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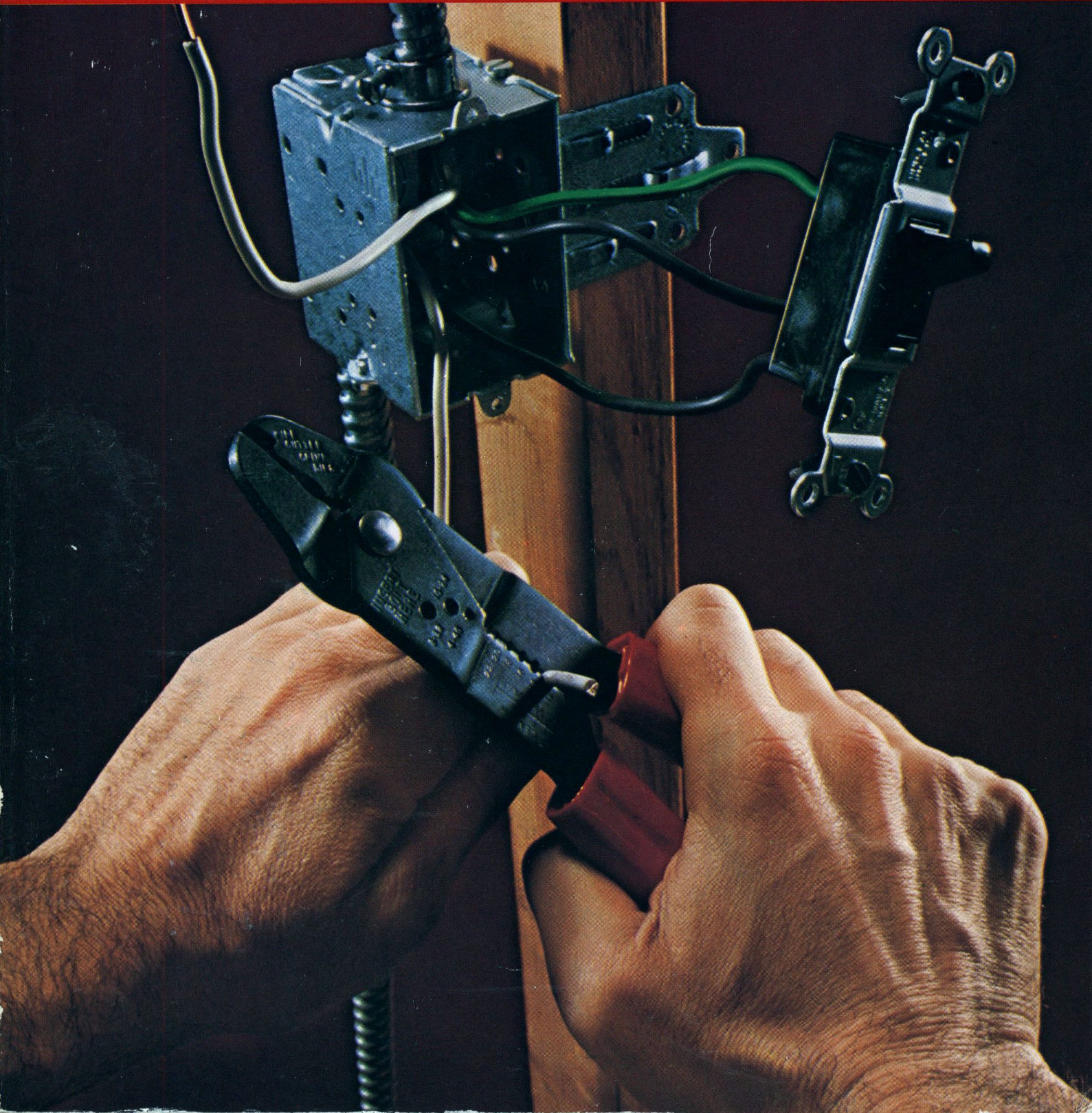
Popular Science Skill Book

How to be your own Home Electrician

by George Daniels



How To Be
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By
GEORGE DANIELS

POPULAR SCIENCE

HARPER & ROW

New York, Evanston, San Francisco, London

Grateful acknowledgment is given to the following companies for supplying some of the information and illustrations that appear in this book: Black & Decker Mfg. Co.; Con Edison; Dent Electric Co.; General Electric Co.; Harvey Hubbell, Inc.; Hopax Electric, Inc.; Kelsey-Hayes Co.; Lightolier, Inc.; Montgomery Ward & Co.; Nu Tone, Inc.; Pass & Seymour, Inc.; Safe Electric Co.; Sears, Roebuck & Co.; Solid Electric Corp.; Stanley Tools; Superior Electric Co.; Wiedl Realty

Published by Book Division, Times Mirror Magazines, Inc.

Library of Congress Catalog Card Number: 64-18091
ISBN: 0-06-010954-8

First Edition, 1965
Thirteen Printings

Second Edition, Revised and Updated, 1976

Fifth Printing, 1977

Manufactured in the United States of America

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INTRODUCTION

ELECTRICITY AND ITS MEASUREMENT. Theory tells us that an electric current traveling through a wire is a movement of electrons—about 6.28 billion billion for each ampere. So, if you're reading this by the light of a lamp with a pair of 60-watt bulbs, you have about 6,280,000,000,000,000,000 electrons hustling through the lamp cord every second. You can't see them or weigh them as they do their work, but you can measure the current they produce. And you measure it much as you would measure water flowing through a pipe. Instead of figuring in gallons per minute, however, as with water, you calculate electricity in "coulombs" per second. But you're not likely to hear that term often, as a current of 1 coulomb per second is called a current of 1 *ampere.* That is the more convenient term you see abbreviated to "amps." on the specification plates of the electric motors you use.

The pressure or "push" that moves the piped water along is measured in pounds per square inch. Similarly, the push behind an electric current is measured in volts. And here again, terms may be combined for convenience. Multiply the number of amps. a device consumes by the number of volts in the power line and you have its rating in *watts*—the measuring units you see marked on light bulbs, toasters, and electric heaters. (On alternating current, this simple mathematics doesn't apply to such things as motors and buzzers because of technical factors.)

WHY POWER COMPANIES SUPPLY ALTERNATING CURRENT. The type of current supplied to most American homes today is 60-cycle alternating current, commonly called AC. Unlike direct current (DC), as from a battery, which always flows in the same direction, AC reverses its direction of flow sixty times a second at 60 cycles.

Power companies use AC because the rapid reversal creates electrical effects that enable them to do essential things that can't be done with DC. For example, they can use a *transformer* (which won't work on ordinary DC) to "step up" voltage for long-distance transmission, while automatically lowering amperage proportionately. (Transmission losses are much greater with high amperage and low voltage than with high voltage and low amperage.) At the destination point another transformer is used to "step down" the voltage and automatically raise the amperage to provide a usable combination. There's a transformer on a utility pole not too far from your house to reduce the several thousand volts carried by the main power lines to the 120 volts required by your lamps and appliances. In most modern systems it also provides the 240 volts needed by heavier equipment.

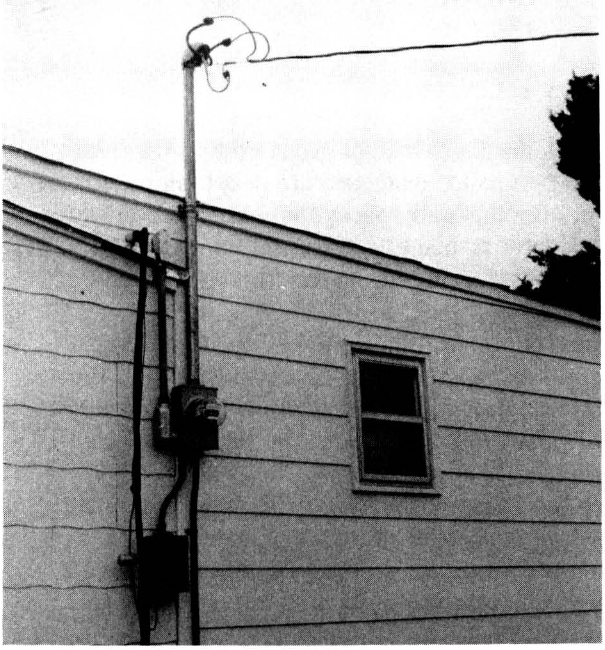
In greatly simplified terms the transformer consists of two completely separate coils of wire wrapped around the same soft-iron core. When AC is fed into the primary (incoming) coil, the rapid magnetic changes in the iron core "induce" a separate AC in the *secondary* (outgoing) coil. And the voltage in the separate coils is proportionate to their relative sizes. If the secondary coil has ten times the number of turns as the primary, it will have ten times the voltage, and you have a "step-up" transformer. When the sizes are the other way around, the outgoing current is lower and you have a "step-down" transformer. This is the same principle used in the transformers that operate a toy train set.

The AC is produced at the power plant by *alternators,* which are giant versions of those used in many cars. Simple devices are often used to explain their operation and demonstrate the principle involved. If, for example, you move a wire downward between the poles (tips) of a horseshoe magnet, it cuts across invisible magnetic lines of force between the magnet tips, and an electric current is actually generated in the wire. If you then move the wire upward along the same path, a new current is generated in it, but the new current is traveling in the opposite direction. An alternator is simply a machine that does the same job (with rotary motion) on a much larger scale.

The relationship between magnetism and electric current plays a part in many of the things electricity does for you though you are seldom aware of it. An electric motor, for example, gets its power simply by harnessing magnetism so its attraction or repulsion will spin an armature and, in turn, the motor shaft. *Electromagnets* make it possible. Made in many shapes to fit their use, they are essentially similar—a soft-iron core wrapped with a coil of wire. Pass a current through the wire and the core becomes magnetized. Shut off the current and most of the magnetism vanishes. Contacts in electric motors switch electromagnets on and off at precisely the right points to utilize their attraction to spin the rotor and shaft.

You can easily make a small electromagnet by wrapping a large nail or bolt with fine wire (one type is called magnet wire) and attaching the ends to a large dry cell. With the wire attached to the battery, the nail is magnetized, and can be a handy tool for picking up spilled tacks or brads. Place the miniature electromagnet, with its cluster of tacks or brads, over a box, disconnect one end of the wire, and the cluster will drop into the box as the magnetic attraction terminates.

So much for the theoretical aspects of electricity. It would require many



Service mast is used to give feeder wires height when service is run to low buildings.

books to cover the subject thoroughly. But, with some of the basic facts in mind, the practical work of house wiring may seem more interesting; and the reasons for certain methods and precautions will be more understandable.

WHERE YOUR WIRING WORK BEGINS. House wiring starts at the *service entrance,* the point where the power comes into your house. The utility company's wires are led in through the *service head* mounted high on your house to keep the wires well above the ground. From the service head they run down the outside of the house to the meter socket that contains the meter on completed jobs. From there they are led into the house (through a fitting made for the purpose) to the *service panel.* This contains the fuses or circuit breakers that protect the inside wiring from short circuits and overloads. It also provides one of several forms of main switch for shutting off all current to the inside wiring, so you can make repairs or modifications safely with all wiring dead. Another installation, the service mast installation, utilizes heavy-duty aluminum tubing to bring the wires from a high point on the roof, down through the roof, inside the house, and to the service panel.

Complete details of the service-entrance installation and the wiring emanating from it are given in a later chapter. But the brief summary of these wiring stages in the following paragraphs will enable you to follow the detailed instructions much more rapidly.

FEATURES THAT MAKE WIRING EASY AND SAFE. On the back of the highest cover of most service panels, you will find a diagram showing exactly how to connect the wiring for each house circuit to the terminal screws provided in the panel. From that point on through the house every wire and every connecting screw is color coded, or in some instances, labeled. Whether you are using cable, conduit, or raceway, most of the time you will be installing just two wires, a black one, a white one, and a bare or green ground-wire. And the working rules are so simple that errors in connection are next to impossible. You need only remember that in all joints and splices the white wire always connects to a white wire, black always to black, and ground to ground. The only exception to this rule is in some switching arrangements as shown in the chapter dealing with switches.

When you install outlet receptacles you will notice that they have one pair of chrome connecting screws and one pair of brass connecting screws. *The white wire is always connected to one of the chrome screws, the black wire always to one of the brass screws. The single green screw on top of the receptacle is for the ground wire or wires.*

Switches, you will note, have brass screws only, and there's an important reason. *Only the black wire is ever connected to a switch, never the white wire.* The reason: the white wire is always the *neutral wire,* and must have a continuous unbroken run through all connections back to the service panel. At that point the grounded or neutral part of the circuit is actually attached to the earth by a wire leading to the water pipes of the house or a metal rod driven in the ground. (This grounding is very important. If lightning should strike the wires outside the house, it has a direct path to the earth, greatly reducing the chance of scattering its effects through the house with possibly fatal results.)

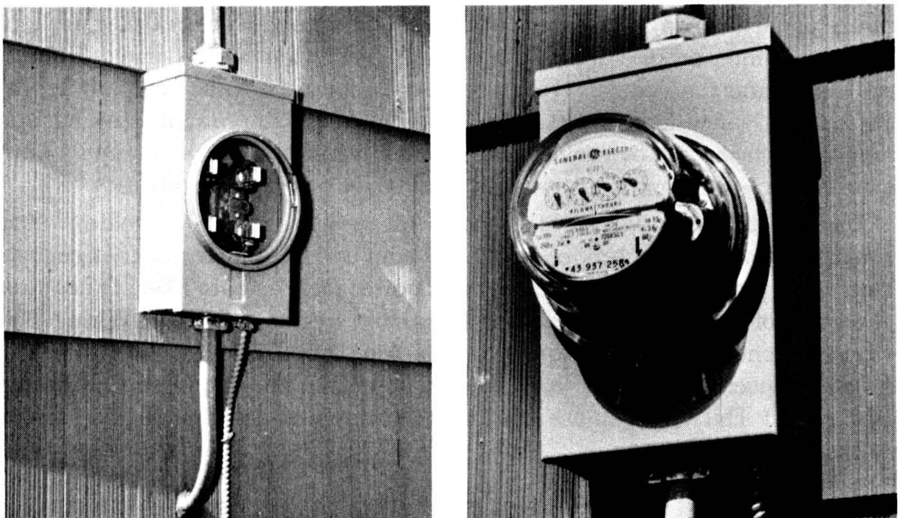
Fixtures for wall and ceiling lights are chrome and brass coded at their connections the same as outlet receptacles. The screws that hold these electrical items in the metal boxes that house them are standardized, as is their spacing. The fittings that lock each type of cable into these boxes are also standardized. All you need do is make certain that you buy the type that matches the cable or wiring system you are using. If it happens to be raceway, you will find fittings available to connect it to any other form of approved wiring.

