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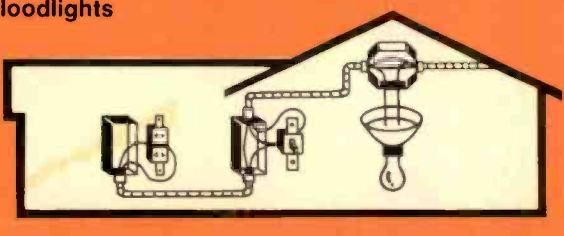
Do your own Electric Wiring Modernizing and Repair

STEP-BY-STEP INSTRUCTIONS TO HELP YOU:

- Replace switches and outlets
- Install a ceiling droplight
- Add a 3-way lighting circuit
- Put in workbench outlets
- Run power to your garage
- Install yard and floodlights



Do your own Electric Wiring Modernizing and Repair

by Louis M. Dezettel

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DO YOUR OWN ELECTRIC WIRING, MODERNIZING, AND REPAIR

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PREFACE

Home owners are the backbone of the do-it-yourself trend. Most home owners will tackle just about any mechanical job around the house—any work in wood, minor plumbing repairs, work in the garden, etc. Most will also dig into a malfunctioning toaster or replace a plug on an appliance; but when it comes to the mysterious wiring hidden in the walls, and the outlets, switches, and fixtures connected to it, there is a mental block that says, "Hands off." Fear steps in because of lack of knowledge.

There is nothing mysterious about the electric wiring in your home. Working with it requires far less knowledge than does doing good work with wood. You do not need to know electrical theory or mathematics. All the information you need to repair, to modernize, and to make electricity serve you better is contained in this book—written in the language of the layman, so anyone who can read can understand it.

The electricity in your home deserves your respect. Carelessly handled, it can be a shock hazard, but nowhere in this book are you asked to handle "live" wires. In fact, if you own a power saw of any kind, you face greater danger in its use than you will in doing your own electrical work in your home. The kind of wiring you will be adding is *safe* wiring.

The special feature of this book is the project section at the end. These projects give step-by-step instructions, with photographs of actual work done, and sketches of cutaway views, for almost every type of home electrical work: wiring a workbench; putting in a ceiling drop light; changing a light fixture; installing surface wiring; and two outdoor projects—an outdoor floodlight and wiring to a garage.

Most communities of any size have certain minimum requirements of good electrical wiring legislated into law. While most follow the standard of the *National Electrical Code*, many have included other restrictions. The information in this book broadly follows the *National Electrical Code* and those of the largest cities in the United States. If you plan on any extensive modernization or extension of the wiring in your home, you are urged to obtain a copy of your local electrical code and look it over very carefully. Contact your power company, it is very helpful in assisting you on the proper material to use and may even have printed copies of the local code that apply to residences only.

For extensive work, it may be wiser to call in the services of a professional electrical firm, but 95% of the average home needs for electrical work can be done by the man of the house, and this book tells you how to do it.

LOUIS M. DEZETTEL

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CHAPTER 1

WHAT GOES INTO YOUR SERVICE ENTRANCE BOX

The purpose of this first chapter is to give you an understanding of the overall electrical system: the form in which electric power gets to your house, how it is distributed throughout your home, and what the terms "volts," "watts," and "amperes" mean.

120 VOLTS IS STANDARD

You've always heard and used the expression "110 volts." Years ago, the standard voltage supplied to homes was 110. Now, generating systems all over the country deliver a single standard of *120* volts, 60 cycles ac for general electrical use.

The move from 110 volts to 120 volts was a deliberate one. With the increased use of electrical appliances in the home, the "load" (or demand) on the electric circuits became greater. This meant that one of two things was necessary: either increase the size of the wires carrying the electric current, or increase the voltage supplied to the circuits. This can be easily understood by comparing the situation with water flowing through a garden hose.

Many homes use a ¾″ inside-diameter garden hose for the lawn sprinkler. Even at the end of a 100-foot length of ¾″ garden hose your sprinkler does a good job of lawn coverage. Your neighbor may have a ½″ hose, and prefers it because it is lighter to handle. But his sprinkler doesn't do as good a job of lawn coverage. That is because the ½″ hose restricts the flow of water more than the ¾″ hose (Fig. 1-1). This resistance to the flow of water results in a loss of pressure at the far end. To get more water out of his sprinkler your neighbor would have to either increase the pressure of the water entering the hose or change to a larger diameter hose. Since the water pressure is not under his control, he either changes his hose to one of larger diameter, or lives with the condition he has.

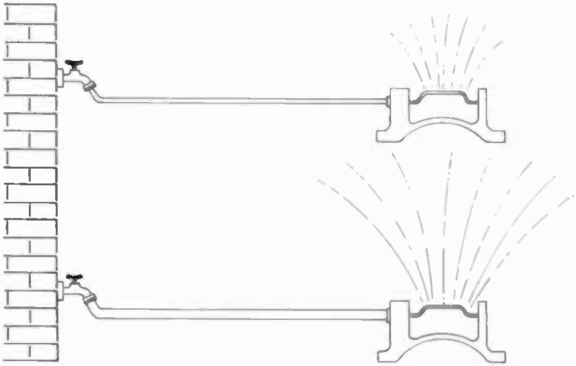


Fig. 1-1. A ½-inch hose restricts the flow of water more than a ¾-inch hose.

Wire resists the flow of electric current just as pipes or hoses restrict the flow of water. To reduce the loss of power one must change to heavier wire or increase the "pressure" (which, in the case of electricity, is voltage). The public service companies supplying electricity found it cheaper to increase voltage than to install all new wires. But even this was not enough, as you will see later on.

VOLTS—AMPERES—WATTS

While we are on the water comparison, let's use it to explain some electrical terms. *Volts* compares with water pressure; *amperes* is the measurement unit of current flow through the wires and compare with the volume of water flowing through a pipe or hose. But our electric light bulbs and appliances are rated in *watts*. The term *watts* represents the total energy or work that is done. It is the arithmetic product of volts times amperes. If you are interested in the amount of current flowing through the wires supplying any appliance, divide the figure for watts by 120 (the voltage). For example, a 120-volt, 100-watt bulb draws .833 ampere. Note that when 110 volts was the standard, a 110-volt, 100-watt bulb drew .909 ampere, and the loss of power in the line itself was a little greater.

240-VOLT SERVICE

As was said earlier, the power companies did more than just change to 120 volts. For a number of years now, nearly all new or remodeled homes have been supplied with 240-volt service. If your home has three wires coming to it from the service poles or from underground pipes you have 240-volt service. The three wires bring in a combination of 240 volts and two branches of 120-volt service. Fig. 1-2 illustrates this. The voltage between the two outside wires is 240. The voltage between the center wire and either outside wire is one half that, or 120 volts. It is something like saying the distance from

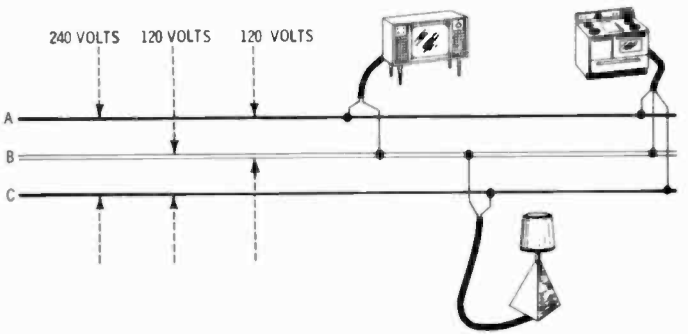


Fig. 1-2. The three-wire service now brought into most homes supplies 240 volts for electric ranges and other high-wattage appliances, and two branches of 120-volt service.

point A to C is 240 miles. Point B is halfway between A and C. Therefore, the distance between points A and B is 120 miles, and between B and C is 120 miles. The center wire is known as the *neutral, common, or ground wire.* It is actually grounded in your home by an electrical connection to a cold water pipe.

Electric ranges, electric dryers, electric hot water heaters, central air conditioners, and some large window air conditioners consume so much power (draw so much current) that the wire sizes required to supply them with current at only 120 volts would be rather large. When these appliances are operated from 240 volts they draw only half the current, and the wires that carry the current can be of reasonable size without too much loss.

As previously explained, the 240-volt lines also give you two 120-volt circuits. Thus, the circuit branches in your home can be split into two separate main circuits, so that the current load on the power company's entrance wires to your home is reduced, as are the losses.

The power company distributes electric power through lines from their generating stations at many thousands

Fig. 1-3. A typical "pole" transformer, used by the power company to reduce 2400 volts to the 240-volt and 120-volt service brought into your home.

of volts. Branches from these lines enter towns and cities at lower voltages. Sub-branches go into the neighborhoods at 2400 volts. The lines you may see going down your alley or in back of your house from pole to pole carry this 2400 volts to pole transformers (Fig. 1-3), which bring the voltage down to the 240 and 120 that enter your home. One pole transformer serves about sixteen homes. You can see, from what has been said before, how economy in wire size is gained through the use of higher voltages in the distribution system. Imagine the diameter of the cables that would be required if all distribution were done at the final 120 volts.

60 CYCLES AC

The standard frequency used today is 60 cycles alternating current (ac).* All the systems in this country are tied together countrywide so that some areas, temporarily needing more power than their own system can supply, can borrow from another. In addition, this tie-in provides a single, constantly corrected, 60-cycle frequency, so that electric clocks all over the country keep exactly the same time.

There are two kinds of electric current: dc (direct current) and ac (alternating current). Direct current could have been more correctly named "unidirectional current ." Dc means that the electrons flow through the wires in one direction only. The advantage of dc is that it can be produced by chemical action. Examples are flashlight batteries and the storage battery in an automobile.

*At one time some cities had 50 cycles ac and some even 25 cycles. The West Coast, for instance, formerly used a 50-cycle generating system to supply nearly all of California. In some cases, large industrial firms would generate their own electricity, and would also supply the cities in which they were located. This was true in Gary, Indiana, where half the city was supplied with 25 cycles from a steel-mill generator. Many small towns had their own gasoline-driven generators. They frequently supplied dc (direct current) instead of ac. Even the Chicago loop (the main business district) used dc until just a few years ago. Several foreign countries, even today, use 50-cycle ac.

Electrons flow from the negative terminal of a battery, out through the lamp or other device in the circuit, and back into the positive terminal.

Sixty-cycle alternating current (ac) changes its direction of flow 120 times a second. Current first flows in one direction, drops to zero; then flows in the opposite direction, drops to zero; then begins a new cycle in the first direction. The changes are not abrupt; they are gradual, following the effect of a rotating a-c generator. When you plot this on graph paper it looks like Fig. 1-4; the waveform is called a *sine wave*. From the top of one peak to the top of the next is one cycle. There are 60 complete cycles in each second of time. The changes in current flow are too fast to make a light bulb flicker, but you can hear the 60-cycle hum if you put your ear to an electric clock.

Alternating current cannot be stored chemically as dc in a battery, but it has one big advantage: It can be transformed from one voltage value to another by the use of transformers.

