WORKING WITH ELECTRICITY
(Fundamentals of Electricity - Unit III)

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I. Wires And Cords

In an earlier part of the Electric Energy Program, we discussed materials called "conductors" which allow electric current to flow freely. The main job of a conductor is to provide a path for electric current — a path with low resistance. We also discussed materials which do not allow electric current to flow freely, called "insulators." Combinations of conductors and insulators keep electricity under control in its proper path.

Electric wires and cords are simple but important combinations of conductors and insulators. They are the means by which electricity travels from its place of generation to its place of use in your home. A cord is the last link for the electricity to travel before it is used to light your study lamp, power a radio, heat an iron or run the electric power tools in the shop.

There are basically two types of electric wiring: one is made of solid conductor and generally heavy insulation used for permanent wiring and usually referred to as "cable." The other is lighter duty, more flexible wiring used with appliances and is usually called "cord."

Most of the permanent wiring or electric cable inside the walls of your home, at businesses and on farms that brings the electricity to the wall outlets is made of solid conductors of copper or aluminum. These solid wires will break after they are bent a few times, so this type of wiring is not suitable for use on portable equipment such as lamps, irons or any kind of equipment which will have to be moved often.

Aluminum cable for interior wiring has been subject to a number of problems. For example, when dissimilar metals such as copper and aluminum are joined together (such as when aluminum wire is connected to a copper screw terminal, or when aluminum wire is spliced to copper wire) corrosion takes place at the junction. This corrosion can cause a dangerous heat build-up. Also, aluminum connections can become loose over a period of time. Therefore, copper is generally the recommended house wiring material for cables and connections. However, heavier aluminum cable used as service entrance cable (from the utility pole to your meter) is suitable where the connections are specifically designed for aluminum.

When replacing cords, be sure you get the type that is suitable for the intended use, and of the correct wire size. Using the wrong cord or not taking proper care of cords can cause serious problems. We should learn more about the types and uses of various cords so we can match the cord to the job.

There are many types of solid and flexible cords as determined by types of insulation or use. For those interested in an in depth study of cord use, secure the latest issue of the National Electric Code from:

The National Fire Protection Association
470 Atlantic Avenue., Boston, Mass. 02210.

Cords Cords are chosen for particular jobs according to the size of the conductors and type of insulation. The size of the wire determines the amount of electrical current that can flow through it, just as the size of a water pipe determines the amount of water that can flow through the pipe. So, the more current that must be delivered, the larger the wire should be.

Also, the longer the wire, the larger it may have to be. This is because more voltage is needed to push the electrons through a longer wire.

Wire sizes have been standardized according to a code called the American Wire Gauge (AWG) code. In this code, wire sizes have numbers such as 12, 14, 16, etc. (always even numbers). The code number increases as the size of the wire decreases. So a number 14 wire is smaller than a number 12. (Generally speaking, No. 14 wire is the thickness of a penny, No. 12 the thickness of a nickel and No. 10 the thickness of two dimes.)

The smaller size wires — such as 16 and 18 — are used to make flexible cords for small appliances that do not use much electricity. Larger sizes, with AWG numbers of 12 or less, are used in permanent wiring and to deliver power to large appliances such as electric ranges.
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<thead>
<tr>
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<tbody>
<tr>
<td>5-25 feet</td>
<td>No. 18</td>
<td>No. 16</td>
<td>No. 14</td>
</tr>
<tr>
<td>25-50 feet</td>
<td>No. 16</td>
<td>No. 14</td>
<td>No. 12</td>
</tr>
<tr>
<td>50-100 feet</td>
<td>No. 14</td>
<td>No. 12</td>
<td>No. 10</td>
</tr>
<tr>
<td>APPLIANCES</td>
<td>radio, TV, hair dryer, mixers up to 1/2 HP</td>
<td>iron, toaster, fry pan, 1 HP motor</td>
<td>hot plate, dishwasher, deep fryer, portable heater</td>
</tr>
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</table>

As a quick guide, a No. 16 wire has a thickness equal to that of a dime, a No. 14 equal to the thickness of a penny, a No. 12 equal to that of a nickel, a No. 10 equal to two dimes and a No. 8 equal to a dime and a nickel.

How do you tell what size conductor is needed by an appliance? We can estimate this closely by looking at the "nameplate" on the appliance to determine how many amps or watts of electric power it uses. We know that volts multiplied by amps give watts. So, if we divide the watts by volts, we'll know how many amps the appliance uses.

If the appliance is on a 120-volt circuit, for example, and is "rated" at 840 watts, we can divide 840 by 120 and get 7; that is, the appliance requires seven amps of electric current. After considering how far the wire must run, we can check the above chart to see what size wire we must use.

On the other hand, we can determine the wattage a wire will carry by multiplying the volts times the amperage rating of the wire. If we have a wire that can carry 15 amps and the voltage is 120, we know that we cannot connect more than 15 x 120, or 1800 watts of electrical load.

Insulators as well as conductors are needed to control electricity. For this reason, insulation is just as important in choosing the proper cord or cable as is the conductor itself.

The thickness and type of insulation used depends not so much on the amount of electric current that the wire will carry (which is important in deciding the size of the conductor), but on the force or voltage of that current. The type of insulation also depends upon the amount of moisture and heat it will be exposed to.

An alphabetical system has been made up to designate different types of cords. The cord type indicates the kind of insulation around the conductor. Insulated cords must conform to the standards set up for each type. You should know about the following cord types:

1. Light-duty Household - Type SP, SPT or PD insulated cord for general use in the home, such as with lamps, radios, etc. Type SP is insulated with rubber, Type SPT with a heat resistant plastic called "thermoplastic." PD has a braided fabric cover over two rubber-insulated wires.

   ![Heater Cord](thread-asbestos-fabric-jacket-wire-rubber)

   **Heater Cord**

2. Heater Cord - Type HPD, HSJ or HPN - must be used for heating appliances such as skillets, irons, toasters, etc. Type HPD, once more common than today, has an asbestos insulation and a braided fabric outer jacket, and should be used only in dry places, such as with electric irons. Type HSJ has asbestos insulation and a rubber outer jacket and is used for damp places. Type HPN looks much like normal household cord but has much heavier rubber insulation. It is not damaged by water or fats and oils.

3. Heavy-duty Cord - Type SJ, SV, SJT or SJO - for use in damp locations, such as garages and outbuildings. SJ has a jacket of good grade rubber and is sometimes called "Junior Hard Service," although it should not be used outdoors. Type SJT is similar but with a thermoplastic cover. Type SJO has a rubber covering that resists oil. Type SV is for use with vacuum cleaners.

4. Extra Heavy-duty Cord - Type S, ST or SO similar in construction and for similar use as the SJ, SJT and SJO, respectively, except the outer covering is stronger and can take extra-hard abuse. This type can be used outside.
Once you have chosen the right size cord and insulation type, you have to be sure that the cord or cable is made according to the safety standards set for that type of cord.

The best way to be sure is to buy only that equipment which bears the UL (Underwriter's Laboratories) seal. The Underwriter's Laboratories is a non-profit organization that sets minimum standards for electrical items. When you see the UL label it means that the item, when new, is safe to use under the conditions for which it was designed or intended.

**Things To Do**

1. As a guide for your future work with electricity, make a display board of the different types of cord and their uses.
2. **Cord Survey** - conduct a survey of your home. List the flexible cords you find, either attached to appliances or the extension cord type. Note how the cords are being used.

II. Electrical Connections

**Cords**

Electric cords are used only to form a circuit and pass on the flow of electricity. Without a cord that works properly, the flow of electricity can be interrupted or stopped.

**Plugs**

The most common type of electrical connection we know is the plug that connects a cord to an electrical outlet or to another cord. Like cords, there are several kinds of plugs for different kinds of jobs. Never use a 2-prong plug with appliances requiring a grounding connector for safety. A typical selection is pictured at the top of page 4.