House wiring is really very similar to assembling a custom-tailored do-it-yourself kit. Buy only materials and components that carry the Underwriters' Laboratories label, as this assures you that the items meet at least minimum approved safety standards. Underwriters' Laboratories, Inc., is a group of electrical labs which perform tests on products submitted to them by manufacturers. If the product meets Underwriters' specifications, it is labeled as such. If you follow the basic assembly rules in the chapters that follow, your wiring will be safe and the job will be easy.

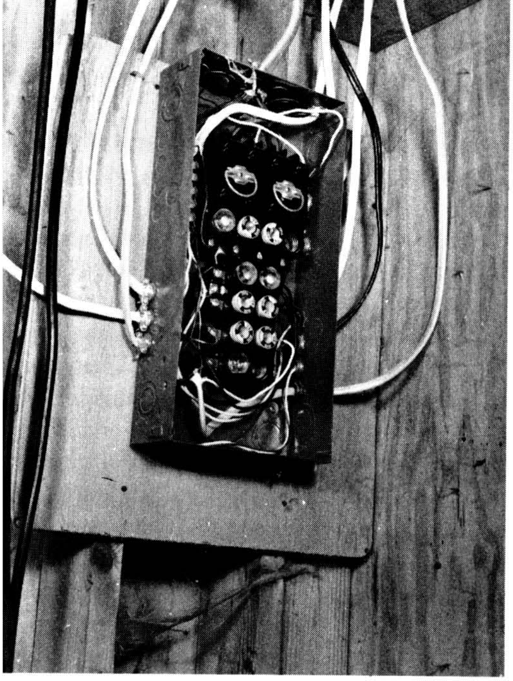
ABOUT SAFETY AND CODES. In all electrical work keep safety foremost in your mind. Work on any wiring only when the current is definitely *off*. And, in making connections to a service panel that is already in use, remember that there are live connections on the power-line side of the switch even when the switch is off. Keep well clear of them. And do not be misled by terminology. The black and red wires of a 120–240 volt wiring-system, for example, are often referred to as the "hot" wires. The white wire is commonly called the ground or "neutral" wire. Never acquire the misconception that the white wire is any less dangerous when the current is turned on simply because it is not called a "hot" wire. It is one side of the circuit, and from the safety standpoint is just as "hot" as either of the others.

Before beginning any house-wiring work, find out if there is a local code in your area, if you require a permit before doing the work, and if inspections will be made. The inspections are often made before the wiring is entirely completed so that internal details are visible. Check the details of the local code, of course, in advance. It may differ from the national code. Your work must comply with it in order to avoid violations that can take considerable time to remedy, increasing your costs and delaying the job. In general, however, the National Electrical Code is the accepted guide to safe materials and wiring practices. It does not tell you how to do a wiring job, but it clearly defines practices, and designates materials, that have proven safe. Study it before beginning your wiring.

UTILITY COMPANIES. If you are planning a complete house wiring job, as in the course of building your own home, consult your local power company *before* you begin. Various factors can determine the part of your house at which the service entrance must be installed. Because of the location of utility poles on the opposite side of the street, for example, it may be necessary to run your entrance wires to one particular end of the house to avoid having them traverse someone else's property. Or it may be necessary to run them to a particular corner of the house to prevent them from passing too low over a highway. If your house is a modern one-story design, it may also be neces-



Meter socket before meter is installed by power company (left). Lower cable runs to entrance panel. Smaller cable (resembling BX) is ground wire, leads to connection with water pipe. When wiring is complete, meter is installed and power connected (right).



Inside house, entrance panel and main switch unit distributes current to individual circuits. This one is open, will have cover and door when completely wired.

sary to install an entrance mast to hold the wires high enough above the ground. As the location of the service entrance determines the general layout of your wiring (as all interior wiring ultimately leads to that point), much extra work could be entailed in revision to suit an unexpected entrance location.

The power company can also give you complete information on the amount of work the company's men will do in connection with the service entrance. This varies. In a sample instance the homeowner does all wiring to the entrance panel and provides the materials from there to the meter socket, and up to the entrance head. Then the power company connects its wires, installs the meter, and the system is ready for use. In most cases the company sends a man in advance to check over the location of your house and any factors that may affect exterior wiring. As a rule he will also be able to supply you with valuable information regarding local codes and regulations.

Usually, too, you will have a choice of service-entrance capacities, often ranging from 100 amp service up to 200 amp service which provides enough reserve for just about any appliances and power tools you are likely to acquire. A service of at least 100 amps is recommeded by the Adequate Wiring Bureau for homes up to 3000 square feet in floor area. Your best bet: Select as large a capacity service as your budget permits. (The larger service panels cost more.) This way you are less likely to be limited later on in your choice of large appliances.

PLANNING YOUR WIRING. If you are wondering how many outlets your various rooms should have you may find the National Code very helpful as a general guide. If a wiring job is to comply with the code (it does not have the force of law) there must be enough *lighting* circuits to supply 3 watts for every square foot of floor space in the house. How far apart should you space your outlets? Again, the code offers a formula: "Receptacle outlets shall be installed so that no point along the floor line in any usable wall space is more than 6 ft., measured horizontally, from an outlet. . . ." Practically, this means keep your outlets no farther than 12′ apart when you plan your layout.

Notice that the circuits mentioned in the preceding paragraph are *lighting* circuits. These are intended to supply your lighting fixtures and power such appliances as vacuum cleaners, radios, and TV sets. You'll need *special appliance circuits,* too, for heavier-load items like toasters and electric irons. And for major appliances like electric ranges and automatic laundries, you'll need *individual appliance circuits.* The greater the power required by an appliance, the greater the capacity of the wires must be, as explained in a later chapter. But the wiring, itself, does not become more complicated. In general, lighting circuits are fused for 15 amps and may be carried by No. 14 wire. Small-appliance circuits are fused for 20 amps and require No. 12 wire, although some localities now set No. 12 as minimum for all wiring.

The important point is advance planning for tools and appliances that you are reasonably likely to want in the future. It is much easier to install the wiring for them when the overall wiring work is being done than later. But, if you must add such wiring to an old house there are ways of making the job easier. You'll find them covered in detail in later chapters on Surface Wiring and Modernizing.

WIRE SIZES AND CAPACITIES FOR 115 VOLTS*

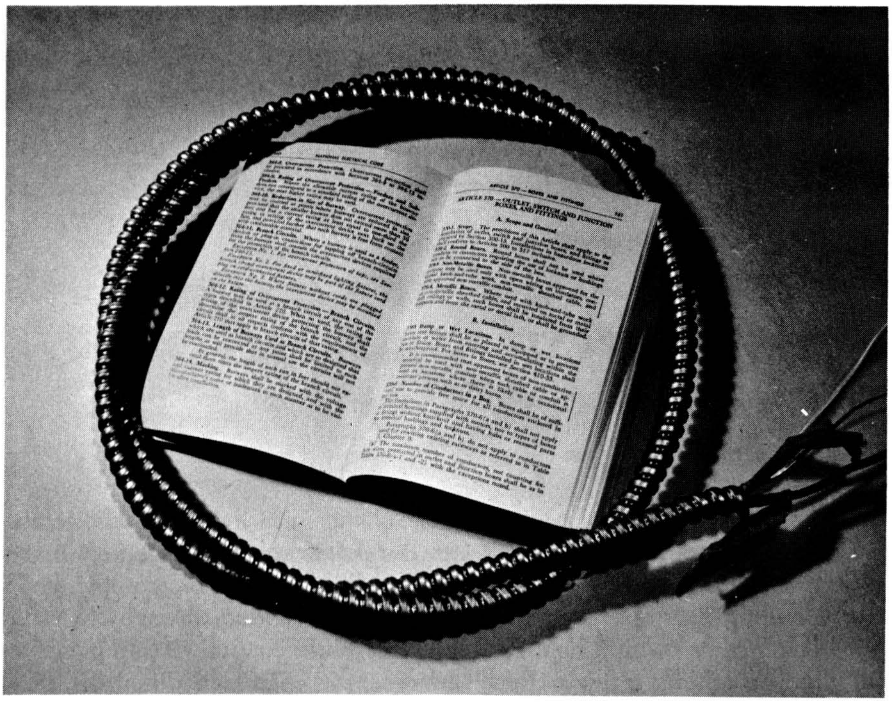
	MAX.	DISTANCE (FEET) ONE WAY FOR AMPS AND WATTS					
WIRE SIZE	FUSE AMPS.	5A 575W	10A 1150W	15A 1725W	20A 2300W	25A 2875W	35A 4025W
14	15	90	45	30			
12	20	140	70	47	35		
10	25	220	110	75	60	45	
8	35	360	175	125	90	75	55
6	45	560	280	190	150	120	85

A FEW WORDS ABOUT THE NATIONAL ELECTRICAL CODE . . .

THE FIRST nationally recommended wiring code, or set of rules, was published in 1895 by the National Board of Fire Underwriters. It became the basis of the National Electrical Code that was drawn up two years later through the efforts of insurance, architectural, electrical, and related groups, all of whose delegates voted for adoption or approval of the Code. Today, expanded and amended many times to keep pace with the ever-greater use of electricity, the National Electrical Code is the standard of the National Board of Fire Underwriters and recommended by the National Fire Protection Association.

The Code aims to assure safe wiring materials, devices, and practices. It is not a wiring instruction manual. It specifies the correct materials to use under various conditions, and it defines the correct methods of using them. It does not have, in itself, the force of law. But when a community adopts the Code as a part of its local regulations, it acquires that force. Often, too, the National Code is combined with a local code which may be more restrictive. Also, local codes vary in the extreme. In a sample sixty-mile range, for example, one city banned homeowners from doing any wiring work. Another not only permitted them to do it, but offered a free pamphlet to help them avoid errors. Another permitted them to do it after paying a considerable fee, and still another had no regulations whatever. So check your local code.

Perhaps because of the many national and local code combinations, the National Code is often misquoted. You may hear, for example, that the National Code prohibits the homeowner from doing his own wiring. Actually the National Code doesn't even touch on the subject. In general, it's a very good idea to have a current copy of the National Code on hand if you plan any wiring work. And, of course, a copy of the local code should be with it. The National Code book is available from The National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210. At this writing, the book is priced at $5.50 postpaid. You can probably obtain a copy of your local code from your electrical supplier.



The National Electrical Code doesn't tell you how to do wiring, but it specifies materials for the job and safe methods for using them.

The code book, itself, is a little under 6½ by 3¼ inches in size, with about 450 pages. It is indexed by "Articles" and sections of articles, all numbered for easy location. For example, if you want to tape a splice according to the Code's recommendations, you can look in the index under "General." Listed under that heading you will find "Requirements For Electrical Installation," followed by the article number and the page number. Because the articles run in order, it is a simple matter to locate the specific one, then the section. If you are accustomed to looking up indexed items by page number, avoid confusing the two systems. Ordinarily, the chances are you can find the subject you want within seconds. When a subject seems to be missing look under other possible classifications. If you still cannot find it the chances are it is not covered by the Code.

Don't let the thickness of the printed Code book mislead you into feeling that looking up a particular item will be complicated. A considerable portion of the book is devoted to special problems (and their solutions) likely to be encountered in industrial and commercial work and other nonresidential wiring.

In general, it is worthwhile for the prospective homeowner-electrician to read through the Code's rules for residential work. The language is plain and clear-cut, and the recommendations logical. And there's an equally important reason for familiarizing yourself with the National Code: you won't be mislead by the various bans and restrictions incorrectly attributed to it.

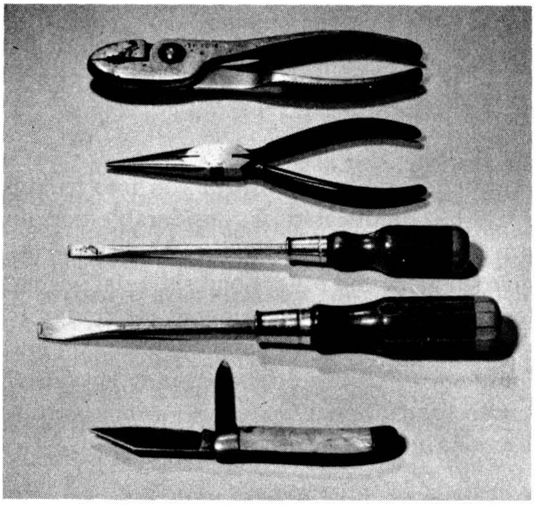
CHAPTER ONE

TOOLS FOR WIRING

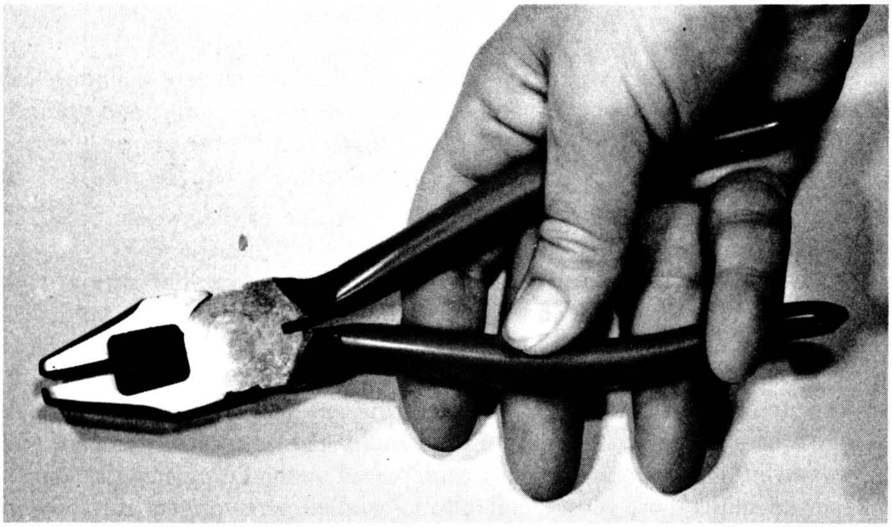
IF YOU have an average fix-it tool kit, the chances are you already have most of the tools you need for house wiring. But a few special extras may be required, depending on the type of wiring you'll be doing. For example, you'll need a reel of "fish tape" if you plan to snake new wiring through old walls. And you'll need a conduit bender if you plan to use conduit. If you plan simple jobs like adding a few outlets, however, the chances are you can do it with everyday tools.

Pliers. Ordinary utility pliers (sometimes called mechanic's pliers) can usually handle most wiring jobs, and are probably the type you have learned to use. Electrician's pliers are, of course, the professional's choice for wiring work, but are not vital to your kit. Their broad jaws get a firm grip on wire and their side cutters do a neat job of cutting it. But, as the jaws do not close completely (in order to give the side cutters positive action) they are not suited to general work.