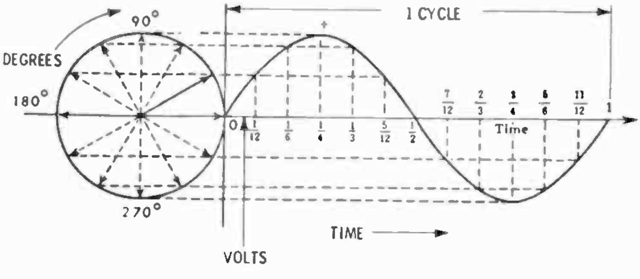


Fig. 1-4. Alternating current changes shown graphically. The curve is plotted against degrees of rotation (of a generator, for example) versus time. The speed of the generator produces 60 cycles per second. The curve is called a "sine wave."

When a current flows through a wire it produces a magnetic field around the wire. Do you remember when you used to wind a coil of wire around a nail to make an electromagnet that could lift another nail or other small piece of iron? Direct current through the wire developed a *constant* magnetic flux that could hold a nail in suspension. If ac were applied to the coil, a *fluctuating* magnetic flux would be developed. Bring this coil near another coil, and the fluctuating magnetic flux will *induce* the flow of ac in the second coil; dc cannot do this.

A transformer is made of two coils coupled magnetically by a soft laminated-iron core which is used for greater efficiency (Fig. 1-5). The voltage induced from one coil to another is related to the number of turns of wire wound around each coil. The pole transformer in back of your home has 10 times as many turns of wire in the primary coil (the 2400-volt side) as in the secondary coil (the 240-volt side). It is said to have a 10-to-1 turns ratio, and thus it steps the 2400-line down to 240 volts.

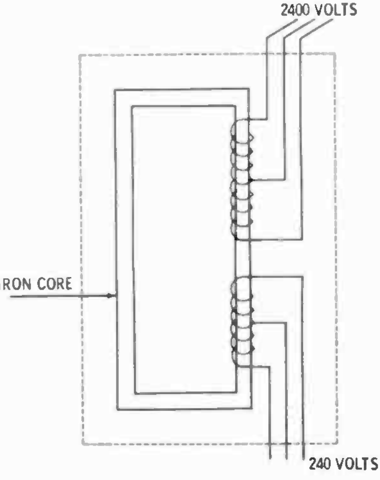


Fig. 1-5. A pole transformer has two coils.

THE SERVICE ENTRANCE BOX

The power company brings its service into your home through a watt-hour meter (which is their property) to your entrance box. This book concerns itself principally with the circuits, outlets, fixtures, and switches from this box on.

The service entrance box (other names are: control box, fuse box, circuit breaker box, etc.) is the point of distribution to the various circuits in the home. It contains the devices (fuses or circuit breakers) that protect against overload to the main entering service as well as in each of the circuit branches. A long cylinder-shaped cartridge fuse or heavy-duty circuit breaker protects the main line from overload. A "60-ampere service," for instance, will have two 60-ampere cartridge fuses or circuit breakers, one in each outside leg of the 240-volt line coming in, plus a number of smaller-rated fuses or circuit breakers in series with each separate circuit branch. One or both of the main fuses or circuit breakers will "blow" or open up if all the lights and other appliances in the house are on and the total current drawn exceeds the fuse rating, even though the currents drawn in the individual circuits do not exceed the rating of these fuses or circuit breakers. More complete descriptions of different kinds of fuses and circuit breakers and how they work will be found in Chapter 2.

Note that fuses and circuit breakers are rated in amperes, which is the amount of current flowing through them. The current in amperes can be figured from the wattage ratings of various appliances by the simple arithmetic described earlier. As an example, if an electric iron is rated at 1200 watts, it will draw 10 amperes of current (1200 divided by 120 equals 10).

The diagram of Fig. 1-6 shows how a typical 3-wire 240-volt service line enters a fuse box and is distributed throughout the house. The middle neutral, or grounded, wire is connected to a metal terminal bar in the box, and from it wires go out to the individual circuits. The two *hot* wires are connected, one each to the main cartridge fuses, and from there to banks of smaller fuses or circuit breakers. A 120-volt hot line is taken off at each smaller fuse or circuit breaker and fed, along with a neutral line, to separate circuits in different parts of the house. There is only one fuse or circuit breaker to each branch.

HOUSE CIRCUIT BRANCHES

Fig. 1-7 is a simplified illustration of a typical small home, showing the distribution of the individual circuit branches to various rooms. The wires are run to the outlet points through metal pipes called *conduit*.

Before doing any repairs, changes, or extensions to the wiring in your home you should be acquainted with

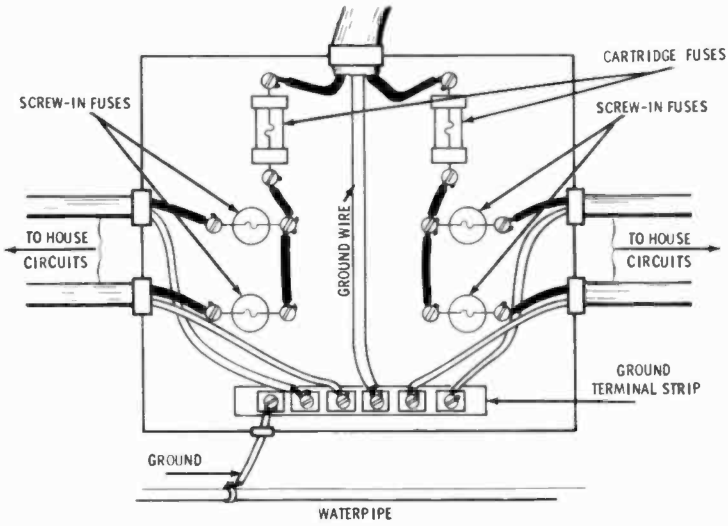


Fig. 1-6. A typical "60-ampere service" box, using fuses. The 240-volt service is brought into the top of the box by the power company. 60-ampere cartridge fuses protect the main incoming line. 15-ampere screw-in fuses protect the separate circuit branches against overload. Note that the "neutral" (colored white) lines are not fused.

what parts of the house the various branches serve. Do it this way: Turn on all the lights in your house. Unscrew one fuse or open one circuit breaker. Make a note of the lights that go out; then restore the circuit. Do this to each fuse or circuit breaker in the box. It is a good idea to mark your fuse box with an initial or number, such as "N" for the north side of the house, or "1" for the first floor, etc. Use adhesive tape or a china-marking grease pencil. In this way you will know later on which fuse to unscrew or circuit breaker to open when you want to do some work on that part of the house. Don't forget to reset electric clocks that have been momentarily stopped in this test.

SAFETY FIRST

CAUTION—First, never work on an outlet or switch box without disconnecting that circuit fuse at the service entrance box by removing the fuse or opening the cir-

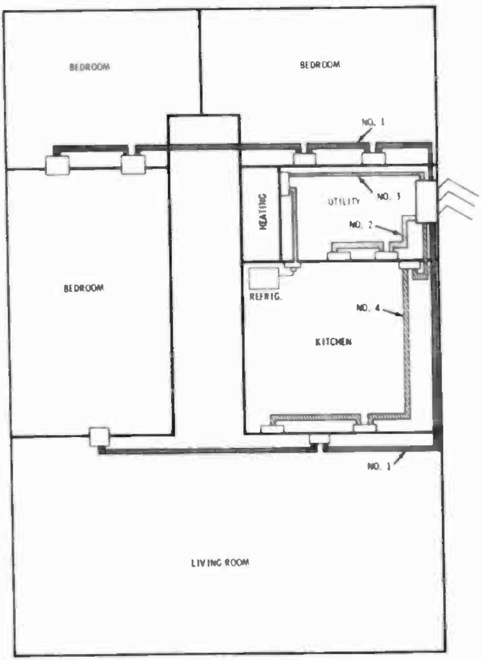


Fig. 1-7. Sample of possible distribution of circuit branches from the central control box. Central heating and refrigeration are separately fused to prevent interruption of these vital services in case of trouble elsewhere in the house. Kitchens should have their own lines because of the heavy loads of high-wattage appliances frequently used in the kitchen.

cuit breaker. Second, if you have a fuse box, and it is in the basement, never remove a fuse if the floor is damp. If you must remove the fuse stand on a wooden stool that you know is dry. Third, never hold onto the metal fuse box with one hand while removing a fuse with the other. Always remove fuses with one hand behind your back. This caution is not so necessary for circuit breakers, since they are fully insulated. Don't take chances. Even 120 volts can be deadly if handled carelessly.

GROUNDED WIRING

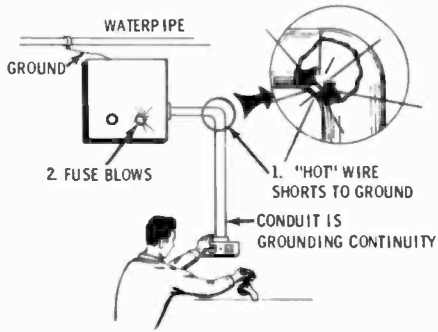
From the power company's service entrance, to your service box, and out to the most remote outlet, all wires are fully enclosed in metal; the metal box itself and the conduit piping are parts of the wire enclosures. In addition, a wire is run from the box to a nearby water pipe. This grounds the entire conduit system.

All of this is to protect you from possible shock hazard, as well as to protect the wire from physical damage. If the hot wire is damaged (such as scraping when it was pulled through the conduit when your house was built) and the bare wire touches the conduit, all that would happen would be a blown fuse or open circuit breaker. (If the bare neutral wire should touch the conduit, nothing would happen, nor would there be any danger.) If it were not for the grounded system the fuse would not blow, and you would be left with a potential shock hazard at outlets that might be near water pipes. Fig. 1-8 illustrates this point.

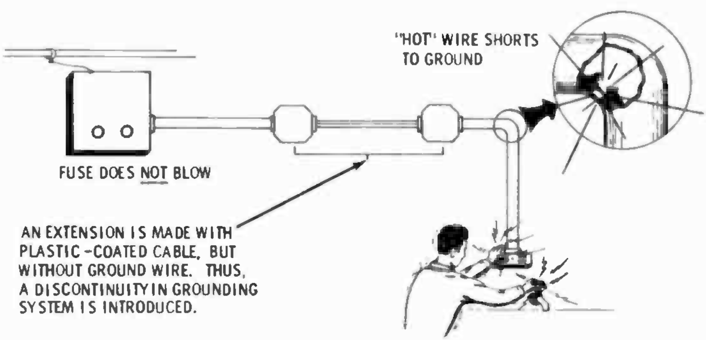
ELECTRICAL CODES

Throughout this book you will see frequent references to local electrical codes. Most communities of any size have certain minimum requirements of good electrical wiring legislated into law. While most follow the standards of the *National Electrical Code,* many have included other restrictions. These codes are part of a building-code law that intends to set standards of construction to keep fire hazards at a minimum. If some code requirements seem unnecessarily restrictive, remember that they were made for your safety.