(a) is a plastic lamp cord plug which is hard to remove from an outlet and is not recommended. Plugs (b) and (c) are quick-connecting plastic plugs that should be used only for light duty lamp cords.

In plug (d) the plug and rubber cord insulation are molded together in one permanent piece during manufacture. Plug (e) is a grounding plug, often used with appliances (such as washers) or with power tools. The third prong is for a ground wire. (See chapter VI on grounding). Plug (f) is a heavy duty grounding plug, used with large appliances such as air conditioners, refrigerators, dryers, etc. Again, the third prong is for grounding.

**Connections**

The first step in making an electrical connection is usually to remove the insulation a short distance back from the end, exposing the conductor. This is called "stripping" the wire. About 3/4 inches is just right for good connections at the terminal screw.

To properly strip a wire, lay it down on your work table with the end facing away from you. If the wire has two or more conductors, you will have to separate them first. Use your knife to split the wire as shown.

Not all electrical connections are ready-made. We need to know how to make good wiring connections, especially when building or repairing something - even when attaching a plug to a wire.

Take your knife and make a tapering cut, as you would when sharpening a pencil. Scrape the conductor gently to remove any fragments of insulation left. If the wires have fine threads wrapped around them remove the threads.
Various Types of Plugs

If the conductor is stranded, twist the strands together gently. Some electricians use special wire stripping tools which are matched to the wire size and remove the insulation in one quick, simple action. You may want to get one like this yourself.

Another common need is to connect one wire to another wire, or make a “splice”. Damaged extension cords should be replaced. As a temporary measure, they may be repaired by splicing. One method often used is the “Western Union” splice, named from the early days when workers were stringing telegraph wires across the frontier. This should not be attempted with stranded wire which is found in extension cords.

First, bend the conductors of two stripped wires at right angles to one another and hook the two pieces together. Then, using your pliers, twist the ends of the wires in opposite directions, wrapping them as tightly as you can around the straight wire.
Another kind of splice is the "rat-tail" splice, which is often used for joints where there will be no pull on the wires. It is used when connecting the permanent wires of building circuits to wires already inside lighting fixtures, or when making connections between wires inside the small steel boxes (outlet boxes) which are set into walls and ceilings. To make a rat-tail splice, simply cross the wires and twist them together tightly. Loop the ends back. Cover splice with electrical tape.

Another kind of special connector is the "lug". These are often used with screw terminals. Lugs are usually held to the wire by a screw or by "crimping" — squeezing the metal part of the lug down tightly onto the conductor. The lug is then fastened to the equipment or fixture with a screw.

Other kinds of split-bolt connectors are often used with larger wires... clamps or other special catch-type mechanisms built into equipment that catches and holds conductors when the stripped wires are pushed into special holds.

These connectors must match the type of wire involved. If the connectors are not labelled, they are suitable only for copper-to-copper connections. Aluminum connectors should be labelled "Al" and copper-to-aluminum "C-A". Use only those connectors labelled for use with their respective wire.

Splicing Cords
Splicing of flexible cords is advised only for temporary service in case of an emergency. A better and safer way is to attach a plug and receptacle similar to that described for assembling an extension cord (see page 8).

Other Connectors
There are many ways to splice or connect wires. The most common of these is a "wire nut" — a piece of plastic that looks like a thimble. Inside is a spring which grabs onto the twisted wires in a rat-tail splice and clamps them firmly together. The plastic shell serves as insulation. These are used inside protective boxes where there is no pull on the wires.

Things To Do
1. Make a display of the different types of plugs and their uses. This will serve as a quick reference in later work.

2. Show how to prepare a wire to connect a screw terminal, how to prepare a Western Union splice and a rat-tail splice for emergency use.

3. Demonstrate how to prepare, splice and tape wires. Use the kinds of wire normally used in home wiring circuits (No. 12, non-stranded).
III. Let’s Put Together Some Basic Equipment

We learn how to work with electricity in order to help us repair electrical equipment that isn’t working properly, or, in some cases, to make our own equipment.

One of the easiest things to fix is an extension cord. Check the extension and appliance cords around your house. Are any of them frayed? Are the plugs worn? Any broken insulation? If you find a faulty cord, you can use what you have learned to repair it until it can be replaced.

The first step is to remove the plug of the cord from the outlet or wall socket. *Never inspect or work on a cord unless you have disconnected it from the outlet.*

If the plug on an extension or lamp cord is bad, you may have to replace it. You can use the quick-connecting snap-on type for most cords.

Snap-on plugs usually have little metal points that pierce the insulation of a cord. These allow you to install it quickly without stripping the wire. They usually come in packages at hardware stores. The best thing to do is to follow directions on the package.

Next, remove the old plug simply by cutting the cord just behind it.

Next, slip the cord through the plug cover.

Then, stick the cut end of the cord into the plug body as far as it will go and press the metal “wings” together so the metal points can pierce the wire. Finally, snap the plug body into the plug cover.

Now you have a “like new” cord. Of course, this plug is not grounded, but we’ll cover that subject later.

![Snap-on Plug]

*Rewiring A Lamp*

Now that you know how to fix a cord and plug, it’s only a small step to fix a complete lamp.

The most common fault found in an old lamp is in the cord, but sometimes the switch or wiring inside the lamp may need repair or replacement.

Let’s take a look at the socket of a lamp. Most lamps have a combination bulb socket and switch unit with a push-through button. Most sockets are made of metal, but some are plastic or porcelain. Some lamps have a separate push switch in the base.

Sockets may become damaged or broken, or the switch may be worn out from too much use. If so, you will need to replace the entire socket.

![Rewiring A Lamp]

*Materials Needed*

- A new socket
- A new cord
- Your tool kit

*Steps To Take*

1. Unplug the lamp!
2. Remove the lamp shade, shade holder, light bulb and glass diffusing bowl (if there is one).
3. Separate the metal socket shell from its cap by pressing on the shell at the place marked “press”, and pull the socket from the cap. You should hold the cap steady with one hand while you press and apply a twisting action on the shell with your other hand.
4. Pull on the socket body to get some slack in the lamp cord. Remove the outer metal shell and insulating paper.

5. Loosen the two screws on the socket body, detach the cord and remove the plug. You can tie a new cord to the end of the old one before you pull it through the lamp base to help “string” the new wire.

6. Pass the new cord up through the lamp base, through the metal tube if there is one, and to the new socket cap. Be sure the open end of the cap is toward the end of the wires.

7. Next, strip about two inches of the outer covering from the cord, or separate a molded rubber cord back about two or three inches from the end. Molded cords have their covering grooved so the wires can be separated simply by pulling them apart.

8. Now, strip the insulation of the two wires to expose about ¼ of an inch of bare conductor. If the conductor is stranded, twist the strands together tightly to prevent any stray strands from causing a short.

9. Now tie a knot in the two wires so the cord cannot slip back through the socket cap. Leave about one inch free above the knot.

10. Fasten the prepared ends of the wires to the socket body by placing the bare conductor of one wire under each screw head. Be sure to wrap the wires clockwise around the screws.

11. Pull the slack out of the cord so that the socket rests in the cap. Be sure the insulating lining is in the other shell and replace it in the cap. A click or snap will tell you when the notches in the shell are locked to the projections inside the cap.

12. Replace the bulb, inspect carefully and test.

*Let's Make A Trouble Light*

A trouble light can be a real help when you have to work on something at night in the yard, basement or garage when ordinary lights won’t reach. You can use it for both a light and as an extension cord.

**Materials Needed**

About 20 feet of 3-wire, No. 16 heavy-duty (hard service) cord — a three-conductor cord with insulation rated for outdoor use. What type of cord would this be?

A heavy duty attachment plug with grounding prong.

A rubber handled socket with a switch — preferably a push switch with a recess in the handle.

A shielded lamp guard. These look like small cages and are made of interlaced wire to protect the light bulb.

