clamped to the armor of the cable; after inserting the connector into the knockout of the box, the locknut must be driven down tightly enough to bite down into the metal of the box. This makes a good electrical connection through the armor from box to box, so that current can flow through the armor from box to box. This happens only in case of accidental grounds. The white wire in the cable is grounded; the armor is also grounded. If the black wire at some point where the insulation is removed accidentally touches the armor or the box, it is the same as touching the white wire. That is a short circuit and causes the fuse protecting that circuit to blow, a signal that something is wrong.

Testing: Make the same tests as with nonmetallic sheathed cable. Then make one more test: at each outlet connect the doorbell between the black wire and the box itself. If black enameled boxes are used, scrape a little of the enamel off the box at the point where you touch the wire from the bell to it. The bell should ring, because touching the bell to the box is the same as touching it to the white wire, for both are grounded. It will not ring as loudly as when touched to both wires, but it should still ring. If it does not, go around and tighten up locknuts on the connectors.

CHAPTER 11

Conduit

There are two different types of conduit. The original type is known as rigid conduit. The newer type is known as thin-wall conduit; the Code calls it Electrical Metallic Tubing (EMT). The rigid type will be described first, and later in the chapter the thin-wall type will also be discussed.

Dimensions: Rigid conduit, size for size, has the same dimensions as water pipe, therefore the same tools are used for cutting or threading. Standard sizes are known as ½, ¾, 1, 1¼, and 2 in. Still larger sizes are used mostly in commercial work. The actual inside diameter is a little larger than the trade size indicated above.

Fig. 11-1. Rigid conduit looks like water pipe but differs in several important respects. It comes only in 10-ft. lengths and each length bears the Underwriters' label.

Conduit differs from water pipe in several ways. It is much softer so that it bends easily; it is carefully inspected to make sure that it is entirely smooth inside to prevent damage to the wires as they are pulled into the pipe; it has a rust-resistant finish both inside and out. The finish may be either galvanized or black enamel. The galvanized is by far the better and has gradually become the commonly used type. The black may be used only indoors. Each length bears an Underwriters' label.

Bending Conduit: If conduit is bent sharply, it will collapse; it must be bent in such a way that the internal diameter is not reduced at the bend. The Code says that the bend must be gentle and gradual, so that if continued into the form of a complete circle, the circle would be at least 12 times the inside diameter of the conduit. If lead cable is to be pulled into the conduit, the diameter of the circle must be at least 20 times the inside diameter of the conduit. Special bending tools are available which make bending easy, but for occasional jobs special tools are not necessary. Bend the conduit around any solid round object such as a post, a keg, or similar object. Factory-bent elbows are also available.

Cutting Conduit: Cut conduit with a pipe cutter or hacksaw. This will leave a sharp edge at the cut which might damage the insulation of the wires as they are pulled into the conduit. You must ream the inside of each cut end to remove these sharp edges. Thread with the same tools used for water pipe.

Installing Locknut and Bushing: Conduit is attached to a box by means of a locknut and bushing, both of which are shown in Fig. 11-2. Their use is made clear from Fig. 11-3 which shows how the locknut is used on the outside of the box, the bushing on the inside. The locknut is not flat, but has teeth on one side; the side with the teeth faces the box. The bushing has a rounded surface on the inside diameter, over which the wires slide while being pulled into the pipe. To install properly, first screw the locknut on the pipe as far as it will go, then slide the pipe through the knockout

Fig. 11-2. Conduit is fastened to boxes by means of locknuts and bushings, both shown above.

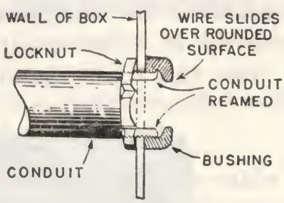


Fig. 11-3. This shows how a locknut and bushing are used. Be sure the locknut is driven solidly home.

in the box, then install the bushing on the inside of the box. Screw the bushing on tight, as far as it will go, and only then tighten up the locknut on the outside of the box, running it home tight so that the teeth will dig down into the metal of the box.

Thin-Wall Conduit: This material is properly known as Electrical Metallic Tubing, or EMT. It is shown in Fig. 11-4, and each length bears an

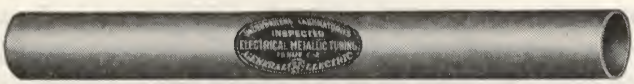
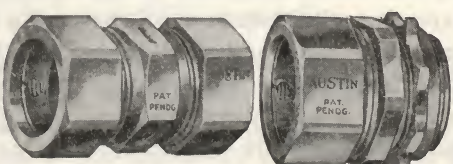


Fig. 11-4. Thin-wall conduit cannot be threaded; it is much lighter than rigid conduit. It comes only in 10-ft. lengths and each length bears the Underwriters' label.

Fig. 11-5. Thin-wall conduit is fastened to boxes using the connector shown at right. The picture also shows a coupling.



Underwriters' label. It comes only in a galvanized finish. It may be used either indoors or outdoors. Size for size, it has the same inside diameter as rigid conduit, but the outside diameter is much less than that of rigid conduit. This is because the wall is much thinner; as a matter of fact, the wall is so thin that it cannot be threaded. Lengths are coupled together and connected to boxes with special pressure fittings—coupling and connector are both shown in Fig. 11-5. Tightening the nut securely clamps the conduit into the fitting.

Cutting and Bending Thin-Wall Conduit: A hacksaw is the most convenient tool for cutting thin-wall conduit. It must be reamed after cutting. Bend it like rigid conduit.

Size Conduit to Use: Whether thin-wall or rigid conduit is used, the Code restricts the number of wires that may be used inside each size of conduit. The size pipe required for each combination is shown below:

Size of Wire	Number of Wires to be Installed						Size Lead Cable	Size Conduit, In.
	1	2	3	4	5	6		
14	½	½	½	½	¾	¾	14-2	¾
12	½	½	½	¾	¾	1	12-2	¾
10	½	¾	¾	¾	1	1	10-2	¾
8	½	¾	¾	1	1¼	1¼	8-2	1
6	½	1	1	1¼	1½	1½	14-3	¾
4	½	1¼	*1¼	1½	1½	2	12-3	1
2	¾	1¼	1¼	2	2	2	10-3	1
0	1	1½	2	2	2½	2½	8-3	1

* Where a service run of conduit or electrical metallic tubing does not exceed 50 ft. in length and does not contain more than the equivalent of two quarter bends from end to end, two No. 4 insulated and one No. 4 bare conductors may be installed in 1-in. conduit or tubing.

Installing Conduit: Whether rigid or thin-wall conduit is used, the procedure is the same. The pipe is first installed, the wires pulled into it later. No run (as the distance from box to box is called) may have more than the equivalent of four quarter-bends in it. All wires must be continuous, no splices being permitted inside the pipe. The conduit is supported by means of pipe straps; it should be anchored every 6 to 10 ft.

The conduit must be cut to the proper length and then bent to suit the purpose. Until you are experienced, you will find it easier to bend first, then cut to the required length. It is best not to mount the boxes too rigidly before installing the conduit, for the finished piece with bends may turn out to be a fraction of an inch too long or too short.

Pulling Wires Into Conduit: Assume that you have installed the conduit for outlets A, B, C, and D of Fig. 9-7 in Chap. 9. The installation will look as shown in Fig. 11-6. You are ready to pull the wires into place. For a short run with just two small wires, they can probably be simply pushed in at one end and through to the next outlet. If the runs are longer, and especially if there are bends, this cannot be so simply done and fish wire must be used. Special fish wire may be purchased; it consists merely of a steel tape about ⅛-in. wide and about 1/16-in. thick. It is flexible enough to go around corners and springy enough so it will not buckle when pushed into the conduit.

In pulling the wires into the outlets of Fig. 11-6, you have a choice of pulling in short pieces from SOURCE to A, two more pieces from A to B, two more from B to C, and still two more from C to D, or you may pull two continuous wires from SOURCE to A to B to C to D. The latter is the simpler plan, so simply push the fish wire in at D to C to B to A until it emerges at SOURCE. Attach the two wires to the fish wire at SOURCE, then pull on the fish wire at D. Have another man at SOURCE help the wires on their way and to keep them from snarling. In this way, a continuous

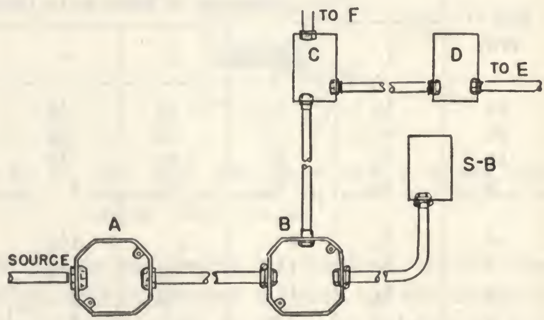


Fig. 11-6. Outlets A, B, C, and D of Figs. 9-6 and 9-7, installed with runs of conduit, ready for wires to be pulled in.

pair of wires will be pulled in from SOURCE all the way to D, at which point about eight inches are left sticking out. Holding tight to D, pull wires out at C until there is a loop about 6 to 8 in. long sticking out of the box at that point, in the meantime feeding in at SOURCE. This loop when cut in the middle (or in some cases merely having the insulation removed at the middle) is the same as the two ends of wire in the case of cable sticking out of the same box. Repeat at B and A, in the meantime feeding in at SOURCE. Two additional wires must be pulled in from B to S-B. This completes the installation of the wires in these four boxes and the procedure from this point onward is the same as with cable—merely installing switches, receptacles, fixtures, and so on.

Be sure to use black wire and white wire as required; there are no exceptions as when using cable. Use white wire only from SOURCE to each outlet, never to a switch. The other wires may not be white. Use black, or black and red to make it easy to trace wires when there are several inside one pipe.

Hangers: When using hangers of the type described in connection with Fig. 8-16, be sure to use the deep type, otherwise there will not be room for the conduit and locknut behind the plaster. Use a plaster ring on top of each box, as described in connection with Fig. 8-18. If the wiring is exposed, either a deep or a shallow hanger may be used.

Testing: Test in exactly the same way as when using armored cable.

CHAPTER 12

Knob-and-Tube System

The very earliest wiring jobs in the United States were installed using the knob-and-tube system; it is still permitted by Code. Labor costs using this system are very high, so it is rarely used. In the knob-and-tube system, Type R or T wires are mounted on porcelain insulators, with additional protection at many points. The insulators used are shown in Fig. 12-1. Use tubes to insulate single wires from timbers through which they run; use knobs for one wire and cleats for two wires to insulate wires from the surface over which they run.

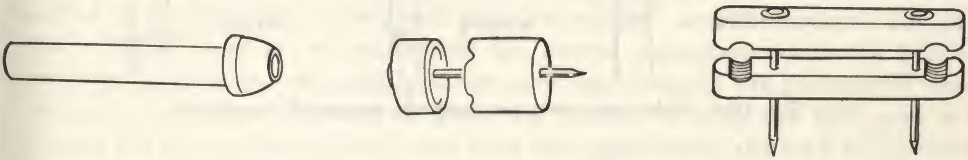


Fig. 12-1. Porcelain insulators used in knob-and-tube wiring.

Splices: When using the knob-and-tube system, splices may be made anywhere, without using an outlet box as is necessary in every other system.

Spacing: If in the finished installation the wires are permanently exposed, you must keep them at least 2½ in. from each other and at least ½ in. from the surface, so you may use cleats for pairs of wires. If they will be concealed, you must keep them at least 3 in. from each other and at least 1 in. from the surface, so you must use individual knobs for each wire.

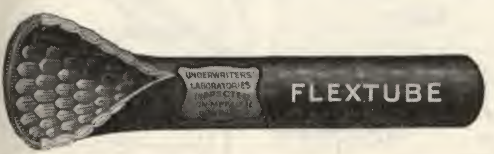


Fig. 12-2. Use loom over each wire, if you cannot maintain separation required by Code.

Fig. 12-3. Wires must be anchored within 12 in. of every box.

Loom: If you can't keep the wires as far apart (or as far from the surface) as required run *each* wire through a *separate* piece of loom, shown in Fig. 12-2.

Outlet Boxes: If the finished wiring is permanently exposed, outlet boxes are not required by Code; this is a carry-over from way-back-when. Be modern, and use an outlet box at every outlet. If the finished wiring is concealed, a box is required at every outlet. You can't bring wires into an outlet box without having the wires come closer together than the Code permits, so you must use a piece of loom over each wire at the box. The Code also requires each wire to be anchored within 12 in. of each box. See Fig. 12-3.

Miscellaneous Details of Installation: Each wire must be supported by insulators at least once every 4½ ft. When making right angle turns in wiring, watch spacing carefully; see Fig. 12-4. When boring holes for porcelain tubes through timbers, bore the holes at an angle; see Fig. 12-5. Where a wire runs along a timber after coming through a porcelain tube through a timber, install a knob, as also shown in Fig. 12-5. Where wires cross each other, install a piece of loom or a porcelain tube as shown in Fig. 12-6. If the wires are installed where they will be subject to mechanical injury, install guard rails or running boards as shown in Fig. 12-7.

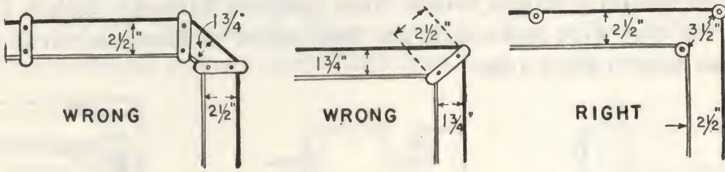


Fig. 12-4. Make sure wires are properly separated at corners.

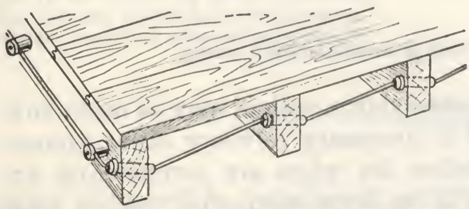


Fig. 12-5. Bore holes for porcelain tubes at an angle, so that tubes will not fall out.

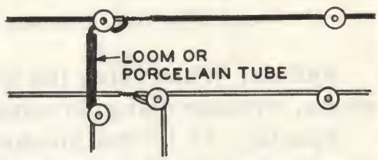


Fig. 12-6. Support wires within 6 in. of every tap.

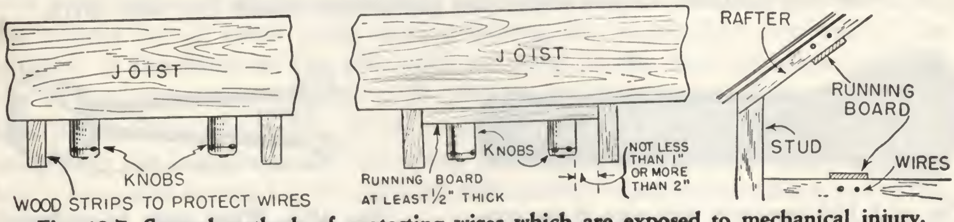


Fig. 12-7. Several methods of protecting wires which are exposed to mechanical injury.

Tests: Proceed as with nonmetallic sheathed cable.

CHAPTER 13

Miscellaneous Wiring

In any wiring job you will always find a few problems the discussion of which did not properly fall into a previous chapter. These things will be discussed in some detail here.

Doorbells and Chimes: These necessary devices are very easy to install. The power is furnished by a transformer, which is a device which reduces 115-volt Alternating Current to a different voltage, still Alternating Current. For doorbells and chimes this is usually about 8 to 12 volts. Doorbell transformers have two "primary" *wire* leads which are permanently connected to the 115-volt circuit, and two "secondary" *screw terminals* for the low voltage. They are so made that the power consumed while the bell is not ringing is very low, usually under one watt despite the permanent connection to the line. When you push the button to ring the bell, you are closing the low-voltage circuit, and then the transformer draws 5 to 10 watts from the 115-volt line. Transformers operate only on Alternating Current.