The UL label on an appliance is important to you. It means that the manufacturer of that appliance has submitted his product to *Underwriters' Laboratories* for



(A) Man is safe.



(B) Shock could be fatal.

Fig. 1-8. Illustration of safety factor of conduit.

testing it against shock and fire hazards. Their requirements for a listing are tough. Any product with a *UL* label can be considered safe to use under normal everyday usage. *Remember, their testing is for shock and fire hazards ONLY*—not for quality of product.

CHAPTER 2

ELECTRICAL DEVICES YOU SHOULD KNOW ABOUT

You are already acquainted with many of the devices and equipment used to wire your home. You have daily contact with switches and outlets, of course; and you probably have noticed the many pipes that go out from your service-entrance box, unless the box has been recessed into a finished wall.

The devices described in this chapter are basically the same as those already in your home, except for some that may be more up to date. These may include newer-type cables, improved switches, 3-contact "safety" outlets, etc. Whether old or new, basic mounting dimensions have remained the same for years, so that new devices can replace old ones very easily.

It is well to keep in mind there are differences between various devices, depending on whether they are used in new construction (while a house is being built) or in "old work" (the electrician's expression for a house already built). For example, solid metal piping, called conduit, is used exclusively in new work, whereas flexible cable, whether metal or plastic-sheathed, is preferred for old work because of the greater ease with which it can be drawn through walls. Junction boxes with special brackets are used for easier fastening to new-work wall studs, but other methods are used to fasten a box to plaster or lathing in old work.

OVERLOAD PROTECTION

The service-entrance box, sometimes called the central control box, is the beginning of our tour of inspection of electrical devices. In modern and more expensive homes, protection is accomplished by circuit breakers. These operate by either magnetic or thermal action, and they open the circuit when the current drawn through them exceeds the ampere rating of the circuit breaker. When an overload trips a circuit breaker, it is only necessary to reset them by a lever, *after* the cause of the overload has been corrected.

Most homes have replaceable fuses in their control box for protection. Fuses contain a strip of lead alloy which, because of its thickness and composition, is designed to melt when the current exceeds the rating of the fuse, and thus open the circuit.

Long cartridge fuses (Fig. 2-1A) are "main" fuses and carry the current of the entire house. They are also used, either in the same box or in a separate one, for fusing heavy 240-volt appliances such as electric ranges or hot water heaters. These cartridges are usually mounted on pull-out blocks, so they may not be visible when you first open the door of the control box. This mounting method permits safe disconnection of the power to the entire house and eliminates the danger of direct handling of the cartridge fuses.

Screw-in type fuses protect individual branch circuits in the house. The most common types are made of the

(A) Heavy-duty cartridge fuse. *(B) Screw-in type fuse.* *(C) Magnetic screw-in circuit breaker.*

Fig. 2-1. Different types of circuit protectors.

same internal material as the cartridge fuses, and once they blow they must be replaced by others (Fig. 2-1B). Some are made to take an extra heavy overload for a few seconds without blowing; these are for special applications, such as a motor starting with a heavy load. Some fuses are made with a number of elements in them, selected by a switch. If one element burns out, you simply turn the switch to the next one. Another type of screw-in fuse is constructed like a circuit breaker. It opens the circuit magnetically. If it trips, you push the plunger on the front of the plug back in to reset (Fig. 2-1C). This closes the circuit again.

CONDUIT AND CABLES

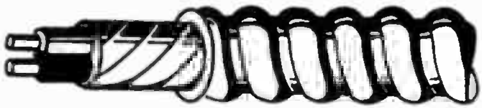
Radiating out from the control box are branches of wires run in solid metal piping called conduit. It is generally referred to as "thin-wall" because of the thinness of its metal walls. The thin material permits easy cutting and easy bending for going around corners. It is now used almost exclusively in new homes at the time of construction. Since it is all metal it provides a completely grounded system (described in Chapter 1). Wires are drawn through it to the junction and outlet boxes. It is the most expensive system of wiring, but it offers the best protection to the wiring system and the home, and is the most permanent. Most communities have electrical code regulations that demand its use in new home construction, but a few communities do not (Fig. 2-2A).

Flexible armored cable, also known as *BX,* provides one of the two most convenient means of making extensions in the home. It consists of a spirally formed steel jacket with insulated cable already in place inside. It is available with two or more conductors. BX provides the electrical path for a "grounded" system, as well as mechanical protection for the cables inside. Some types have an extra bare ground wire running through for more positive grounding. Flexible armored cable (Fig. 2-2B) is not waterproof and must not be used in areas of high humidity or where water may be dripping.

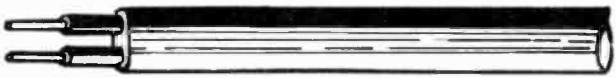
It definitely is not to be buried underground for supplying power to a garage, for example.

For years, a favorite nonmetallic cable was one known as *Romex*. It has now been replaced with a more durable plastic-covered cable. This is available in two forms: one with a lighter-weight plastic jacket, which is popular for use inside the home; the other with a heavy plastic jacket that many electrical codes now permit to be buried in the ground for running to the garage or other remote buildings. The plastic (Fig. 2-2C) is impervious to moisture and other corrosive effects, but must not be used in areas where it may be subject to mechanical abuse or physical wear.

(A) Metal pipe called "thin-wall" conduit.



(B) Flexible armored cable.



(C) Plastic-sheathed cable.

Fig. 2-2. Three common types of cables for running lines from box to box.

Plastic-covered cable is available with two or more wires inside. It can also be obtained with an extra "ground" wire inside, which is used to tie junction boxes together into a grounded system where this is important (for example, as the supply line to a garage).

The cables mentioned above may be purchased with different size wires in them for different requirements as to current needs. Table 2-1 is from the Chicago electrical code, and is generally similar to codes all over the country. *Circuit wires* refers to principal branches out of the control box. Taps are considered short branches off one of the junction boxes which, the code says, should not be more than 18 inches long. The code also says that fuses or circuit breakers shall not have a current rating higher than the current listed in the table for that wire size. The chances are you will not need more than 15 amperes of service to any outlets that you may install, so that for all practical purposes you will be dealing only with wire size No. 14.

Table 2-1. Typical Code Requirements for Different Current Needs

CIRCUIT RATING	15 Amp	20 Amp	30 Amp	50 Amp
CONDUCTORS: (min. size)				
CIRCUIT WIRES	No. 14	No. 12	No. 10	No. 6
TAPS	No. 14	No. 14	No. 14	No. 12

Circuit Wires are the individual circuits extending from the main control box. *Taps* are extensions made to the indivdual circuits. Total current expected to be drawn at one time must not exceed the ampere figures shown.

JUNCTION BOXES

Metal junction boxes are available in various sizes and shapes. Their dimensions are pretty well standard, no matter who the manufacturer is. More specifically, their screw fittings on the front are standardized, and will take anybody's switches, outlets, or other hardware.

The most popular large boxes are called "4-inch boxes" (diameter) and are made in round, octagonal, and square shapes (Fig. 2-3). They are used mostly as ceiling junction boxes for hanging fixtures, and they are roomy enough to carry extra wires for distribution to other points. The square type is frequently used as a large outlet or switch box in unplastered areas, such as a basement. They are available either with knockouts for connecting thin-wall conduit, with special clamps for nonmetallic plastic cable, or with special clamps for flexible armored cable (BX). *E*, *F*, and *G* illustrate various covers available for these boxes.

Fig. 2-4 illustrates a number of smaller boxes used for switches and outlets. The variety of these is even greater than for the large boxes described above. The greater variety is mostly in the number and types of mounting brackets available for use in "new work." *A*, *B*, and *F* of

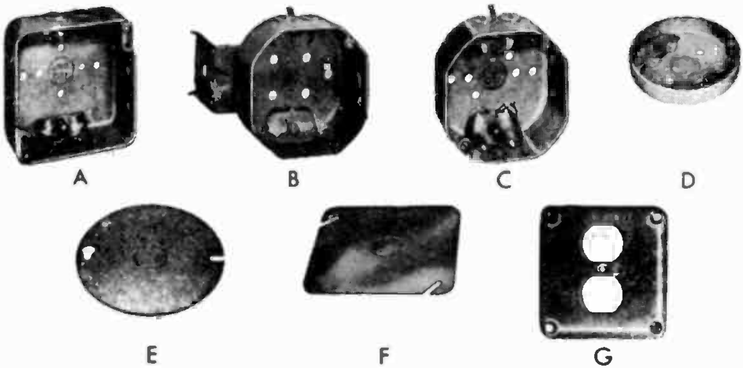


Fig. 2-3. Four-inch boxes generally used as junction or ceiling fixture boxes. They are available in several depths, depending on how many wires they must accommodate. *A* is a square box that is also frequently used as a multiple-switch or multiple-outlet box in work areas and garages with unfinished walls. *B* and *C* are octagonal boxes, showing the built-in clamps for plastic cable. *B* shows one version of a box with an attached bracket for installation in "new work." *D* is a round fixture box, available in depths as little as ½" for use in installing fixtures in "old work." *E* is a cover for octagonal or round boxes. *F* is a cover for the square box. *G* is a cover for a square box with a duplex outlet.

Fig. 2-4 are of special interest to home owners planning extensions in "old work." *A* is the type with pull-up ears on the sides that clamp the box to a plasterboard wall. A detail of how it works is shown in Fig. 2-5. All of these boxes also have knockouts for conduit. Some have clamps for plastic-sheathed cable; others have clamps for flexible armored cable. *F* and *G* are recommended for exposed mounting, such as on a workbench. *H* is a metal front plate used with a duplex outlet.

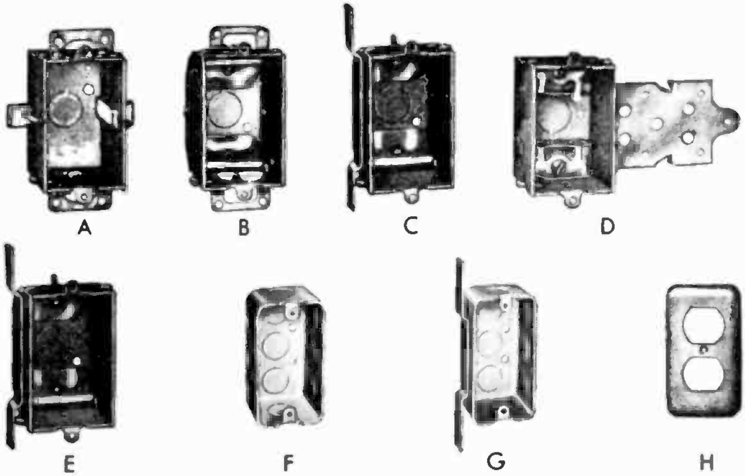


Fig. 2-4. Small boxes used to hold switches and outlets. *A* has pull-up side ears that hold the box to plasterboard and *Sheetrock*. *B* is fastened to the lathing in plaster walls with the top and bottom ears. Both of these boxes are for "old work." *C*, *D*, and *E* have brackets welded on for attaching to wall studs in "new work." *F* and *G* are for exposed mounting, such as at work benches; *H* is a metal cover for these types, providing accommodation for a duplex outlet.