A rough service light bulb and your tool kit.

To assemble your trouble light, follow these steps:

1. Remove about two inches of the outer covering of the cord at each end. Separate the wires and cut away the filler material.

2. Slip the plug housing over the end of the wires. Be sure the open end of the housing is toward the end of the wires.

3. Prepare the end of the wires as you did for the lamp socket earlier.

4. Stick the stripped wires into the wire entrance holes in the plug body (or place them under the screw heads if the plug is so constructed). If screws are used for the connection, connect the wire with the black insulation to the brass-colored screw; connect the wire with the white insulation to the silver-colored screw; and connect the wire with the green insulation to the green-colored screw. This green connection is the grounding connection and should not be made in any other way. The grounding screw also has a hexagon-shaped head to distinguish it from the others, which are round.
5. Tighten the screws (if the wire is attached under the screw heads, make sure the wire is wrapped clockwise around the screws).
6. Snap or screw the plug body into the plug housing.

7. Tighten the plug clamp screws on the plug housing so the cord can’t slip.

Things To Do

Make an Extension Cord

Extension cords can be quite useful, if made of large enough wire to carry the current the extra distance.

Materials Needed

12 feet of 3-wire, No. 16 stranded cord (a good quality of plastic or rubber-insulated Type SJ or SJT will do nicely)
A plastic or rubber plug with cord grip and grounding prong
A connector with cord grip and grounding receptacle
Your tool kit

Steps To Take

A. To assemble the cord, strip the outer insulation from each end of the cord back about three or four inches.
B. Separate the three wires inside the cord and strip about ¼ inch of insulation from the end of each and keep the respective strands twisted together.

8. Moving now to the other end of the cord, prepare the end as you did above in step 3.
9. Separate the parts of the rubber handled socket as you did with the lamp socket earlier.
10. Insert the cord through the rubber handle and the socket cap. Tie a hold knot in the wires.
11. Connect the wire to the terminal screws on the socket body and re-assemble the rubber-handled socket.
12. Screw in the light bulb and test your cord.
13. Attach the shielded lamp guard to the socket and tighten the holding clamp.

C. Slip the cord and the connector onto the wire.
D. Assemble the plug as described in the section you just finished.
E. Unscrew the two longer screws that hold the connector together.
F. Connect the three wires to the proper terminals on the outer part of the connector. (Make sure not to connect the ground wire to the “hot” terminal in the plug).
G. Carefully put the two parts of the connector back together.
H. Inspect your cord carefully and test it.
IV. Home Wiring and Safe Practices

We now know something about wires and about handling electrical wiring. This knowledge will serve well in learning about home wiring.

We learned about circuits in an earlier portion of the Electric Energy Program. We know that electricity must follow a complete path, or circuit, from its source to the point of use and back again. We learned that when several devices are connected to a circuit, they may be connected either in "series" or in "parallel."

In series, the current must flow through each device in the circuit for all of them to work. If one is turned off, or, for example, if one light bulb connected in series burns out, all of them will go off.

In general, a house will have several such parallel circuits for lights and outlets, and several for large appliances. These circuits are often called "branch" circuits.

Each circuit, in turn, is connected in parallel to the main power supply line entering the house. These main lines are called the "service drop", because they usually are dropped from a utility pole to "service" your house. (Many places now use underground wiring.)

From the service drop, electricity goes through a meter which records the kilowatt-hours of electrical energy flowing into your home.

The electricity then goes to a service entrance panel where the power for the entire house can be cut off by operating up to six disconnects. Next, the electricity enters a fuse box or circuit breaker panel, where it is split into all of the branch circuits that serve the different rooms and/or purposes in your house. Sometimes the fuse box or circuit breaker panel is called the "distribution panel." This can be a part of the service entrance panel.

In a home, there are three kinds of circuits. (See illustration on page 10.)

1. General Purpose Circuits These serve lights all over the house and convenience outlets everywhere except the kitchen, where portable appliances are most often used. Most general purpose circuits are rated at 15 or 20 amps.

2. Small Appliance Circuits These are used to supply convenience outlets in the kitchen, laundry and dining areas where portable appliances are most often used. Generally they are designed to carry more electric current than general purpose circuits. Small appliance circuits are usually rated at 20 amps.

3. Individual Large Appliance or Special Purpose Circuits These are designed for large appliances that use a lot of electric current by comparison. Often, one circuit is used for each such appliance. Each circuit may be rated at 30, 40 or 50 amps, such as for a water heater, clothes dryer, electric range, etc., or as much as 70-100 amps for central heating units.

Things To Do

1. Sketch and explain the general layout of your home wiring system from the service drop to the branch circuits.
V. Planning Home Wiring

In planning a wiring system for a home, electricians must consider three things: electrical loads, convenience to the user and safety.

**Electrical Loads**

Why can't we use just one big circuit to supply electricity to all of the lights and outlets in a home?

The answer is that the capacity of each circuit is limited by the size of its wires. We learned this previously. The larger the wire size, the more electrical current it can carry.

\[
\frac{4500 \text{ watts}}{230 \text{ volts}} = 19\frac{1}{2} \text{ amps}
\]

This works the same for an entire circuit. So, if you have a general purpose circuit rated at 20 amps, and operating at 115 volts, the total wattage of all appliance or lights that can be connected to that circuit should not be more than 20 amps x 115 volts equals 2300 watts. We say the maximum load on the circuit can not be above 2300 watts.

An electrician knows, then, that he should not connect so many lights or outlets to one 20-amp circuit that the total wattage goes over 2300 watts. If, for example, the lights and appliances in use in, say, three rooms in a home total 5000 watts, the three rooms need at least two separate 20-amp circuits. The electrician goes over the design of a new home in this way, deciding what usage is likely to be required, and designs enough separate circuits, with the proper size and type of wiring cable, to handle all of the lights and appliances expected to be in use.

What happens if we connect too many appliances or lights to one circuit so the total wattage goes over what the circuit can handle? The result is an "overload."

For example, on a 20-amp circuit, you may have turned on fixtures and appliances that total 2100 watts. Divided by 115, that means about 18.2 amps are flowing through the circuit. Everything is okay.

But suppose your father turns on some shop tools that are powered from the same circuit. The total wattage goes up over 2800, which divided by 115, gives a current of over 24 amps. Now, you have an overload.

Such an overload could lead to overheating and even a fire hazard if it were not for fuses and circuit breakers. Before an overloaded wire can heat up, the fuse "blows" or the breaker "trips", turning off everything on the circuit. Before replacing the fuse or resetting the breaker, you would have to turn off something on the circuit; otherwise it would just blow or trip again.

Another wiring problem is "voltage drop."

You remember that electrical pressure is necessary to force current through resistance. Voltage is expended, or used up, in pushing current through resistance. That is, the voltage measured at the end of a wire will be slightly lower than it is at the supply end. The difference is voltage drop.

The longer or smaller the wire, the higher the resistance, and the larger the voltage drop. Usually, the
voltage drop is so small that we can ignore it. However, if the wiring is too small (increasing the resistance) or if the wire is too long (again increasing the resistance), the voltage drop can be large enough to affect the operation of appliances or motors connected to it. Lights dim, heaters, irons and cooking appliances take longer to heat up and motors may overheat.

The following table shows the change in performance of different types of equipment for different amounts of voltage drop. A minus sign means a drop in performance; a plus sign means an increase, as compared to operation at the normal “rated” voltage.

To reduce voltage drop, as well as overloads, use large size wire to compensate for the distance the wire must run. Or, add more circuits.