The installation is very simple. Consider the two "secondary" or low-voltage terminals on the transformer as the SOURCE for a circuit, the bell as the outlet, and the button as a switch. Breaking it down this way makes all these diagrams very simple. Figure 13-1 shows the installation of one bell with a push-button in one location. If a button is wanted in an additional location, install it as shown in the dotted line, in parallel with the first button.

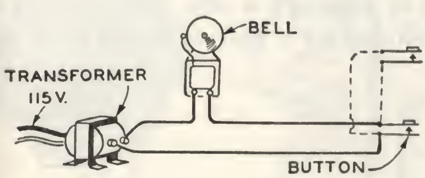


Fig. 13-1. The wiring of a doorbell with a transformer is very simple, as this diagram shows.

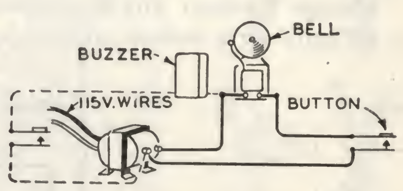


Fig. 13-2. Adding a buzzer for the back door to the diagram of Fig. 13-1 is easy, as shown above.

In most installations, a single bell is not considered enough. The usual system is to install a bell for the front door, a buzzer for the back door. See Fig. 13-2 and you will see that it is the same as Fig. 13-1 for a single bell, with the buzzer added as shown in the dotted lines.

Instead of doorbells, musical chimes are becoming very common. One of them is shown in Fig. 13-3. The better ones are so arranged that when the front door button is pushed, two musical notes are sounded, and when the back doorbell is pushed, only a single note is sounded. No matter how long the button is held down, the sound does not repeat. This is a great advantage over the harshness of the ordinary doorbell which usually rings much longer than is necessary. It is just a matter of time before the ordinary doorbell will be practically unknown. The wiring of these devices is the same as for the doorbell.

Because the usual transformer used for doorbells and chimes cannot deliver a great deal more than 10 volts, nor more than about 5 watts, there is no danger of shock or of fire even in case of accidental short-circuit. Therefore the wire used for this low-voltage wiring does not need much insula-

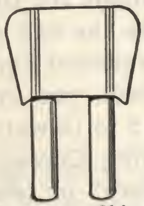


Fig. 13-3. Chimes are rapidly replacing bells.

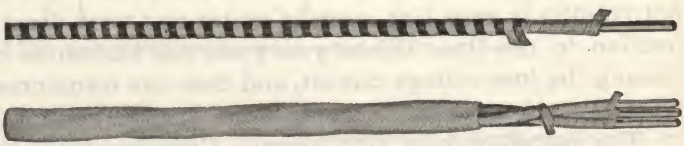


Fig. 13-4. Shown above are wires for connecting doorbells and chimes. Because of the low voltage involved, such wires need little insulation.

tion, and the bell wire of the kind shown in Fig. 13-4 is commonly used; it is insulated only with a couple of layers of paraffined cotton or with a layer of plastic. Staple it to the surface over which it runs.

Garage Wiring: The minimum wiring in a garage is one light, turned on or off only by a switch in the garage, and fed by a pair of wires from the

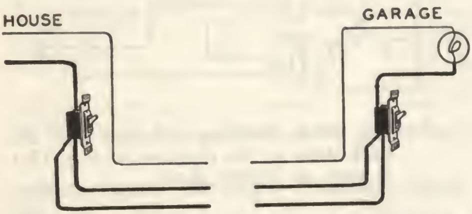


Fig. 13-5. Diagram for garage light fed from house, with 3-way switch at each end.

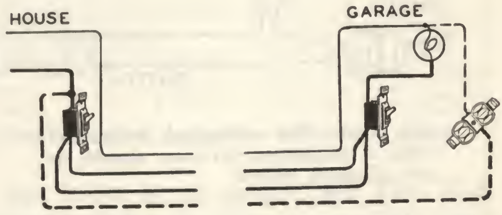


Fig. 13-6. If a receptacle that is to be permanently ON is to be added, four wires are needed.

house. Most people will demand a light that can be turned on and off from either the garage or the house, which requires a 3-way switch at each end, wired as shown in the basic diagram of Fig. 13-5. Three wires are required between the house and garage.

Every garage should have a receptacle outlet. It is very convenient to have this receptacle always ON, instead of being turned on and off with the garage light (so that you can plug in a battery charger and have it work all night without having the garage *light* on all night). That requires *four wires between house and garage. Follow the diagram of Fig. 13-6.

Underground or Overhead Wires: Underground wires used to be the exception, because of the very high cost of lead-covered cable. But lead-covered cable is little used today, and a special wire which is not particularly expensive and which may be buried directly in the ground is used instead. As a result, underground wiring is quite common today. The installation of this style of cable is described in Chap. 17 concerning farm wiring.

If you are going to use overhead wires, there are several ways in which the wires can be brought out of the house and into the garage. Figure 13-7 shows a very convenient entrance cap requiring only a single hole through the wall; use it at both ends. It is suitable for use with cable as pictured; you can also use conduit by running it directly into the fitting, which accommodates ½ in. conduit. Figure 13-8 shows another way of using the ordinary entrance cap as used for service entrances, a short piece of conduit, and an outlet box inside the building.

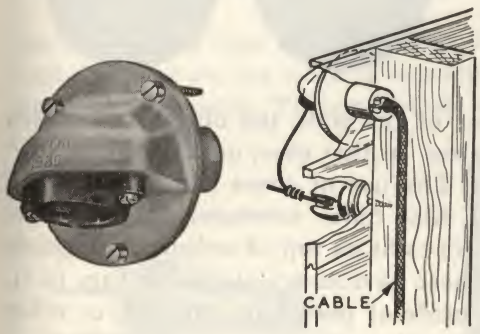


Fig. 13-7. The easiest way of bringing wires into a garage or similar building, is to use the special fitting shown.

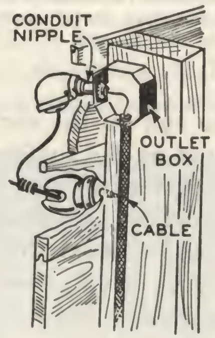


Fig. 13-8. Another method of entering a building.

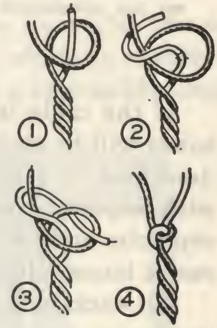


Fig. 13-9. An Underwriters' knot is easy to make.

Drop Cords: Today drop cords are little used. If you have need of one, remember the Code requirement of an Underwriters' knot at each end of the drop cord, as shown in Fig. 13-9. This puts the mechanical strain on the entire assembly of copper plus insulation, instead of on the copper only. The Underwriters' knot should also be used on the ends of any portable extension cord.

* There is a "trick" circuit using only three wires, but it does not meet Code requirements.

Plug-in-Strip: Few houses have all the receptacle outlets that the occupant would like. There is now available a plug-in strip which makes an outlet available every 6, 12 or 18 in. as desired. It is shown in Fig. 13-10. It is usually installed directly above the baseboard, with a wooden molding above the plug-in strip, so that the whole assembly appears to be part of the baseboard. It is not cheap, but it is worth its price.

Fig. 13-10. Plug-in strip provides outlets every few inches.

Basement Wiring: If the basement is well finished, with plastered ceilings, the wiring is no different from that of any other part of the house. There are, however, so many different kinds of construction in a basement that different types of wiring must be used, depending entirely on the particular circumstances involved.

Fig. 13-11. Receptacles and switches mounted on round covers which fit ordinary outlet boxes are commonly used in basements, barns, garages and similar locations. All-bakelite covers are considered safer than metal covers.

If the cable is to run on the surface of the wall, the outlet and switch boxes will be mounted on the surface also. In that case, use "handy boxes," described in connection with Fig. 8-5. The use of these boxes does away with exposed sharp edges or corners. Also quite commonly used are receptacles and switches mounted on covers to fit on top of ordinary octagonal outlet boxes, either 3½- or 4-in. size. These devices are shown in Fig. 13-11.

All sockets in basements should be made of porcelain, bakelite, or other insulating material, but not metal. Ordinarily, when you stand on the basement floor, you are apt to be more or less in contact with moist earth, the ideal condition for a shock. Use sockets and other devices made of insulating materials—Safety First.

Laundry Receptacle: In Fig. 13-12 you will see a special 3-pole receptacle and a plug to fit; the plug is a 3-prong plug. When appliances are fitted with this 3-prong plug and 3-conductor cord, the third prong and third conductor are connected to the frame of the appliance, usually a motor. The third connection in the receptacle is connected to ground. Then when the appliance with the 3-conductor wire and the 3-prong plug is plugged into the 3-pole receptacle, the frame of the appliance is grounded. This is a safety measure, and minimizes danger of shock from defective appliances. The Code requires one of these receptacles in every laundry room of every house.

You might immediately object that this special receptacle is of no value in your house, because you have only appliances with ordinary 2-prong plugs. The Code is still right: either ordinary 2-prong plugs or the special 3-prong plugs will fit this special receptacle. Over a period of time, there will be a gradual changeover on appliances from 2-prong to 3-prong plugs.

Clock Receptacles: Everybody uses electric clocks, and the kitchen is one place where a clock is necessary. But in the average kitchen the electric clock has a long unsightly extension cord running to it. Use a special receptacle of the type shown in Fig. 13-13; it fits down into its outlet box so that the plug on the clock is concealed behind the clock, which is mounted over the receptacle. The cord of the clock needs to be only a few inches long.

Fig. 13-12. The special laundry receptacle at left can be used with either 2-prong or 3-prong plugs.

Fig. 13-13. Mount your clock on top of a special clock-hanger receptacle.

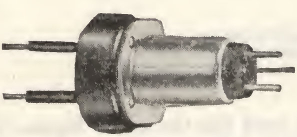


Fig. 13-14. The low-voltage (small) end of this relay projects out of the outlet box.

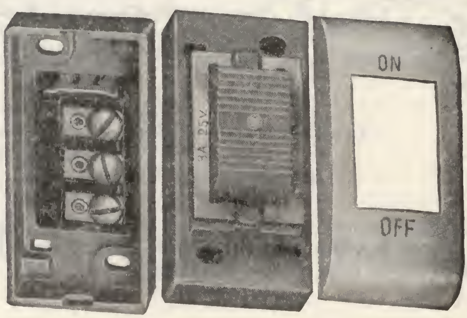


Fig. 13-15. The switches used in remote control wiring are shown in two views above, with cover at right. The same kind of switch is used at every location; use as many switches as you wish to control one outlet (or several outlets if you wish).

Remote Control Wiring: In this new method of wiring, the 115-volt wires run to the various outlets where power is consumed, in the usual fashion. They do *not* run to the individual switches.

In each outlet box where power is consumed, a very small relay (which is an electrically operated switch) is installed with one end projecting out of the outlet box through a knockout. Then a 24-volt transformer is installed in some convenient location, and furnishes power to operate all the relays. Because the voltage is low and because the transformer delivers only a very few watts even if short-circuited, the wiring between the transformer, the relays and the individual switches, greatly resembles doorbell wiring. Inexpensive wire, insulated for only a low voltage, is run from the transformer to each relay, then to as many switches as you wish. The wire does not need to run through conduit nor does it have to be cable of the armored or nonmetallic sheathed type. Run it or fish it through walls, staple as required. The switches do not need outlet boxes. Each switch is really a double push button. Pushing the top end of the button on any switch momentarily, turns on the light; pushing the bottom end momentarily on any switch turns it off.

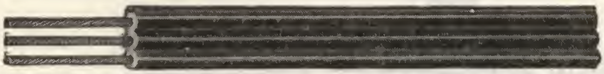


Fig. 13-16. There are only 24 volts on the control wires in remote control wiring, so inexpensive wire is used.

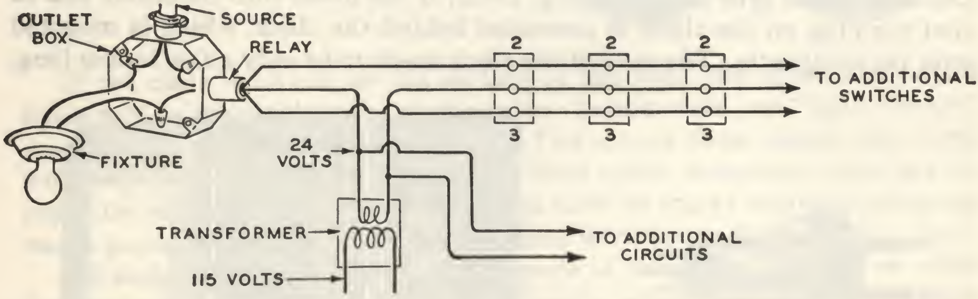


Fig. 13-17. Typical remote control circuit. One transformer is used for the entire house. The same circuit is often used for remote control yard lights except that the transformer is usually mounted in the base of the yard light.

Fig. 13-14 shows one of the relays, Fig. 13-15 one of the switches, and Fig. 13-16 the general type of wire used. Figure 13-17 shows the wiring circuit.

Heavy-Duty Receptacles: Ordinary duplex receptacles may be used for a maximum of 15 amp. at not over 125 volts, or 10 amp. at not over 250 volts. Larger receptacles rated at 20, 30 and 50 amp. are also available. Plugs that fit ordinary receptacles will not fit the larger ones.

When you install a receptacle for a 230-volt appliance, be sure to use one of the larger ones, so that 115-volt appliances cannot be plugged into it accidentally. The 50-amp. range receptacle shown in Fig. 14-2 is readily available anywhere and suitable for any heavy-duty load up to 50 amp. The third wire may be disregarded if you wish, or use it to ground the appliance.

Outdoor Receptacles: Every home deserves to have at least one outdoor receptacle, if for no other reason than to operate outdoor Christmas tree lights. See Chap. 17.

Wiring 230-volt Appliances with Cable: The neutral wire does not run to a 230-volt load. If you use armored or nonmetallic sheathed cable, one of the two wires in the cable will be white, which may be used only for a grounded neutral wire. Solve the problem by following Code Sec. 2006a. Paint both ends of the white wire black; the cable will then be considered as containing two black wires.

CHAPTER 14

Wiring of Heavy Appliances

The Code classifies all appliances into two groups: portable and stationary (permanently installed). It is sometimes difficult to decide whether a specific appliance is portable or stationary. Common sense must rule. An appliance which is intended to be used in several locations is naturally portable. An appliance which is intended to be plugged into any convenient receptacle is portable. An oil-burner motor once installed will never be moved from one receptacle to another, and is therefore stationary. The Code however classifies an electric range as portable, presumably because in moving you can take it with you from one house to another.

Disconnecting Means: Every appliance must be provided with a means of disconnecting it from all ungrounded wires (Code Art. 422). If the appliance is portable, a plug-and-receptacle arrangement is all that is required. Each must of course have a rating in amperes and volts not less than the rating of the appliance in amperes and volts.

If the appliance is stationary (permanently installed) and is rated at *not more* than 300 watts (or *not more* than 1/8th hp.), no special disconnecting means is required. The branch-circuit protective equipment (fuse or circuit-breaker) is considered sufficient.

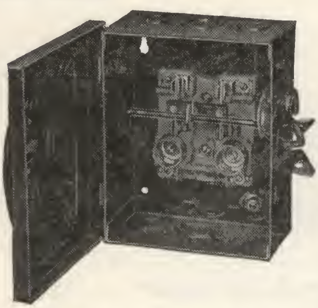


Fig. 14-1. A typical switch for appliance circuit.

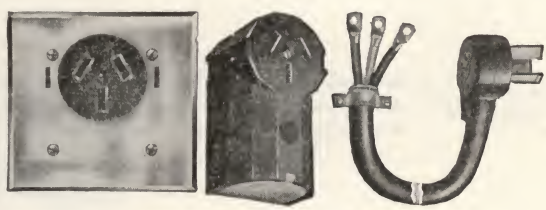


Fig. 14-2. Ranges are connected to 50-amp. 250-volt receptacles of the type shown here. The pigtail is connected to the range, then plugged into the receptacle.