Outdoor outlets, for supplying power to rotisseries, outdoor lamps, electric hedge cutters, etc., are of special construction to keep water out of the electrical wiring inside (Fig. 2-6). These boxes are of cast metal and have watertight bushings that take ½″ conduit only. The out-

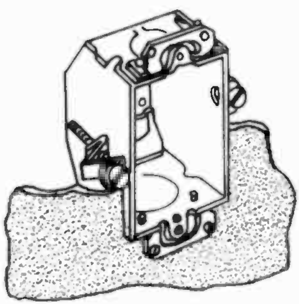
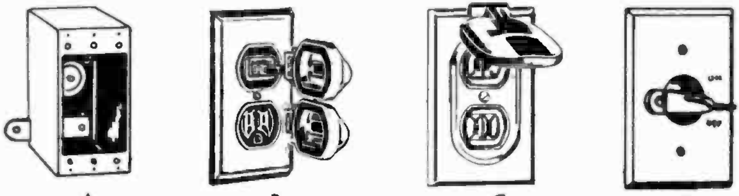


Fig. 2-5. Mounting details for the box shown at *A* in Fig. 2-4.



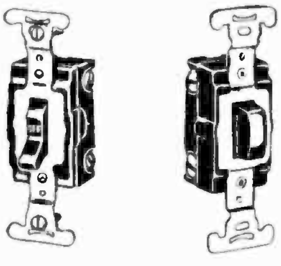
A B C D

Fig. 2-6. Boxes and outlets of special construction to make them waterproof. *A* is a cast metal box with watertight bushings for use with thin-wall conduit. *B* and *C* are outlets and covers. *D* is a water proof switch.

let and switch front plates have rubber gaskets around the edges to make them watertight, and the outlets have hinged doors that snap shut when they are not in use. **FOR SAFETY OUTDOORS, FOLLOW THIS RULE:** Use only outlets having the ground terminal; if your outdoor appliances are not already so equipped, change their cables to the three-conductor type with three-prong safety plugs.

SWITCHES

The snap-action toggle switch is still the most often used in homes (Fig. 2-7A). It is inexpensive (under 40¢), so replacement of one that has gone bad is better than attempting to repair it. However, there are improved switches available for slightly more money. Three that are direct replacements, having the same appearance and using the same decorative front plates, are: (1) a silent-



A B

Fig. 2-7. *A* is the general appearance of the average standard snap-action toggle switch, as well as of the silent mechanical switch, silent mercury switch, and the delayed-action switch. *B* has a push bar on the front; push for "on"; push again for "off." Switches are installed with large ears at the top and bottom and flush against the front of the wall.

action mechanical switch, (2) a silent-action mercury switch, and (3) a delayed-action switch. The mercury switch contains a small vial of mercury coupled to the toggle lever. When the lever is raised, the vial is tipped and the mercury flows down to one end and completes the circuit to two contacts. These switches are not only silent in action, but they last a long time. The delayed-action switch holds the circuit on for a couple of minutes after you snap it off. It is handy for driveway lights, for example, where you want lights to remain on until you

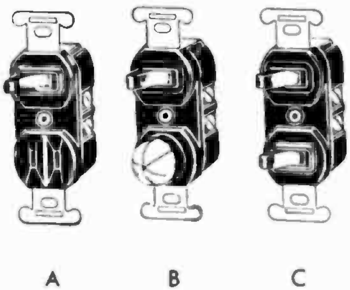


Fig. 2-8. Toggle switches in combinations. *A* is a toggle switch and an outlet with, or without, ground terminal. *B* is a switch and a pilot light. *C* is two switches in one device.

drive away. Another switch has a pushbar on the front; push once for "on," push again for "off." This type (Fig. 2-7B) takes the same front wall plate as the toggle switch.

Also fitting the same boxes are combination-type switches. You can get a switch with either a standard or a ground-type outlet, a switch and pilot light, or two switches on one box (Fig. 2-8).

For up to three functions from one box, the smaller, interchangeable devices are worth investigating (Fig. 2-9). They are an outlet, a toggle switch, and a pilot light (neon). They may be used in any combination of two or three.

OUTLETS

Standard outlets are always double, because two outlets fit the same box. Fig. 2-10 shows five types. *A* is most universally used. *B* accommodates some of the older

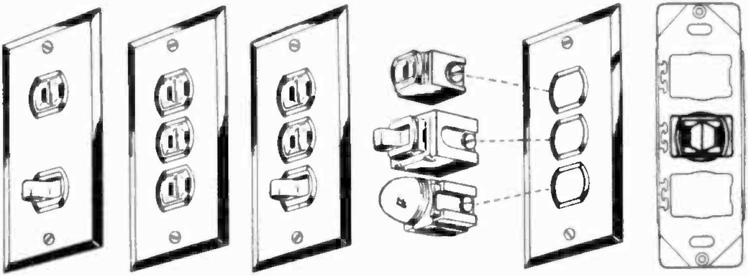


Fig. 2-9. A pilot light, a toggle switch and an outlet are available in what is called "interchangeable" devices. They may be used in any combination of two or three. They crimp to a special plate (shown at right) for mounting to an outlet box.

polarized plugs: one with one blade wider than the other; one with blades perpendicular to each other; and the standard parallel-blade plug of today. *C* has rotatable front covers that keep children's inquisitive fingers from making contact with the electrical terminals inside. *D* is the latest type with U-shaped ground terminal added. These take the new three-prong safety plug now used on most large appliances and power tools. The same sockets

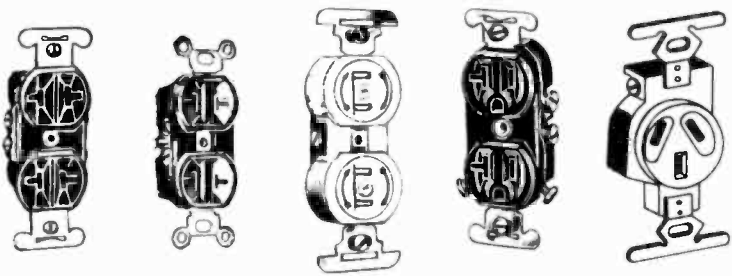
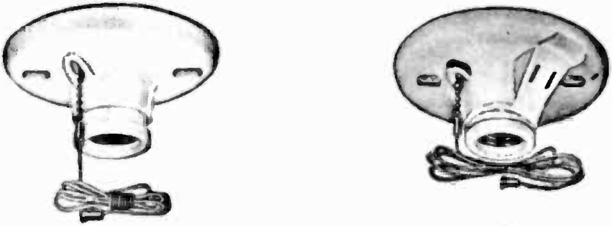


Fig. 2-10. Here are some of the various types of outlets. Most are double (duplex), since two fit the same box. *A* is the most commonly used duplex outlet. *B* is slotted to take some of the older plugs. *C* has spring-loaded rotatable covers to keep children from poking metal objects into the terminals. *D* is for use with the three-prong safety plug, but also takes the standard two-prong plug. *E* is called a "crowfoot" outlet, for 240-volt wall outlets.

also accept the standard two-prong plug. Several heavy-duty, three-contact outlets are available for 240-volt appliances, such as electric ranges, electric dryers, electric hot water heaters, and 240-volt air conditioners. The one shown at *E* is often called a *crowfoot*, three-contact outlet. It fits the regular switch-type box and is most often used for window air conditioners requiring 240 volts.



A B

Fig. 2-11. Porcelain ceiling outlets with pull-chain switches. They are inexpensive and are frequently used in closets and areas where a fancy fixture is not needed. *A* is the standard type with Edison socket. *B* includes a convenience a-c outlet.

As outlets, we must include the porcelain ceiling outlet frequently used in closets and other areas where appearance is not important enough to warrant a fancy fixture. They usually have a pull-chain switch built in (Fig. 2-11).

Single or double outlets (Fig. 2-12) are fitted to round cover plates for the 4″ junction boxes described earlier. They are for use in unfinished basements, garages, and general utility areas, where walls are not plastered. One is used in the workbench outlets project described in a later chapter.

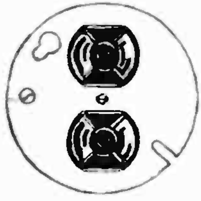


Fig. 2-12. A duplex socket in a 4-inch round cover plate for 4-inch octagonal or round junction boxes.

Fig. 2-13. Devices used for surface wiring where exposed wiring is not objectionable. They interconnect with plastic covered cable tacked in place. *A* is a duplex outlet. *B* is a toggle switch, used with *C*, a light bulb outlet.

RACEWAYS

An easy-to-install type of extension wiring is called *surface* wiring. These take the form of metal troughs, or raceways; or they may be just heavy, plastic-covered cable. There are several forms, some of which are pictured in Fig. 2-13.

FITTINGS

The types of couplers or special hardware used in electric wiring are almost without number. Only the most popular are described here.

Fig. 2-14 illustrates fittings for fastening thin-wall conduit to the knockouts in boxes. *A* is a split male thread

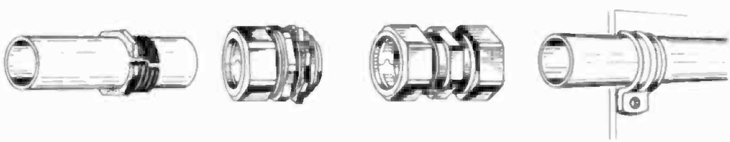


Fig. 2-14. Fittings for use with thin-wall conduit. *A* is a split nut that is placed on the end of the conduit. It is usually supplied with *B*. The thread is tapered. When *B* is threaded onto it and pulled up tight there is a tight friction fit. *C* is similar in use but is double-ended and splices two lengths of thin wall together. *D* is a bracket for holding thin-wall conduit to wood rafters and joists.