Small-nosed pliers are one type you should have for wiring work. They



For fix-it jobs like replacing switches and outlets, all you need are these common tools (from top): mechanic's pliers, small-nose pliers for looping wire ends, electrician's screwdriver, standard ¼" screwdriver, and pocket knife. If knife does not have punch blade, add an awl.

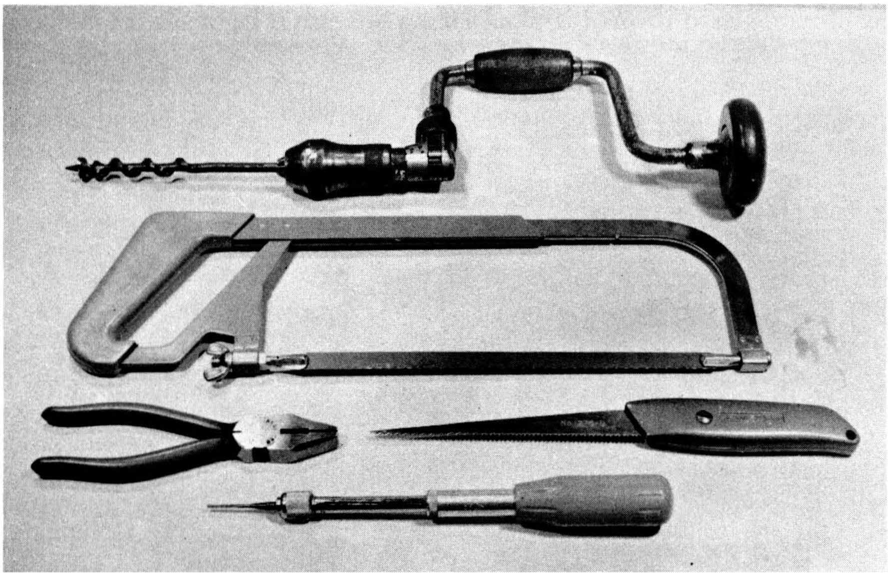


When doing wiring work, hold pliers with little finger on inside of handle and use finger to open pliers.

make it very easy to form the small loops in wire ends to fit terminal screws, and they come in handy for reaching into tight quarters in outlet or switch boxes. They also have a wide variety of other uses for odd jobs around the house or in radio, electronic, or ignition work.

Insulated handles on pliers are desirable from the standpoint of comfort. But don't ever consider them as sufficient safety factor for handling live wires. A pinhole in the plastic and a drop of perspiration could prove disastrous.

For bigger jobs involving armored cable, conduit, or raceway, you'll need these extra tools: brace and bit, hacksaw, compass saw to make wall openings, electrician's pliers for easier splicing, Yankee push drill to start screw holes for mounting outlet boxes on wood framing.



Stick to the practice of working on wiring only with the current definitely off.

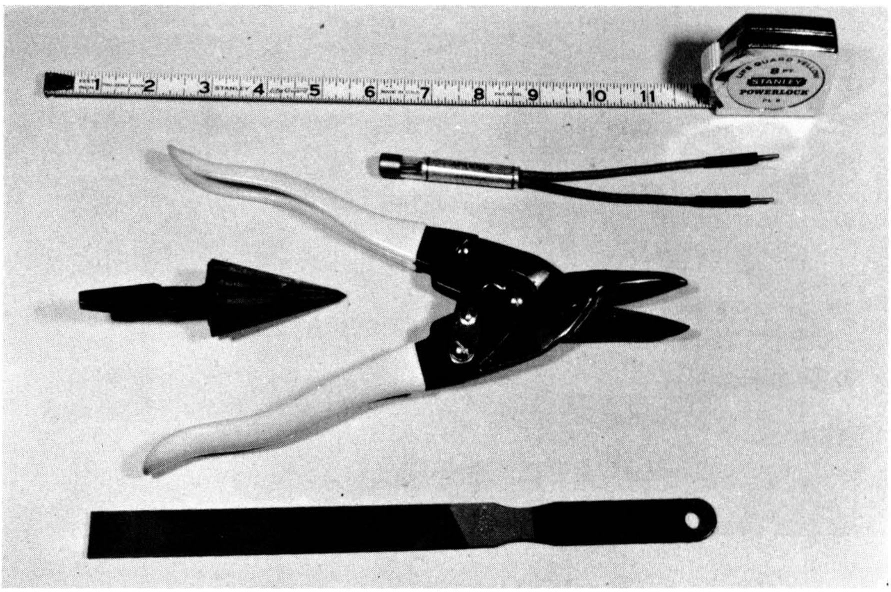
Screwdrivers. Favor plastic-handled screwdrivers for comfort and durability. If you must do any work in the entrance panel after the power lines are connected, the insulated plastic handles are safer. Even with the main switch *off*, there are live connections on the power-line side of the switch. So again, don't count on the handle to protect you completely from shock.

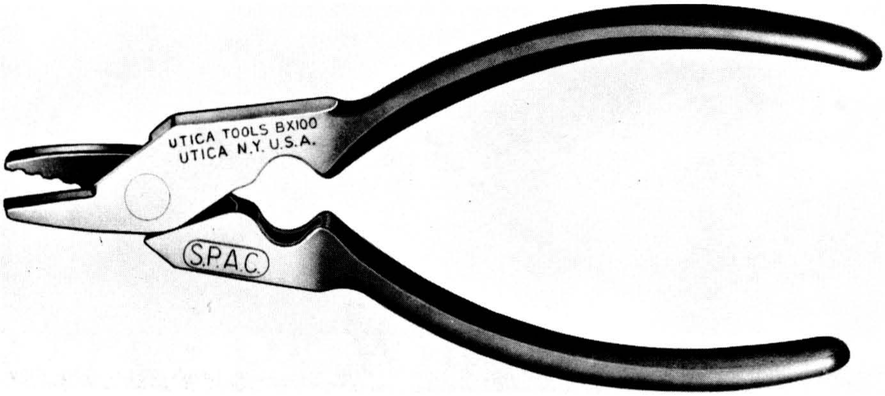
You will find an electrician's screwdriver handy both in your wiring work and on general fix-it jobs. It has a long, slender blade with the flat portion of the blade tip the same width as the round shaft. This lets you work in tight spots and—in fix-it work—drive screws that are deeply recessed. Pick one with an insulated blade shaft. One of your screwdrivers should be rugged enough to take a hammer tap on the end of the handle. This is regarded as poor tool technique but it's probably the most widely used method of opening a "knock-out" in an outlet box. Most good plastic-handled screwdrivers can take it without damage. A large "mechanic's" screwdriver is a great help in tightening large terminal screws in entrance boxes.

Hacksaw. For cutting armored cable, conduit, and other types of wiring material, a hacksaw is a valuable tool to have in your kit. Use a fine-toothed blade, as most of the metal you'll be cutting will be thin. A coarse-toothed blade is likely to catch and chip teeth when used on thin stock.

Metal Snips. Quicker and handier than the hacksaw on flexible armored cable, metal snips are less likely to cut into the wires when all you want cut is the armor. Some electrical suppliers also stock a somewhat similar tool designed specifically for cutting armored cable. Metal snips like Stanley's avia-

Essential tools for extensive electrical work (from top): flexible rule with lock button, neon test light, aviation shears for cutting armored cable and sheet metal, pipe reamer (left of shears) for smoothing sawed conduit, special Simonds mower blade file for smoothing inside of small hacksawed raceway.





Special plier-cutter tool for cutting and working BX armored cable.

tion snips are likely to have a wider range of uses after the wiring work is finished.

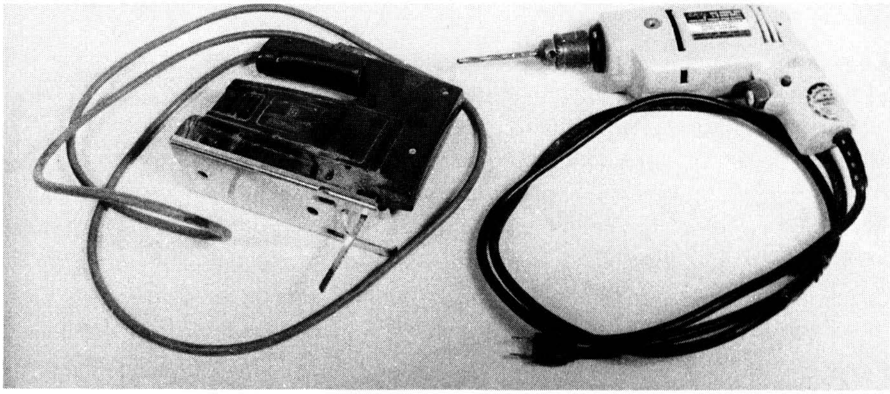
Soldering Tools. If electricity is already available, and the section of the wiring you are working on is not yet connected into the system, an electric soldering iron or soldering gun is the best tool for the job. If electricity is not available, your best bet is a torch and an old-fashioned soldering iron.

In selecting any of these tools, check their heating capacity. Favor a large one over a small one, as the wire ends to be joined must be heated quickly by the soldering tool to a temperature high enough to melt the solder. This assures adhesion of the solder to the wires, and a thorough bond between the joined pieces. You must be able to touch the solder to the heated wire and melt it so that it flows into the windings of the splice and adheres to all parts.

Insulation Stripping Tools. There are various multipurpose plier-type tools designed both for cutting and bending wire and for stripping the insulation from it. Your electrical supplier stocks at least one. This is a handy tool for extensive wiring jobs like an overall house installation. But for the small job or occasional electrical repair the pocket knife is hard to beat.

The Circuit Tester. This is a somewhat specialized tool that is most likely to figure in checking wiring after it is completed to determine if a current is present. In its simplest form it is a small neon glow lamp with a pair of wire leads extending from it. Insulated ends on the leads allow you to hold them with their protruding metal contact tips against wires carrying current.

If, for example, you want to know whether there is danger in touching the outer shell of a kitchen appliance while turning off a faucet (remember, your wiring is connected to the water pipe for grounding), you can place one of the tester leads against the appliance, the other against the faucet. If the test light glows there is a "potential," or current from one to the other. This is often the case with older appliances that are not connected to the outlet with grounded plugs. If you encounter this condition, turn the plug around so the prongs are in opposite positions in the outlet, and repeat the test. Usually you will find that the test light does not glow. Then mark plug and outlet with paint so the plug can be replaced in the outlet in this position. Any old appliances of this nature should be replaced with properly grounded new appliances.



For work that requires a lot of boring, a power drill can save much effort and time. Electric saber saw is handy for cutting holes in walls. And when mounted with a metal-cutting blade, it can be used for cutting raceway and conduit.

Woodworking Tools for Electrical Jobs. A hammer, a hole-boring tool, and sometimes a chisel will be useful for wiring work. You'll need the hammer for driving the staples that hold armored cable to house structural members and for a variety of jobs including the tapping open of knockouts in outlet boxes. If no electricity is available, you can use a bit and brace to bore the holes in studding and general framing through which cable will be led. Naturally, a power drill speeds the work if there's current available. The chisel comes in handy in conduit work (where you'll also need a keyhole saw) and in other wiring where a recess must be made in wood.

Insulating Tapes. The most widely used type of insulating tape is usually referred to as "plastic tape" and commonly includes a vinyl layer. It is very thin, but insulates better than older types many times its thickness. The fact that it is so thin makes it very handy to use in small outlet and switch boxes where thicker tape would result in a bulky splice. Although this type of tape is suited to almost all your wiring needs, it can't be used at extremely low temperatures, as in an unheated building in cold weather. A special form made by Johns-Manville, however, can be used at temperatures as low as 10 degrees below zero without cracking.

In extremely damp or wet areas, rubber tape is used, as it actually vulcanizes itself together at overlap areas to form a continuous sealed tube. It is thicker than the plastic tape but not as tough. To protect it after it has been applied, give it a covering of friction tape, which has ample resistance to the usual types of mechanical damage.

Solderless Connectors. These are made in several types to reduce the need for soldering splices. In their handiest form they consist of a hollow plastic cap with a spring-like wire winding inside to serve as a conical thread. To connect a pair of wires you simply insert them inside the thread and give the cap a few turns. The wires are twisted together in a gentle spiral by the motion and firmly locked together by the conical thread. They provide a safe and convenient way of doing electrical work without the delays of soldering. After turning down the connector, give a slight tug on each wire to insure that the wires are firmly held together.

CHAPTER TWO

TYPES OF WIRES AND WIRING TECHNIQUES

ELECTRICITY IS carried from its source to the point where it is used by wires covered with insulating material. Copper has long been the most common type of wire used, although aluminum is used in certain types of wiring, such as long-distance transmission lines, because of its lightness and strength.

Wire Sizes. The size of each wire is determined by the cross-sectional area measured in circular mils. One circular mil is equal to the area of a circle whose diameter is 1/1000th of an inch. Wire sizes are designated in the United States by the American Wire Gauge (AWG), also called the Brown and Sharpe Gauge (B&S). The sizes range from the smallest at 40 (B&S) and even 60 (AWS) all the way up to 0000; the smaller the wire, the bigger the number.

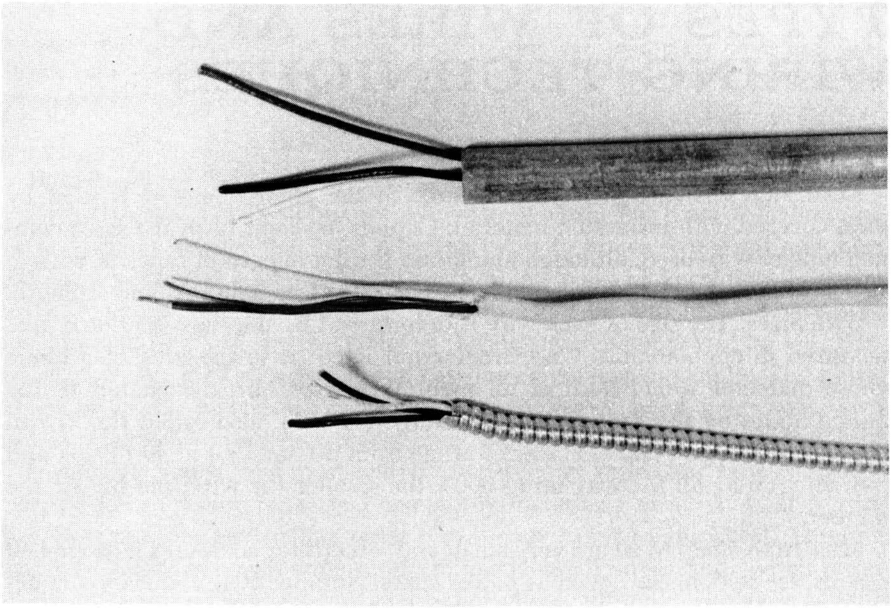
Sizes from 50 up to 20 are very small and, except for such uses as door-bell circuits, are seldom employed as power wires. Number 50 is about the diameter of a human hair and weighs about 1 pound per 60 miles. Wire of this type is used in delicate electrical instruments and electronic work.