If the appliance is stationary (permanently installed) and is rated at *more than* 300 watts (or *more than* 1/8th hp.), you have two choices. If the branch-circuit protection is a circuit-breaker, of an ampere rating not greater than that of the wires serving the appliance, that is sufficient. For 115-volt appliances, use single-pole breakers; for 230-volt appliances, use 2-pole breakers. If the branch-circuit protection consists of fuses, you must install a separate switch of the general type shown in Fig. 14-1: single-pole for 115-volt appliances, two-pole for 230-volt appliances. The fuses in this switch must not exceed the amperage rating of the wire in the circuit.

Ranges: When the oven and all the burners of a household range are turned to their maximum heat, the total power consumed may be as high as 14,000 watts, although the usual is a lower figure. It very rarely happens that every part of a range is operating at its maximum heat.

When burners are turned to their higher heats, they operate at 230 volts; at lower heats, they operate at 115 volts. To supply either 115 or 230 volts as required, depending on the position of the individual switches on a range, it is necessary to bring all three wires to the range. The three wires are terminated in a heavy-duty receptacle of the general type shown in Fig. 14-2, and rated at 50 amp., 250 volts. The range in turn is connected to a 3-wire "pigtail" with a 3-prong plug which fits the special receptacle, also shown in the same illustration.

The wire from the service equipment to the range receptacle is 3-wire service entrance cable, with bare neutral. This is the only application where entrance cable with bare neutral is permitted by Code for interior wiring. Because of the peculiar circuits inside electric ranges, the neutral wire can never be made to carry as many amperes as the two hot wires can be made to carry. For that reason the neutral wire of the cable may be smaller than the two hot wires. The usual wire size of the cable from the service equipment to the receptacle is No. 6 with No. 8 neutral if preferred. For smaller ranges No. 8 wire, with No. 10 neutral if preferred, is often used.

The frame of the range must be grounded, according to the Code. The frame is internally grounded to the neutral wire of the pig-tail to the plug; plugging it into the receptacle automatically grounds the frame.

Clothes Dryers: Dryers are rapidly growing in popularity. They are basically 230-volt devices, consuming up to 4,000 watts. Some of them have 115-volt motors as components. The frames of them must be grounded. The 1953 Code authorizes the use of 3-wire service entrance cable for connecting a dryer, and grounding the frame to the uninsulated neutral of the cable, provided only that the cable is No. 10 or heavier. This will automatically ground the dryer. Since a dryer is considered a permanently-installed appliance, you must provide a circuit breaker or switch, as already discussed.

Water Heaters: The power consumed by heaters ranges from 1,500 to 3,500 watts, always at 230 volts. The wiring is most simple. Merely run two wires from the service equipment to the heater, usually No. 12 wire.

If the branch-circuit protection consists of circuit breakers, provide one 20-amp. 2-pole breaker. If the service equipment consists of the usual range-switch of the general type shown in Fig. 7-2, usually there are a couple of special terminals provided for water heater. On most brands these are not protected by the main fuses. Run wires from these terminals to the disconnect switch discussed earlier in this chapter.

CHAPTER 15

Finishing an Installation

All the wiring described up to this point is done as the building progresses. Switches, receptacles, wall plates and fixtures are installed only after the house is plastered, papered, and painted. This portion of the work is only a very small part of the total and is very easy.

Installing Wiring Devices: Figure 15-1 shows how to mount a switch and its plate on a switch box. The switch is mounted in the switch box using machine screws that come with the switch. The plate in turn is installed on the switch proper using screws that come with the plate.

Inspect any switch or receptacle or similar device; you will see that the holes for the screws which hold the device to the box are not round but oval. These openings are oval so that the device can be mounted straight up and down in the wall even if the box is not mounted straight up and down. See Fig. 15-2, which shows a box mounted crookedly.

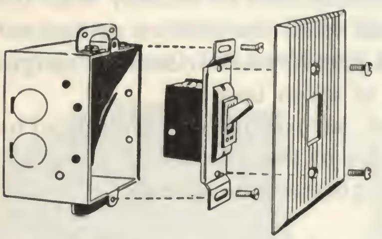


Fig. 15-1. The switch or other device is first mounted in the box, the plate then fastened to the device.

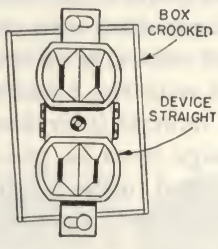


Fig. 15-2. Devices can be mounted straight in a crooked box because of oval holes in strap.

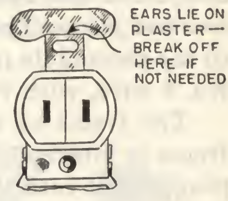


Fig. 15-3. Plaster ears are helpful in aligning a device flush with the plaster.

Boxes should be installed so that their front edges are flush with the plaster. This is not always done and often you find boxes which are somewhat below the surface of the plaster. If the device is mounted flush with the box, it will be too deep inside the wall so that it will not stick far enough through the openings in the plate, when it is finally put on. That not only makes an untidy job but also makes it hard to operate switches. For this reason spacing washers are usually supplied with switches and similar devices; these washers are placed between the device and the switch box, to raise the device up so that the plate will fit properly. Better devices have "plaster ears" (See Fig. 15-3), which will lie on top of the plaster and bring the device to the proper level, even if the box is somewhat below the surface of the plaster. You can easily break off the ears, if for any reason they are in the way.

Mounting Wall Plates: When mounting wall plates, do not draw up too tightly on the mounting screws. The most common plates are made of bakelite, and are fairly easily damaged. On plates for duplex receptacles there is only a very narrow strip of material between the two openings and, if you pull down too tightly on the screw, you will crack this bridge and ruin the plate.

Hanging Your Fixtures: On some fixtures one wire is white, the other black. More usually both are the same color, but one has a colored tracer thread woven into the covering of the wire. The white wire, or the wire with tracer, always goes to the white wire in the box. The other wire goes either to the black wire in the box, or to the switch. The wires from the fixture may be soldered to the wires in the box in accordance with soldering instructions in Chap. 4 and then taped. Solderless connectors may be used instead.

The Code says that all fixtures must be mounted on outlet boxes. The very simplest fixtures can be mounted directly on outlet boxes using screws supplied with the fixture. This method is shown in Fig. 15-4. Somewhat larger fixtures often use a special strap supplied with the fixture, and this method should be clear from Figs. 15-5 and 15-6.

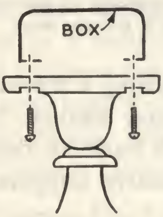


Fig. 15-4. Small fixtures can be mounted directly on the outlet box.

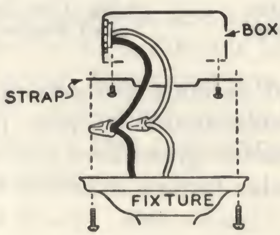


Fig. 15-5. Sometimes a strap is first mounted on the box, the fixture mounted on the strap.

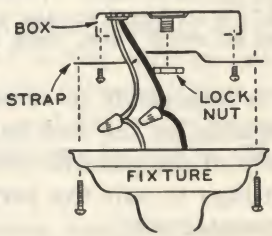


Fig. 15-6. Another method of mounting a fixture.

Still larger fixtures are commonly hung directly on a fixture stud mounted in the bottom of your outlet box, or the fixture stud which is part of the hanger on which your box is supported. The "stem" of the fixture is threaded to fit the fixture stud. The canopy is made to slide down the stem; when the work at the outlet box is finished, all connections made, slide the canopy up to conceal the wiring. All this was shown in Fig. 8-17.

Wall brackets are mounted in various ways, depending on the particular kind of outlet box used. In new work today, switch boxes instead of outlet boxes are usually used for wall brackets, because wall brackets are often so small that they will not cover the larger outlet box. Usually a strap is used which mounts directly on the switch box, the fixture then mounting on the strap. See Fig. 15-7. Regardless of the type of box used, if a fixture stud is present, use a brass adapter which rigidly supports the bracket. See Fig. 15-8.

An outdoor porch fixture is easily installed. If it is on the ceiling of a porch, or on the side of the house but protected by the porch roof, wire it in the same way as indoors. If it is exposed to the rain, wire as in indoor work but make sure the fixture has a porcelain socket, and rewire it with No. 14 rubber-covered wire in place of the No. 18 fixture wire usually used.

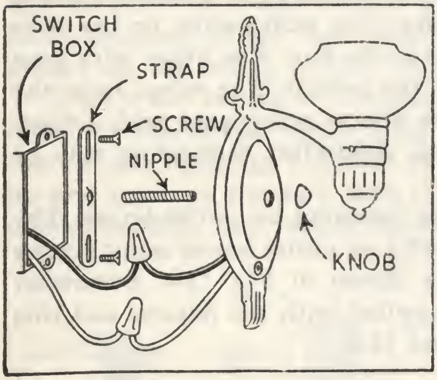


Fig. 15-7. Wall brackets are usually mounted on switch boxes, using a strap.

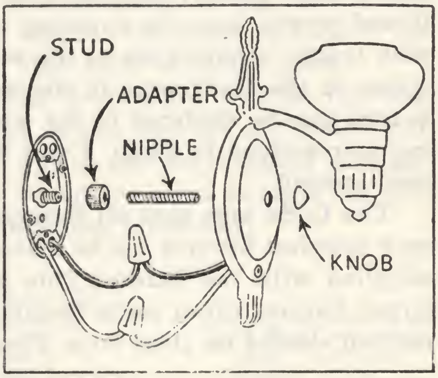


Fig. 15-8. Another method of mounting a wall bracket, using a fixture stud.

It is impossible to cover all possible methods of mounting a fixture; it all depends on the size and construction of your particular fixture. With the help of the general information given here you should have no trouble, for fittings to suit the particular fixture involved are usually supplied by the manufacturer.

CHAPTER 16

Old-Work Installations

Everything in previous chapters describes "new work," or the wiring of buildings while they are being built. This chapter will describe the wiring of buildings after they have been completed; this is known as "old work." There is very little difference between the two, except that in old work there are a great many problems of carpentry. The problem is to cut an opening where a fixture is to be installed, another opening where a switch is to be installed, and then to get the cable inside the wall from one opening to the other—with the least amount of work, and without tearing up the plaster more than is necessary.

One house to be wired may be five years old, another may be a hundred years old; different builders use different methods of carpentry. All this means that every job will be different. No book can possibly describe all the methods used and all the problems that you will meet. Watch buildings while they are being built to get an idea of construction at various points. In "old work" good common sense is of more value than many pages of instruction.

In general, old work requires more material because it is often wise to use ten extra feet of cable to avoid cutting extra openings in the plastered walls, or to avoid cutting timbers. In locating outlets, bear in mind that all wires must be fished through walls and ceilings. Sometimes by moving an outlet or a switch a foot or so, a difficult job of boring through joists or other timbers can be avoided. Many problems can be solved without cutting any openings except the ones which are to be used for outlet boxes and switch boxes. Others require that temporary openings be cut in the wall, which must later be repaired.

Systems Used in Old Work: The conduit system cannot be used unless the building is being practically rebuilt. Knob-and-tube system is impractical, and too expensive. Use either armored or nonmetallic sheathed cable, as is the custom locally.

Code Requirements for Old Work: For new work, boxes must be at least 1½ in. deep. For old work, boxes may be as shallow as ½ in., but only when use of the deeper boxes would injure the structure of the building. Figure 16-1 shows such shallow boxes. Since it is impossible to do so, the Code does not require that cable be anchored every 4½ ft., as in new work. The cable is simply pulled into the walls and anchored only to the outlet and switch boxes. Each piece must be a continuous single length from box to box.

Temporary Openings: Sometimes a temporary opening must be made in a wall, so that cable can be fished around a corner. On papered walls, use a sharp safety-razor blade, cut through the two sides and the bottom of a square. Soak the cut portion with a wet rag, which will soften the paste. Lift the cut part off the wall, bend it upwards, using the top edge as a hinge. Use a thumb-tack to hold it in place, out of the way. When the wiring is finished and the plaster replaced, paste the paper back into place.

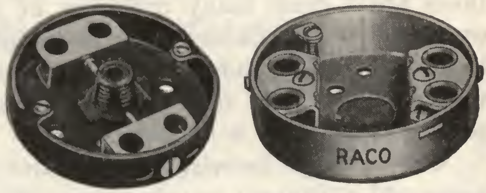


Fig. 16-1. If boxes 1½ in. deep would injure the structure of the building, the Code permits boxes as shallow as ½ in., the type shown here.

Preparing Openings: In all wiring the plaster must come up close to the box. It is impossible to cut an opening of the exact size of the box, so it will be necessary, after the wiring is finished, to replace the plaster so that it will come up close to the box. Use a mixture of plaster of paris, or prepared patching plaster.

In most cases the switch and outlet boxes are supported directly or indirectly by the lath under the plaster, so choose the locations for the openings carefully. A location fairly close to joists and studs is best because there the laths are strongest. On the other hand, if located too close to a stud or joist, there may not be enough room to bring the cable freely into the box without awkward bends and extra work.

Make a mark on the wall approximately where you want the box to be. Bore a small hole through this mark. Probe with a stiff wire to make sure there is no obstruction and if you find sufficient free space all around, mark the full size of the opening. Don't make your opening too snug. Allow about ⅛ in. extra so that you can slide the box easily into the opening. With a keyhole saw, enlarge the bored hole sufficiently so that a hacksaw blade may be inserted. Insert this blade in such a way that the actual sawing is done as you pull the blade *out* of the wall toward yourself. If you saw as you push the blade *into* the wall, you will probably loosen the laths from the plaster, making a very flimsy mounting for the box. Hold your hand against the plaster as you pull out. Saw the opening to the required size and shape.

Mounting of Switch Boxes: In sawing the openings for switch boxes, remember that the length of a switch box is approximately the same as two widths of lath, plus the space between the laths. If you remove two complete widths of lath, the mounting brackets on the switch boxes will just barely reach the next two laths. As a result the wood screws by which you attach the boxes (1-in. No. 5 screws are commonly used) will come very close to the edges of the laths, and the laths will split, making a very loose mounting and an unsatisfactory job. Remove one width of lath completely, and part of another on *each* side of the opening. Figure 16-2 shows the wrong and the right way, and should be self-explanatory.

Whether connectors are used or whether the box has clamps for holding the cable, the cable is attached to the box while it is still outside the wall. Run the cable into the box through knockouts in the bottom, rather than the ends or sides of the box. This makes it much easier to insert the box into its opening in the wall.

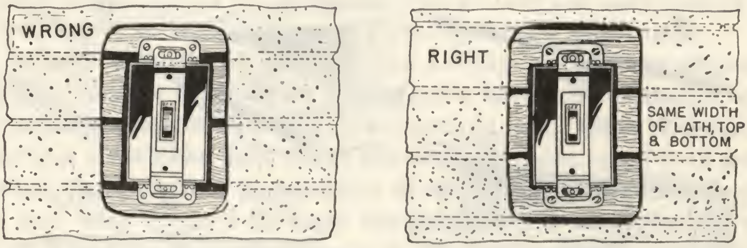


Fig. 16-2. In cutting an opening for a switch box, cut away one whole lath, and part of another lath on each side of the one completely cut. This provides a *rigid* mounting for the box.

Anchoring Outlet Boxes: Boxes which are 1½ in. deep should be used at all times if possible; use the shallower kind only when it is impossible to use the deeper ones.

If there is accessible space above the ceiling on which the box is to be mounted, and if there is no floor above (or if a board in the floor can be easily lifted as will be explained later), mount boxes using a straight bar hanger. Bend the ends at right angles so that the straight portion is just long enough to fit between two joists, and mount as shown in Fig. 16-3.