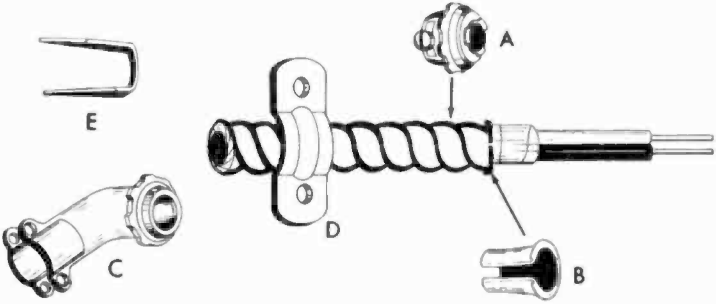


Fig. 2-15. The coupler at *A* fastens flexible armored cable to knockout holes in junction and outlet boxes. Except for the screw on the side, used to hold the coupler to the cable, it fastens to the box in the same way as the thin-wall conduit. *B* must be fitted in between the outer armor and the insulating wrap just under it, before the coupler is slipped on. *C* is a right angle coupler for armored cable. Either the strap at *D* or the staple at *E* may be used to fasten the cable to rafters and joists.

that fits onto the end of the conduit. *B* screws onto this thread and, when pulled up tight, makes *A* grip the conduit. The locknut on *B* is removed; the conduit is slipped into the knockout hole and the nut put back on from the inside of the box to hold the conduit in place. *C* is a double-ended fitting which, with two *A* fittings, is used to splice two lengths of conduit together. There also are right angle elbows to bring conduit into a box at a sharp

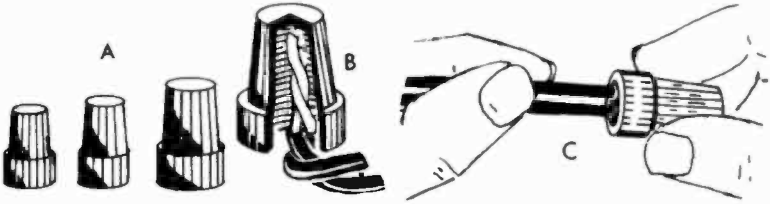


Fig. 2-16. Solderless connectors called "wire-nuts" are used exclusively today to splice wires together for indoor wiring. *A* shows three sizes but there are many, depending on the size and number of conductors being spliced. *B* shows the internal construction. Internal threads twist the wires together. *C* shows how simple it is to make a splice with a wire-nut. Just insert the two wires, and turn the connector clockwise.

right angle. *D* is a clamp for fastening conduit to wood rafters or studs when long lengths are used.

Flexible armored cable has its special kinds of fittings. Fig. 2-15 shows some of these. *A* is used to fasten the armored cable to boxes. It is a one-piece fitting that fastens to the armored cable with side screws to make a pressure fit. The cable is then fastened to the box in the same way as conduit. An important piece of hard-

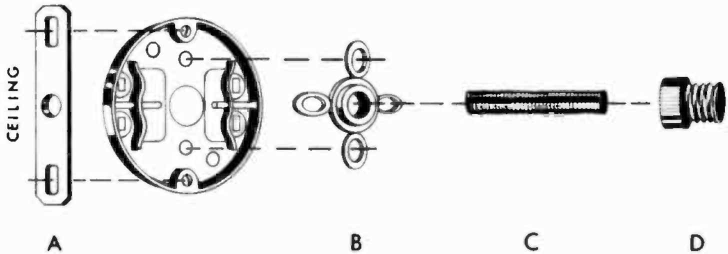


Fig. 2-17. Fittings used to hang fixtures from ceiling boxes. *A* is a strap for fixtures, that mount with two wide-spaced screws. *B* is a stud that screws to the box and accepts the nipple at *C* and is used on center-bolt mountings. *D* is an extension nipple.

ware for armored cable is the insulating bushing (*B*). This must be fitted into the inside of the armored cable, between the outer metal and wires. It protects the wires from possible cuts by the rough edges of the spiral outer jacket where it has been cut. *C* is an elbow for armored cable. *D* is a strap for holding the cable along its length. Staples (*E*) may also be used.

Fig. 2-16 shows wire-nuts or solderless connectors used to splice wires together. These are used exclusively today for indoor home wiring. They are faster than soldering, are secure when put on right (as shown in *C*), and permit easy wiring changes later if it ever becomes necessary or desirable.

There are many other special fittings to make the job of installing electrical fixtures easier. There are studs, nipples, and hangers, too numerous to mention or illustrate. Some of the most popular are shown in Fig. 2-17.

CHAPTER 3

SIMPLE REPLACEMENTS

Probably the most frequently replaced electrical item is the plug on the end of electric cords. Many of these are molded onto the cord and cannot be used over again. Frequently the wire breaks inside the plug, which is usually due to pulling on the cord when you remove a plug from a wall outlet.

PLUGS

Fig. 3-1 shows some of the variety of plugs that may be purchased. *A* is one of the least expensive, and yet it is a preferred plug; it has a grip handle for easy pull-out and is flat for use in closely spaced multiple outlets. Plug *D* has built-in fuses for separate overload protection of an appliance. *E* is a replacement plug for 3-conductor safety cords now used on most large appliances and power tools.

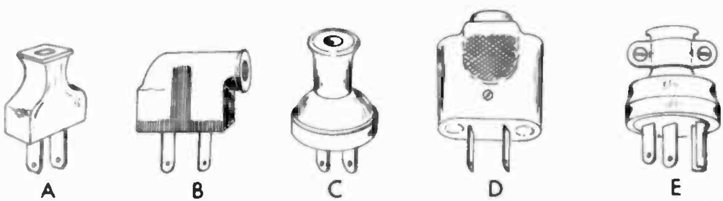


Fig. 3-1. A few representative plugs used as replacements on line cords.

To replace a defective molded-on plug, clip it off the cord. Put the cord through the new plug. Rip the two conductors apart for about 2 inches. Most cords are of the *zip-cord* type, with a rib indent down the middle that makes it easy to rip the conductors apart. If you have a strong thumbnail you can start the rip by pressing hard with your nail. Otherwise, use a knife to start it. Skin the insulation off one half inch of the ends of the two wires. Make an *underwriters' knot* as shown in Fig. 3-2. Pull the cord tight from the back of the plug so the knot lies down in between the two prongs of the plug. Bring the ends of the wires around the prongs. Twist the

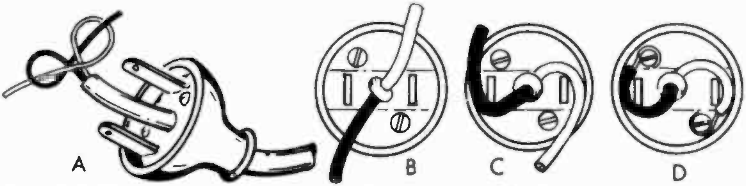


Fig. 3-2. Replacing a plug on an electric cord. Push the cord through the back of the plug. Tie an Underwriters' knot.

strands of the skinned ends and bring the ends around the screws *clockwise,* as illustrated. It is important that the wire ends be wrapped around the screw under the head in a clockwise direction; otherwise the wire will squeeze out as you tighten down on the screws.

The round, heavy-duty cord (known as *SJ* and *SV* cable) does not rip apart and will not fit the small plug mentioned above. Use a rubber plug such as *C* in Fig. 3-10, which has a larger hole and a long-stemmed handle. Cut the outer insulation away from the cord about two inches from the end with a sharp knife. Be careful not to cut through the wires inside; remove just the outer insulating jacket. The rest of the operation is as described above.

CORDS

Fig. 3-3 shows how to repair a break in a cord. Cut away the broken section and expose about two inches of the separate insulated conductors. Skin the insulation off one half inch of each of the wire ends. Splice the sections together as shown. It is important that the two splices point in opposite directions so they are not directly next to each other. Carefully and thoroughly tape one splice *before* you make the second splice. If you don't you won't have room to maneuver the tape between the wires. The four basic steps, after the wire ends are skinned, are: (1) splice two ends together by twisting them, (2) wrap that splice with tape, (3) splice the other two ends together, and (4) wrap tape over the entire cable. *Caution:* While this is an easy way to repair an electric cord, it

(A) Remove insulation from ends.

(B) Twist the two ends together.

(C) Tape that splice first.

(D) Twist other two ends together.

(E) Wrap tape around entire splice.

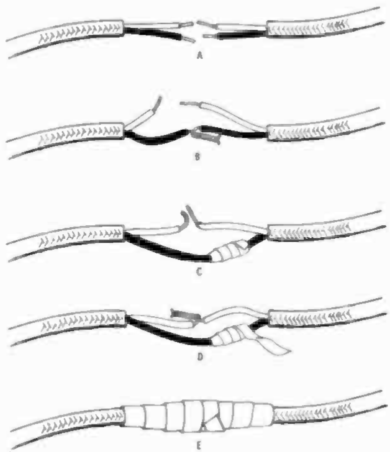


Fig. 3-3. It is easy to splice a broken cord.

lacks the mechanical strength of the original cord. If you pull hard on it, the splices will come apart, so keep that in mind when you use it. It can be made mechanically strong by soldering the splices before taping, if you have a soldering iron. Use rosin-core solder only; any other kind will corrode the copper wire.

If you don't mind taking a lamp or appliance apart, a better repair of the cord is a replacement with a new one. There are various kinds and qualities available. Your best bet is to replace the cord with another like it. Replacement cords are supplied with plugs already attached (usually of the molded-on type). The only thing to keep in mind is to observe the way the old cord was connected to the lamp or appliance, and install the new cord in exactly the same way.

SWITCHES AND OUTLETS

Each time a switch is thrown to the off position, a small arc occurs between the contacts inside. Eventually, this arcing will corrode and pit the contacts so badly that there will be resistance to the flow of current. This results in heating of the metal of the contacts, and further deterioration, until replacement becomes necessary. You will recognize this when lights occasionally flicker when you turn them on, or refuse to come on altogether.

Switches are easy to replace. Fig. 3-4 is an exploded view of the assembly of a switch and front plate to a wall box. When purchasing a new switch, this is a good time to consider a different type. Reread Chapter 2 for a description of the different kinds available.

The first thing to do in replacing a switch is **TURN OFF THE CURRENT AT THE CONTROL BOX—REMOVE THE FUSE OR FLIP THE CIRCUIT BREAKER OFF.** Then it is perfectly safe to touch the wires in the switch box.

Remove the front plate, and save it and the two screws. Remove the two screws holding the switch, and pull the switch toward you. The wires connected to them always have enough slack to permit your bringing the switch out far enough to work on them. Loosen the terminal screws

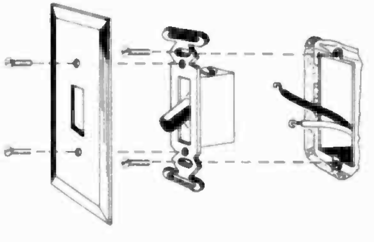


Fig. 3-4. Replacing a toggle switch.

and remove the wires. Put the new switch on by reversing the above steps. Be sure to install the wires on the terminals in a clockwise direction. Fig. 3-5 shows the right way and wrong way to put wires under a terminal screw head. Sometimes a wire will come into a switch box, attach to a switch terminal, and go out again without terminating at the switch. The only precaution here is to be sure the loop around the screw is a tight one.

When you fasten the switch back into the box you may find that there is a lot of looseness in its fit. The fastening screws should be drawn up so that the back surface of the top and bottom ears are flush with the outside surface of the wall plaster. Also, the switch mounting hole is slotted to allow for adjustment to set it truly vertical. If the plas-

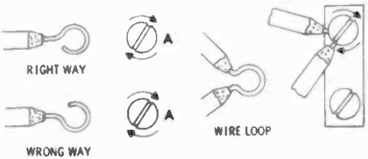


Fig. 3-5. Right and wrong way to wrap a terminal wire around a screw (*A*). Be sure the loop is pinched up tight under the screw head before tightening.

tic is broken away so much that the ears cannot rest on it, adjust the screws to bring the ears in line with the plaster. The switch will become secure in its place when you put the front plate on.