<table>
<thead>
<tr>
<th>PERFORMANCE CHANGE CAUSED BY VOLTAGE DROP</th>
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<tr>
<td>Per cent</td>
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<tr>
<td>Voltage Drop</td>
</tr>
<tr>
<td>EQUIPMENT CHARACTERISTIC</td>
</tr>
<tr>
<td>Heat Output</td>
</tr>
<tr>
<td>(heaters, irons, etc.)</td>
</tr>
<tr>
<td>Light Output</td>
</tr>
<tr>
<td>Motor Starting Force</td>
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<tr>
<td>Heat in Motor Windings</td>
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</tbody>
</table>

Upgrading wiring to correct problems of overloading or voltage drop can be quite costly. This is a problem facing persons who have older homes which are not adequately wired to use today's electric appliances.

What are some of the tell-tale signs that your “housepower” isn’t up to par?

1. A shrinking TV picture — the picture draws in from the sides of the screen, loses contrast or the sound becomes distorted.
2. Frequent fuse blowing or circuit breaker tripping.
3. Heating appliances are slow to do their jobs.
4. Lights dimming when other appliances are turned on.

You will remember the three types of circuits — general purpose, small appliance and individual large appliance. With this in mind, we can easily map out all the circuits needed and bring them together at the distribution panel. Then we can figure the size of the service entrance needed to serve all of these circuits.

As an example, let's consider a home that has 1800 square feet of floor area, eight small appliance outlets, a 12,000-watt electric range, a 4,500-watt water heater, a 16,000-watt electric heating system, 5,000-watt air conditioning unit (cooling), a 1,500-watt dishwasher, a 5,400-watt clothes dryer and a 700 watt washing machine. The range, heating system, air-conditioning system, clothes dryer and water heater each operate on 230 volts; all else uses 115 volts.

Let's see how this house could be wired adequately, as recommended by the National Electric Code.

1. General Purpose Circuit: 1800 square feet divided by 500 square feet per circuit (rule of thumb) equals 3.6 (use 4) circuits. 1800 square feet x 3 watts per square foot equals 5400 total watts.
2. Small Appliance Circuits: Allow 1500 watts maximum per circuit, rated at 20 amps. 8 outlets divided by three outlets per circuit equals 2.7 (use 3) circuits.
3. Range: Figure on 8000 watts instead of the full 12,000. Why? Because all of the heating elements plus the oven are not usually turned on at one time. This is called “diversity factor.” Requires one circuit rated 40 amps — use 40 amps as the circuit rating.
5. Heating System and Air Conditioning: (16,000 watts divided by 230 volts equals 69.6 amps — use 70) Air Conditioning: (5000 watts divided by 230 volts equals 21.7 amps — use 30). The heating and air conditioning are not likely to be on at the same time for a heating system rated a 16 kw. When both electric heat and air conditioning are used, use the higher wattage of the two to determine the total load. Normally electric heat will be served by many circuits from a subpanel.

Now we can make a chart that shows how our home should be wired:
Give your appliances and lights a square meal

Shrinking TV picture

Too much fuse blowing or breaker-tripping

Watch for these signs of starvation

Heating appliances slow

Lights dimming

CIRCUITS

NUMBER  VOLTS  WATTS  AMPS

General Purpose  4  115  5400  20
Small Appliance  3  115  4500  20
Dishwasher  1  115  1500  20
Washing Machine  1  115  700  20
Electric Range  1  230  8000  40
Electric Water Heater  1  230  5000  30
Electric Heating System  1  230  16000  70
Air Conditioning  1  230  -0-  30
Electric Clothes Dryer  1  230  5400  30

46,500  280

In total, then, for adequate capacity, our properly wired house will have:
1. Nine 115-volt, 20 amp circuits
2. Three 230-volt 30 amp circuits
3. One 230-volt 40 amp circuit
4. One 230-volt 70 amp circuit

What size service entrance will this home require?

If you add up the amp sizes of all the circuits, you would get 280 amps! However, that would be assuming that all appliances and lights are to be used at once. As you know, that almost never happens.

Electricians therefore use a rule of thumb from the National Electric Code which says:
1. Figure the first 10,000 watts of total capacity at 100% (full usage) equals 10,000 watts.
2. Figure the remaining watts at 40% of capacity: 46,500-10,000 equals 36,500 x 40% equals 14,600 watts.
3. Add the two figures: 10,000 plus 14,600 equals 24,600 watts.
4. Divide by 230 volts: 24,600 divided by 230 volts equals 106.95 amps.
5. Select the next highest standard service entrance.
size. Standard sizes are 100, 150, 220 and 400 amps. In this case, we would use the 150 amp service entrance.

Sometimes another method is used, allowing an extra 20 percent for future capacity in sizing the service entrance. Can you use this method to test your home to see if it is adequately wired? This method may give you enough capacity, but sometimes the house will be wired inconveniently as a result.

**Wiring for Convenience**

Electricians must consider the convenience of the persons who will use the wiring system. No matter how well wiring is designed electrically, it is of little use if not laid out conveniently.

There are several rules of thumb electricians consider in laying out wiring for convenience.

1. An electrical outlet is recommended for every 12 feet of wall space. Outlets should be located near the ends of wall spaces, rather than the center, thus reducing the likelihood of being concealed behind large pieces of furniture.
2. An outlet is recommended for every 4 feet of work-counter space in kitchens.
3. A light switch should be located so lights can be turned on before you enter a darkened area and off as you leave.
4. Hall and stair lights should be controlled from a switch at each end of the hall or stairway.
5. If a room is lighted by floor and table lamps, some outlets should be controlled by switches located near doors.
6. Whenever possible, one half of the lights and outlets in a room should be connected to one circuit and the other half to another circuit. If a fuse blows on one circuit, the lights and outlets on the other circuit will still work.
7. Proper illumination is an essential element of modern electric living. The amount, type and location of outlets for lighting and permanently installed light fixtures should be fitted to the various visual tasks carried on in the home.
8. Have a couple of “empty” circuits in your distribution panel for future needs.
9. Design circuits so they can have additional outlets added if they are needed for convenience.

**Wiring for Safety**

Of course, the overriding concern in any wiring system must be safety.

Some general safety procedures are followed by electricians in designing and working on house wiring:

1. Work under the supervision of someone who knows how to handle electricity.
2. Remove the fuse or flip the circuit breaker before working on a circuit. Place a note on the fuse or breaker so that someone will not turn on the power again while you are working on the circuit.
3. Always use the correct sizes and types of conductor cable.
4. On new installations, use only outlets that accept three-prong grounding plugs and make sure every metal box and accessory is grounded.
5. No switches or outlets should be located near bathtubs, laundry tubs, sinks, radiators, metal registers or metal piping.

One way that helps assure safe electrical wiring is through the establishment and use of proper electrical codes. For example, the National Fire Protection Association has drawn up a set of regulations known as the National Electric Code (NEC). Although these codes are not national laws, many states have made them state laws. The NEC is a minimum requirement and some local codes are even stricter.

Often a state, county or city may also require that you have your wiring plan approved and take out a permit before doing any major work. Furthermore, it may be required that a load inspector examine the new wiring to make sure it follows the codes before the power company will hook up to the new circuits and start delivering power. While an installation which meets NEC requirements will be safe, it may not be adequate for all your needs.

**Drawing Electrical Plans**

Just like house plans, road maps, etc., electrical plans are drawn for a home wiring system so any electrician can tell where electrical equipment is to be located just by looking at the plan.

The following is an example of a simple electrical
plan. Shown are the outline of the walls, openings for doorways, three convenience outlets, one ceiling light controlled by a switch located next to the left-hand door, and an outdoor light controlled by a switch located by the right hand door. The dashed line indicates which switch controls the light, not the actual path of a wire. A list of symbols & what they represent is shown on page 16.

The following sketch shows a more complete electrical plan, which should be drawn whenever you want to add electric wiring. Notice where the electrical equipment is located.