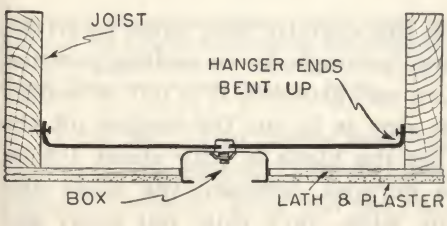


Fig. 16-3. When there is accessible space above the ceiling on which the box is to be mounted (or the floor can be lifted), use an ordinary box hanger.

If you can't work from above, and the work must be done from below, the easiest way to mount a shallow box is by using an old-work hanger, shown at A in Fig. 16-4. It consists of a straight bar of metal and a sliding fixture stud mounted upon it, but not removable. A small piece of wire is usually attached which prevents losing the hanger inside the ceiling.

Cut an opening into the ceiling, large enough so that you can slip the hanger through it and for the cable to come through. Remove the plaster over a space as big as the outlet box. Slip the hanger into the opening, as shown in B. Let the stud hang down through the opening. Turn the hanger so that the bar lies at right angles to the lath. Remove the center knockout in the bottom of the box and slip it over the hanger, tighten the locknut on the stud inside the box, and the mounting is complete. In the meantime, of course, you will have anchored the cable to a knockout in the bottom of the box by means of a connector or clamps.

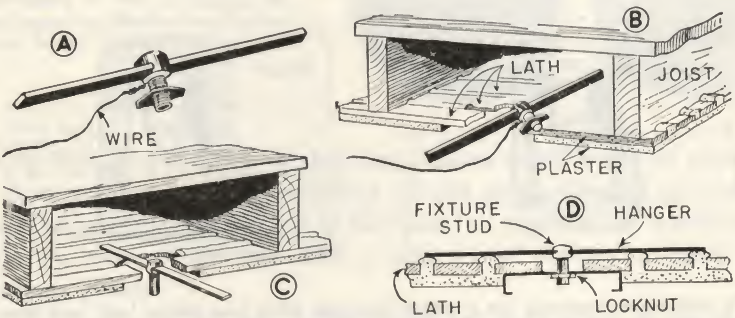
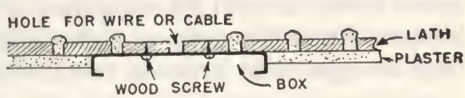


Fig. 16-4. When a box must be mounted entirely from below, use an old-work hanger.

Occasionally you can mount the box directly on lath, as shown in Fig. 16-5. Use this method only with the very lightest fixtures because all the weight of fixture and box is supported by one or two laths. An old-work hanger distributes the weight over at least half a dozen laths.

Fig. 16-5. In some localities mounting a box directly on lath is permitted.



Lifting Floor Boards: Often a board in the upstairs floor must be lifted, to get at the ceiling space. If the flooring is rough, as in ordinary attics, this is no problem. If the lumber is tongued and grooved, it is not so simply done without marring the floor. The first step is to cut the tongue off the boards. A putty knife cut off short so that the blade is only about 1½ in. long, makes an excellent chisel for the purpose. Sharpen the blade and you will have a chisel about 1 or 1½ in. wide, very thin, but short and stubby, which makes it strong. With this you can get down into the crack between two boards and chisel off the tongue as far as necessary. Then bore two holes in the board as close as possible to joists—see Fig. 16-6. With a keyhole saw, cut across just as close to the joist as you can. It is best to cut at an angle so that the board, when it is replaced, more or less forms a wedge. The board should be removed over the space of at least three joists, so that the board when replaced rests firmly on at least one joist. When replacing the board, first nail a cleat to the joist at each point where you sawed across. These cleats must be very solidly nailed so that when the board is replaced there will be no springiness.

Problem: Two Openings on Same Wall: In Fig. 16-7 cable must run from the opening A to opening B, both in the same wall. Depending on the structure of the building, the cable may run in one of three ways. The simplest way is marked "Route 1" in Fig. 16-7. Use this route if the floor boards can be easily lifted in the floor above, so that the cable can be dropped down from above, to the location of opening A and opening B.

If it is very difficult to get into the ceiling space from above, it may be possible to run the cable down through the basement as shown by "Route 2" in the same picture. If the wall is an outside wall, there will probably be an obstruction where the floor joins the wall. In most cases it is possible to bore upward through this at an angle from the basement. Then, push two pieces of fish wire upward through the bored holes until the ends emerge at A and B. Then, by pulling at A and B, fish the opposite ends of a piece of cable upward until the ends come out at A and B.

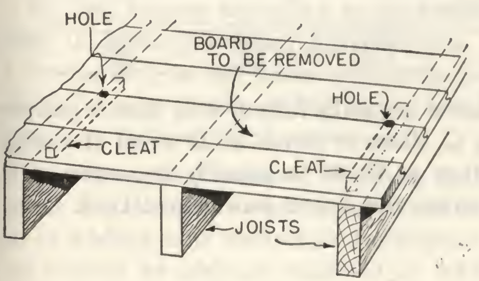


Fig. 16-6. Sometimes floor boards must be lifted. If the boards are tongued and grooved, cut off tongue on each side with very thin chisel, then saw across next to joists.

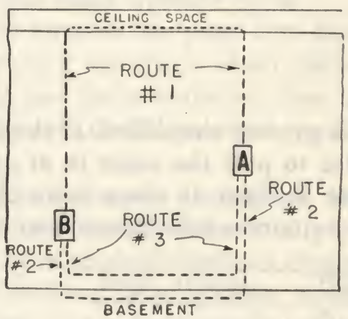


Fig. 16-7. In running cable from A to B (both on same wall) there is usually a choice of three routes for cable. The best route depends on structure of building.

If the wall is an inside wall, there will probably be no partitions in the basement immediately below this wall, so that it should be possible to bore straight upward. Then fish the cable upward to opening A and opening B.

Cable Behind Baseboard: In the problem above, if it is impossible to run the cable through either the ceiling space above or the basement below, use "Route 3"—run the cable behind the baseboard along the bottom of the wall. First remove the baseboard. Then make a small opening into the wall behind the baseboard, directly under A, and another directly under B. The next step is to cut a channel in the plaster between these two openings, in the space between two laths, forming a trough into which the cable can be laid. Fig.

16-8 shows the completed installation and the details of this picture should make the method clear. Naturally, after the installation, the baseboard must be replaced. *Be extra careful not to drive the nails into the cable.*

Problem: Cable from Opening in Ceiling to Opening in Wall: Our problem in this case is to run cable from an opening in the ceiling which, in Fig. 16-9, has been labeled C, around the corner at D, and down through the wall to opening E. It may be a very simple problem, or it may be a difficult one, all depending upon the construction of the house. If the ceiling joists run in the direction shown in the small inset of the same picture, the prob-

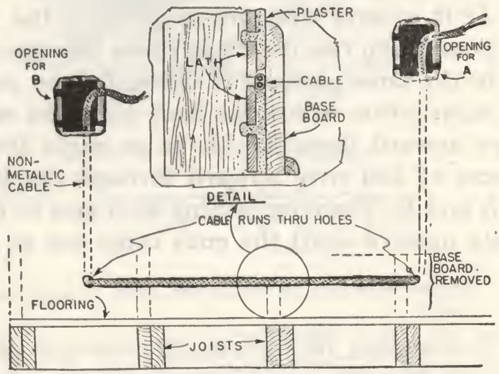


Fig. 16-8. Many times cable can be run to advantage in a trough cut in the plaster between laths, behind the baseboard.

lem is greatly simplified. If the floor above is easily lifted, it is then a simple matter to pull the cable in at opening C, drop it down at D until it comes out at E. Even if there is an obstruction at D, as is usually the case, it is easy to bore a hole down from above after the board has been lifted.

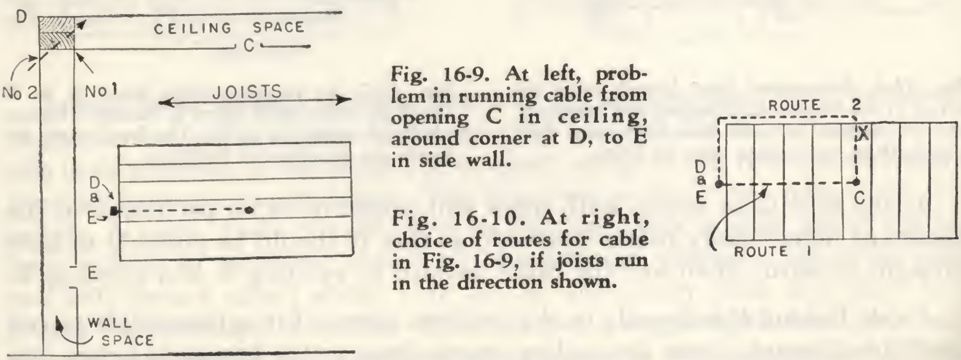


Fig. 16-9. At left, problem in running cable from opening C in ceiling, around corner at D, to E in side wall.

Fig. 16-10. At right, choice of routes for cable in Fig. 16-9, if joists run in the direction shown.

If it is impossible to lift the floor above, the cable must be gotten around the corner at D some other way. An opening must be made into the wall. Sometimes it is made at point marked "No. 1" through the plaster, next chiselling away part of the obstruction. Push a length of fish wire into this opening until the end shows up at C. Pull it out of C until the opposite end is at opening D. Then carefully push it down inside the wall until the end shows up at E. You then have a continuous fish wire from C around D to E. Attach the cable to the fish wire at one end, pull at the opposite end, and fish it through the wall until you have a continuous cable from C to E. Sometimes it is easier to do this from the opposite side of the wall, as at point marked "No. 2," boring upward through the obstruction as shown by the dotted arrow. Then using fish wire, pull in the cable as before. After the cable has been fished, patch the plaster and the job is finished.

If the opening E is not directly below point D, but is to the right or left, run the cable over (if the floor board above can be removed) to the proper point above E and drop down. If the flooring cannot be removed, drop from D down to the baseboard; behind the baseboard run over to a point below opening E, and then run upward to E.

If the joists of the ceiling run in the wrong direction, as shown in Fig. 16-10, there is again a choice of routes. If the floor above can be removed, follow "Route 1," boring holes through the joists through which the cable is to run. If the floor cannot be lifted, make an opening at point X, drop the cable down at X to the baseboard below, run it behind the baseboard, around the corner to a point below E, and from there upward to E.

No two houses are alike, so you will simply have to use your own horse-sense in getting around obstructions. Temporary openings often have to be made, and in all cases you will probably use more material than you would for new work. A few extra feet of cable cost much less than the time it takes to follow the shortest route.

Additions to Previous Wiring: Additions to previous wiring are made just as if a complete wiring job were involved. Such small jobs usually consist of adding new outlets or switches. If you have *studied* previous chapters you should be able to make such additions without any trouble, but the following paragraphs will give you some hints for a few specific outlets. *Always turn off the main switch when working on existing wiring.*

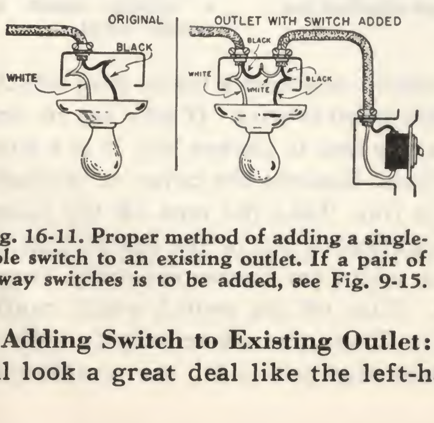


Fig. 16-11. Proper method of adding a single-pole switch to an existing outlet. If a pair of 3-way switches is to be added, see Fig. 9-15.

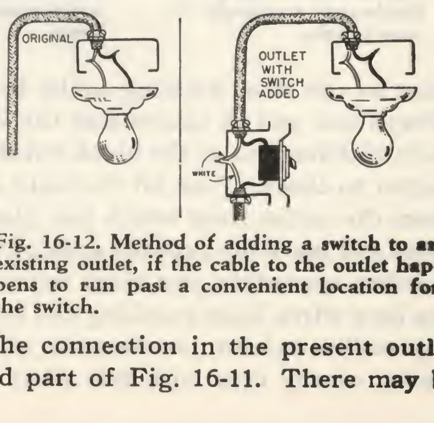


Fig. 16-12. Method of adding a switch to an existing outlet, if the cable to the outlet happens to run past a convenient location for the switch.

Adding Switch to Existing Outlet: The connection in the present outlet will look a great deal like the left-hand part of Fig. 16-11. There may be more wires in the box than shown, but there will be only two wires connected to the fixture, one of them white, the other black. In the right-hand part of Fig. 16-11 is shown the same outlet after the addition of the switch. To make the proper connections at the fixture, cut the black wire to the fixture, thus producing two new ends of wire. These two new ends are connected to the two wires in the cable which runs to the switch. The black wire *from the fixture* is connected to the black wire in the new piece of cable; the black wire of the cable which runs up to the original outlet box, is connected to the *white* wire in the *new* piece of cable. This is contrary to general practice, but is the one case where the Code permits a black wire to be attached to a white, and is covered in more detail in connection with Fig. 9-9 in Chap. 9.

The connections are more simple if the cable to the fixture runs up through the wall past the approximate location where the switch is to be placed. In that case, if you can get at this cable, cut the black wire in the cable, connect the two new ends to the switch itself, all as shown in Fig. 16-12.

If a pair of 3-way switches is to be added, instead of a single-pole switch, proceed as outlined above except add the two 3-way switches as discussed in connection with Fig. 9-15.

Adding Baseboard Outlet: This is very easily done as shown in Fig. 16-13. The end of the cable which in Fig. 16-13 is marked "To SOURCE,"

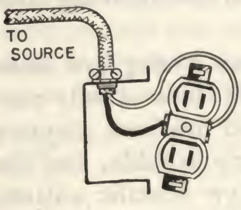


Fig. 16-13. Wiring a new baseboard receptacle is most simple.

Fig. 16-14. A weatherproof socket makes an excellent test lamp.

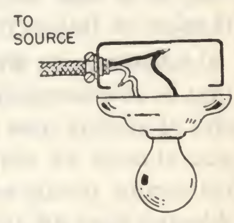


Fig. 16-15. Wiring for a ceiling outlet is equally simple.

must be run to an existing outlet box which contains a black wire which is *always* hot, and of course also the white neutral wire. If you are in doubt as to whether one of the black wires in any box is always hot, it is a simple matter to check. Turn off the main switch. Remove the cover or the fixture from the outlet from which you plan to run. Take the tape off the connections and leave the exposed ends of wire sticking out of the box so that they are then accessible, one black wire, one white (of course carefully keeping the bare wires from touching the box). *Turn off the switch which controls that outlet,* and turn on the main switch. Then take a test lamp (a bulb in a socket of any type with two short wires attached to it; the weatherproof socket of Fig. 16-14 is very handy for the purpose) and touch these two wires to the wires in the outlet box. Any two wires where the bulb lights (regardless of whether the switch controlling that outlet is on or not), may be used as the SOURCE for the new run of cable. *Be sure to turn the main switch off again before working on the wires.*

Adding New Ceiling Outlets: A new ceiling outlet may be installed as shown in Fig. 16-15, the two wires marked "To SOURCE" being run to the nearest outlet with a permanently hot wire, as outlined in the preceding paragraph.

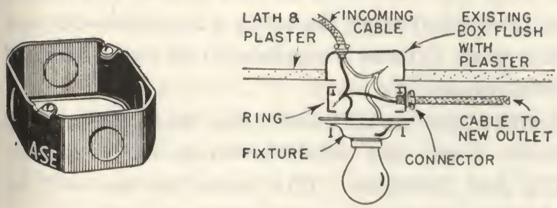


Fig. 16-16. Using extension rings makes it easy to add to existing outlets in locations where the new wiring may be permanently exposed.

Extension Rings: Where the new wiring may be permanently exposed as in basements, it is sometimes convenient to use an extension ring which is like an outlet box without a bottom. Remove the fixture of the existing outlet, attach the extension ring to the flush box, and anchor the cable for the new run to the extension ring. Replace the fixture on top of the ring. All this should be clear from Fig. 16-16.