Outlets seldom go bad, but there are reasons for replacement: an outlet may have become smeared with paint when you last decorated; if there are young children around you may want to replace the outlet with the covered type (see Chapter 2); in your basement or work shop, you should install the 3-contact, grounded safety outlets. Replacement is exactly like a switch replacement. Again, be sure to **TURN OFF THE CURRENT AT THE CONTROL BOX.** Grounded outlets will require that you add a small grounding wire. This is shown in Fig. 3-6.

The ground terminal in grounded outlets is connected internally to the mounting ears, and ground is made automatically when you mount the outlet into a box. However, because screws sometimes loosen and may not make

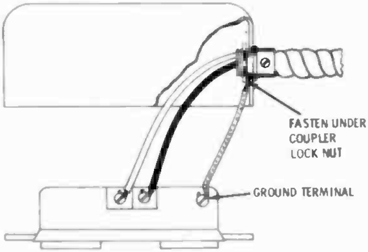


Fig. 3-6. On safety duplex outlets, the ground terminal is connected internally to the mounting ears. For added safety, connect a wire from the external ground terminal to a tight screw or nut on the outlet box.

a good ground, most electrical codes require that the extra ground wire be added.

FIXTURES

Modernization steps taken in a home nearly always include modernizing the electric fixtures by replacing a ceiling fixture with something more up to date (or taking it out altogether); replacing wall fixtures; and replacing kitchen incandescent lights with fluorescent types. Replacing a fixture is a little different from replacing a switch or outlet: (1) there are two standards for mounting fixtures, and since the facilities on the junction boxes may be different, mounting adapters may be required; (2) fixture wires are *spliced* to the junction-box wires (lighting fixtures don't use screw terminals).

Fixtures are mounted either by a threaded nipple in the center, or by two screws near the edge. While your new fixture may mount by one or the other of these two methods, the one you are replacing may have been mounted the opposite way to that required by the new fixture.

The four basic methods of mounting fixtures are shown in Fig. 3-7. *A* shows a nipple-mounted fixture fastened to a stud in the outlet box. To splice to the wires coming through the center of the nipple you will have to add a "hickey" between the nipple on the new fixture and the old nipple on the outlet box. The location of the two screws on the two-screw type of fixture is usually too far apart to fasten directly to the screw holes of the junction box. An adapter strap is used as shown in *B*. The same adapter strap will center-mount to a box nipple as shown in *C*. *D* shows the reverse—a nipple-mounted fixture fastened to a box without the center nipple or stud.

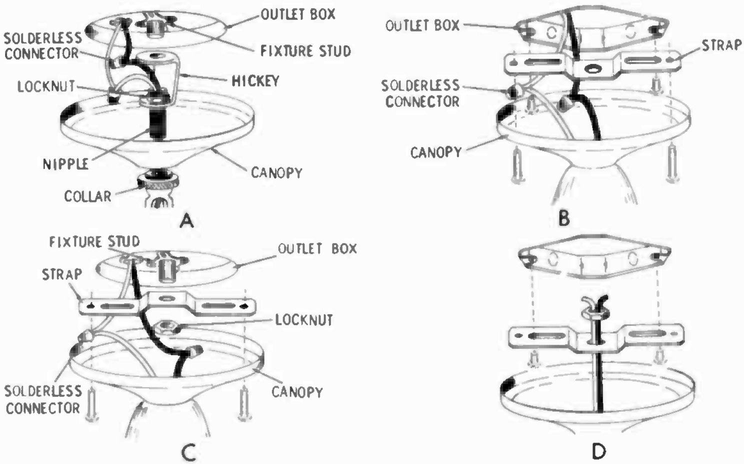


Fig. 3-7. Methods of mounting a fixture to a ceiling box. *A* shows center nipple of fixture connected to center nipple of box. A "hickey" is used to allow the wires to feed out of the fixture nipple. Fixtures with wide-spaced mounting screws are fastened to a strap which has been fastened to the more closely spaced screws of the ceiling box (*B*). In *C* the strap is turned around and fastened to the nipple on the box. In *D* an adapter strap is used to fasten a fixture with a center nipple to a box without a nipple.

Wall fixtures mount the same way as ceiling fixtures. There is one possible exception: When mounting a center-nipple-mounted wall fixture to a small box, such as that used for switches and outlets, a different strap is used. It is a smaller strap, and the center hole is threaded to take the nipple. This is shown in Fig. 3-8.

Obviously the fixture wires are spliced to the outlet wires *before* the fixture is mounted to the outlet box. An easy way to do this is to tie the fixture up close to the outlet box with a stout string or cord. This leaves both hands free to make the splices.

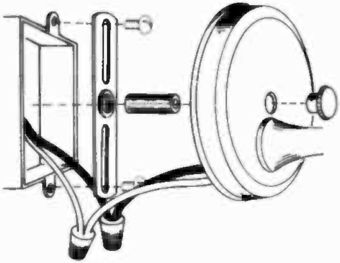


Fig. 3-8. Wall fixtures are frequently mounted to the smaller outlet- or switch-type boxes. If the fixture has a center nipple, obtain a bracket that has a threaded hole in the center to take the nipple.

Use wire-nuts (see Chapter 2) to splice the wires together. Chances are the old fixture used wire-nuts. They can be reused. If the wires were soldered, clip off the old connection (best done with a diagonal cutter), scrape the insulation off one half inch of the ends of the junction box wires, and use new wire-nuts. Hold the two wires together. Slip the nut on and twist it clockwise. The nut has threads inside it that will thread onto the wires at the same time that it twists them together. Don't turn them up too tight or the wire may break; just turn the wire-nut enough to hold firmly.

CHAPTER 4

HOW TO INSTALL INSIDE WIRING

Whether you add another outlet in a room or wire a complete new room addition, the basic procedure is the same. You must get cable from an existing box to a new one, or from the central control box to, perhaps, a number of additional boxes.

As outlined in Chapter 2, metal piping called thin-wall conduit is used in new work. This is an electric-code requirement in most communities. A new home under construction is new work. A new additional room built onto an existing home is also considered as new work.

One purpose of the code is to prevent damage to the wiring by workmen putting in the finish work of walls and flooring. Since the addition of a new room usually requires a building permit, and the work will be checked by an inspector, you are urged to comply with the regulations.

Thin-wall conduit and boxes are installed when the house or room addition is framed in, but before the plaster and finish floor are put in. However, the wires are not drawn through the conduit until the plastering and flooring are all done.

First, install boxes for fixtures, outlets, and switches. Figs. 2-3 and 2-4 in Chapter 2 show a number of switch and outlet boxes with brackets suitable for new work. Ceiling boxes are hung from a telescoping adjustable hanger, which is nailed to adjacent rafters. (Fig. 4-1.) **Caution**: You must know the thickness of the plaster or whatever finish is to be used, since the boxes must be mounted with their front edges flush with the front surface of the plaster or finish.

If you plan to install a 240-volt air conditioner be sure to put in an outlet box under the window ledge on which the air conditioner is to be installed. The outlet receptacle for this will be a 3-terminal "crowfoot" type shown in *E* of Fig. 2-10 in Chapter 2.

Next, install thin-wall conduit. Assuming a room addition, ½-inch diameter conduit should handle all normal requirements. It will accommodate up to four No. 14 conductors. This means you can even include the wire for a 240-volt window air conditioner in the new room. Remember that if you do want a 240-volt line you will need to go clear back to the central box for the power. Without an air conditioner, the extra current requirements of the average room addition is usually low enough to add to an existing branch circuit without exceeding the fuse protection rating; take the power from the box nearest to the new room. The use of flexible armored cable is permitted from the existing branch circuit junction box to the nearest new box in the room addition.

Run conduit across the roughed floor from one wall box to another. You will need to notch the "plate" below the wall box. The plate is the board on which the vertical 2 × 4 studs rest (Fig. 4-2). To get to the ceiling boxes, run conduit from the nearest wall box up through a hole drilled in the "header" (the long board nailed to the tops of the wall studs) and across the ceiling rafters if there

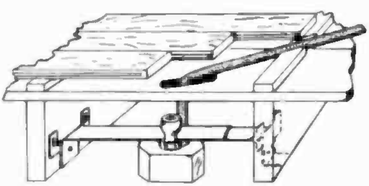


Fig. 4-1. A ceiling box is supported by an adjustable bracket nailed to the rafters. The lower edge of the box must be flush with the surface of the finished wall. Note the long slot cut into the rough floor, to take the gradual bend of the conduit.

is to be an unused attic. If you have a flat roof, the conduit must come up through the header at a spot that will permit you to run the conduit between the rafters to the junction box. If there is to be a second floor, you can save on wiring material by going through the rough flooring of the second floor as shown in Fig. 4-1. The cut above the box must be a long slot to take the wide bend of the conduit.

As implied by the name, thin-wall conduit has a thin wall that allows fairly tight bending without breaking. While this conduit can be bent in a vise, a better job is done with a special bending tool (Fig. 4-3). It is important that the bend be smooth and without kinks. Remember that you will need to fish wires through it later.

While an electrician cuts conduit with a special tool that leaves no burrs, you can cut it with a hacksaw. Follow this with a good deburring job by reaming out the inside edges with a reamer, and using a file on the outside edges.

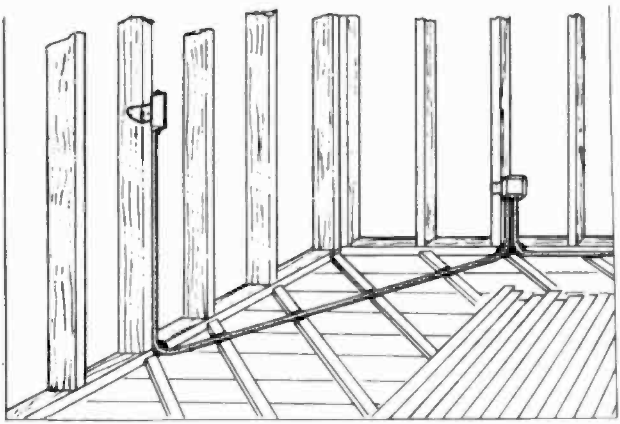
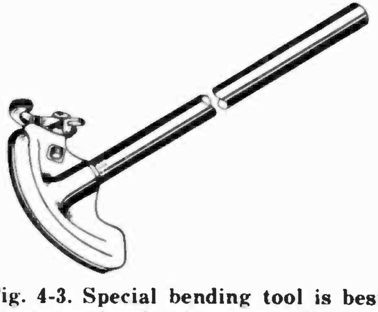


Fig. 4-2. Easiest way to put in conduits in "new work" is to lay them across the rough flooring. Note notches in "plate." This is better than notching the wall studs to run conduit across the wall. Boxes and conduit are installed while room is still in the rough. Wire is drawn through the conduit, and fixtures are installed only when the room is completely finished.

The next job is putting the conduit in place, fastening it into knockout holes in the boxes, and supporting it along its length at intervals. Fig. 4-4 shows how to remove the knockout slugs in the boxes. Be sure to select the smaller ½-inch knockouts if ½-inch conduit is being used. Install the split male screw over the end of the conduit, then screw on the female part of the coupler. Draw it up tight (Fig. 2-14 in Chapter 2). Insert the conduit with its coupler installed in the knockout hole of the box and secure it from the inside with the fluted-edge locknut that came with the coupler. Fig. 4-5 shows the conduit installed in a box. Use hooked straps to fasten the conduit to studs or rafters at intervals. Lengths of conduit can be spliced by using special double couplers.