![Floor Plan Diagram]

**Things To Do**

1. **"Audit" Your Branch Circuits**
   Find out which lights and outlets are on which circuits at home. Follow this procedure:
   A. Turn on all the lights in your home.
   B. Unscrew and remove the fuse or trip the breaker on the first circuit.
   C. Write down the amperage rating of the circuit.
   D. Write down which rooms are served by the circuit by noting which lights are now off. Check outlets in the affected room or area with your test lamp to see if they are on the same or a different circuit.
   E. Write down the wattage of the lights and appliances to be used in the circuit.
   F. Replace the fuse or reset the breaker.
   G. Unscrew and remove the fuse or trip the breaker on the next circuit and continue to follow this procedure until you have completed all the circuits.
   H. Prepare a circuit chart and attach to the distribution panel as a handy reference.

I. **Prepare a second chart to see if the wattage of lights and appliances in use on each circuit may exceed the circuit capacity.** For those circuits where the demand for amps may exceed the circuit rating, observe caution by not using all appliances on that circuit at the same time.

J. **Point out to other members of your family which circuits may be overloaded.**

K. **Develop a plan for distributing the load if there appears to be an overload on one circuit.**

2. **Draw an Electrical Plan of Your Home**

Using the electrical symbols as shown on the next page, draw a floor plan (sketch of a room layout showing walls, doors, windows, etc.) of your home. Locate switches, outlets and light fixtures. Are the outlets located according to the general guidelines mentioned in this lesson? Make a chart like this:

<table>
<thead>
<tr>
<th>No.</th>
<th>Serves</th>
<th>Fuse Size</th>
<th>Voltage</th>
<th>Item Connected</th>
<th>Wattage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Living Room</td>
<td>20</td>
<td>115</td>
<td>TV</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 lamps</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vacuum</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Radio</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1100</td>
</tr>
</tbody>
</table>
VI. Grounding

In an earlier part of the Electrical Energy Program, we talked about how electricity likes the ground, and that electric current will choose the shortest path to the ground, even though that path might be through a person's body.

Electrical wiring and appliances are designed so that normally this will not happen. The wires, terminals, coils and heating elements — all of the current carrying parts — are usually well insulated or otherwise protected.

Sometimes, however, through damage or heavy use, this insulation or protection fails. When this happens, other metal parts, such as the frame of an appliance or the outside of a switch box, may become electrically charged or "hot".

If these parts are not grounded (connected to permanently moist earth with a conductor of sufficient size), the current will seek whatever other path is available. If you should touch such a metal part, that path just might be you.

If the frame of the appliance is grounded, then any leakage will flow to ground through the ground wire — instead of through someone who touches the frame. If this current flow is great enough, it may cause the fuse to blow or the breaker to trip. If the flow is not great enough to cause this, it will trickle away to the ground slowly, harmlessly — except to increase your electric bill.
Because of the obvious importance of grounding, electrical codes require that wiring and equipment be grounded when installed.

Two types of grounding are used in electrical systems: "system grounding" and "equipment grounding".

**System grounding** involves the connection to ground of all the "neutral", or return, wires of all of the branch circuits in the building. A separate "grounding conductor" then joins the " neutrals" of both the service entrance wires and the branch circuits to a ground rod or metal water pipes.

This type of grounding protects from two things: voltage "surges" through the service entrance wires and wiring shorts inside the building.

In the first case, either an insulation break in the power company's supply transformer, an accidental contact between the service drop and high voltage wires or lightning may cause excessively high voltage to enter the building's electrical system. If the neutral wire is not grounded, these high voltages could cause fires and seriously injure or kill. When the neutral wire is grounded, these high voltages will be led straight to the ground before they can cause harm.

In the second case, if an insulation breakdown occurs in the building wiring, the "hot" wire will form a short circuit with the neutral wire. The short circuit will cause a fuse to blow or a breaker to trip.

**Equipment grounding** involves the grounding of all exposed metal parts of the wiring system, including the frames of electrical appliances. It is accomplished by connecting these exposed metal parts into the system ground.

This wire may be bare or insulated with green-colored rubber or plastic. The ground wire is connected to the frames of all metal outlet and switch boxes, light fixtures, frames of all permanently wired equipment and finally to the grounding connector at the distribution panel.

Grounding plugs have three prongs — a rounded one in addition to the two blade-shaped prongs. The third prong indicates that the cord contains a ground wire. This ground wire will be connected directly to the frame of the appliance to which the cord is attached.

An extension cord with a ground wire completes the electrical path from the appliance to the grounded electrical outlet.

Most new electrical systems include outlets with three holes which will accommodate grounding plugs. The "third hole" in the outlet is connected to the ground wire in the circuit.

Remember, it doesn’t pay to cheat your grounding system by using extension cords without ground wires!

If you have an appliance or extension cord with a three-prong plug and the outlets are the two-prong type, use an adapter which connects the ground prong to a flexible wire with a simple lug on the end. If the outlet boxes are connected to ground, you can connect this adapter ground wire to the center screws of the outlet cover plate.

![Receptacle Grounding](image-url)
Modern Grounding-Type Convenience Outlet

You can check to see if the center screw is grounded by using a simple test light as shown...one probe to the hot side of the outlet and the other to the coverplate screw. If the light goes on, the center screw is grounded. One of the project ideas at the end of this lesson shows how to make a test light.

What can you do if your appliance cord does not have a ground wire? You can add a separate ground wire. This can be done with an appliance which is permanent in its position. Simply fasten one end of a copper wire under a convenient screw on the metal case or frame of the appliance. Connect the other end by means of a screw-type connection to the service entrance neutral (where the white wires of all circuits are connected). The wire you use should be no smaller than those supplying power to the appliance. You can tape it to the regular cord for the distance that the two run together. Protect the wire from damage.

If your home is equipped with three-hole, grounded outlets, use the same separate grounding wire, this time using a special three-prong grounding plug. You can remove the two-prong plug from the appliance cord and replace it with a three-prong grounding plug, connecting your ground wire to the third prong inside the plug.

Ground Fault Circuit Interrupters

A new safety device is the ground fault circuit interrupter, or “GFCI.” It will prevent shocks that are strong enough to injure a person and will work with either grounded or ungrounded appliances.

The GFCI has an electronic circuit that acts something like a balance scale. It will detect if more electricity is flowing in one wire than the other.

Under normal operation, the same amount of electricity flows through both wires.

However, if a fault has occurred in the appliance and you touch it while being grounded yourself, some electricity will flow through you. Thus, less electricity will be flowing through the return or neutral wire of a circuit than the other wire.

The GFCI “senses” the imbalance or difference in current and opens the circuit so you will not be hurt.

Ground fault circuit interrupters are available in three styles. One style can replace a regular circuit breaker. The whole circuit will then have ground fault protection. Another type replaces regular convenience outlets. Any appliance plugged into this outlet will have ground fault protection. A third style plugs into a regular grounded outlet. The appliance then plugs into the interrupter.

GFCI’s can be found at some electrical stores and in some mail-order catalogs. They should be used in places where electricity must be used near water—bathrooms, outlets in garage areas and out-of-doors locations. The 1981 National Electric Code requires them for such use.
**Steps To Take**

1. Strip about three-quarters of an inch of insulation from the wire leads of the socket.

2. If the wire is stranded, twist the bare conductors together tightly. If possible, apply solder to the twisted strands so they won't become frayed.

3. Place the bulb in the socket.

4. To test a receptacle, place one lead in one of the outlet slots and one lead on the coverplate mounting screw (see illustration on page 18).

5. If the bulb lights, the receptacle is grounded.

6. If the bulb does not light, switch the lead from the first outlet slot to the other one next to it. The bulb may light this time, indicating that the receptacle is grounded. If it does not light, the receptacle is not grounded.

7. Use the chart below to record the results of your test throughout your home.

---

**Things To Do**

Receptacle Grounding Check:
Check your home wall receptacles to see if they are grounded or ungrounded.