Sizes 18 and 16 are used in stranded form in common lamp cord, which is discussed in detail below. Stranded wire size is the overall size of the group of strands, not the size of the individual strands. It corresponds in diameter to solid wire of the same size designation.

Numbers 6 and 4 are used in either solid or stranded form and are normally employed as service-entrance leads to homes and small buildings, and for heavy power circuits. Wires larger than 6 are for carrying heavy power loads from 55 up to as much as 320 amperes, in weatherproof 3/0 size, and are used in some instances for service-entrance cables and for industrial purposes. Number 4/0, used for the same purpose, is almost ½″ in diameter.

Cords. Wires that are used in the home to operate appliances, lighting fixtures, etc., are called cords, and are classified according to how they are used and constructed. The simplest and most common type is *lamp cord,* which consists of two stranded copper wires covered by rubber or plastic insulation. These are usually available in brown or ivory-colored insulation, but are manufactured in several other colors as well.

The second type of cord is *heater cord,* used with heat-producing appliances such as toasters, irons, hot plates, portable heaters, etc. This cord consists of two copper wires covered by rubber insulation, a layer of asbestos fiber and a heavy cotton braid cover. Today's modern appliances utilize a heavy-duty cord covered with a heat resistant plastic insulation, instead of the old-style asbestos and braided-cotton covering.



The three basic kinds of cable runs are, from top to bottom, conduit; nonmetallic, plastic-covered cable; and flexible armored cable.

The third type is *heavy-duty cord,* which has two or three conductors protected by fiber plus rubber or plastic insulation. In the three-conductor type of heavy-duty cord, each wire is covered by a different colored rubber insulation, usually one black, one white and the other green. This color-coding tells you that the black is the "hot" wire, white is the "neutral" wire and the green is the "ground" wire. Three-wire cord is used, for example, with portable power tools; the black and white wires are the conductors while the green wire is connected to the metal case of the tool, thus grounding it. This minimizes the possibility of electric shock if an internal defect develops in the tool. For more detailed information on cords, see Chapter Eight.

Cables. To carry the heavy load of electricity from the service entrance of a home to the distribution panel where the fuses or circuit breakers are located, large multiple-strand wires, or cables, are used. From the distribution panel the various circuits are carried by several types of conductors approved by the National Code for use in residences and farm buildings. There are three basic types of approved multiple-strand cables used in interior wiring, not including the surface wiring covered in another chapter.

Flexible armored cable. One of the most widely used and one of the easiest to install, this cable is available with either two or three insulated wires with an outer wrapping of tough paper and enclosed in a spiral-wrapped galvanized steel armor. The armor is wrapped in such a way as to be flexible. You are likely to hear this type of cable referred to as BX, which is actually a trade name. But there are other trade names for similar cable, such as Flexsteel. (By whatever name you buy this or any other type of wiring material, make certain that it carries the UL approval.) Armored cable of this type can be used in general wiring, concealed or exposed, but it may not be used in damp locations or out of doors.

Nonmetallic, plastic-covered cable. Probably the most common material used in house wiring, plastic-covered cable consists of two or three wires encased in a wrapping of paper with an outer casing of plastic. In the waterproof version, the wires are embedded in a solid plastic shell of insulation. An older, similar type of wire was called Romex, and Cresflex, which consisted of wires inside a specially treated fabric braid.

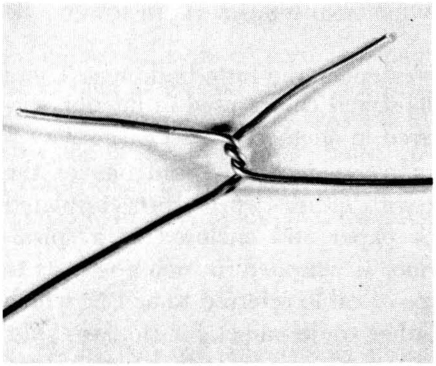
There are basically two types of plastic-covered cable: NM, used for dry indoor locations, consists of wires covered with a paper wrapping, then with an outer plastic shell. A newer, dual-purpose type cable is called NMC and is used for almost all types of wiring, either wet or dry. Its wires are embedded in a solid-plastic protective sheathing.

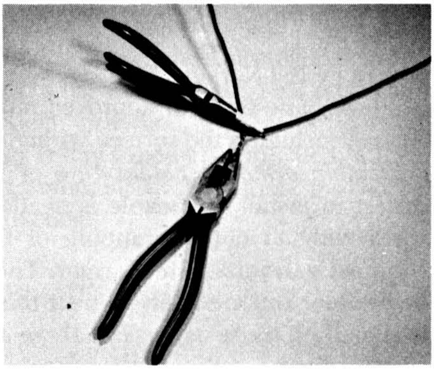
Thin-Wall Conduit. A light steel tubing which is bent with a special tool to conform to the path the wiring must follow, thin-wall conduit is not made with the wires already in it, as the cables described previously. It is installed somewhat like plumbing, then the wires are pulled through it. As it is not flexible, and must be bent to shape on the job, quite a bit more work is involved in using it, but codes in some areas require it. It is made in 10′ lengths that can be joined with threaded couplings that clamp over the ends of the conduit, which need not be threaded for the purpose.

Where the conduit enters an outlet box or other type of box (always metal), a connector attaches to it in the same manner. The threadless end of the connector is first fitted over the conduit and tightened. Then the connector is inserted through the box knockout hole and fastened with its own lock nut. After the conduit is installed and connected to the boxes the wires are pulled through it, leaving about 8″ of wire inside the box at the end of each run to allow for connections.

Conduit is cut with a hacksaw and reamed at the cut ends with a pipe reamer to remove any sharp burrs left by the sawing, so as to remove any chance of insulation damage. The wire size in the conduit is matched to the capacity of the circuit.

The only other type of wiring you are likely to use in home installations is surface wiring, covered in a separate chapter under that heading. This is especially suited to use in old houses when the wiring is to be modernized, as it entails a minimum of wall openings.





Simple pigtail splice is made by twisting ends of two wires to be joined as shown at left. (Soldering wire used in these illustrations for clarity.) When using wire larger than No. 14, use one pair of taped pliers to hold wires (protecting insulation), another pair, preferably electrician's pliers, to do the twisting (right).

How Cables are Designated. The types of cable just described are available at all electrical suppliers in areas where they are commonly used. They are designated by letter names. Armored cable such as that carrying the trade name BX, for example, is referred to in the national code as Type AC. But if you ask for BX you can be sure the electrical supplier will know what you mean, as the trade names are as widely used as the letter designations, perhaps more.

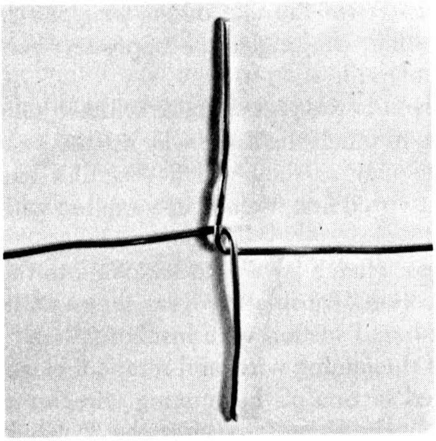
Nonmetallic sheathed cable is designated as Type NM. When it is designed for use in wet or damp locations it is designated as Type NMC, which, of course, can be used also in dry locations.

The oldest form of underground cable is designated as Type USE (Underground Service Entrance). A newer type designated as Type UF (Underground Fused) first got its code recognition in 1953. This can be used in much the same way as type USE (underground), except that it must be protected by fuses or circuit breakers at the starting point. For instance, if you want to run underground wiring from your house to a separate garage, you must provide fuses or circuit breakers for the wiring at the house end. In multiconductor types with two or three wires. Type UF looks exactly like Type NMC. Some brands also have dual Underwriters' stamp for use as Type UF-NMC, which means they can be used for interior wiring or underground runs. If the various letter designations confuse you, explain to your electrical supplier what you want to do, and he will be able to specify the correct cable for the purpose. He is also likely to know of any local code restrictions on cable types.

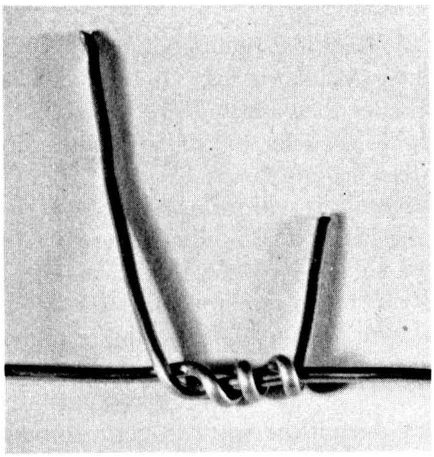
BASIC WIRING TECHNIQUES. Most of your splicing will involve the joining of either two or three wires together. When you wire a switch, for example, you will be joining the two white wires, as only the black ones connect to terminal screws. The code requires that all splices be mechanically and electrically secure. In other words, the joint has to be strong and it has to make good electrical contact. Completed, it must be as good a conductor as the wire.

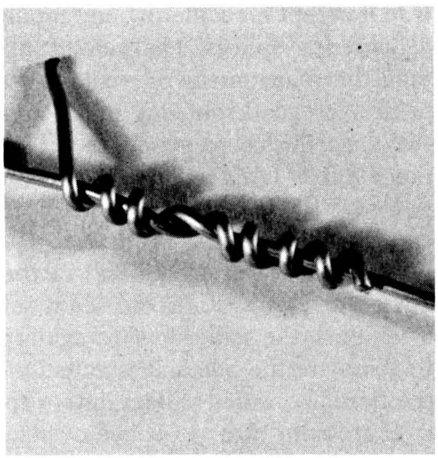
The Pigtail Splice. To make this splice, bare about 2″ of the wire ends and strip them clean. With the bared ends close together and parallel (insulated sections lying side by side) grip the bared sections as close as possible to the insulation. Then twist the bared ends together like rope. On heavier wire like No. 12, a second pair of pliers comes in handy for the twisting. Five or six turns are about enough. Turn the remaining ends back alongside the twist so they won't tend to poke through the tape later. This type of splice is not intended to take tension, but you can test your work with a light pull on the wires. Then you are ready for soldering.

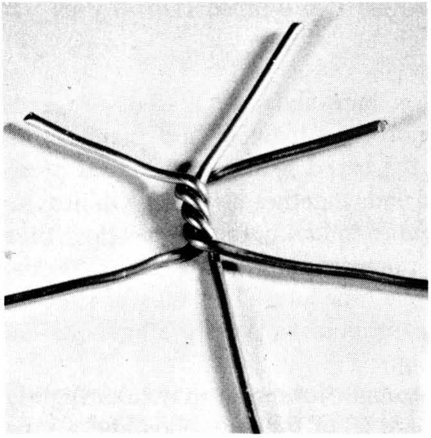
The Western Union Splice. This is a stronger form that may take slightly longer to make but it can take tension. Bare 3″ of the wire ends and scrape them clean. Give each wire a right-angle bend about half an inch from the insulation and hook the two bends around each other. Hold the overlap with pliers and bend the free bared end of one wire to start wrapping it around

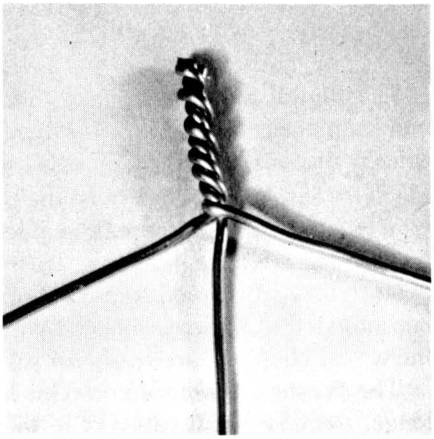


Three steps in making the Western Union splice: First, join wire ends by making an L-bend in each wire (left). Twist one end (in this case the right-hand one) around the main part of the other wire (bottom left). Complete splice by wrapping other end around second wire (bottom right).









Bunch splice, used when more than two wires are to be combined, starts like this (left). All wires are twisted together like strands in a rope. Completed bunch splice is shown at right.

the other, working toward the insulation. When the first one is wrapped as far as it reaches, do the same with the other, working in the opposite direction. The finished job will take plenty of pull.

The Bunch Splice. The name often given to the pigtail splice when it joins more than two wires, this splice is made in much the same way as the usual pigtail. Twist the three wires simultaneously so they will fit together like the strands in a rope. If two strands are twisted first, then over-wrapped with the third one, the splices will not be as secure.

The Tap Splice. This is the type to use when a wire is to be joined to the run of another wire. Strip about a 1″ section of insulation from the running wire and scrape it clean. This will be a bared section with insulation beginning again at each end. Bare about 3″ of the joining wire, and scrape it clean. Now, starting at one end of the 1″ bared section of the running wire, wrap the joining wire toward the other end. In the usual wire sizes the 3″ bared length will wrap just about all the way along the bared inch. That's all there is to it except for soldering and taping.

Soldering Splices. The trick in splice soldering is to quickly heat the wires until the solder melts on contact with them and flows into all crevices like paint. Any good soldering iron (large is better than small) will do the trick. Although rosin-core, wire-type solder can be used for the job without additional flux, it is a good idea to use a non-acid (rosin) flux also.

Smear the flux over the splice before heating. It will melt and run into the crevices the solder will fill later. Hold the splice against the soldering iron with pliers, touching the end of the wire solder (it looks like silver wire) against the wires until you see it soften and begin to spread into the twist. Then push the solder inward against the wire to supply enough more solder to complete the bond. It is actually drawn into the crevices by capillary attraction, like water soaking into a sponge.

It helps to turn the splice over quickly during the work to get a smooth filling on both sides. Allow a few seconds for cooling with the iron removed from the wire. You can tell when the solder has hardened by a change in the surface sheen.

Taping. There are three types of electrical tape in common use. The most widely used is vinyl plastic tape, as it has the greatest insulating power for any given thickness. This allows a very safe and thorough taping job inside of small outlet and junction boxes without danger of inconvenient bulk at splices.