If you do use flexible armored cable between the existing last box in your house to the nearest new box, put this in also before the new room is finished. Since flexible armored cable has wires already in it, you must avoid the temptation of connecting it up to the power at this time. Install it between boxes (details on installing flexible armored cable appear later in this chapter), but **CUT OFF THE POWER IN THE BRANCH CIRCUIT** before you open the box. Allow about 8 inches of free wires in the box; *do not connect them,* but curl them up and tuck them away in a corner of the box. Put the box back together again and restore the power. You will



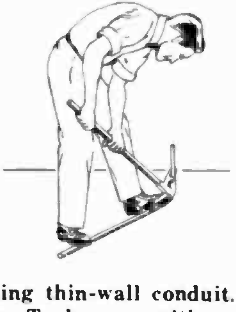
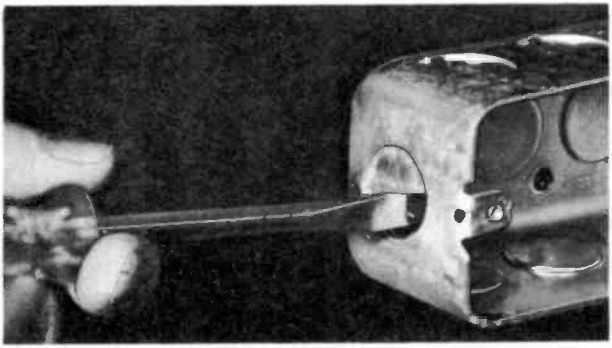
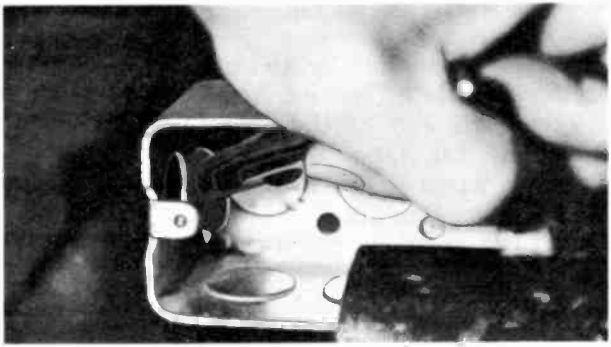


Fig. 4-3. Special bending tool is best for bending thin-wall conduit. It assures bends of proper radius, without kinks. Tool comes without handle. Handle can be a piece of rigid gas pipe.



(A) A light tap on a screwdriver pushes the knockout part way out.



(B) Slug is then removed with pliers.

Fig. 4-4. Method for removing knockouts from boxes.

make the connection to power later, when all the wiring and fixtures are in.

Wires are "fished" through the conduit. You can push the wires through short runs without difficulty. For long runs use a "fish tape," which is available in a choice of lengths. Use wires of different colors on this standard: White is the neutral or "cold" wire. Black is the "hot" wire. Red is the "hot" wire from a switch to a fixture or a switched outlet; red is also the other "hot" wire of a 240-volt line, if you use one. Push a white and black wire

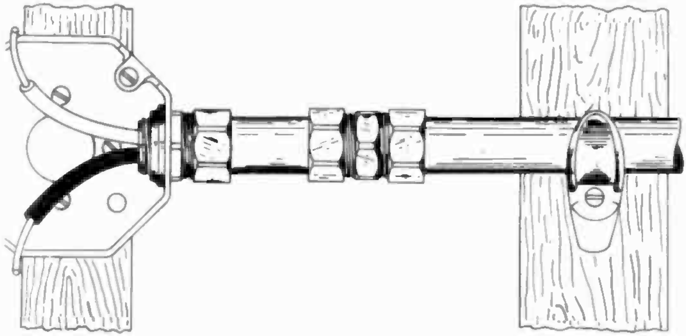


Fig. 4-5. Details of conduit installed in a junction box (*A*). Also shown is double-ended coupler (*B*) for splicing lengths of conduit, and bracket (*C*) for supporting long lengths.

through a short conduit by twisting the ends together for the first couple of inches. Allow six to eight inches of slack at each end of the conduit. On long conduit runs push the fish tape through from one box to the other, tie the wires to it (Fig. 4-6), and pull the wires back through the conduit.

Refer to the previous chapter on installing switches, outlets, and fixtures. Fig. 4-7 is an example showing the wiring of an outlet, a switch, and a fixture, where the initial power originates in the ceiling box. Note the three wires going from the ceiling box to the switch box.

You can easily work out your own lighting circuit if you remember that all outlets are wired in *parallel* across the line. Switches are wired in *series* with the fixture or outlet they are to control, and the combination is connected in *parallel* across the line. Fig. 4-8 shows this in semischematic form.

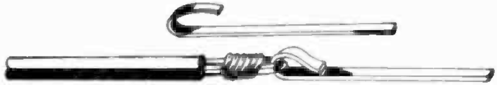


Fig. 4-6. Fish tapes (sometimes called "snakes") are made of spring steel, but are thin enough to flex around corners in the conduit. If it does not come with a hook as illustrated, heat the end over a gas flame until it is red hot, and bend the end over.

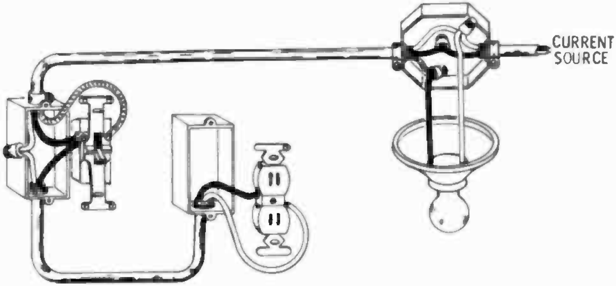


Fig. 4-7. Wiring system when the feed line comes into the ceiling fixture box. Note the three wires from the fixture to the switch. If the feed line comes into the outlet box, only two wires would be needed between switch and fixture.

OLD WORK

Putting extensions in old work (homes that are already finished) is much more difficult. You don't have the advantage of fastening boxes to studs or rafters. Fishing cable through the walls and ceiling presents special problems.

As mentioned in Chapter 2, flexible armored cable (BX) protects the wires inside from mechanical damage and provides a "grounded" system. However, it must not be used where it is subjected to excessive moisture, such

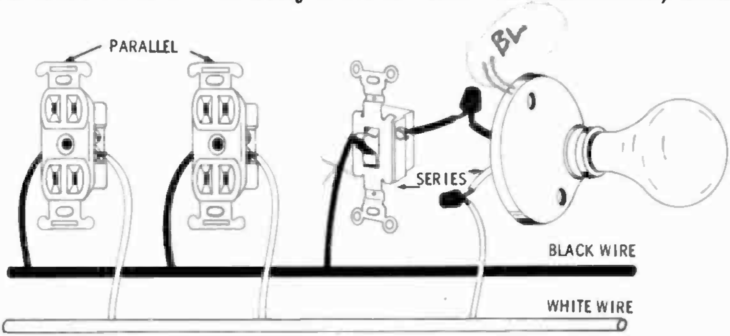


Fig. 4-8. Duplex outlets are connected in "parallel" across the line. Switches are connected in "series" with the light or outlet they control, and the combination is connected in parallel across the line.

as steam or dripping water. Flexible armored cable is not waterproof.

Before you start any modernizing work it is well to know something about the construction of your house. In which direction do your ceiling rafters run? They usually run across the narrowest width of the room. If you plan an outlet on an outside wall, be sure there is space behind the wall. Frame houses have 2 × 4's between all walls, including the outside. Brick veneer (one course or layer of brick on the outside) houses also have 2 × 4 outside walls. Regular brick (two or more courses of brick) usually have furring strips between the brick and inside plaster walls, leaving only about a ½-inch space between to work with. If you must put an outlet or switch on an outside wall built with furring strips, you will need to chip away some of the brick to make room for the box, and then run the flat plastic-covered cable to it. In a brick home of this type you are better off sticking to work on inside walls only.

PLASTIC-COVERED CABLE

Plastic-covered cables are permitted for old-work extensions in most localities and in new work in some. It has the advantage of being water- and corrosionproof, and it is easy to handle. It is also easy to cut, and to snake through tight places. While some plastic cables come with a third, or ground, wire for tying all boxes together into a grounded system, electrical codes generally do not recognize this as adequate. The codes specify that cover plates and fixtures be made of *Bakelite* or similar insulating material, or if metal, be located at least six feet from the nearest ground point, such as a radiator or water pipe. A disadvantage to plastic-covered cable is its susceptibility to physical damage. Therefore, it must not be used in exposed areas.

Plastic cable is easier to work with than flexible armored cable and is preferred wherever it is concealed and not subject to mechanical damage. It can be cut with pliers and it usually contains a strong cord molded

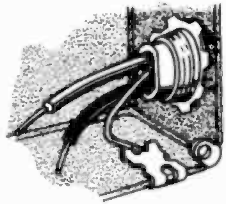


Fig. 4-9. Plastic cable with ground wire connected with a spring clip. Scrape the surface of the box clean before you slip the clip on, to provide a good ground contact.

under the outer jacket that is used to "rip" the outer jacket down to expose about 8 inches of wire. The outer jacket will then hang loose and may be cut away from the rest of the cable with a knife. Couplers, similar to those used for armored cable but made especially for plastic cable, are used to fasten it into the knockout holes of existing boxes. This cable is also available with an extra ground wire, and it is recommended that you use this kind. Fishing and installing are otherwise the same as for armored cable. Fig. 4-9 shows plastic cable with a ground wire fastened in place in a box.

FLEXIBLE ARMORED CABLE

Fig. 4-10 shows the method of cutting and installing flexible armored cable. Cutting is a little tricky. Clamp the cable in a vise to hold it securely. Use a hacksaw and cut diagonally across the face of one section of the spiral. Once cut through, a twist of the cable will break the over-

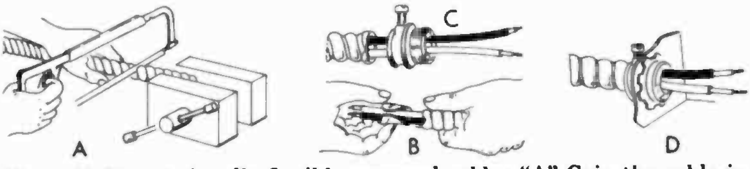


Fig. 4-10. How to handle flexible armored cable: "A" Grip the cable in a vise about 8" from the end and cut *diagonally* across the face of one spiral section. Be careful not to cut into the cable. Flex the cable sharply and the cut piece will break off. Slip it off the wire conductors. "B" Insert a split insulating bushing between the outer jacket and the first layer of insulation. "C" Slip a coupler onto the outer armor, snug up against the fiber or plastic bushing and end of the armor. "D" Take the locknut off the coupler. Place the cable into a knock-out hole in the box. Put the locknut back on and tighten firmly. Skin about one-half inch of insulation off the ends of the wires.

lapping edge apart, and the outer sheath can be slipped off the wires inside.