CHAPTER 17

Farm Wiring

There is little difference in wiring a house on a farm, as compared with one in the city. But when discussing the problems that come up in wiring the rest of the farm, you must first decide what kind of farm you are thinking about. There are many kinds of farms.

The ambitious city worker who chooses to live on a few acres just beyond the city limits, big enough to keep a cow or two and also to raise his own vegetables (with maybe a few left over to sell), will be officially classified as a farmer, despite his full-time city job. Outside of the house, his needs for electric power will be small as compared with those of a full-time farmer raising mostly grain crops. And the grain farmer's needs will be small indeed as compared with the dairy farmer's needs.

In this book let us think in terms of farms of some size, and in terms of what they really are: food factories. Let's not think in terms of farm wiring, but rather in terms of wiring for factories. The factories we will be thinking about happen to be food-factories, or farms.

If any manufacturer of clothing or stoves or any other product depended on hand-power to run his machinery, he would go out of business very quickly. To stay in business he depends on the cheapest of all sources of power: electric power. For power in their fields, farmers today depend on tractors. Tractors are not cheap, but nevertheless are better investments than horses. For power in the farmyard, farmers also depend on electric power, but many of them not to the extent that they should, probably because for many farmers electric power is a relatively new kind of power, and they do not fully understand all the advantages that it has to offer.

Farmers with small electric bills are apt to complain about the expense. Those with large bills do not complain because they know that in buying the power, they are buying one of the biggest bargains available. The more electric power they use, the less other expense do they have.

To use large quantities of electrical power requires a well planned and properly installed wiring system and lots of electrical equipment, in total costing in most cases less than a tractor, and still proving to be the better investment. Let's consider some of the things that need discussion in order to properly wire a food-factory, a farm.

Problems in Farm Wiring: The farmer uses about the same amount of power in his house as does his friend in the city. But most farmers use far more power on the rest of their farm, than in the house. There is of course the lighting load of the other buildings, but the real load lies in the other equipment needed in the business of farming. This includes all sorts of motor-driven machinery; water heaters, milk coolers and similar equipment for the dairy, extra lighting for forcing egg production, incubators and brooders, crop drying equipment, heaters to keep water for livestock or poultry from freezing, and hordes of other equipment.

As a result you must use large wires to carry the heavy amperages without undue voltage drop. Too many overhead wires lead to a messy appearance of the farmyard so you may wish to use underground wiring. Heavy loads require heavy service equipment and many circuits. Buildings with livestock present a high-humidity problem requiring special attention. These and many other problems will be discussed in separate paragraphs.

Grounds: In city wiring, a single ground connection in the house is sufficient; the underground city water system is automatically available for a good ground. In farm wiring, one ground is not enough. If the service wires come from a yard pole, one ground must be provided there. One must be provided at the house. The Code requires one at every building which houses livestock, and also at every building which has two or more circuits.

If there is underground water piping on the farm, use it for the ground if it is at least 10 ft. long. However, it is not likely that there will be underground piping conveniently located at every point where a ground must be installed, and ground wires must run in a short, direct line to the ground. Therefore you must use a substitute for the water pipe. The Code used to call such substitutes "artificial grounds," now calls them "made electrodes." The usual form of farm ground is a special ground rod with a steel core and a copper layer on the outside, driven at least 8 ft. into the ground. It must be at least ½ in. in diameter. Water pipe if galvanized is acceptable according to the Code, but not always to the local inspector. Pipe must be at least ¾ in. in diameter, and also driven 8 ft. into the ground. If the ground is very dry or very sandy, several rods or pipes may have to be driven to secure a low-resistance ground that will serve its purpose. When several rods are used, keep them at least 10 ft. apart, for unless this is done, two or three rods are little better than one.

Do note that if you have underground piping *less* than 10 ft. long, you must ground your electrical system to both a driven ground *and* the underground pipe (Code Sec. 2581). This is a very important safety measure and must not be overlooked.

If the ground rod is copper-coated, use a clamp made of copper or brass; if the ground is galvanized iron, use a clamp made of iron. Iron clamps were shown in Fig. 7-20; one of the copper type is shown in Fig. 17-1.

Do use extreme care in installing grounds, so that the installation will not be easily damaged. The ground must be permanent, for the ground connection is a safety device. Likewise, have your inspector check your ground to make sure it is a low-resistance ground; the Code requires that the ground resistance must be under 25 ohms. A 25-ohm ground is just passable, and is not a very good ground. If necessary, add additional ground rods. It is also wise to "salt" the ground; pour salt water into the ground around the rod twice a year; this will greatly reduce the ground resistance and give you a better ground.

In most places the custom is to let the top of the ground rod project a few inches from the ground. The ground clamp is permanently exposed. In other localities the ground rod is driven about two feet from the pole (or building) after first digging a trench about a foot deep from rod to pole. The top of the rod is a few inches above the bottom of the trench. The ground wire runs down the side of the pole (or building) to the bottom of the trench, then to the ground clamp on the rod. After inspection the trench

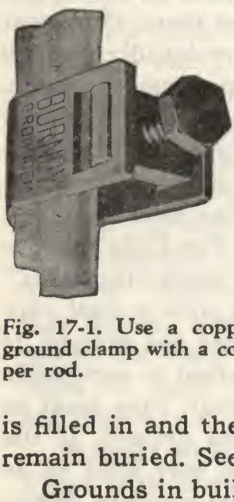


Fig. 17-1. Use a copper ground clamp with a copper rod.

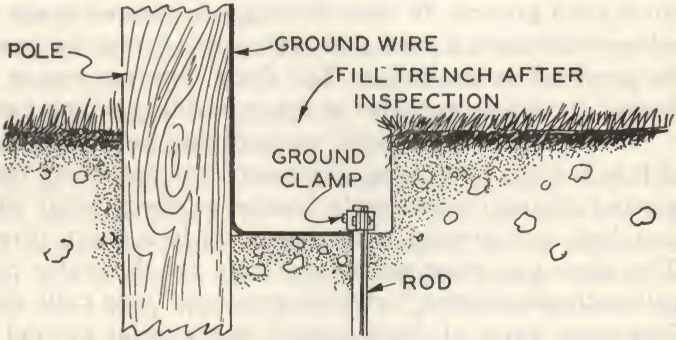


Fig. 17-2. In some localities, the top of the ground rod is below the surface of the ground. Fill the trench after inspection.

is filled in and the rod, the clamp and the bottom end of the ground wire remain buried. See Fig. 17-2. Use the method favored in your locality.

Grounds in buildings housing livestock should be installed so that seepage from animal manure does not saturate the ground around the rod. Chemical action in time eats up the wire, the clamp and sometimes even the rod, so that what was once a good ground turns out to be no ground at all.

Use Nonmetallic System: Conduit wiring when installed with a permanently good ground constitutes an excellent system with many advantages. On farms, however, poor grounds are the rule rather than the exception, so one of the basic requirements for a good conduit installation is missing. Moreover, buildings that house livestock usually have very high humidity, which leads to rusting of all metals, including conduit. The corrosive action from the chemicals in the excreta of animals speeds up the process. Experience has shown that when conduit systems are installed in barns and similar locations, the conduit actually rusts away; ground connections sometimes disappear; metal outlet boxes also rust away.

Now in a well-grounded and properly maintained conduit installation, an accidentally grounded wire inside conduit or inside a box leads to a blown fuse, indicating trouble. The ground can be located and the fault repaired. But if the conduit is rusted away, near the ground, that leaves you with *ungrounded* lengths of conduit. An accidental ground inside the conduit does *not* lead to a blown fuse; there is no indication of a ground. Then, if a person or an animal touches this ungrounded length of conduit, with a "hot" wire accidentally grounded to the inside of it, what happens? At the minimum, an unpleasant shock; at worst, a dangerous or fatal shock. Very many electrocutions of animals can be traced to this situation. That is what is responsible for the fact that conduit systems are rarely used on farms: nonmetallic sheathed cable is used instead.

Barn Cable: Ordinary nonmetallic sheathed cable as described in Chap. 9 is a very excellent material when used in dry locations. Experience has shown however that when used in moist or wet locations, especially in farm buildings housing livestock, its life is very short. Especially where it runs through bored holes in timbers, mildew and rot attack it from the outside. The jute filler cord inside the cable acts like a wick, pulling moisture into the cable from the ends, thus attacking it also from the inside. In due course of time, sometimes after only 2 or 3 years, the cable falls apart leaving a very dangerous, poorly insulated installation, leading to considerable danger of shock and fire.

Fig. 17-3. For farm wiring a special type of nonmetallic sheathed cable is used. The Code calls it Type NMC. It will outlast ordinary cable many times when used in barns.

For that reason the special barn cable illustrated in Fig. 17-3 was developed. Each conductor is insulated with its own water-resistant insulation; the several conductors are imbedded in neoprene which is especially resistant to moisture, mildew and other fungi. It will outlast all other cable, and is the only type that should be installed in barns and similar moist locations. The Code calls it Type NMC. (See also Type UF-NMC on page 118.)

Nonmetallic Outlet Boxes: Metal boxes when used in barns and similar locations, tend to rust out just like conduit. Moreover, consider metal boxes used with nonmetallic sheathed cable. Even if the box is in perfect condition, when a "hot" wire becomes accidentally grounded inside the box, the entire box becomes "hot." Any person or animal touching the box will receive a shock which can be quite dangerous to humans and even more so to animals. For that reason, boxes of nonmetallic material such as bakelite or porcelain are being used more and more; their use is a form of insurance. An assortment of them is shown in Fig. 17-4. Use them like metal boxes. However, the Code does not require that cable be anchored to the box with connectors, as when using metal boxes. It does require that the cable be anchored to the surface within one foot of every box.

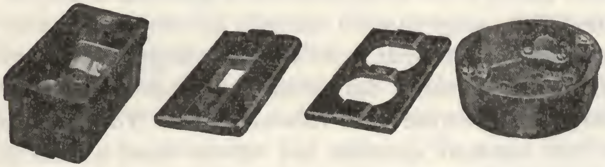


Fig. 17-4. Especially on farms, boxes made of an insulating material are frequently used.

Likewise popular for farms (as also for surface wiring anywhere) are combination devices shown in Fig. 17-5. Each device is both box and switch, or box and receptacle, and so on, ready to use. Plenty of terminal screws inside each device make it unnecessary to splice wires.

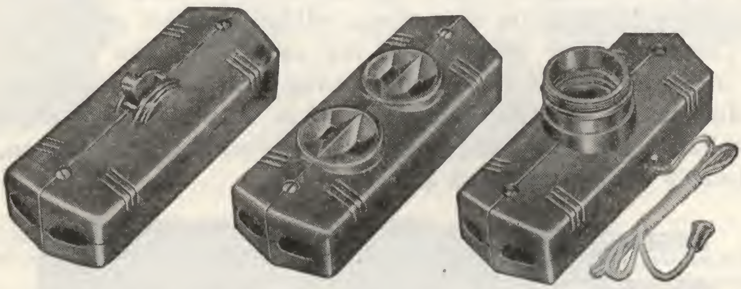


Fig. 17-5. Each of these devices is a combination outlet box plus switch or other device. They are popular in basements, farms and many other locations. Use with nonmetallic sheathed cable.

For the same reason of safety, do not use brass sockets in farm buildings. If you use lights with pull-chain control, be sure there is an insulator in the pull-chain, or at least a piece of cord on the end of the chain. This is a precaution towards safety against accidental grounds.

T-rated Switches: R. E. A. regulations call for the use of T-rated toggle switches. The difference between ordinary and T-rated switches has already been explained in Chap. 8. T-rated switches cost so little more than ordinary switches that their use is recommended in all locations.

Very Small Farms: Occasionally there is a very small farm in which very little electrical power is used in the barn and other buildings. In that case the barn can be lighted by a single circuit run from the house. Treat the wires from house to the barn just like wires from house to garage, as already covered in Chap. 13.

The Meter Pole: On practically all farms today, the Power Company's wires end on a pole in the farm yard. On the pole is found the meter and usually a switch to disconnect the entire installation. The wires are grounded at the pole. From the top of the pole, sets of wires run to the house, to the barn, and to the other buildings to be served. At each building there is a service entrance as already described in Chap. 7 except without the meter: more about that later in this chapter.

There is a right and a wrong location for the meter pole. Why is there a pole in the first place? Why not run the wires to the house, and from there to the other buildings, as was done when farms were first being wired? That leads to very large wires to carry the total load involved; a very large main switch in the house; expensive wiring to avoid voltage drop which is wasted power; a cluttered farmyard, and many other complications.

Locate the pole as close as is possible to the buildings where the greatest amount of power will be used per year; on modern farms, the house rarely consumes the greatest total. That also means locating the pole so that the largest wires will be the shortest wires. In that way you will find it relatively simple to solve voltage-drop problems without using wires larger than would otherwise be necessary for the number of amperes to be carried. The large expensive wires to the buildings with the big loads will be relatively short, and the smaller less expensive wires to the buildings with the small loads will be relatively long; this keeps total cost down.

Basic Construction at Pole: The three wires from the power line end at the top of the pole. The neutral wire is always the top wire. Note that the neutral from the power line is spliced at the pole to the neutral running on to the various buildings, so that in effect the neutral is a continuous wire from the power line direct to every building. The neutral wire is grounded at the pole as will be explained later. The neutral is also continued down to the meter socket, where it ends.

The two "hot" wires from the power line run down to the meter socket, then back to the top of the pole. This makes a total of five wires from the top of the pole to the meter socket. The usual construction is to run all five of them inside a single conduit to the meter socket. In other localities, three wires are run to the socket in one conduit and two run back to the top of the pole in another conduit. Use whichever method seems to be standard in your locality; consult your local inspector.

The entire installation is shown in Fig. 17-6. Regardless of the details of the installation, leave at least one-third of the circumference of the pole clear, so that linemen and repairmen can climb the pole without trouble.

Installing the Meter Socket: The meter socket is usually furnished by the Power Company, but installed by the contractor. Mount it securely about 5 ft. from the bottom of the pole. If a switch or circuit breaker is also used, mount it about 5 ft. from the bottom, the meter socket just above it.