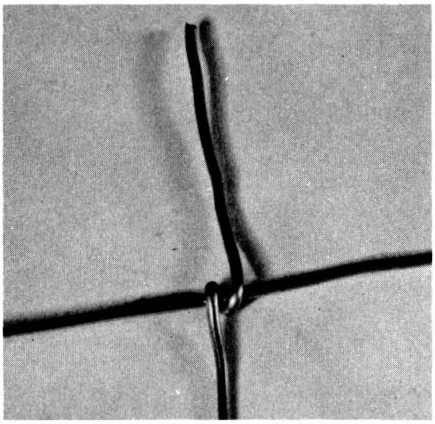
Rubber tape is used where moisture is a problem. When this tape is spirally wrapped around a wire, with tape edges overlapping, it actually vulcanizes itself together, forming a completely waterproof hose. (If you need a small piece of rubber hose in an emergency you can make it this way. Wrap a round pencil with cellophane or similar plastic, then wrap on the rubber tape. Slide it off and you have your hose.)

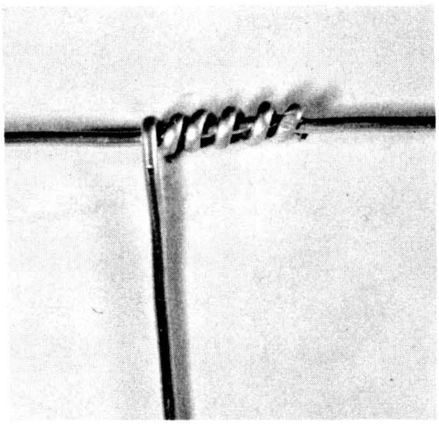
Friction tape, the old standby, is seldom used today, as far as insulating taping is concerned. Some of the top quality types can be used alone for insulating purposes, but generally are not because of their porosity. Friction tape is widely used over rubber tape, however, to protect it from abrasion or mechanical damage, as the rubber used is very soft.

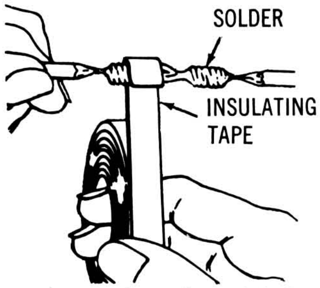
If you are doing tape work at low temperatures, as in an unheated garage in winter, you may require a special low-temperature type of vinyl tape, as the standard form cracks when flexed in very cold weather. The special form can be used at temperatures as low as 10 degrees below zero.

Taping technique. Start your taping a little more than a tape width back on the insulated portion of the wire and wrap on to the splice, pressing the tape down firmly into hollows. Wrap across and beyond the start of insulation at the opposite end for a distance equal to that at the start. Then tape back again, spiralling the wrapping in the opposite direction, so the spirals criss-cross.

First stage in making tap splice (left) shows tapping wire with turn around running wire. Splice is completed (right) by simply continuing twist of tapping wire around running wire. All splices are soldered and taped before using wires.







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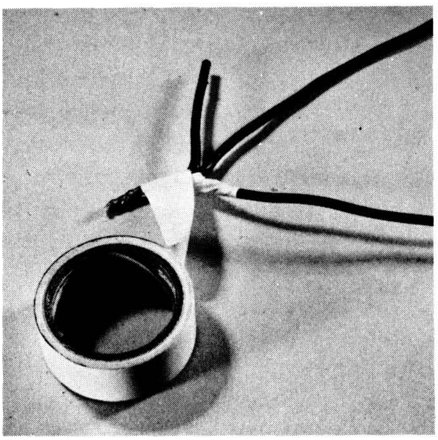
Tape all splices after soldering. If soldered sections are rough, give them an extra layer, then wrap from well back on insulation onto and across bared section to insulation, then back again.

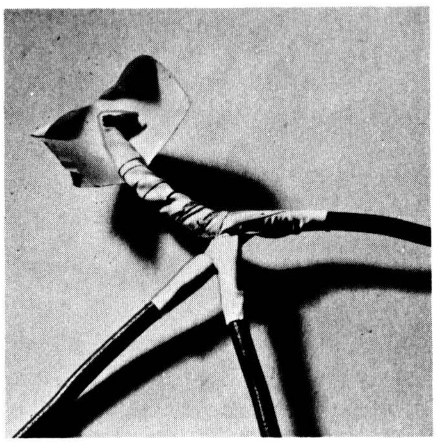
In all wrapping, allow an ample overlap of the tape edges. In the past, three to four layers of rubber tape were used followed by two or three layers of friction tape. Now you can do it all with about three or four layers of plastic tape. In general, if the plastic wrapping is a little thicker than the insulation on the wires, you're on the safe side. Be sure the finished job is smooth, with no loose turns or ends that can catch and cause unwrapping. (You can get the technical insulating rating of both wire insulation and tape for precise matching, but it's rarely done.)

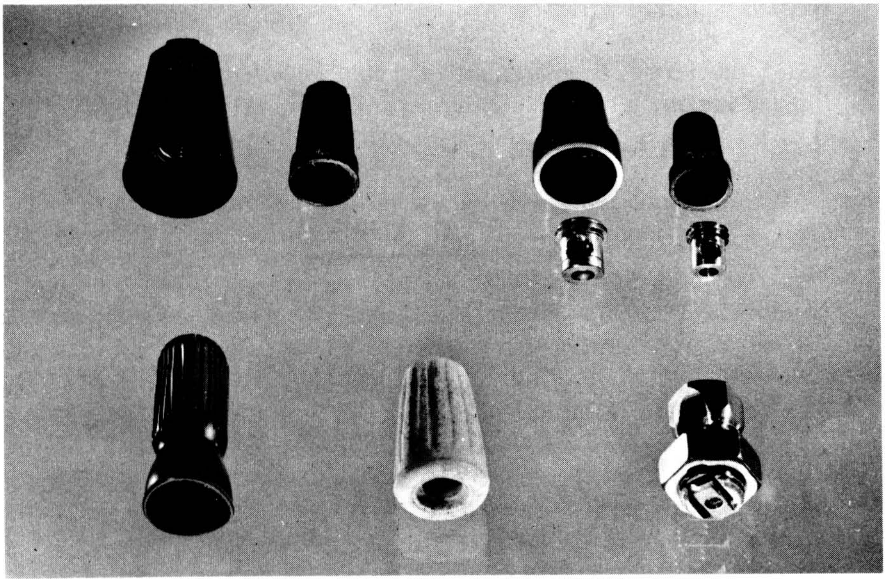
Solderless Connectors. A splicing job can be simplified with screw-on connectors, which can be applied in seconds.

Bare the wire end just far enough to fit all the way up into the cap of the connector, and be sure the wires are scraped or sanded clean. Then hold the bared wire ends together, pointing in the same direction and screw the solderless connector on them. A metal thread inside the connector tapes toward the upper end so as to press the wires tightly together as it tightens. If the ends of the wires have been bared to the proper length, no taping is necessary. If

In taping bunch splice, start tape on one branch and run onto bare section (left). Tape a little way beyond the end of bare wire (right), then back onto other branches. Fold over excess at end of splice and use a separate piece of tape to make an extra turn or two. Rubber tape is best for complex splices like this one.





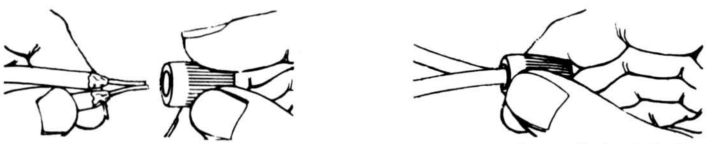


Types of solderless connectors available to the home electrician: Upper left, two sizes of connector that simply screws on wire ends. Upper right, two sizes with connector containing setscrew which is tightened on wires, then cap is screwed on. Bottom left, flexible plastic screw-on connector; center, screw-on ceramic type for high temperatures; right, brass, heavy-wire connector, tightened with wrench. This one must be tape wrapped.

bare wire extends below the connector (as when too much wire has been bared), tape the exposed portion, or unscrew the connector and shorten the wires.

An uninsulated and somewhat lower priced form of solderless connector is also available. This type saves the trouble of soldering but requires tape. It is still a time and work saver.

A Splicing Tip. Before starting on splicing work for the first time, you can learn the best wire-handling techniques by practicing a little with a few lengths of wire solder. This is soft enough to splice without the aid of pliers, providing an easy way to see just how the wires fit together during twisting in each type of splice. And when you are through with your practice you can still use the scrap pieces of solder for soldering. As the wire solder compares in size to rather heavy copper wire (No. 12 or larger) it will also give you a good idea of the space the splices will take up and the length of wire needed to make a given number of turns around another piece.



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To use screw-on connector, bare just enough of wire ends to extend all the way into the cap. Place wires side by side and screw connector onto wires.

CHAPTER THREE

HOW TO INSTALL HOUSE WIRING

BEFORE STARTING any wiring work, especially if it is of a major nature, find out if there is a local wiring code. You can usually do this by phoning the building inspector or your power company. If there is a code obtain a copy before undertaking any electrical job on your own. Often, communities use the National Electrical Code as the general basis for their regulation, but add certain rules especially applicable to the area.

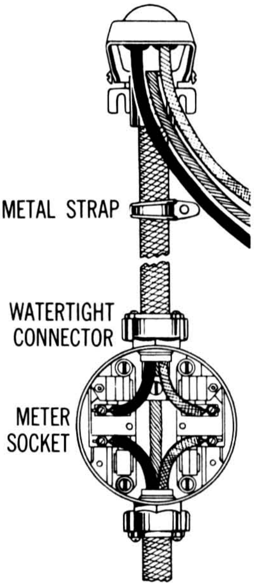
The local attitude toward non-professionals working on wiring, the homeowner, for example, varies widely. Some large cities prohibit the non-professional from doing any wiring work at all. Others not only permit it but supply pamphlets and other data to help the non-professional avoid errors. Some require that a permit be obtained and that inspections be made by an official of the building department at various intervals as the work progresses. These are among the important points to know before you undertake your wiring job. The rest is mainly a matter of careful work.

On any complete job of house wiring contact your power company in advance. In most cases they will send a representative to check over the location. He will be able to tell you what materials you must supply and what materials and work the power company will furnish in connection with your service entrance. He can also advise you on the best location for the entrance so that entrance (overhead) wires will not traverse someone else's property or otherwise create problems.

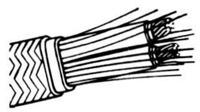
THE SERVICE INSTALLATION. Three separate wires enter your house in a modern service installation, one with black insulation, one with red insulation, and one bare. The bare one is called the neutral, or ground wire. The other two are called "hot" wires. Actually all three are hot in the sense that they are carrying current, and all three must be treated with equal respect as far as danger is concerned.

The bare neutral wire is connected to a metal "neutral strip" inside the service panel (you may call it a fuse box). Another wire from this strip runs to a connection on the water pipe of the house, or, if there is no water pipe, to a metal rod made for grounding purposes and driven into the earth. If the length of the water pipe is less than 10′ underground, the ground wire should be connected both to the pipe and a ground rod.

The black wire commonly is connected to the left terminal of the "main disconnect" and the red wire to the right-hand terminal. Also in the panel



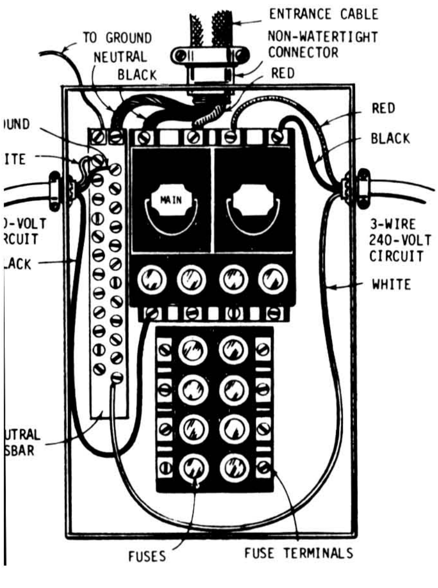
Three lead wires must extend out of entrance head at least 36″. Middle wire is the neutral bare wire and usually connects to center wire of overhead wires, as shown on next page.

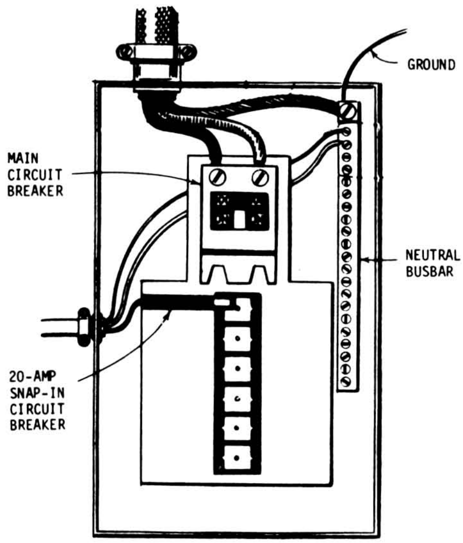


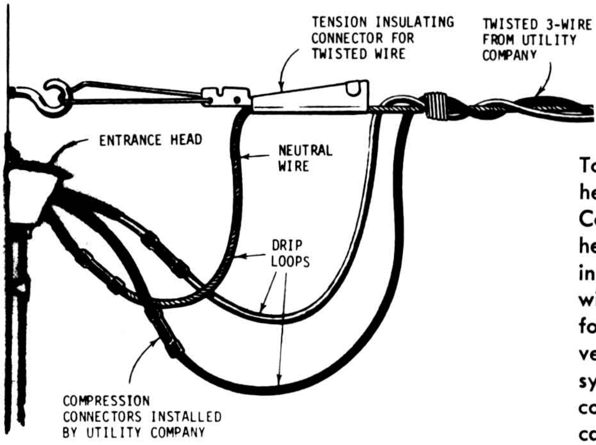
Bare neutral third wire consists of uninsulated strands wound around the two insulated wires.

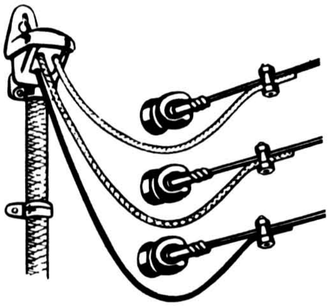
Twist strands together, from point where you peel cover, and third wire is ready to connect.

These are the two types of entrance panels in common use today. The fused entrance panel shows typical wiring for a 120-volt circuit at its left and for a 240-volt circuit at its right. The circuit-breaker entrance panel here is wired with a single 20-amp circuit.





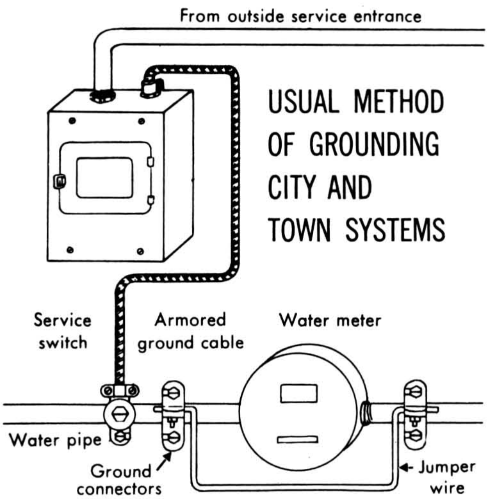




To connect wires from entrance head to overhead wires, the Code requires that the entrance head be installed above the top insulator of incoming power wires, and that drip loops be formed in each conductor to prevent water from entering the system. Or use the newer tension connector, as shown, with twisted cable, again forming protective drip loops.

are the starting terminals of the separate pairs of wires that will be the individual circuits of the house wiring, each with its own fuse. There are also terminals for 3-wire circuits such as those required by electric ranges and other high-wattage appliances.