**Materials Needed**
One molded rubber (outdoor type) bulb socket with built-in wire leads
One 230-240 volt, low wattage light bulb, rough service

---

<table>
<thead>
<tr>
<th>Room</th>
<th>Number of Receptacles</th>
<th>Number Grounded</th>
<th>Not Grounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dining</td>
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<tr>
<td>Kitchen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hallway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedroom</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bedroom</td>
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<td></td>
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</tr>
<tr>
<td>Den</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VII. HOME WIRING EQUIPMENT

Knowing how an electrician approaches the task of wiring or re-wiring a home, we should now take a look at some of the equipment used; the wiring cable, switches and outlets, fuses and circuit breakers.

Wiring Cables and Conduits

Just as with the cords for appliance used around the house, wiring cable is identified by conductor size (AWG code) and by insulation type.

There are three general types for home wiring use:
1. Non-metallic sheathed cable
2. Metal-clad armored flexible cable
3. Conduit wiring

Non-metallic sheathed cable now has three or more conductors. Two conductors are for the usual current-carrying circuit, consisting of the “hot” wire from the source and the “neutral” or return wire. The third is for a ground wire. There may also be an extra wire for special applications. This kind of cable is often called “Romex”.

Type NM has a flame resistant covering for use inside in dry locations.

Type NMC is for use inside or out in damp locations above ground.

Type UF is for use underground and can be directly buried or run through the spaces within masonry walls.

Metal-clad armored flexible cable has one, two, three or four individually insulated conductors bound together by a flexible metallic enclosure, which gives excellent protection against damage.

Type AC and ACT must be used in dry places. The conductors in type AC have rubber insulation. In both types, a bare ground wire is present just under the metal enclosure.

Type ACL has conductors with rubber insulation, and, in addition, a lead sheath which surrounds the whole bundle of wires. This type of cable can be run underground or buried in concrete.

Type MC cable is used mostly for commercial and industrial wiring.

Conduit wiring has four types which are handled basically the same. The conduit serves as a strong “pipe” through which the individual current-carrying wires are strung. The conduit itself serves as a ground wire. Conduits use connectors to fasten on to metal outlet boxes.

a. Rigid conduit is a metal pipe that forms a strong protective channel for wiring.

b. Electric Metallic Tubing (E.M.T.), or thin-wall conduit, is the same size as rigid conduit, but has thinner walls so that it can be handled more easily.

c. Intermediate Metal Conduit (I.M.C.), has a wall thickness between rigid and thin-wall conduit.

d. Flexible conduit looks much like metal-clad armored cable, but contains no wires until they are placed there.

Many different types of wire are made for use in conduit. All are individually insulated.

Types TW and THW are used most often in home wiring. Both are single-conductor (non-stranded) wires with plastic insulation. In larger wire sizes, the conductors are stranded. These two types can be used in dry or damp locations. Type THW is resistant to heat, in addition to being resistant to moisture.
Similar types, RW and RHW, are used in the same areas, but use rubber instead of plastic insulation.

Whatever type of wire or cable, common practice calls for one of the circuit conductors to have black insulation, another white.

The black conductor should always be connected to the source side of the circuit, and is always considered to be the “hot” wire. The white wire is always in the neutral or return leg of the circuit.

The National Electric Code specifies how many individual conductors can be placed safely in each size conduit.

The only exception to the black-white practice is when a piece of cable is used to connect a switch to a light fixture — also called a “switch loop.” Here, the white wire serves as the continuation of the “hot” wire from the switch to the fixture.

Switches

A switch enables you to control electricity - to complete a circuit or break a circuit - as you wish. Although a switch is a fairly simple device, there are several things you should know about the kind used in home wiring. The most common type of switch is the “single pole” light switch. A single pole switch controls the lights from a single location. These switches are always placed in the circuit so that electricity flows through it before it gets to the light or appliance as shown above. Think about this for a moment. If the switch is between the power source and the appliance, the electricity stops at the switch when it is open. On the other hand, if the switch is placed in the white or “neutral” wire, electricity will be present at the appliance outlet even when the switch is in the off position. This could cause a shock if you touched the appliance and, say, a ground pipe at the same time.

A more complex type of switch is a 3-way switch, which can be used to control the same light, or lights from two locations (or from more than two locations, when used with four-way switches). For example, you may want to be able to turn a hall light on and off from either end of the hall.

With 3-way switches, a light can be controlled in this manner. Trace the path of electricity in each sketch. Can you see how the lights can be turned on or off by flipping either switch A or switch B?
A 4-way switch is still more complicated, but allows even more flexibility in controlling lights or appliances. A 4-way switch used in combination with two 3-way switches will allow one light or group of lights to be turned on and off from any one of three separate locations.

Again, trace the electrical path in the sketch below which shows the layout of a 4-way circuit. Actually, you can use any number of 4-way switches in the circuit. Each added 4-way switch adds another point where the light can be turned on or off.

For the sake of simplicity, the grounding wire to all switches is not shown in these wiring diagrams. In actual use, however, it should be connected to outlet boxes. Single pole, 3-way and 4-way switches are wired differently, but the basic mechanism is about the same — a set of metal contacts that is closed into a circuit or opened as the switch is flipped. The contacts are of the tumbler or snap type, which provides fast “make-and-break” action, eliminating “arc” or flashing of the current.

Three-way and four-way switches differ in construction among different manufacturers. The only way to be sure of your wiring is to either look at the diagram included in the box the switch is packed in, or check the internal connections with a continuity tester.

Flipping the switch produces a characteristic “click” as the contacts spring into or out of place in the circuit. This mechanism is enclosed in a plastic or “bakelite” case, with the proper mounting hardware and terminal screws to attach wires on the outside.

Just as there is a custom behind the use of black wires as hot wires and white wires as neutrals, the same custom is used in connecting such wires to switches and other wiring equipment. Black wires are always connected to brass-colored terminals; white wires are always connected to silver terminals. A green terminal is the grounding terminal, and is for the third or ground wire in an electric cable. Screw terminals on switches are not color-coded — they are brass for hot wires.

Switches are mounted inside metal switch boxes which are recessed into walls.

Finally, a cover plate is placed over the box, shielding all but the switch handle and keeping the live parts out of reach.

Another kind of switch mechanism is the mercury switch. These switches have two contacts sealed into a small glass tube containing a few drops of mercury. The tube is attached to the lower lever of the switch. When the switch is flipped, the glass tube is tipped, the mercury flows to the end of the glass tube containing the contacts. Mercury, a good conductor of electricity, closes the circuit. Mercury switches have the advantage of being both quiet (no “click” when the switch is flipped) and long lasting.
Other Types of Switches

There are several other types of switches or controls occasionally used for special purposes around the home or other buildings.

1. Knife Switches. These switches are also simple. They use a hinged blade to open and close a circuit. They are not safe for use with house current when they are exposed.

   For this reason, they are only found in enclosed switch boxes. Main switches at distribution panels are occasionally of this type.

2. Time Switches. These work like alarm clocks. They have contact points connected to a circuit. A clock drives the mechanism and when it reaches the time set, the contact points close and the current goes on. Your clock radio has a time switch to turn it on at "get-up time" in the morning.

3. Photoclectric or Light-Sensitive Switches use electric eyes made of selenium. Selenium is a material that conducts small amounts of electricity only when light is shining on it. The selenium can act as a switch to automatically turn lights on when it gets dark. Many towns and cities use photoelectric switches to control their street lights.

4. Contact Switches. Sometimes known as micro switches, these are very simple. They work like a doorbell push button. They can be set to be off when pushed in, such as the ones which control the lights in your refrigerator or the courtesy lights in your car. When the door is open, the switch is released and the light goes on.

5. Temperature Switches or "Thermostats" turn equipment on or off when the temperature in a certain area gets too high or too low. Thermostats are of two common types: bi-metal strip or wafer.

   The bi-metal strip type has two thin pieces of brass and iron soldered together. When this "sandwich" strip gets warm, it bends, since one metal heat will expand it more than the other. When the strip bends, it makes contact between two contact points.

Thermostat operation

Some thermostats are designed to let you select the temperature at which you want it to trip on or off. Thermostats like these are used to control home heating and air conditioning systems, electric fry pans, roasters, irons, etc.