Insulators on Poles: Near the top of the pole install insulator racks of

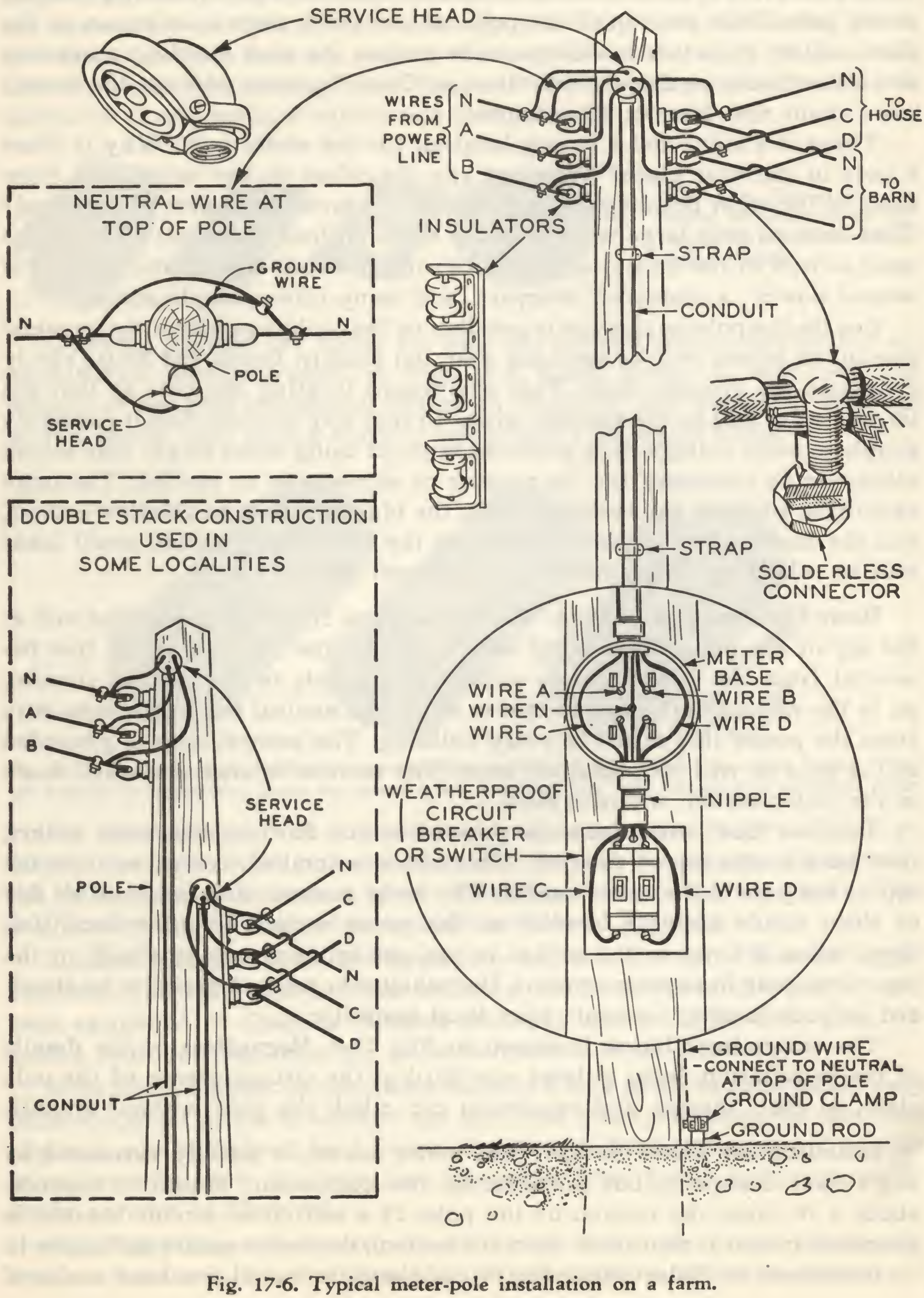


Fig. 17-6. Typical meter-pole installation on a farm.

the general type that were shown in Fig. 7-6. Provide one rack for the incoming power wires, one for each set of wires running from the pole to various buildings. Remember that the pull on the wires in a heavy wind, or under ice conditions in northern climates, is terrific. Anchor the racks with heavy lag screws. Better yet, use at least one through-bolt all the way through the pole, for each rack.

Installing the Stack: Whether you use a single-stack construction (all wires in one conduit) or the double-stack, the general procedure is the same. In the past the conduit has often ended at a point below the insulators, which then required great care in installing the wires to make sure that a drip-loop was provided, as was shown in Fig. 7-16. The purpose of the drip-loop is to prevent water from following the wires into the service head. The Code requirement today is to bring the top of the conduit to a point above the topmost insulator, as shown in Fig. 17-6, thus automatically solving the water problem.

At the top end of the conduit use a service head of the general type shown in Fig. 7-18, with the right number of holes in the insulator. Run wires through the conduit; white for neutral, black or other color for the hot wires.

In practice, the switch, meter socket, the conduit with wires inside, and insulators are usually pre-assembled on the pole before the pole is erected. When the pole goes up it is ready for wires to be installed on the insulators.

Connections at Top of Pole: The wires on the pole will be of large size. Even on the ground they are difficult to solder; at the top of the pole it is doubly difficult. Don't bother with solder. Use solderless connectors of the type that were shown in Figs. 4-16 and 4-17. These connectors being made of metal, must be taped after installation.

Connections in Meter Socket: The two "hot" wires from the power line always run to the top terminals in the meter socket. If the usual switch or circuit-breaker is used below the meter, the connections are as shown in the inset in Fig. 17-6. If this switch or circuit breaker is not used, the two wires C and D in Fig. 17-6 run directly to the bottom terminals of the meter socket. The neutral wire is connected to the center terminal on the meter, for grounding purposes. The neutral is not necessary to make the meter operate.

Ground at Pole: Formerly it was the common practice to run the ground wire out of the bottom of the meter socket, to a ground rod at the pole. It has now been found that better protection against lightning is obtained if the ground wire is run from the ground rod directly to the neutral wire at the top of the pole, outside the conduit containing the service wires. Bare No. 6 wire is ordinarily used. Tuck the ground wire in along the side of the conduit, so that it is held by the same straps that hold the conduit in place. In some localities it is stapled to the pole on the side opposite the conduit.

Be sure to protect the ground (and especially the connection of ground wire to ground rod) against mechanical damage. Protect it against damage from livestock, or from vehicles driven too close to the pole. The ground is a safety device; make it a permanent ground.

Size of Wires on Pole: The size of the wires in the stack on the pole must be big enough for the total number of amperes required for the farm. Once upon a time No. 6 wires with 55-amp. capacity were considered big enough for any farm; today they are too small for most farms. No. 4 wires are quite common, and No. 2 with 95-amp. capacity is a sensible choice, and a minimum requirement on many R. E. A. projects. The No. 2 wires with 95-amp. capacity also match the standard 100-amp. switch or circuit breaker, this being the next largest standard size above 60 amp. Wires larger than No. 2 are needed on many really modern farms.

The table in Chap. 11 will tell you what size conduit to use with different sizes of wires.

Wires from Pole to Buildings: To decide upon the size of wire required for any overhead run, you must consider three factors. The wire must be big enough to satisfy all three of the following three conditions:

1. It must carry the ampere load of the building, based on Code Table of carrying capacities as shown in Chap. 4.
2. It must carry this load without excessive voltage drop, as discussed in Chap. 4.
3. It must be strong enough, considering the length of the span, so that it will not break under the stresses caused by wind, ice loads, and contraction during cold weather.

The right size for conditions 1 and 2 can be determined from the voltage-drop table in Chap. 4. For mechanical strength, use a minimum of No. 10 for spans up to 50 ft., No. 8 for 100 ft. and No. 6 for 150 ft. If distances greater than 150 ft. are involved, use an extra pole.

If the wire is installed on a hot summer day, remember that a copper wire 100 ft. long will be a couple of inches shorter next winter when the temperature is below zero. Leave considerable slack lest the insulators be pulled off buildings during winter.

Wiring One Building Through Another: It is not necessary to run wires from the pole to every building to be served. Smaller buildings with small loads can be served by wires from some other nearby building, just as the garage in city wiring is served by wires from the house. Indeed the wires between buildings on farms are handled just like garage wiring; follow procedures already outlined in Chap. 13 for garage wiring.

The Code requirements with respect to buildings served through other buildings are simple. If all the outlets are on the same circuit and all of them can be turned off by switches, no further protection is necessary. If however when all the lights are turned off, there is still a receptacle that is alive, then a disconnecting means must be provided. If there are several circuits, a disconnecting means must be provided.

The disconnecting means may be a small circuit breaker, or a small switch of the general type shown in Fig. 14-1. If there are only two service wires, use a single-pole breaker or a switch with one fuse. If there are three service wires, use a double-pole breaker or a switch with two fuses. The rating of the circuit breaker or the fuses in the switch depend on the size of wire in the branch circuit within the building.

Note that if a building has only a single circuit and that is fed by wires from another building where they are protected by fuses or circuit breaker, no protection is required at the building served; if it is fed by wires from the pole, protection is required.

Tapping Service Wires at Building: Often two buildings are quite close to each other, and can then be served by a single set of wires from the pole, which should run to that building with the greater load. Naturally the wires must be heavy enough for the combined load of both buildings. At the service insulators of the first building, make a tap and run the wires

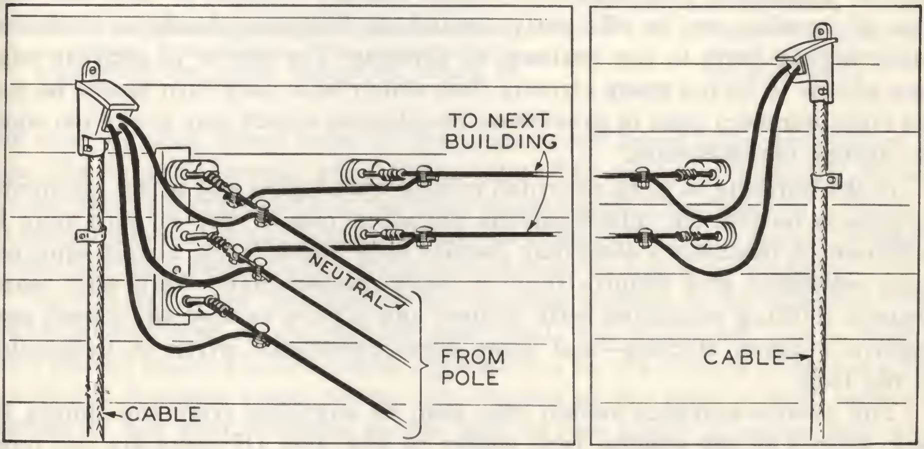


Fig. 17-7. When two buildings are near each other, tap the service wires from pole where they are anchored on the first building. Run them to the second building.

on to the second building, all as shown in Fig. 17-7. At the second building, proceed just as if the wires came directly from the pole.

If the second building is very small and requires only 115 volts, tap off only two wires including the neutral, as shown in the picture. If the second building has a considerable load so that 115/230 volts are desirable, tap off all three wires. Remember the requirement for separate service switch and ground at the second building, as discussed in other paragraphs.

Entrance at House: Install the entrance at the house substantially as was shown in Chap. 7, except that there is no meter to install. Let the service entrance cable or the conduit end at a point above the insulators; from there it runs directly to the service entrance switch inside the house. Run the ground wire from the neutral where it is anchored on the building, directly to ground at the bottom. Run it alongside the conduit or the cable.

The wiring inside the house is the same as in other houses, and as already covered in other chapters. Be sure to install plenty of circuits, especially if the farm happens to be one of the small ones in which some of the work of the dairy is done in the house instead of in a special building as on the larger farms.

Entrance At Other Buildings: At each building served by wires from the yard pole, there must be a service entrance similar to that at the house. The important question in every case will be: what size of entrance switch is to be used? If there are more than two circuits, a 30-amp. switch may not be used, for then the Code requires a 60-amp. switch as a minimum.

How many circuits should a farm building have? Each farm building is part of a business establishment: install enough circuits so that the business of farming can be efficiently carried on. Skimping leads to inefficient work, higher costs in the business of farming. Far better to provide what may appear to be too many circuits (but which later may turn out to be just the right number) than to provide an installation which may prove too small for future requirements.

If the building is to be provided mostly with lights and a few incidental receptacle outlets for miscellaneous purposes, one or two circuits may be sufficient. A machinery shed may require only one circuit; a well equipped farm workshop may require four; a really modern dairy barn with water heaters, milking machines, milk coolers and all the related equipment may require a dozen circuits—and large service-entrance wires in proportion to the load.

The service-entrance switch may then be anything from the simple 30-amp. switch of the general type shown in Fig. 14-1 (if there are not more than two circuits) to the well known range-switch of Fig. 7-3 which provides 12 plug-fuse 115-volt circuits (or a small number of 230-volt plug fuse circuits, each pair of fuses serving one 230-volt circuit), plus a couple of cartridge-fuse protected circuits for motors, water heaters, and so on. The greater the number of circuits you provide, the less the likelihood of future overloaded circuits, with blown fuses and other troubles.

Barn Wiring: Barns in general naturally have a great deal of humidity especially in the winter. Proper ventilation will greatly reduce this humidity, but few barns are sufficiently ventilated. The moisture will naturally collect in the coldest parts of the barn, and in winter that means the outside walls. Therefore avoid running cables on outside walls, for the alternate wetting and drying damage the wiring. Use only the special barn cable already described. It is preferable to use nonmetallic outlet boxes.

It is best not to run cable along the bottoms of joists or other timbers, because it would be more or less subject to mechanical injury. Don't run it at right angles across the bottoms of joists even if running boards are used. The cable will receive far more protection if you run it along the side of a beam, then along the side of a joist to the middle of the aisle to each point where a light is to be installed, as shown in Fig. 17-8. It will take less cable (and lead to less voltage drop) if you run cable down the middle of

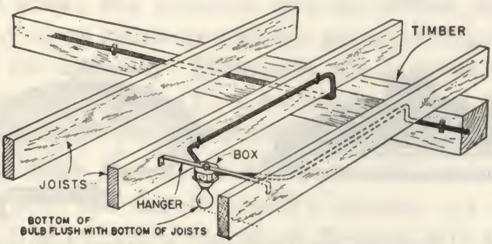


Fig. 17-8. Run cable along a substantial timber, to prevent later damage. The bottom of the bulb should not project beyond the bottom of the timber.

Fig. 17-9. Use protected receptacles in hay-mow wiring.

the aisle through bored holes in the joists; such bored holes should not be near the extreme bottom edge of the joist. The exact method will depend on the details of carpentry in the barn being wired. The important object is to install cable so that it cannot easily be damaged, and to install it where it will be kept away from excessive moisture as much as possible.

Do not skimp on the number of lighting outlets to be installed. The preferable number is one behind each stall; the minimum is one behind each pair of stalls. Do not install light outlets on the bottom of timbers, but preferably between joists so that the bottom of the bulb is flush with the bottom of the joist. Damage to the bulb is less likely to occur that way. Lights should be controlled by toggle switches. It will be found to be a great convenience to have at least some of the lights controlled by a pair of 3-way switches located at either end of the barn.

Switches should be installed in protected spots so that they cannot easily be damaged by animals. Mount them at elbow height so that you can operate them even if both your hands are full.

Receptacle outlets should be installed where they will not readily be bumped by animals. Most barns have too few outlets. The right number will depend largely on the kind of barn being wired: a dairy barn will require many, a horse barn on most farms comparatively few. Install enough of them so that extension cords need not be used.

Hay-mow Wiring: Be sure to provide a light where it will actually light the stairway or ladder to the hay-mow; this will tend to prevent accidents. Hay-mow lights should be controlled by a switch on the main floor. A pilot light at the switch will be found to be a great convenience.

The dust in a hay-mow is explosive, and an explosion can occur if an exposed bulb is broken. When a bulb breaks it burns out, but during that short fraction of a second while it is burning out, the filament is at an exceedingly high temperature, and can set off an explosion. Therefore for hay-mows, it is best to use dust-tight enclosures for bulbs, known as vapor-proof receptacles, as shown in Fig. 17-9. In many localities their use is required.

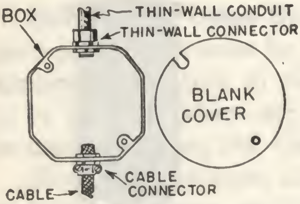


Fig. 17-10. Method of changing from cable to conduit wiring.

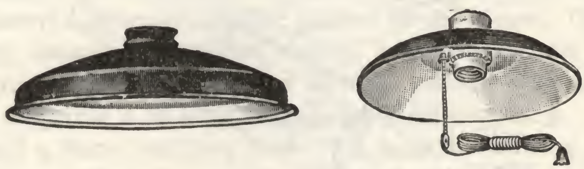


Fig. 17-11. Reflectors pay dividends. A 60-watt bulb with a reflector gives as much useful light as a 100-watt without a reflector. Keep reflectors clean.

The Code requires that nonmetallic cable must be given special protection when it runs through a floor. For hay-mow wiring, most inspectors will require more protection than the Code calls for. In a hay-mow, there is always danger that a pitchfork will puncture unprotected cable and cause a short-circuit. Therefore it is quite reasonable that inspectors require extra protection, from the floor up to a point where hay will never be in contact with the cable. Occasionally an inspector will permit cable installed in the corner formed by wall and stud, with a piece of board nailed over it for protection. More often the cable is run through pipe or conduit. The change-over from cable to conduit is made very simply as shown in Fig. 17-10. Type R or T wire is used inside the conduit. The box is covered with a blank cover.