About the Two Voltages. The operation of the 3-wire system is simple. If you were to connect a voltage-measuring device to the black wire and to the neutral wire (the neutral wire is covered with white insulation in all interior wiring), you would get a reading of 120 volts. If you were to connect the same instrument to the red wire and the neutral wire, you would get the



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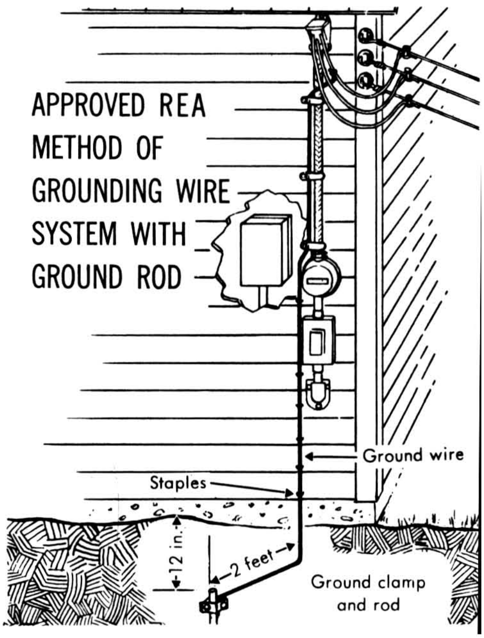
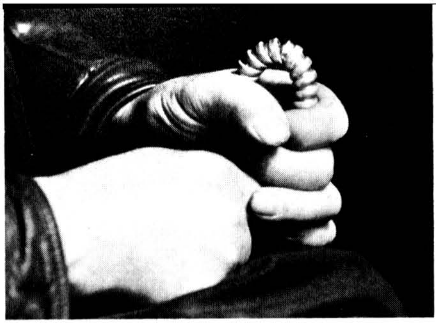
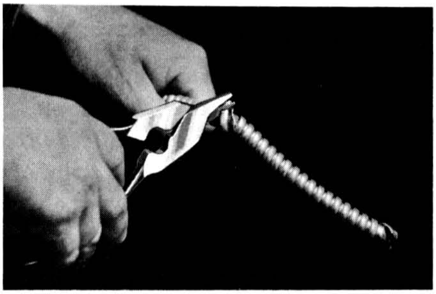


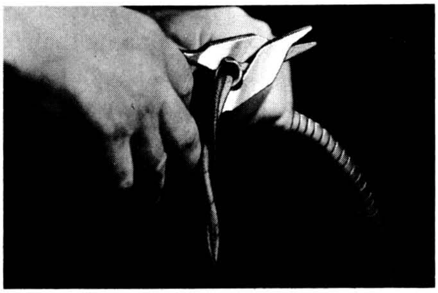


First step in cutting BX armored cable is to make a sharp bend, squeezing cable enough to buckle armor.

Next, twist cable against direction of spiral to spring out buckled section of armor so cutting tool can be slipped under it.

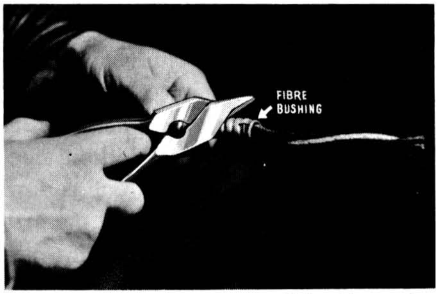


Slip cutting tool under raised section and cut through armor, taking care not to damage enclosed wires.



With large jaw recesses of cutting tool, reshape end of armor that was buckled in severing the cable.

Final turn of spiral is shaped to conform with those behind it with jaw tips of cutting tool. Cable is now ready for bushing.



Kelsey-Hayes Co.

Fiber bushing is slipped over wires and pushed back to edge of armor. If wires are covered with paper wrapping, remove first.

same reading. But if you connect it to the black wire and the red wire (called the "hot" wires), you would get a reading of 240 volts. These, then, are the basic connecting arrangements used to supply either voltage, according to the needs of the appliance.

The diagram supplied with the service panel should make it clear exactly which terminals should be used to start circuits of either voltage. If it is not clear to you ask your supplier to explain it. And, if you have any doubt whatever as to whether your connections are correct, pay a professional electrician to check them over before you have your power connected. In localities where inspections are made, the inspection will include this point. The connections are not at all complicated, and no maze of wiring is involved, as in a TV or radio chassis. But take no chances if you are not sure of your work.

Installing Wires in the Service Panel. The tool work begins with your first connection. Sometimes the circuits are wired from the outlets back to the service panel, then connected in. Other times they are started from the panel and led out to the outlets. So long as the power is *off*, either method is practical. For simplicity we will start at the panel (before the power is connected) and lead a typical circuit out to the fixtures and outlets.

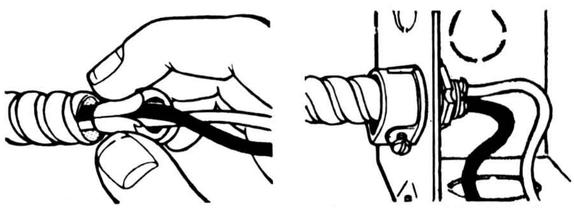
With the cover off of the panel hold the wiring cable against it to determine the length of wire that must be freed to run from the wall of the box to the connecting terminals. Assume that BX cable, one of the most commonly used types, is being installed. If you require 8″ of free wire to reach the terminals, you will have to remove that much metal armor from the end of the cable.

Cutting the cable. Bend the cable sharply at the 8″ mark and squeeze the bend inward until the armor buckles. You can feel it buckle and you will note that one of the spiral turns at the center of the bend bulges outward. Now grip the cable with your hands on both sides of this buckling point and twist it against the direction of the spiral winding until the buckled turn of armor moves out enough to slip the jaw of a metal snip between it and the wires, which are exposed at this point. Snip through the strip of armor and you can slip the severed section off the end, freeing the wires. You can use a hacksaw to sever the armor instead of metal snips, but it takes longer and calls for care to avoid cutting into the wires.

If a jagged point remains on the severed end of the armor, trim it off so it will not cut into the wires' insulation. If the end of the armor is distorted (not likely), it is easy to reshape it with pliers. After a little experience you will be able to snip off armor without need for trimming or reshaping. If you are a regular user of fix-it tools, you can probably do it the first time.

Attaching bushings. With the armor slipped off the wire end, remove the water-repellent paper wrapping around the wires back to the point where the armor begins. Next slip a plastic bushing over the wires and push it back into the armor. These are standard items sold by the box at electrical suppliers. A small collar around one end prevents them from slipping all the way into the armor. Never make a BX connection without using a bushing. The

Two important steps in attaching armored cable to outlet box: (left) insertion of fiber bushing to protect wire; and (right) attachment of connector to hold bushing in place and connect cable to outlet box.



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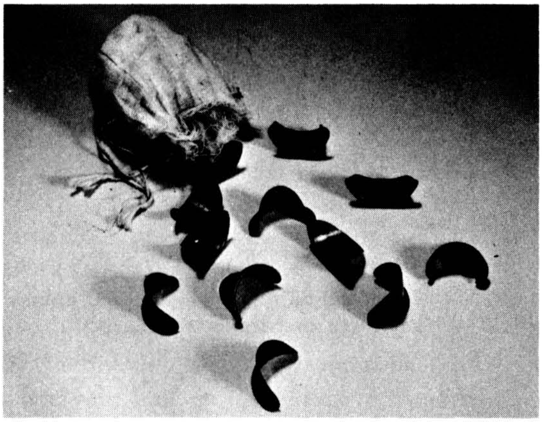


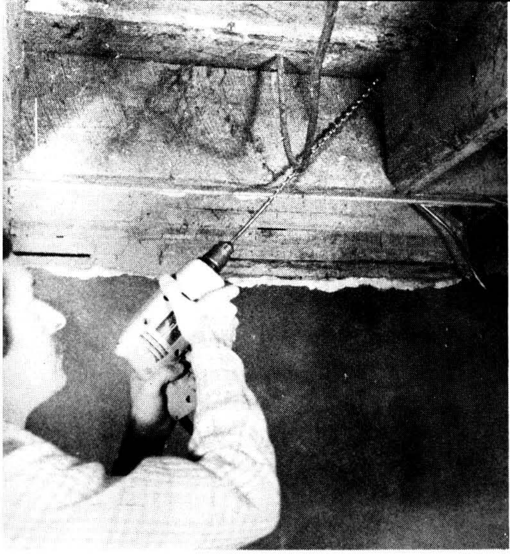
Fiber bushings for BX cable ends can be purchased by the bag. Batch here would be enough for the average home wiring job.

bushing prevents the wire insulation from being chafed or cut by the end of the armor.

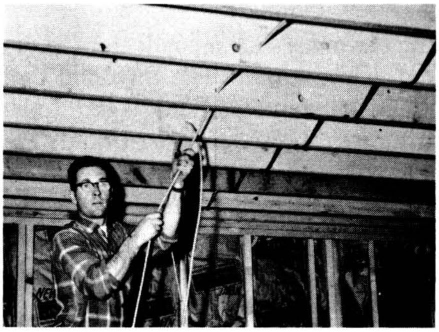
Installing the connector. With the bushing in place slide a connector (made for BX) over the wires and on to the end of the armor. The threaded end should face outward, toward the wires. Seat the connector snug against the armor end and the bushing inside it, then tighten the setscrew that holds the connector to the armor.

Opening panel "knockout." Now you are ready to open a "knockout" in the metal case of the service panel. (The same type of knockout is used in all metal wiring boxes, for outlets, switches, etc.) To open it, note the location of the small points at which it is attached to the metal around it. Then place a screwdriver against it midway between these points and give it a sharp hammer tap. This partially opens the disk-shaped knockout. Grip the opened disk rim with pliers, give it a little twist, and it comes free, leaving a hole that exactly fits your cable connector. *Do not* open any knockouts that are not to be used. On service panels and all other metal boxes used in your wiring you will find knockouts in a variety of locations to permit wiring to enter and leave along the most direct path.

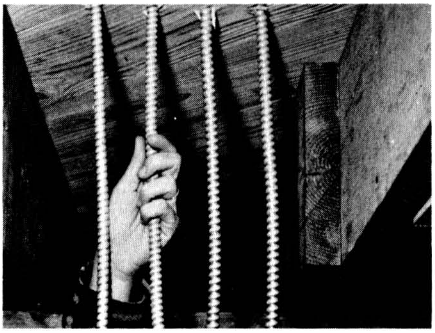
To connect wires to service panel, insert the connector through the hole left by the knockout and screw the locknut on its threaded inner end. As these nuts must be used in many boxes much too small for the use of a wrench, they are made with notches around their perimeter. To tighten them, insert a screwdriver blade in a notch and either pry the nut around or hammer-tap it around to tighten it. Tightening takes only a few seconds but it is important. The armor of the cable, like the white wire inside it, is grounded. Its connections to boxes should be both mechanically and electrically sound. Then, if the insulation on a black wire should be damaged, or a black wire splice poorly insulated so that the black wire contacts the inside of the cable armor or box, a fuse will blow and warn of the trouble. Poor connections between armor and box could result in sparking or arcing in such a case. This can sometimes take place without blowing a fuse, yet create sufficient heat to cause a fire. While such occurrences are not frequent it pays to take all precautions to prevent them.



Extra-long bit for power drill aids in boring holes in hard-to-reach work.



After boring holes in joists, thread armored cable through, taking care to remove all kinks or sharp bends.



These cables lead into wall above, holes having been bored *downward* through sole plate of upper wall. From basement point of entry, they will go to power source.

HOW TO RUN WIRING THROUGH THE HOUSE. Starting from a basement service panel, the BX usually emerges from the top of the panel and runs to the ceiling. If the joists (beams) are exposed, there are three ways in which the cable may be run:

(1) If the cable must run crosswise of the joists, it may be led through holes bored in them. If you have a power drill (and a current supply for it), this is the easiest system. If you must work with hand tools, you can still do the same job, but with some bit-and-brace effort.

(2) You may also nail a board under the joists and staple the cable to that.

(3) If the cable runs parallel to the joists, it may be stapled to their sides.

The cable must be supported at spacing not greater than every 4½′. (For overhead runs closer spacing is better.) It must also be supported within a foot of every box connection. Where the cable is bent around a turn it should be of such a radius that if it were a complete circle it would be at least ten times the diameter of the cable. This eliminates any chance of buckling the armor. Your first bend is likely to be where the cable changes direction from vertical to horizontal (above the service panel) for its run across the ceiling joists.

Leading Wiring from Floor to Floor. When wiring runs from one floor to another, as from the basement to the first floor, it must, in most cases, emerge inside an upper wall in order to complete its run to outlets or fixtures. In new work (a house under construction) this is done simply by boring a hole downward through the sole plate (wooden base of the wall framework) to emerge through the ceiling of the floor below. In doing this, however, you must avoid boring into a joist, as you would have to bore all the way through it. Aim to have your hole so located as to come out between the joists below. In old work, as in improving old house wiring, the hole is also bored from above, but by a different technique described under Modernizing Old Wiring, in another chapter.

Once your cable has been led to the upper floor, it is run through holes in the studs (wall posts) just as it was run through the joists. With most hand or power boring tools you will have to bore these holes (in both cases) at a slight angle, as the boring tool will not fit between the framing members to bore straight. This gives a wavy path to the cable, but does no harm.

Nonmetallic Cable and Conduit. The same general procedure described for BX applies to nonmetallic cable, except that the armor-cutting and removing is not required as the cable is not armored. Different connectors are used, of course, made specifically for the cable being used. It must be mounted with special straps, however, never with staples.

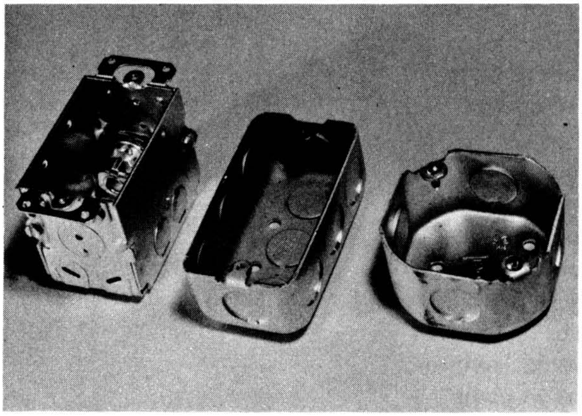
Conduit must be bent with a conduit bender to take the curves that lead it from vertical to horizontal runs, and it must be cut, fitted, and connected with couplings. It is held to the framework by special straps. After the conduit is mounted and connected to the boxes, the wiring is pulled through it. In most areas, however, you are permitted to use cables for wiring, saving greatly on time and work.