Outlets

The outlets are another important part of the electrical system.

The most common outlet is the "duplex" outlet which has two receptacles for cord plugs. Older type duplex outlets had two openings or slots for each plug. Newer outlets have three openings for each plug.

The two blade shaped prongs on the plug connect to the hot and neutral wires of the circuit. The rounded prong connects to the ground wire.
There are other, special purpose outlets that are often used in the home. Electric clothes dryer outlets have a different opening than range outlets because the dryer outlet is not wired as heavily as a range outlet. Air conditioning outlets are different from both range and dryer outlets for the same reason.

Other special outlets you may find are clock outlets, floor, dishwasher and weather-proof outlets with spring loaded covers for outdoor use.

**Fuses and Breakers**

You may remember our discussion of electric watchdogs in an earlier unit of the Electric Energy Program — that is, fuses and circuit breakers. These are devices designed to cut off the current by causing an open circuit when the current goes over a preset value or rating. The ampere rating of fuses and circuit breakers are matched to the ratings of the wire size in the circuit to which it is connected.

They can be found in many different ampere ratings. You will usually find the rating printed or stamped on the fuse or breaker. Examples are 15, 20, 40, 60, 100 and 200 amperes. Which ones can you find in your home?

Both types are wired in series with each circuit so all the current going into the circuit has to go through the fuse or breaker first.

These watchdogs will let the current pass easily as long as it is less than their ampere rating. If the current goes above the rating, the fuse blows or the breaker trips — causing an open circuit which stops the flow of current.

Let's take a look at each kind of electric watchdog. **Fuses** All fuses have a short, fine piece of wire or strip of metal inside that is very special. We call this the "element" of the fuse. The element is the weakest link in the whole wiring systems. When a short circuit occurs or an overload develops, the entire circuit heats up — including the fuse element. However, the fuse element is so weak that it will melt long before the rest of the wiring does. This stops the flow of electricity.

There are two kinds of fuses according to their shape; plug fuses and cartridge fuses.

Plug fuses are the most common type used in the home. They have plugs with threads just like a light bulb and screw into sockets in the fuse box. Plug fuses are not made in sizes larger than 30 amperes.

Some fuses have only one element that takes care of both shorts and overloads. Others have two elements: one made especially to handle shorts and the other especially for overloads. These fuses give better protection and are a bit more convenient than single element fuses. Let's see why.

With a two-element fuse, the element designed to handle shorts will melt or "blow" very quickly. This is important, since shorts can be dangerous.

The second element, however, takes its time. If it sees an overload, it "waits" before it blows, just in case the overload stops quickly. This convenient characteristic is why two-element fuses are also called "time delay" fuses.

There is another type of time-delay fuse that uses an insert so that only one size fits the element. A larger size fuse would create a hazard.

As you will see later, electric motors require a big push of current or "surge" to get them started — just as you have to give an extra hard push to start a big barrel rolling across the ground. Once the motor is started, the current settles down to a lower level to keep it going. Your refrigerator or air conditioner has such a motor. They need a big push of current to get started.

A two-element fuse lets this quick surge pass without blowing, and that is a big help to you. After all, it would be inconvenient to have to replace a fuse every time your refrigerator started!

The sketch below shows how this two-element fuse works.

![](image)

A look inside a two-element plug fuse: (a) parts of fuse are shown, (b) a short circuit causes fuse link to melt, and (c) solder melts and spring pulls fuse link out of solder cup when circuit is overloaded.

When replacing a blown fuse, be sure to replace it with one of the same ampere rating. One with two low
a rating would blow unnecessarily, while one with too high a rating may let too much current pass and allow the wires to overheat.

You can avoid any mix-up in fuse ratings by using "Type S" fuses, also commonly known by the trade name "Fustat." The fuse itself is the same as the time delay fuse discussed earlier, but will not fit an ordinary fuse socket. A special adapter must first be installed in the fuse socket. Once installed, the adapter cannot be removed. The adapters come in different sizes for 15-amp, 20-amp or 30-amp fuses. The 15-amp adapter will accept only a 15-amp fuse; the 20-amp adapter will accept only a 20-amp fuse, and so forth. Type S fuses thus prevent the use of the wrong size fuse, as well as the foolish and unsafe practice of placing a penny under the fuse.

Type S fuse and adapter

Cartridge fuses can be found in sizes up to several hundred amperes. Like plug fuses, they can be bought with either a single element or with two elements.

The inside of a cartridge fuse with 2 elements

Circuit Breakers Circuit breakers do the same job as two-element fuses. Like fuses, they are available in many different ampere ratings. Circuit breakers have a bi-metallic strip that gets warm and bends when electricity flows through it, much like a thermostat. As the flow of electricity increases, the strip gets hotter and bends.

If the strip bends enough, it causes a spring trigger to be released, which in turn opens the circuit, stopping the flow of current. When the trigger is released, the circuit breaker is said to be "tripped".

Some circuit breakers also utilize the thermal-magnetic delay principle which makes allowances for the surge of power necessary to start air conditioners and other motors.

When the metal strip straightens (which happens quickly), the trigger can be set back to its original position and the current can flow again. This is called "resetting" the circuit breaker. The circuit breaker trigger can also be used as a handy switch to turn off the entire circuit, when you have to work on the circuit.

Junction boxes are used where two or more cables come together and must be spliced or connected. When junction boxes are used in wiring, they may be concealed in attics, under floors, or in other out-of-the-way locations, but they should always be accessible in case maintenance or future wiring changes become necessary.

Note that, per custom, all black ("hot") wires in a junction box are twisted together and all white ("neutral") wires are twisted together. The exception, again, is the case where a switch loop is connected within the junction box.

All cable connections must be made in junction boxes, or inside of the similar metal boxes that house switches, fixtures or outlets. The cable must be one continuous piece from box to box and never should be cut or spliced. Also, all boxes must be connected to the ground wires of each and every cable that enters them, so the entire grounding system will remain intact and interconnected.

The following illustration shows how wiring is connected to each of the several basic kinds of wiring devices we have discussed.
VIII. Maintaining Home Electric Equipment

The user of electrical equipment should know some of the basics of how to care for the equipment. Let's look at some important tips on how to take care of your electrical equipment and learn how to make some simple repairs.

Maintaining the Wiring System
Most of the time, you will not need to be concerned with the wiring inside the walls, attic or basement of your home. Such wiring is made to last a long time. If proper insulation has been chosen for the conditions and all connections soundly made, you should not have to disturb it.

Switches, wall outlets and light fixtures are another matter. Although generally quite reliable and in need of little or no day-to-day care, contacts and terminals can get loose or corroded, switch mechanisms can wear out, light fixtures can become obsolete. When this happens, you will want to know how to replace them.

Remember, before working on any device, trip the circuit breaker or remove the fuse for the circuit you are working on. Double check that the circuit is dead, either by trying to turn on a light or appliance that is connected to or controlled by the outlet or switch you are going to work on. Use your test light to double check. Leave a note on the distribution panel so that some well-meaning person doesn't come along and reset the breaker or replace the fuse while you are working.

Replacing Single-pole Switches
From time to time, one of the simple light switches in a home will quit working properly. If this happens, you'll want to replace the switch. Or, you may want to replace an old switch with a new, quieter mercury switch.

After checking that the circuit is off:
1. Remove the screws holding the cover plate on the switch and remove the plate.

   This plate prevents your touching the electrical parts of the switch and improves the appearance of the switch and wall.

2. Remove the screws holding the switch in place in its metal box.

3. Pull the switch out of the box as far as the wires will allow.

4. Loosen the screw terminals and unhook the wires from the switch. If the old switch is “back-wired”, find out how to disconnect the wires before you try to remove them.