In many localities it is the custom to wire the entire hay-mow with rigid or thin-wall conduit; the cable then ends on the main floor. This is a safety measure protecting the wiring in the hay-mow against mechanical injury, which might easily occur if cable is installed exposed to hay forks. The cable is not at all likely to rust out, for in the hay-mow it is not exposed to fumes and moisture as on the main floor. When wiring with conduit, the change-over is easily made as already shown in Fig. 17-10. It is well to seal off the wires in the conduit with sealing compound, at the bottom end of the conduit; this will prevent moisture from being drawn into the conduit.

There is a Code requirement that you must ground isolated sections of conduit or metallic armor, if over 25 ft. long; it is wise to ground even shorter lengths. That is easily done. Instead of using 2-wire cable from the service equipment to the outlet box where the conduit begins, use 3-wire cable. Use the third wire to ground the conduit. Connect one end of the third wire under locknut of cable connector on box where the cable begins; connect other end to the neutral strap in the service equipment.

Reflectors: When exposed bulbs are used, half of the light goes downward, the other half goes upward and strikes the ceiling. Ceilings in barns and similar buildings are usually dirty, so that most of the light is absorbed, not reflected. As a result nearly half of the light is wasted. Use a good reflector for each bulb, and the half of the light which is otherwise wasted will strike the reflector and be thrown downward. *A 60-watt bulb with a good clean reflector usually gives as much useful light as a 100-watt without the reflector.* Reflectors are inexpensive and some available types are shown in Fig. 17-11. A kerosene lantern with a smoky chimney gives little light; clean the reflectors regularly for maximum efficiency.

Poultry Houses: It has been well established that if light is provided to lengthen the day in poultry houses, egg production will greatly increase. For this purpose, one 40- or 50-watt bulb with a reflector about six ft. from the floor, for every 200 square ft. of floor area, is considered sufficient.

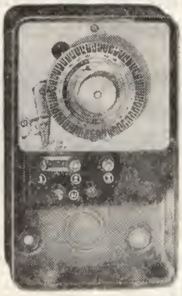


Fig. 17-12. A time switch for poultry house.

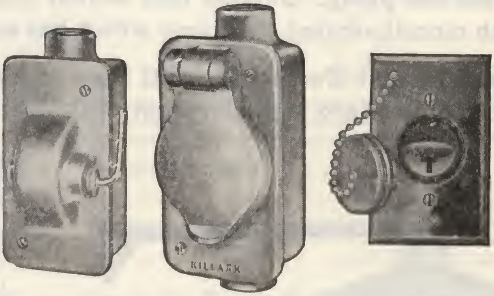


Fig. 17-13. Ordinary receptacles and switches may be used outdoors if they are mounted in protective weatherproof housings.

When the time comes to turn the lights off, don't turn all of them off at the same time. The lights should first be dimmed and after half an hour or so turned off completely. Unless this is done, the hens will not go to roost but will stay where they are when the lights are turned off. In the morning the procedure should be reversed: dim lights first, then brighter lights.

All this of course can be done by hand by the use of proper switches, but it is much better to install a special time switch designed for the purpose. At the time set, the switch turns the lights on in the evening, later dims them, then turns them off; in the morning the procedure is reversed.

An inexpensive switch of this type is shown in Fig. 17-12.

Outdoor Receptacles and Switches: Ordinary receptacles and switches are designed for indoor use. If used outdoors without further protection, they will become damaged, and such installations would not be safe. However, such ordinary devices are quite suitable for outdoor use if mounted inside special weatherproof housings, several types of which are shown in Fig. 17-13. For heavy-duty receptacles, see Chap. 14.

Water Pumps: Every farm worthy of the name will have an electric water system. The many advantages of electric pumps to provide running water need not be repeated here. However, it is well to stress one point: fire protection. A hose connected to a pressure water system is a thousand times as effective as a bucket when it comes to fighting a fire. But in case of fire, it is common practice to pull the main switch, and then the water pump—the fire pump—stops. At the very moment when water pressure is needed as never before, there is no pressure.

The solution is simple. Wire the pump in immediately after the meter, between the meter and the main disconnect switch on the pole. Operating the main switch will kill all electrical wiring on the farm, except the water pump. All this is permissible under Code Sec. 2321a. This kind of installation will require a separate weatherproof switch (or circuit-breaker) on the pole for the pump. Beyond that switch the wiring is that of an ordinary branch circuit serving the pump which has already been covered in Chap. 14.

Yard Lights: Every farm will have at least one yard light; many farms have several. Yard lights are not only useful, but are also a great help in

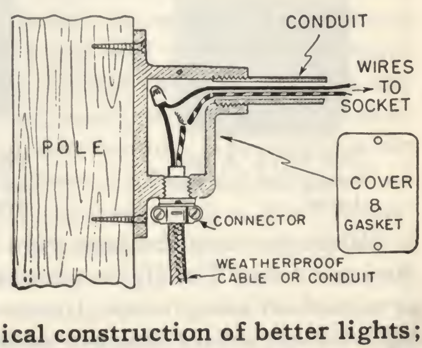


Fig. 17-14. A typical yard light. Note the construction at the right, making a thoroughly weatherproof installation.

preventing accidents. Fig. 17-14 shows typical construction of better lights; note the cast box to house splices of wires. The opening at the bottom fits either ½ in. conduit, or a connector for cable or thin-wall conduit.

A yard light should be controllable from at least two points: house and barn. This requires three wires, all as shown in Fig. 17-15. It is contrary to Code to feed a yard light by tapping the wires on the meter pole.

A yard light installed as just outlined requires a considerable quantity of wire and other materials, especially if it is controlled from several points. Ordinary No. 14 wire may be electrically large enough, but often a larger wire must be used for mechanical strength. All that makes the installation somewhat expensive, which led to the development of remote-

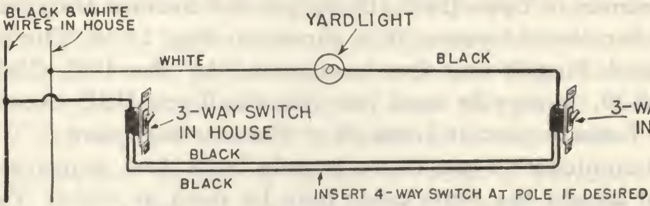


Fig. 17-15. Proper method of wiring for a yard light.

control yard lights operating on the principles already outlined in Chap. 13.

A typical remote-control yard light is shown in Fig. 17-16. The housing contains the step-down transformer, the relay, and a fuse protecting the transformer and the light. That makes it permissible to connect the yard light directly across the wires on the meter pole, if that is where the light is mounted. Only low-voltage wires extend beyond the base of the yard light. Because of the low voltage, an inexpensive special 3-wire cable is

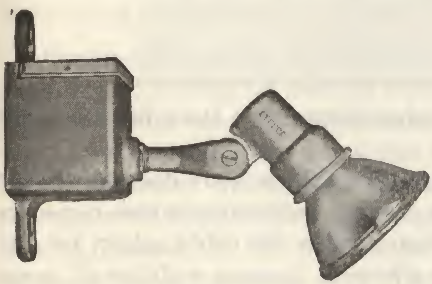


Fig. 17-16. The remote-control yard light has many advantages.

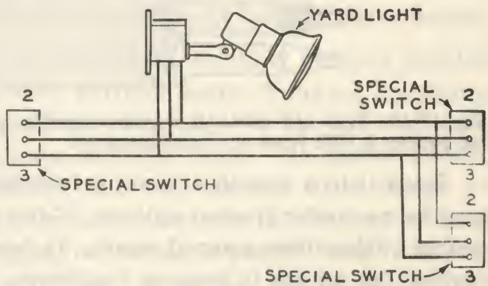


Fig. 17-17. Wiring diagram for remote control yard light. Compare with Fig. 13-17.

used from the light to each location where an on-off push button is installed. Install as shown in Fig. 17-17.

The bulb shown as part of the yard light is available in either the floodlight type to light up a considerable area, or the spotlight type to light up a smaller area more brightly. Be sure to buy bulbs with a special "hard" glass, for ordinary bulbs will break when cold rain hits the hot lighted bulb.

Underground Wiring: More and more service entrances and also wires between buildings are being put underground, producing neater installations. It greatly reduces danger from lightning, and does away with the problem of long spans coming down under ice loads in northern climates.

Most underground wiring is done using special cables designed for direct burial without further protection. These have special water-resistant insulation on the conductors which are then imbedded in a tough outer jacket. The Code recognizes two types, available in single- or multi-conductor.

The most common is Type USE (Underground Service Entrance) which has been in use for over 15 years. It is shown in Fig. 17-18. The new Type UF (Underground Fused) was first recognized by the 1953 Code, and is shown in Fig. 17-19. It may be used just like the Type USE except it must be protected by fuses or circuit breakers at the starting point.

In the multi-conductor type, many brands have dual approval as Type UF-NMC. That means the same cable may be used as either Type NMC (page 105) or Type UF, in other words the same cable may be used for interior wiring of say a barn, and for the underground runs to and from the building. But do use good common sense in installing any kind of underground cable.

Fig. 17-18. Underwriters' Type USE cable is designed to be buried directly in the ground without further protection. It is available also as 2- or 3-wire cable.

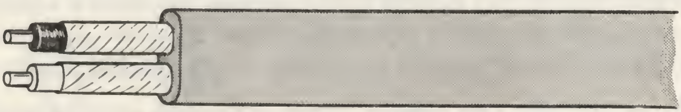


Fig. 17-19. Type UF cable. It is also available in single-conductor type. Use it like Type USE but protect it with fuses or circuit breakers.

Bury it in a trench at least a foot deep, preferably a little deeper. There may be no underground splices. Keep the several individual wires close together rather than spaced apart. In locations where the cable might be disturbed (as where it crosses roadways, or where it crosses cultivated areas where there may be future digging) lay a board or similar protective material above the cable before filling the trench. Wherever it comes up out of the ground or enters a building, provide slack in the form of an "S" curve which will allow expansion as the earth moves under action of frost.

Where the cable runs through the foundation of a building, have it run through a piece of pipe which should then be filled with waterproof insulating compound, to prevent water from flowing into the building. If it runs up the side of a pole, it must be protected against damage. It can be boxed in but preferably should run through pipe or conduit, up to the bottom of the meter socket. If change-over is to be made from overhead to underground wiring, let it run through conduit to the point where the overhead wires end, terminating the conduit with the usual service head.

CHAPTER 18

Electric Motors

A strong man working hard can deliver no more than about 1/10th horsepower continuously over a period of several hours. If the man is paid $1.00 an hour, it costs at least $10.00 for a horsepower for an hour. At average rates an electric motor will deliver a horsepower for an hour for 5¢. The motor costs little to begin with. It will operate equally well on a hot day or a cold day. It never gets tired, and costs nothing except while running. It uses electric power only in proportion to the power it is called upon to deliver. With reasonable care it will last for many years.

How Motors are Rated: A motor is rated in horsepower. This means that unless it is a special-purpose motor it will deliver the horsepower stamped on its nameplate hour after hour, all day and all week without a stop, if necessary.

Starting Capacity: Motors can deliver far more power while starting than after they are up to full speed. The proportion varies with the type of motor; some types have starting torques 4 or 5 times greater than at full speed. Naturally the amperes consumed during the starting period are much higher than while running at full speed. That means the motor will heat up quickly should it not reach full speed, because of too heavy starting load. Therefore the right kind of motor must be used for each machine, depending on how hard it starts. This will be explained later in this chapter.

Overload Capacity: Almost any good motor will for short periods develop from 1½ to 2 times its normal horsepower, without harm. Thus a 1 hp. motor is usually able to deliver 1½ hp. for perhaps 15 minutes, 2 hp. for a minute, and usually even 3 hp. for a few seconds, without harm. No motor should be deliberately overloaded continuously, but this ability of a motor to deliver more than its rated horsepower is most convenient. For example, in sawing lumber, ½ hp. may be just right, but when a tough knot is fed to the saw blade, the motor will instantly deliver, if needed, 1½ hp., then drop back to its normal ½ hp. after the knot has been sawed. A water pressure system using a ½ hp. motor may ordinarily require only ½ hp. or less, except for the last few minutes of running while the pressure builds up from 35 to 40 pounds, when ¾ hp. may be needed. The motor will automatically take care of it.

Gasoline Engines vs. Electric Motors: An engine is rated at 85% of the maximum horsepower that it can deliver at any given speed while new; as it gets older, its maximum horsepower diminishes. Unlike an electric motor, it has little overload capacity. That explains why it is often possible to replace a 5-hp. engine with a 3-hp. electric motor, sometimes even a 2-hp.

If the engine always runs smoothly, if it seldom labors and slows down, it can be replaced by an electric motor of a smaller horsepower. On the other hand, if the engine is always laboring at its maximum power, the motor that replaces it should be of the same horsepower as the engine, because no motor should be expected to *continuously* deliver more than its rated horsepower.

Power Consumed by a Motor: The amperage drawn from the power line depends on the horsepower delivered by the motor—whether it is overloaded or underloaded. The watts are not in proportion to the amperes (because in motors, their "power factor" must be considered). You pay for the power in watts, but must provide wire size in proportion to the amperes. The figures below are for a 2-hp. 230-volt motor. As the motor is first turned on, it consumes momentarily about 45 amp. After it has come up to speed but if permitted to idle, delivering no power, it consumes about 6½ amp. As the motor is called upon to deliver various horsepowers, the power consumed increases, as follows:

Hp.	Amps.	Watts	Hp.	Amps.	Watts
Idling	6½	400	2½	13½	2,250
½	7½	550	3	16½	3,000
1	9	1,150	3½	19½	3,650
1½	10½	1,500	4	25	4,400
2	12	1,900			

Speed of Electric Motors: The most common speed for a 60-cycle motor is a theoretical 1,800 rpm. Actually the motor runs at a little over 1,750 rpm. while idling, somewhere between 1,725 and 1,750 rpm. while delivering its rated horsepower. When overloaded the speed drops still more. If overloaded too much, the motor finally stalls.

The speed of ordinary A. C. motors *can not be regulated* by rheostats, switches or similar devices. Special variable speed motors are obtainable but they are expensive special-purpose motors and will not be described here.

Reversing Motors: The direction of rotation of a repulsion-induction motor can be changed only by shifting the position of the brushes. On other types of A.C. motors it is changed by reversing two of the wires coming from the inside of the motor. If a motor must be reversed often, a special switch may be installed for the purpose.

Temperature Rise in Motors: Like all electrical devices, motors heat up in use. However, if a well designed motor is run continuously, delivering the horsepower stamped on the nameplate, the temperature of the motor will not increase by more than 40° Centigrade or *72° Fahrenheit, *over and*

* Do not confuse *change* in readings of thermometers with their *actual* readings. When a Centigrade thermometer reads 40°, a Fahrenheit thermometer reads 104°. While a Centigrade thermometer changes by 40°, the Fahrenheit changes by 72°. Thus, if the Centigrade changes from 40° to 80°, the Fahrenheit changes from 104° to 176° (by 72°).

above room temperature. On a hot summer's day the temperature of the air in an enclosed pump-house, for example, may be as high as 110°; add to this the 72° rise and you have a total of 182°, not far below the boiling point of water. This will feel decidedly hot to the hand but will be entirely safe so far as the motor is concerned. Install motors so that air can get at them for cooling.

Dual-voltage Motors: Larger single-phase motors are usually designed so that they may be operated at either 115 or 230 volts. The motor has four leads. Connected one way, the motor operates at 115 volts; connected the other way, it operates at 230 volts. See Fig. 18-1.

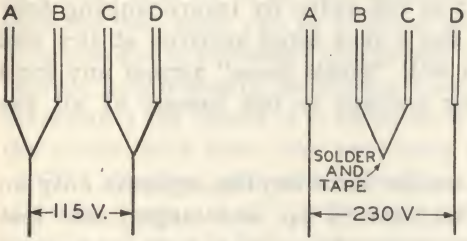


Fig. 18-1. By reconnecting the leads, the motor can be used on either 115 or 230 volts.