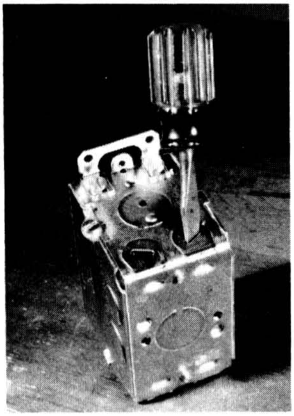
THE CARPENTRY AND MECHANICS OF NEW WIRING. The methods of cable and wire connecting that follow apply to the work you will do in all types of standard boxes, whether for outlets, switches, or fixtures. And you need not be wiring a new house in order to use these methods. They will be used in finishing an expansion attic or a basement game room (which we may assume will not be in a damp basement). And they will be used in modernizing the wiring of an old house.

Outlet Boxes. There are several types of outlet boxes, though the ones you will use most narrow down to two types:

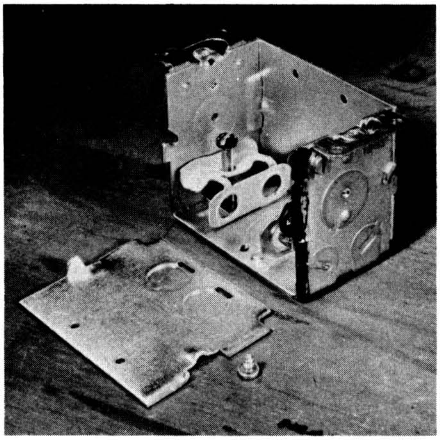
The rectangular outlet box is the one in which you will mount your switches and outlet receptacles as well as various types of wall fixtures. These can be "ganged," or joined, to form a larger box to contain more outlets or perhaps a pair of outlets and a switch. To join two boxes, remove the screw-held side wall from each, fit the open sides together and replace the screws.

The junction box is the other type you are likely to use frequently. In its

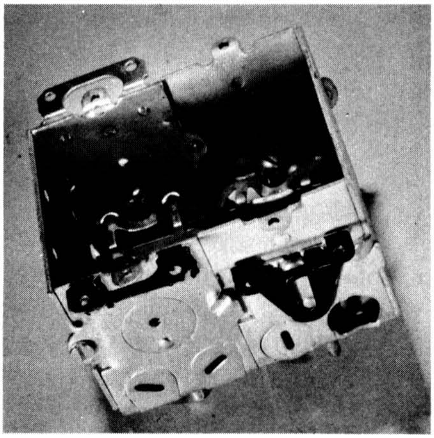




Standard types of boxes used in house wiring are shown at left. From left: standard switch box, surface-mounted box, junction box. All have assorted cover plates to match, depending on use to which they are put. Some types of knockouts (right) can be removed by merely inserting a screwdriver in slot and prying knockout disk free.



Side can be removed from switch box by taking out a single screw. Note built-in clamp, found on some boxes, which eliminates need for cable connector.



Added space for complicated wiring jobs can be attained by removing side from each box, forming a gang box which is held together by the original screws.

commonest form this box is roughly octagonal in shape, though it is often considered a square with flat corners. Only four of the eight perimeter surfaces have knockouts for cable connections. These are the boxes most often used to enclose splices. If used for this purpose only, they are closed after the work has been done, using a plain metal cover made for the purpose. Covers are also made for them with openings for switches, also with bulb sockets. The socket type is available with or without a pull-chain switch. The switch and bulb adaptations are very handy for use in basements and garages where wiring is exposed.

To install a ceiling light, for example, you need merely lead any approved type of cable to the desired location and connect it to the box, running the wires to the proper terminal screws of the bulb socket cover. If this is a pull-chain type no other switch is needed. A variety of small holes are punched in the box to permit fastening directly to the ceiling joists or other framing, or to assorted metal brackets made for the purpose when direct fastening is not possible.

The rectangular box eliminates the need for the armored cable connectors described earlier, as they have built-in clamps to hold the cable. This saves both work and money. You will still need the connectors, however, for other types. And regardless of the type of clamp or connector you will always need the protective fiber bushing inside the cable end.

Special Boxes. There are a great many special kinds of boxes made in standard form to solve special problems and meet particular wiring situations. Space limitations prevent describing them all. But, if you have a particular wiring problem involving the size or shape of a box, you can usually find the answer at your electrical supplier.

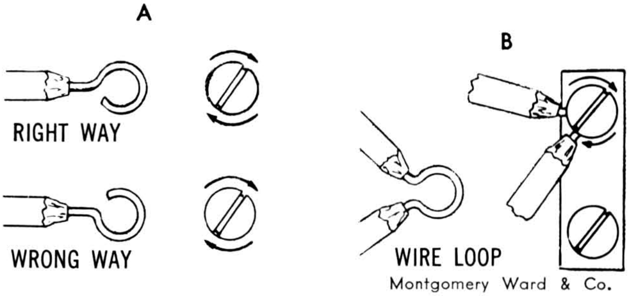
There are shallow boxes designed to fit in thin walls, narrow ones for cramped space, large ones for multiple outlets, and ceiling types designed to support chandelier loads. Simply pick the one that suits the special condition you have to meet. And, in run-of-the-mill work, use as large a standard box as you can rather than a small one. This makes the wiring easier and reduces the chance of trouble from "jammed-in" splices.

Mounting Arrangements. Boxes of all types may be mounted between studs or joists by means of brackets that extend across the space between the framing members. Many of these are adjustable so that the box need not be centered between the frame members, but located anywhere between. Mounting directly on a frame member is also a simple matter with brackets made for that purpose. All are standardized for use with the types of boxes for which they are intended. When a box must be mounted in a finished wall, as in up-dating the wiring in an old house, there are simple clamp-in devices (described in the chapter on old-house wiring) that anchor the box solidly in the plaster or wallboard. These do not require attachment to the actual wood framing. All types, as shown by the illustrations, can be installed with simple everyday hand tools. In short, it is safe to say that there is practically no house structure situation for which a mounting device is not available for electrical outlets.

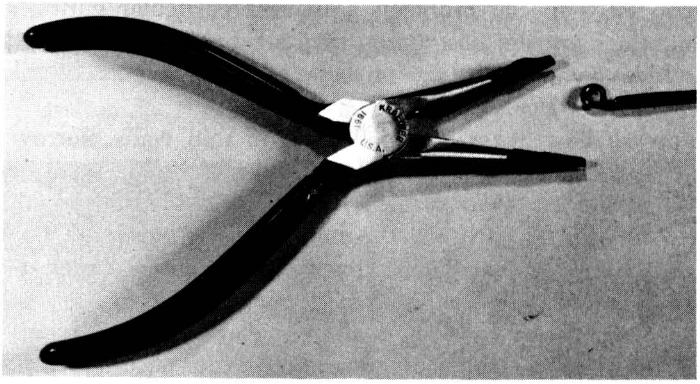
When cable and box systems cannot solve the problem you can usually use raceway multi-outlet combinations. In narrow form, this type of wiring permits outlets along runs where only the width of a calling card is available, often the case under a floor-to-ceiling picture window.

Fastenings. Brackets may be mounted with nails unless the box must be attached to them first, involving danger of damage to the box in nailing. In that event the mounting should be with screws. Also, in any situation where a pull-out load will be imposed on the fastening, a screw is the logical choice.

Wiring the Boxes. When your cable reaches an outlet, switch, or fixture box, it is connected to it just as described for the connection to the service



When connecting wire to terminal screw, always bend loop in wire so that in tightening screw you tighten loop (A). If wire connects to terminal screw and runs on (B), bare enough of wire to make a loop as shown.



To prevent nicking wire on plier's jaws when forming loop, wrap jaws with friction tape.

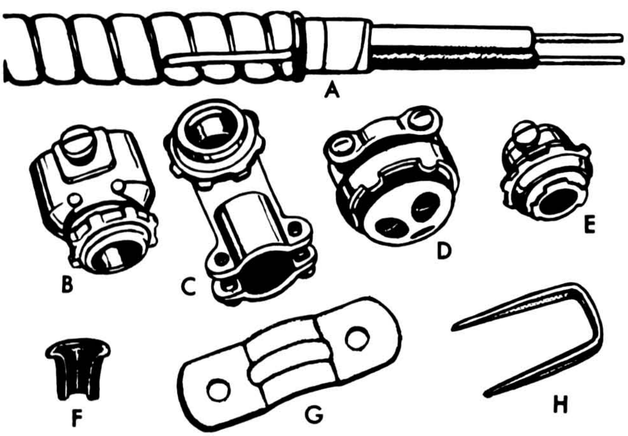
panel. The same connectors (unless built-in), fiber bushings, and locknuts are used. In cutting the armor it is important also to avoid cutting the thin, flat, bare metal strip that runs parallel to the wires inside. This is built into the cable for positive grounding from one end of the run to the other. It should be bent back over the outside of the armor so that the connector will clamp it tight when it is clamped to the armor with its set screw.

The wire connections. At outlet boxes and similar ones you should allow about 8″ of insulated wire (by removing that much armor) to facilitate connecting to the terminals on the receptacle or switch. This may seem to be more than necessary, but it permits the connections to be made and the receptacle or switch to be mounted in the box without cramped wiring that might loosen connections. It also permits easy replacement of the receptacle or switch if it should fail at a later date.

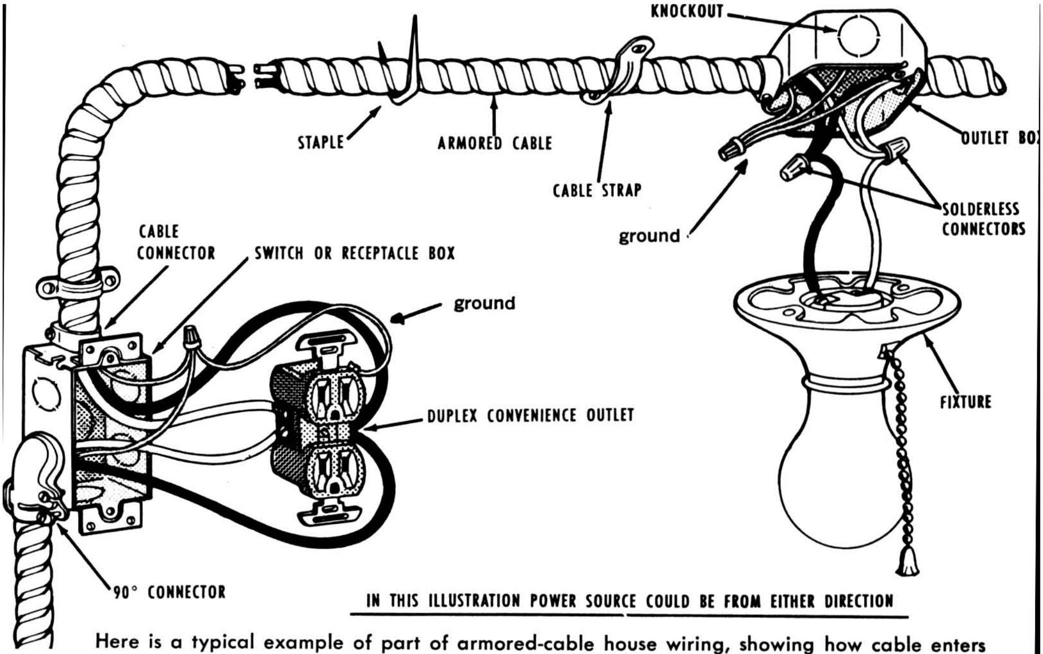
Strip the insulation from the ends of the wires, leaving enough bare wire to connect to the terminal screws. This is easily done with a pocket knife, using it as in sharpening a pencil. This leaves a conical taper or the end of the insulation. *Do not* cut straight inward through the insulation. There are good reasons for this. The tapered end of the original insulation provides a better grip for tape if the wire is to be spliced rather than connected to a terminal screw. And the pencil-pointing type of knife action greatly reduces the chance of making a deep scoring cut into the wire. This scoring, which might result from cutting straight in through the insulation, makes a weak point in the wire and invites breakage when the wire is flexed. And flexing is necessary when arranging wires in the box or installing receptacles or switches.

Use the small-nosed pliers to form the loops in the wire ends which go around the terminal screws, and *always* form the loop in the direction the screw turns to tighten. If the loop is formed in the opposite direction it will tend to open as the screw is tightened, making an unreliable connection. If more wire is bared than necessary to go around the screws, trim some off with the wire cutters (most small-nosed pliers have side cutters) so as to reduce the chance of shorts.

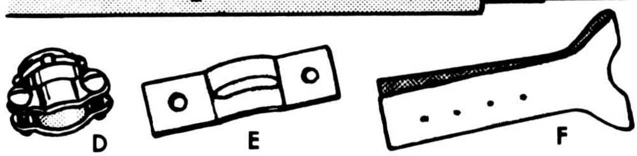
Always connect the white wire to the chrome screw, the black one to the brass screw. Never connect them the opposite way. This applies to both outlets and fixtures. If a splice is to be made inside the box, *always connect the white wire to a white wire, black to black.* Remember, too, that all splices *must* be enclosed in an approved box. All runs with any type of cable *must* be continuous from box to box. When connecting to a switch, you will note that the switch unit has only brass terminal screws. This reminds you that only the black wire is ever connected to a switch, never the white wire. When a switch is connected into a circuit, the incoming black wire and the outgoing black wire are both connected to it, one to each of the brass screws. The two white wires remaining are either spliced, soldered, and taped, or connected to each other with solderless connectors.



Armored-cable components: A. 2-wire cable with bare grounding wire inside armor. B. Duplex connector for admitting two cables at one knockout. C. Connector for right-angle attachment of cable. D. End fitting for changing from cable to 2- or 3-wire open wiring. E. Cable connector to hold cable in box which has no clamp. F. Fiber bushing to protect wires at cable end. G. Mounting strap. H. Staple for mounting armored cable.