5. Scrape the bare ends of the wires to remove dirt and corrosion.

6. Loosen the screw terminals on the new switch. If it is back-wired, find out how the wires should be installed.

7. Connect the wires to the terminal screws of the new switch. Remember to: (a) keep the switch right side up so the off and on markings read as they should (b) loop the wire around the screw terminal in the same direction the screw is turned when being tightened and (c) connect the black and white wires
to the brass-terminals and the ground wire (if it is present) to the ground terminal. All screw terminals are the same color (brass) on switches. Be sure the connections are tight.

8. Push the switch back into the box. Make sure the wires fold up neatly behind it.
9. Replace the screws that hold the switch in place. Make sure the switch is straight up and down even if the outlet box is not.

10. Replace the switch cover plate. Be careful not to tighten the screws so much that you bend or crack the switch plate.
11. Turn on the electricity to the circuit again.
12. Test the switch to see if it works.

Replacing 3-way Switches

3-way switches are more difficult to replace than single-pole switches, because the wires must be connected to the correct screws on 3-way switches. The two “traveler wires” between the switches can be turned around, but the “switch leg” wire must go to the “switch leg” terminals only.

The sketch below shows the usual positions of the switch leg terminal. If your switch doesn’t look like this, get help to find the switch leg terminal by using a continuity tester.

When you replace or connect a 3-way switch, be sure to find which switch is faulty. Usually just one switch will be the culprit. Follow the same steps in replacing a three-way switch as outlined for replacing a one-way or single-pole switch, except note the difference in wiring.

Replacing 4-way Switches

Most 4-way switches have terminals in an arrangement as shown below. The wires must be paired correctly on each side of the switch. Make sure the wires on top go to the top terminals and the wires on the bottom go to the bottom terminals.

To replace a four-way switch, follow the same basic directions for replacing a single-pole switch, except notice the difference in wiring.

To check the wiring, hook the wires together as shown below.

Replacing an Electrical Outlet

To replace a duplex outlet, just follow these steps:
1. Turn off the power to the circuit supplying the outlet. Test to be sure that it is off, either by plugging in a lamp you know is in working order or by using a test lamp.
2. Remove the screws holding on the cover plate and remove the plate.
3. Remove the screws holding the old outlet in place.
4. Pull the outlet out of its box.
5. Loosen the screw terminals and unhook the wires from the old outlet.
6. Connect the wires to the correct screw terminals of the new outlet.

If you have a two-prong (non-grounded) outlet, simply connect the black wire or wires to the brass-colored screws and the white wire or wires to the silver-colored screws.

If you have a three-prong (grounding) outlet, connect the black and white wires as shown. Then, connect the ground wire (bare or covered with green insulation) to the green-colored, hexagon-shaped (six-sided) screw. Always replace the grounding outlet with another grounding outlet. Remember that the black wire is the “hot” wire.

7. Tighten all screw terminals. Make sure the wire is looped around the screw in the same direction you turn the screw when tightening it.
8. Re-check all connections.
9. Push the outlet into the outlet box making sure the slack wire is neatly folded behind it.
10. Replace the screws that hold the outlet in place. Make sure the outlet is positioned straight.
11. Replace the outlet cover plate and the screws that hold it.
12. Turn on the electricity.
13. Test the outlet with a test lamp.

Replacing Lighting Fixtures

You may want to replace a lighting fixture because it is broken, or you may wish to replace it with a different fixture. Fixtures for incandescent bulbs are usually mounted in one of four ways:

1. The fixture may be screwed directly to the outlet box.

2. The fixture may be screwed to a mounting strap that is fastened to the outlet box.

3. The fixture may be screwed to a mounting strap that is fastened to a center stud, which is similar to a large hollow bolt.
4. The fixture may be mounted directly with a center stud.

To replace the fixture, follow these steps:
1. Shut off the electricity to the fixture. Remember, just turning off the wall switch does not assure that the electricity has been shut off at the connections inside the fixture!
2. Remove the glass globe or any other decorative part of the fixture.
3. Remove the light bulb or bulbs.
4. Remove the screws or center stud holding the fixture to the outlet box or mounting strap. Or, you can loosen the screws enough to rotate the fixture so the screw heads slip out of the key-hole slots in the fixture.

5. Disconnect the wires going to the fixture.
6. Add any parts to the outlet box that are needed to mount the new fixture.
7. Connect the circuit wires to the fixture. White wires go to white wires; black wires to black wires.
8. Follow the reverse of steps 4, 3, 2 and 1.

Correcting Overloads

One of the simplest and most common maintenance chores involving home wiring is the replacement of a blown fuse or the resetting of a tripped circuit breaker.

When a light goes off or an appliance will not work, first check to be sure that the lamp or appliance is getting electricity. Use your trouble lamp to check the wall outlet. If electricity is present, the trouble is in the lamp or appliance — not in the wiring system.

Another possibility might be that the power is off to the whole house. If no other lamp in the house is working, you have a power failure. Call the power company. Don't wait for someone else to call.

If the power is not off, the problem is most likely a blown fuse or a tripped circuit breaker.

Unplug or turn off the light or appliance you last turned on just before the circuit went dead.

If the circuit went dead instantly after turning on the appliance or lamp, you may have a short. Disconnect the appliance for later examination or, if a permanently wired fixture seems to be the culprit, check the switch and the fixture for shorts, while the current is still off.

Wires that have worked loose from terminal screws and have made contact with another wire or ground are often the source of such trouble.

If the circuit went dead a few minutes after turning on the switch of the light or appliance, the problem is likely an overload. Turn off the light and disconnect the appliance.

You'll either have to reduce the load on that circuit somehow or move the appliance to a different circuit.

If you don't take these steps first, you will probably just blow the fuse or trip the breaker again.

Locate which fuse is blown or which breaker is tripped. Stand on a dry board if the fuse box or
distribution panel is in a damp location.
Replace the fuse with one of the same ampere rating, or reset the breaker by turning it first all the way off, then back to on.

4. Check From the Source to the Use.
   If an appliance fails to operate, we are apt to think that the trouble lies within the appliance itself. In many cases, however, this is not true. Instead, the reason it doesn’t work is that it may not be receiving electricity from the outlet or through the cord.

   A. Plug another appliance or light into the same outlet. If it works, then you have eliminated possible trouble up to that point. If it doesn’t work, go to the fuse or circuit breaker.

   B. Check the plug and cord of the appliance. If it is a detachable cord (one with plugs at both ends), remove it from the appliance. Using your continuity tester, attach one clip to one of the wall plug prongs, and touch the other to the metal contact in one or the other of the slots in the appliance plug. One or the other should cause the bulb to light. Then move the first clip over to the other prong and a touch of the second clip in the other slot should cause the bulb to light again. (If the cord has a temperature control or switch built into it, make sure that this is in the “on” position).

   C. If the cord and plug are attached, follow similar procedures, but it will be necessary to “open up” the appliance to get at the terminals to which the cord is connected.

   D. If the cord and its connections are good, then you should start checking the appliance itself for a broken wire, a bad element or an open circuit. Touch the clips of the continuity tester to various points along the wiring within the appliance to determine whether there’s a path for the current.

   If you cannot pinpoint the trouble, or if you can’t repair it when you do locate it, then you should call an electrician, take the appliance to an authorized service agency, or discard the appliance altogether.

Things To Do

1. Check Appliances for safety
   It is good to check your appliances occasionally for shock hazard. To do this, touch one clip of your continuity tester to the metal frame of the appliance. Touch the other to the cord prongs, one at a time. If it doesn’t go on, there is no apparent shock hazard.

   Be sure that the appliance is disconnected from the outlet while you are testing.

2. Appliance Troubleshooting
   Show how to check an appliance cord and plug with:
   A. a test lamp
   B. a continuity tester

3. Appliance Service Project
   Make an appliance service chart. Leave plenty of room to write in the type of service needed and dates done. Post the chart on the inside of a cabinet door, or someplace where you will see it from time to time as a reminder to follow up on service.