If there is a choice, always operate your motor at the higher voltage. At 230 volts, it will consume only half as many amperes as at 115 volts; with any given wire size, the voltage drop will be only one-quarter as great (when measured as a percentage) on the higher voltage, as on the lower voltage.

Types of Motors: There are many different types of motors in use. Only the more common ones can be described here.

Split-Phase Motors: This type of motor operates only on a single-phase A.C. It is the most simple type of motor made, which makes it relatively trouble free; there are no brushes, no commutator. It is available only in sizes of 1/3 hp. and smaller. It draws a very heavy amperage while starting. Once up to full speed, the split-phase motor develops just as much power as any other type of motor, but it is not able to start heavy loads. Therefore do not use it to drive any machine which is hard to start, such as a deep-well pump, or an air compressor that has to start against compression. Use it on any machine which is easy to start, or on one where the load is thrown on after the machine is up to full speed. It is entirely suitable for washing machines, grinders, saws and lathes, and general utility use.

Capacitor Motors: This type of motor also operates only on single-phase A.C. It is a comparatively new type of motor, having come into general use during the last 20 years. It is almost identical with the split-phase type, with the addition of a "capacitor" or a "condenser" which enables it to start much harder loads. There are several grades of capacitor type motors available, ranging from the home-workshop type which starts loads from 1½ to 2 times as heavy as the split-phase, to the heavy-duty type which will start almost any type of load whatever. Capacitor motors usually are also more efficient, than split-phase, using less watts per horsepower. The amperage consumed *while starting* is about half that of the split-phase type. Capacitor motors are commonly used only in sizes up to 10 hp.

Repulsion-Induction Motors: The type of motor, properly called the "repulsion start, induction run," is commonly called a repulsion-induction or "R-I" motor; it operates only on single-phase A.C. Usually it is so designed that it will operate on either 115 or 230 volts, by interchanging four wires which come out of the motor. It has a very large starting ability and should be used for the heavier jobs; it will "break loose" almost any kind of hard-starting machine. The starting current is the lowest of all the single-phase types of motors.

Three-Phase Motors: These motors, as the name implies, operate only on three-phase A.C. Three-phase motors in sizes ½ hp. and larger, cost less than any other type, so by all means use them if you have 3-phase current available. *Do not assume because you have a 3-wire service that you have 3-phase current; more likely you have 3-wire 115/230 volt single-phase current. If in doubt, see your power company.*

Direct Current Motors: Direct current (D.C.) is found in the downtown sections of some large cities like Chicago and New York, and in some small towns. All 32-volt farm plants are Direct Current as are a few of the 110-volt farm plants.

There are many types of direct-current motors; the most ordinary is the compound-wound, suitable for general purpose work. The speed is usually around 1,800 but varies considerably more than in A.C. motors, and varies considerably with the voltage and the load. Idling, it may be as high as 2,400 rpm., unlike the A.C. type which never exceeds about 1,750 rpm. for common types.

Universal Motors: This type of motor operates on either D.C. or single-phase A.C. However, it does not run at a constant speed, but varies over an extremely wide range. Idling, a universal motor may run as fast as 15,000 rpm., while under a heavy load the same motor may slow down to 500 rpm. This of course makes the motor totally unsuitable for general purpose work. It is used only when built into a piece of machinery where the load is constant and definitely predetermined. For example, you will find this motor on your vacuum cleaner, your sewing machine, on some types of fans, on electric drills, etc.

Motor Protection: It takes a good deal more power to start any machine than it does to keep the same machine running; this is proved by the fact that you start your automobile in low gear. So also with electric motors—it takes considerably more amperes to start a motor, than to keep it running at full speed at rated horsepower. An ordinary washing-machine motor may require from 5 to 6 amp. while delivering full rated horsepower, but may require as much as 30 amp. for a few seconds while coming up to speed.

Likewise, when a motor is overloaded so that it is forced to deliver more than its rated horsepower, it consumes more than its normal amperage.

A motor will not be damaged by current considerably greater than normal flowing through it *for a short time;* it will burn out if excessive current flows *for a considerable time* (just as you can walk at 4 miles per hour for a long distance, but can't run at 10 miles an hour for more than a short distance). Therefore it is necessary to protect the motor with a device which will let a current considerably more than normal flow for a *short* time, but which will disconnect the motor if it flows for a *considerable* time. Unless this is done, the motor may burn out, requiring an expensive rewinding job.

The simplest protective device is an ordinary fuse, but this hardly protects the motor at all; if it is big enough to carry the *starting* amperage, it is so large that it will carry the overload amperage continuously, thus not protecting against overloads. Fuses of the time-lag type are suitable; the amperage of the fuse should not be over 140% of the amperage stamped on the nameplate of the motor. If an amperage greater than this is selected, it will provide less protection against overloads. When using fuses to protect motors use one in each wire if the motor operates on 230 volts, but only one (in the black ungrounded wire) if it operates on 115 volts.

The best protection for a motor is a thermal overload device which carries normal current permanently without tripping, carries a small overload for a long time, and trips quickly if a very large overload is imposed. In the case of small motors such devices are often built into the motor, and are known by various names, such as "Thermotron," "Thermoguard," and so on. When they trip, merely reset them after the motor cools off. Motor starters with thermal overload devices are also available in the form of separate devices which usually include start and stop switches.

Wiring for Motors: Wiring for motors is not different from wiring for other devices except that the size of wire used must be watched very carefully, and that switches for starting and stopping the motors are usually installed near the motor. If the right size wire is not used, there may be so much voltage drop in the wires that you may have only 90 volts on the motor instead of 115 volts, which in turn means that the motor will overheat, and develop only 70% of the power it would deliver at normal voltage. If the motor is on a water pump or other hard starting device, the motor may not be able to start on the low voltage with the result that it will burn out. The table below will show the size of wire to use when the motor is various distances from the fuse cabinet.

Hp.	Volts	ONE-WAY DISTANCE TO MOTOR							
		No. 14	No. 12	No. 10	No. 8	No. 6	No. 4	No. 2	No. 0
¼	115	140	220	350	560	890	1,400	2,300	3,600
⅓	115	110	170	260	420	660	1,100	1,700	2,700
½	115	90	140	220	350	560	890	1,400	2,200
¾	115	60	100	160	250	400	640	1,000	1,600
1	115		80	130	200	320	450	800	1,300
¼	230	560	890	1,400	2,250	3,600	5,700	9,000	
⅓	230	420	660	1,050	1,670	2,600	4,200	6,700	
½	230	350	550	880	1,400	2,200	3,500	5,600	8,900
¾	230	250	400	640	1,010	1,600	2,600	4,200	6,500
1	230	200	320	500	800	1,300	2,000	3,200	5,100
1½	230	140	220	350	560	900	1,400	2,300	3,600
2	230	110	170	270	430	690	1,100	1,800	2,800
3	230			190	310	480	860	1,200	1,900
5	230				190	290	470	740	1,200
7½	230					210	320	520	820

The figures in the table above show the maximum ONE-WAY distance in feet that each size of wire will carry the amperage required for motors of various sizes, with 3% voltage drop. If the motor is overloaded, the drop will be greater. If you expect full power from your motor, do not skimp on wire size.

Problems with Large Motors: Often a farmer feels a need for a motor of 10 hp. or more. Upon looking into the subject he learns that *single*-phase motors larger than 5 hp. or possibly 7½ hp. are almost impossible to obtain, and are very expensive. He also discovers that the transformer serving his farm is too small to operate a motor larger than 3 hp. or possibly 5 hp. The power company probably objects to installing a larger transformer, because that would be like the farmer buying a 10-ton truck, just because 10 tons had to be hauled occasionally, with the usual load only a ton or two.

In turning to 3-phase motors, he learns that they are available in any size, cost less per horsepower than single-phase motors, but discovers that the nearest 3-phase line is many miles away. What then is he to do? The answer is to use smaller machines. For example, instead of a large hammer mill which requires 10 hp. or 15 hp. to operate, use a smaller mill that requires only 3 or 5 hp. Small hammer mills are available which are very efficient, having more capacity *per horsepower* than the larger mills. Even ear corn can be ground with as little as 2 hp. The smaller mill may have to be operated more hours altogether, but may require fewer men to operate, costs less to begin with, and costs less to operate because the smaller machine has more capacity per horsepower.

Belts and Pulleys: Keep belts reasonably loose; most belts are run too tight, leading to worn belts, worn bearings, and burned-out motors; they increase the power required to operate a machine. "V" belts in general are most suitable; for motors bigger than ½ hp. two or more belts in parallel are required. "V" belts may be operated quite loosely with considerable slack.

Regardless of the type belt used, avoid very small pulleys. The smaller the pulley, the sharper the bend in the belt, and the shorter its life. Moreover, a belt running over a 1½-inch pulley makes contact with only a very small surface of the pulley (measured in square inches). This leads to considerable slipping and extra belt wear. For any speed, there is a choice of several pulley combinations; for example, a 1½-inch pulley on motor and 3-inch pulley on machine, or a 3-inch pulley on motor and 6-inch pulley on machine, give the same machine speed. Use the larger pulleys for longest belt life and greatest efficiency.

The following table will be helpful in determining pulley combinations for any speed wanted on the machine. It is figured for a motor running at about 1,750 rpm. and some allowance has been made for belt slippage.

Diam. Motor Pulley	Diameter of Pulley on Machine, Inches														
	1¼	1½	1¾	2	2¼	2½	3	4	5	6½	8	10	12	15	18
1¼	1725	1435	1230	1075	950	850	715	540	430	330	265	215	175	140	115
1½	2075	1725	1475	1290	1140	1030	850	645	515	395	320	265	215	170	140
1¾	2400	2000	1725	1500	1340	1200	1000	750	600	460	375	315	250	200	165
2	2775	2290	1970	1725	1530	1375	1145	850	685	530	430	345	285	230	190
2¼	3100	2580	2200	1930	1725	1550	1290	965	775	595	485	385	325	255	215
2½	3450	2870	2460	2150	1900	1725	1435	1075	850	660	540	430	355	285	240
3	4140	3450	2950	2580	2290	2070	1725	1290	1070	800	615	515	430	345	285
4	5500	4575	3950	3450	3060	2775	2295	1725	1375	1060	860	700	575	460	375
5	6850	5750	4920	4300	3825	3450	2865	2150	1725	1325	1075	860	715	575	475
6½	8950	7475	6400	5600	4975	4480	3730	2790	2240	1725	1400	1120	930	745	620
8	.....	9200	7870	6900	6125	5520	4600	3450	2750	2120	1725	1375	1140	915	765
10	.....	.....	9850	8620	7670	6900	5750	4300	3450	2650	2150	1725	1430	1140	950
12	.....	.....	.....	.....	9200	8280	6900	5160	4130	3180	2580	2075	1725	1375	1140
15	.....	.....	.....	.....	.....	.....	8635	6470	5170	3970	3230	2580	2150	1725	1425
18	.....	.....	.....	.....	.....	.....	.....	7750	6200	4770	3880	3100	2580	2070	1725

CHAPTER 19

Stand-by Generating Plants

When electric power fails during a storm or other emergency, what happens? In homes we could perhaps tolerate being without lights and similar conveniences for some hours or even days, but the oil burner stops too; then there is no heat. On farms, lack of power also means no running water, no milking machines, no motors of any sort. In hatcheries, batches of eggs in incubators may be ruined. In hospitals lack of light in operating rooms is most serious. Lack of power during an emergency in any establishment is serious in proportion to the use being made of electric power in that establishment. Stand-by or emergency generating plants that develop 60-cycle 115/230-volt power are now available anywhere, in many capacities. A typical 3,500 watt plant is shown in Fig. 19-1.

Fig. 19-1. A 3,500 watt 60-cycle 115/230-volt generating plant.

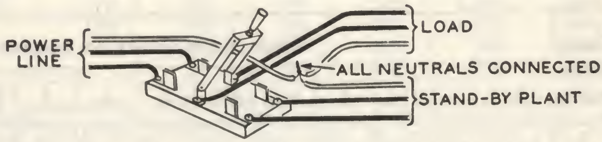


Fig. 19-2. When using a stand-by plant, always use a double-throw switch to disconnect your wiring from your power line. This is a very important safety measure.

Stand-by Plants are Insurance: If the initial cost of a stand-by plant seems high to you, spread its cost over a ten year period; the result is a relatively low cost per year. Consider this cost as you would consider the cost of any other insurance. In the case of a stand-by plant, you have the added advantage of having had the benefit of the insurance, and still owning the plant which can always be sold for a substantial part of its original cost.

Types of Stand-by Plants: For a farmer, the simplest source of emergency power is a tractor-driven generator. Mount the generator permanently in a convenient location. In case of emergency, drive the tractor to the right spot, run the generator by belt.

Gasoline engine driven plants are more common and more usually used. Some plants must be hand-cranked when needed; others have an electric starting system just like your automobile. You have a choice of controls. The simplest control means you must throw a hand-operated switch, then start the plant. Others are completely automatic so that in case of emergency the plant starts, takes over the load as long as the emergency lasts, then stops and returns the load to the normal power line.

Regardless of the type of control, if the plant is engine driven, start it once a week and let it run for about 15 minutes. An automobile that has stood idle for six weeks or more will not start quickly even if the battery is fully charged; neither will any other gasoline engine. Exercise the plant once a week to be prepared for an emergency.

Size Plant Needed: If the plant is to be fully automatic it must be big enough to take over *any* loads that may be connected at the time an emergency occurs. For a home or farm, that would in most cases mean a plant of 5,000 or 10,000 watts capacity. If the plant is to have manual control, if you have to see to it that it is started after an emergency occurs, a smaller plant can be used. In case of emergency, decide what electrical loads you can do without. You can get along temporarily without the water heater, so turn it off. You can get along temporarily without operating the electric range. On a farm you can see to it that the water pump is not running when some other motor is running. In that way you can select the items that must be operated, and in doing so you can control the total load so that a 3,500 or 5,000 watt plant will be big enough, instead of the 5,000 or 10,000 watt plant that would be needed for fully automatic operation.

Use a Double-throw Switch: Regardless of the size or type of plant or control that you use, always use a double-throw switch to completely disconnect your wiring from the power line, before throwing it to the stand-by plant. The simplest switch is shown in Fig. 19-2. In one position of the switch everything is connected to the power line; in the other position, it is connected to the generating plant. The switch may be hand-operated as shown in the picture (but enclosed in a steel box like an entrance switch) or an automatic electrically-controlled switch. For a single-phase 3-wire installation, a switch with two blades is usually considered sufficient, although in many localities a three-blade switch is required, switching the neutral along with the hot wires.

To use a stand-by generating plant without such a double-throw switch is dangerous and unfair to others. During emergency, the transformer serving your premises is dead; the power to the line is shut off at the power station or substation. Linemen are probably working on the line. If you connect a stand-by plant to your wiring *without* using the double-throw switch, you also feed power from the plant to the transformer serving your premises. The 115 or 230-volt power from the plant is stepped up by the transformer and the high voltage travels out over the high-line. The linemen think they are working on a dead line, but are actually working on a hot line. That is most dangerous, and several deaths of linemen have been traced to this source.

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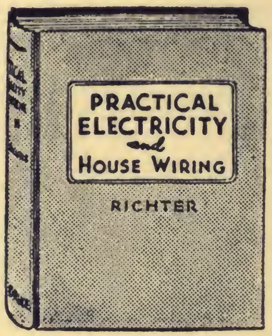

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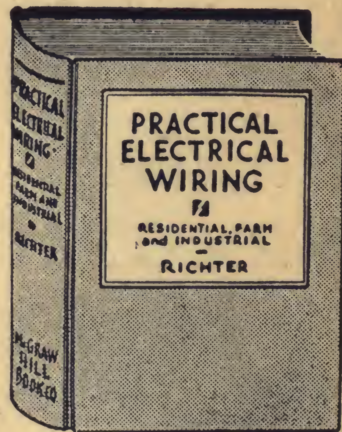

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