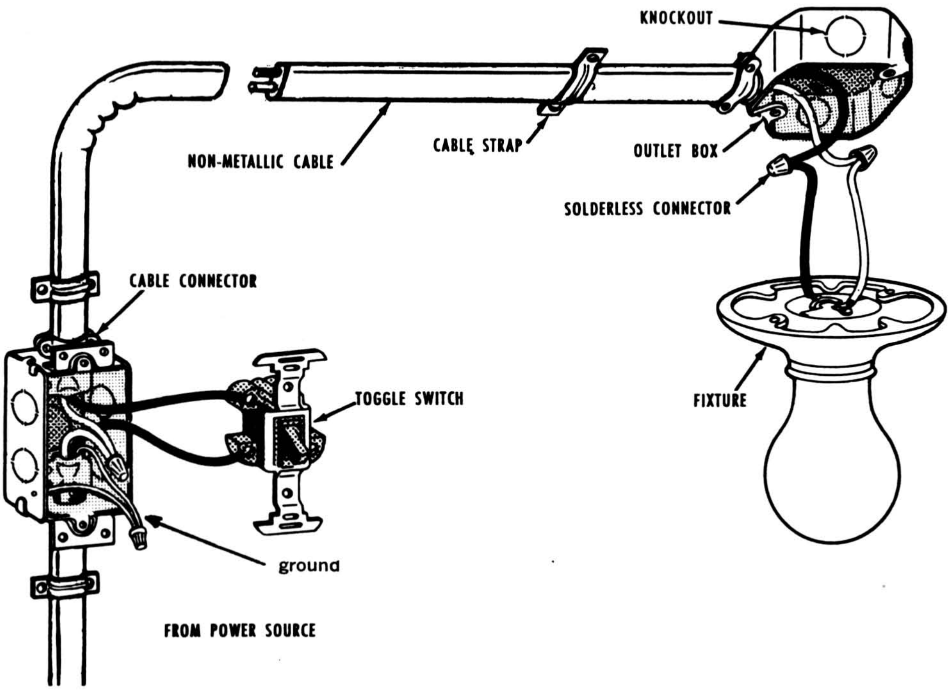
Here is a typical example of part of armored-cable house wiring, showing how cable enters and leaves outlet and fixture boxes, and method of connecting wires to outlet and fixture. Cable can be supported on structure with staples or straps.



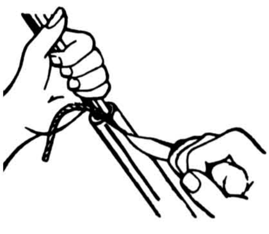
Nonmetallic-cable components: A. Cable with two wires plus ground wire. B. 2-wire cable with no ground wire. C. Plastic-covered cable. D. Cable connector. E. Mounting strap. F. Cable ripper to slit braid so wires can be separated.

The easiest way to make connections to terminal screws and to splice and tape wires (or use solderless connectors), is with the wire ends pulled well out of the box. This way, you are working in the open, not in the cramped space of the box. That is one of the reasons for the liberal wire length allowance. When you push the work back into the box, whether it is simply splices or terminal connections, form the wires into a shape that will bend easily into the box without putting a strain on the connections or splices. It is wise to arrange the wires so that when they are bent they tend to tighten rather than loosen the terminal screws. This seems like an insignificant detail, but it can do much to avoid loose connections.

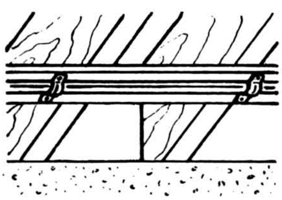
Devices That Make Wiring Easier. Included here are devices that make connections simpler and others that make wiring generally more versatile. You will find these items at electrical suppliers and at large hardware stores, but not necessarily at small dealers or at the dime store.



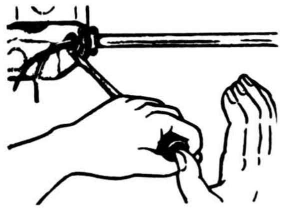
Nonmetallic cable is here wired from switch to fixture. Straps, not staples, are used in mounting this type of cable, and special connectors are used to attach cable to boxes.



ı baring wires of nonmetallic able, you can use pocketknife to it braid, but be careful not to amage insulation on wires.



If cable runs at right angles to joists, mount it on a 1-by-3 running board nailed across joists.



If box does not have its own clamp, and connector is used, tighten nut inside box by pushing its slotted rim with screwdriver.

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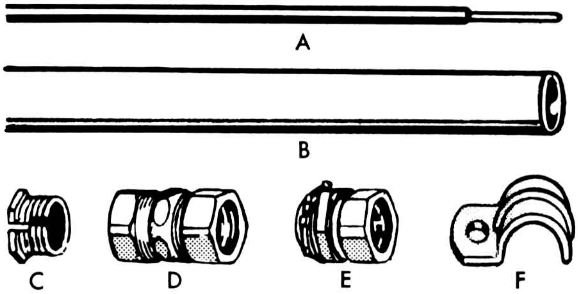
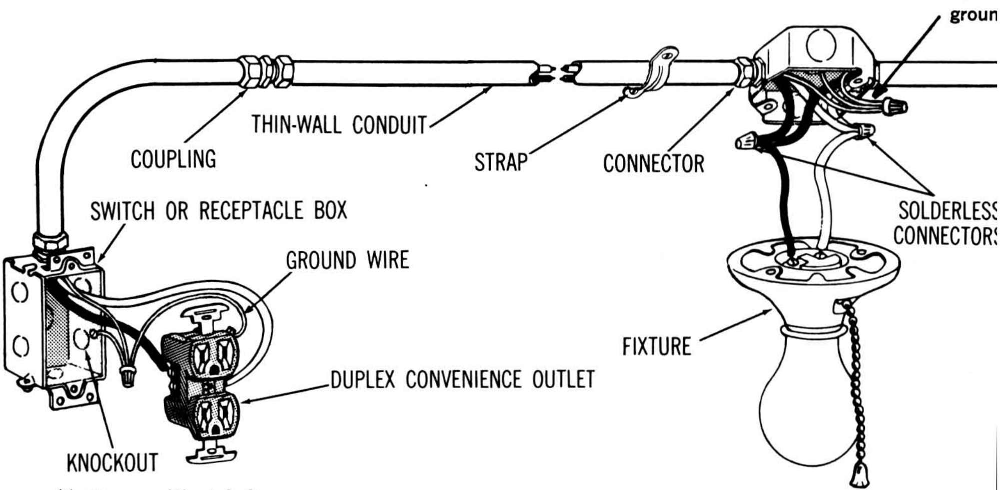


Components for wiring with conduit: A. Type TW color-coded wire used in conduit. B. Thin-walled conduit. C. Adapter for attaching thin-walled to rigid conduit. D. Coupling. E. Connector. F. Pipe strap to be used every 6′ on exposed runs, every 10′ on concealed runs.



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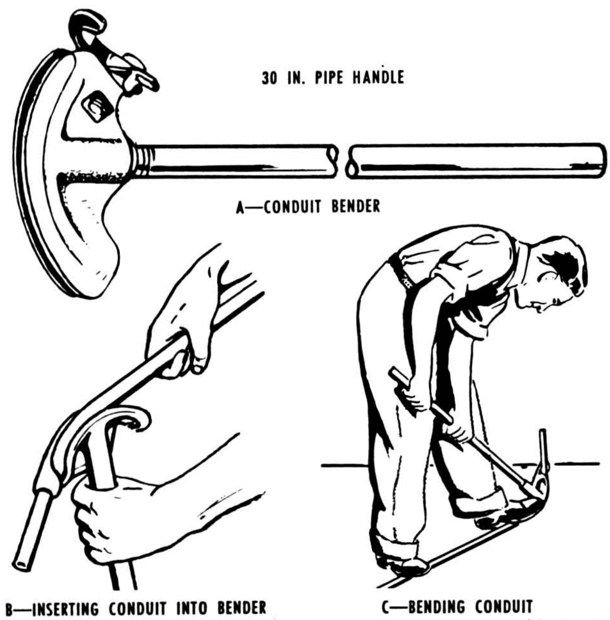
Conduit must be bent to fit installation before it is mounted. Wires are then drawn through it, special couplings are used to join lengths. All wire splices must be in boxes, not inside run of conduit.

Back-wired receptacles. You can eliminate the need for forming loops in wire ends for terminal screw connections, for example, by using "back-wired" receptacles. In the back-wired devices, the bared wire ends are simply inserted in holes in the back of the device. Then the screws at the sides (in the usual "side-wiring" position) are turned up tight. This clamps internal metal contact plates against the inserted wires and provides thorough contact. No loops in the wire are used. As to the stripping of insulation from the wire ends, stripping guides on the device assure the proper length. These guides are hollows made in the surface of the device. If you rest the wire in the hollow with the end against the end of the hollow, the edge of the device indicates the point where stripping should start. Stripped in this way, the wire has no exposed metal section when in place.

Push-in connection. Simpler still is the "push-in" type of connection. This consists merely of holes in the back of the device matched to the wire size. Push the bared wire ends (stripped according to the strip gauge) into the holes, and spring contacts make the connections and lock the wires in place. To release them for changes or alterations, a small pocketknife is pushed into a slot usually labeled "release" close to the insertion hole. The tip of the blade spreads the spring contacts that grip the wire, releasing their grip.

Interchangeable devices add versatility to your wiring by enabling you to combine a variety of devices in a single standard box. These are available in standard side-wired form (where the wire is looped under a terminal screw) or in the back-wired or push-in form outlined above. Outlets, switches, pilot lights, or other devices such as night lights may be fitted into the clamping plate, which usually takes three devices. Once in place, the devices are held there by small clamps which can be released any time the arrangement is changed. Each device is wired individually. A cover plate made to match the spacing of the clamping plate is used to finish the job in the conventional manner.

INDIVIDUAL ROOM WIRING AND LIGHTING TIPS. With the wide range of compact, interchangeable wiring devices on the market today, it is possible to have two or three switches, combinations of switches and outlets, with or without pilot lights, in the space usually required for a single old-



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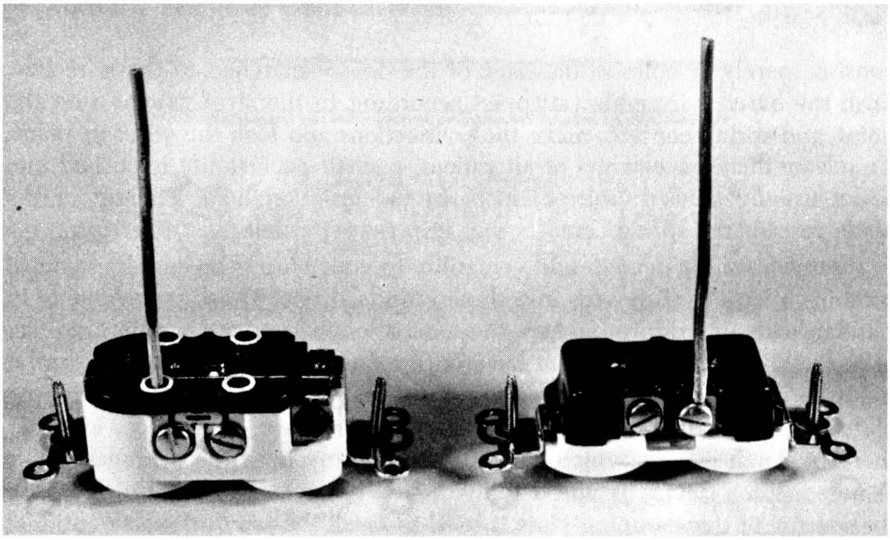
Special device for bending conduit is available. Method of bending is shown in B and C.



Back-wired receptacle (left) does not require that loops be formed in ends of wires for connecting them to terminal screws as in side-wired receptacle at right. Wires are merely slipped into holes, held by tightening terminal screws.

fashioned switch. Rocker switches, almost as quiet as mercury switches, but with the added advantage that they can be mounted in any position, as they are mechanical, can have luminescent rocker buttons that give off a slight glow all night long—when exposed to any light source. For dark areas, such as hallways or staircases, switches are available with contoured handles illuminated by a small neon lamp, a safety factor in many parts of your home.

Location of Wiring Devices. Generally speaking, switches should be placed at the latch side of doors, or the traffic side of open archways. Wall switches are normally placed about 48″ above the floor. Convenience outlets, mounted 12″ above the floor, for ease in using vacuum cleaners, etc., should be spaced so that no point in any usable wall space is more than 6′ from a convenience outlet. Of course furniture arrangements, window spacings, and general architectural features will in most instances dictate a deviation from any hard and fast rule, but with these figures in mind, you can plan your wiring for the most comfort and convenience.

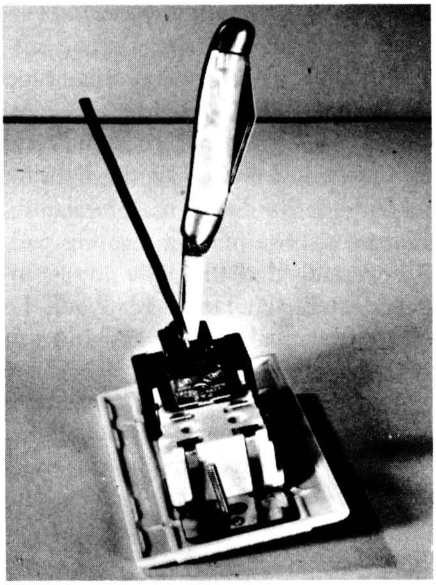
The Living Room. As most entertaining and family fun takes place here, careful attention to the overall lighting effect is a must. Control of illumination is easy with use of proper switches, and strategic placement of the convenience outlets permits use of radio, hi-fi, or movie projector to suit your mood. Switches placed at all entrances to the room can turn on one or all the lamps. Indirect lighting for decorative effect, or to light a display of your pet collection, can be turned on independently, or you can have any combination of lighting.

Convenience outlets should be mounted near any chair where light is required for reading, and don't neglect the desk area . . . experiment here with lamps to achieve the illumination best suited to your desk-work. Too much light creates glare, too little can make letter-writing a chore rather than a pleasure. Outlets for these areas can be planned in advance if you have a mental picture of your furniture arrangement before the outlets are installed. In an old house, where rewiring is required anyway, try out your furniture design before putting in new outlets and switches. Wall switch control of some lamps may be desirable and possible when two-circuit outlets are used.

If you want a modern wall clock in the living room, by all means install a clock-hanger outlet for it. With a recessed space for the plug, and a built-in hanger, the cord is out of sight, no dangling unsightly wire to spoil the effect.

If air conditioning is to be installed in the room, there should be a three-wire grounding type outlet near the window where the unit will be placed.

The Dining Room. In addition to the usual ceiling fixture or chandelier in the dining room, combination outlets and switches make for convenience



Push-in wire connections on some switches and receptacles (left) eliminate terminal screws and wire loops. Just push wire into hole; to release, insert narrow blade in slot.

Front and back view of interchangeable device that permits combining outlet, switch, and night light in one box (bottom). Pencil points to strip gauge, which shows amount of insulation to remove from wire.