Both flexible armored cables and plastic-covered cables are available with two or three wires in them, and sometimes even with an extra ground wire. The wires follow the color code mentioned earlier for use in conduit. The extra ground wire is double assurance of good grounding.

Use plastic-covered cable for behind-the-wall runs. Use armored cable for exposed installations, such as workbench, unfinished basement, and inside the garage. The total measurement of cable should be the length required to go from box to box plus about 16 inches (to allow 8 inches of wire out of each end).

INSTALLING BOXES

Make your decision on cable before you purchase the junction boxes. Boxes are available with built-in clamps for use with flexible armored cable, or with clamps for plastic-sheathed cable. A special outlet or switch box is made for fastening to plasterboard walls (walls of large plaster sheets nailed directly to studs as compared to lathed and plastered walls) ; it is shown as *A* in Fig. 2-4, and 2-5 of Chapter 2.

Standard switch boxes may be installed in walls that are plastered over lathing. By locating the cutout in the wall properly, the boxes may be screwed to the lathing. Putting boxes into walls is easy. Start by making a template from the pattern shown in Fig. 4-11.

Fig. 4-12 shows step by step how to install a switch or outlet box in walls that are lathed and plastered. Fig. 4-13 shows you the step-by-step procedure for installing a box in walls that do not use lathing (plasterboard, *Sheetrock*, *Masonite*, etc).

Before you cut into the wall, be sure to pick the right spot for outlets and switches. Outlets should be about 10 inches above the floor and, in kitchens, about 5 to 10 inches above the height of the table or work space. Locate switches at the opening side of a door, not on the

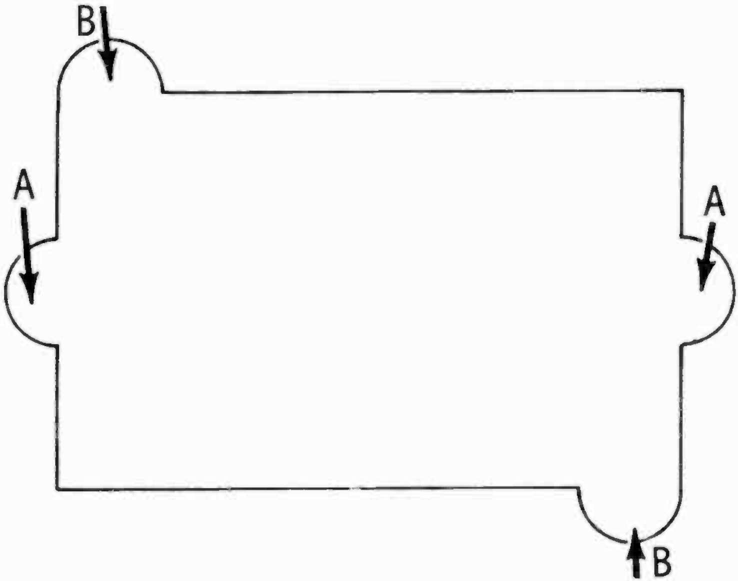


Fig. 4-11. This is an exact size pattern for use in cutting out a wall for a switch or outlet box. The ears at *A* and *B* are for holes to be drilled into the wall. *A* is for clearing a screw ear on the box. *B* is a starting hole for cutting the plaster.

hinged side where it is harder to reach them when you come into a room.

Your choice of ceiling box will depend on whether or not you have access to the ceiling from above (as through an attic) or whether it is a concealed ceiling (as between floors, or if the roof is flat). If you have attic access, locate the spot in the attic where you want the fixture, and cut a hole in the plaster from the attic side, centered between rafters. If you have insulation that has been poured in, you will need to move the granules to one side, of course; if rolls of insulation have been used cut it away and move it to one side. Cut a hole slightly larger than the box. Remember that the edge of the box must be flush with the room side surface of the ceiling. Fasten the

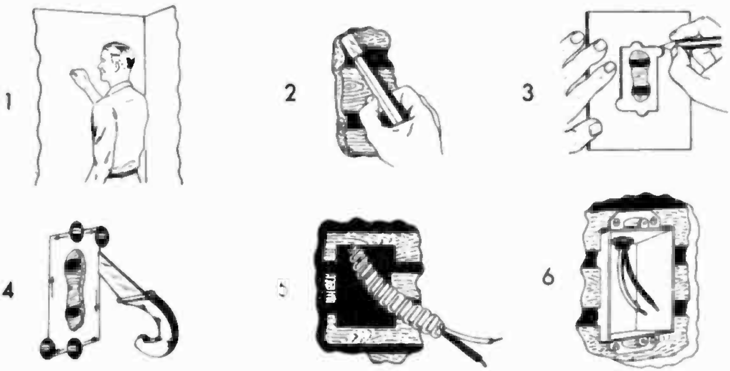


Fig. 4-12. Step-by-step procedure for installing a switch or outlet box in a lathed and plastered wall. (1) Find space in the wall approximately between joists, by tapping and listening for hollow sound, or using a magnetic nail finder. (2) Notch out a section of the plaster with a screwdriver or chisel, to locate a spot where one lath board will be in the center of the cutout. (3) Use the template you made from Fig. 4-11 and draw the outline of the cutout. (4) Drill the four holes shown in the template. Cut out the plaster with a keyhole saw, starting from the corner holes. Do not cut through the upper and lower lath boards; cut out only the center one. (5) Draw the cable through from behind the wall and install it into the outlet or switch box. (6) Set the box in place and screw the ears to the upper and lower lath with wood screws. The ears are adjustable on the box and should be set beforehand so the front edge of the box is flush with the front surface of the wall.

box in place with the same type of bracket described earlier in this chapter for conduit installations in new work.

For concealed ceilings, all the work is done from the room side. (See the project on installing a drop ceiling fixture in the last chapter of this book.) Use a shallow box (Fig. 2-3, example *D*, in Chapter 2). Cut a hole from the room side, slightly smaller than the box. In this case the box hangs below and up against the ceiling. Follow the steps in Fig. 4-14.

Fishing cables to a wall-mounted switch or outlet box may present some problems. If a new outlet box is being installed on an inside wall of the first floor and you have

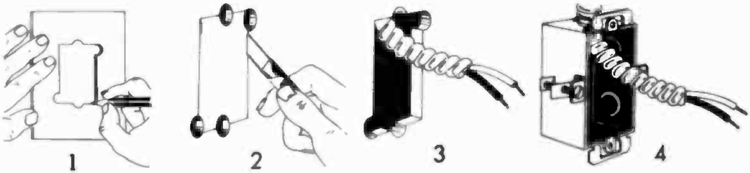


Fig. 4-13. Installation of a box in plasterboard is similar to that shown in Fig. 4-12, except the type of box used holds onto the plaster or similar flat material. (1) Outline the cutout on the wall with the template of Fig. 4-11, after finding the center between joists. (2) Cut out the plasterboard with a hacksaw. (3) Draw the cable through and fasten into the box, using a type such as Figs. 2-4A and 2-5 of Chapter 2. (4) Place the box in position and draw up on the two screws on the sides. The side ears will draw up behind the wall, and the two ears at top and bottom will hold from the front. Before installing the box, adjust the top and bottom ears so that the front edge of the box is flush with the front of the wall.

an unfinished basement or crawl space, run the cable from the nearest accessible junction box in the basement or crawl space through the "plate" below the planned location of the new outlet. The spot should be centered between the joists, which is usually the equivalent of centers between the wall studs. Drill a hole up through the 2-inch thickness of the plate, using a long ⅝-inch electrician's bit and a hand brace (Fig. 4-15).

If the outlet is being installed on an upper floor, with an unused attic above it, run the cable from a ceiling

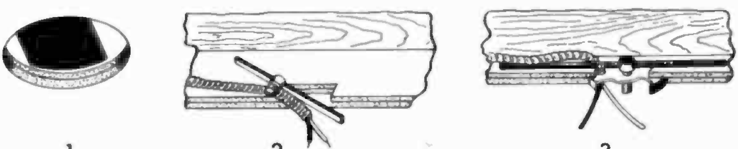


Fig. 4-14. In concealed ceilings a shallow 4-inch round box is fastened to the outside. (1) Cut a round hole slightly smaller than the box. (2) Slip a long bar with a stud and nipple at its center into the cut-out. Center the stud over the cutout. (3) Fish the cable through and couple it to the junction box. Place the box slowly up against the ceiling and maneuver the nipple through the center hole. Place a locknut on the nipple and tighten.

junction box to the outlet through the header board. A complete installation such as this is described in the last chapter, under installing an outlet from the attic. If neither attic nor basement work space is available, you must cut across from one outlet to the other by cutting a channel out of the plaster between the two. This method is part of the description of installing a drop ceiling fixture.

Bring the cable up (or down) to the box cutout in the wall. Remove a knockout from the box while it is still off the wall. Bring the cable through and fasten it in place with the clamps in the box. Insert the box into the wall cutout and fasten it in place.

Skin ½ inch of insulation off the ends of the wires; twist the bared ends *clockwise* around the screws of the duplex outlet, one on each side. If you have used cable with the extra ground wire, secure the ground wire to one of the clamp screws.

Break off the long slotted ears from the duplex outlet with pliers if you have used a box installed in plaster-

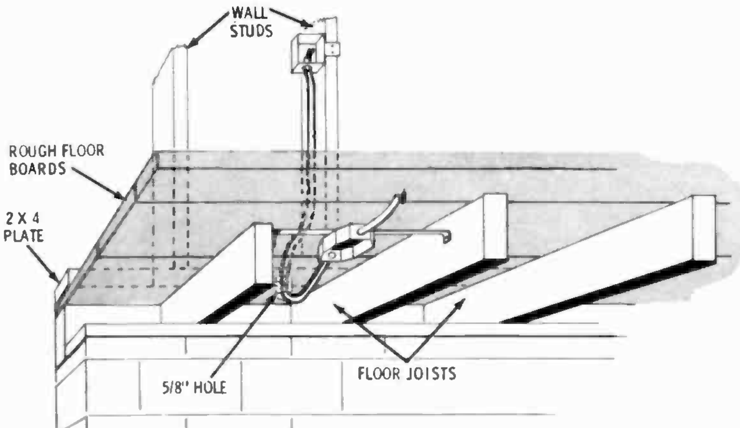


Fig. 4-15. To feed cable to a new outlet from the basement, drill a ⅝-inch hole through the "plate"; this is the 2 × 4 put down on the ends of the floor joists when the house was built, and on which the wall studs were nailed.

board; they are easy to break off. If left on they would interfere with the adjustable ears on the box (they may be left on in new-work box installations, and on boxes fastened to the lathing in old work because the adjustable ears on the box are not in the way). Install the outlet in the box so that the back of the remainder of the ear is flush with the front surface of the wall. Connect the ground wire to one of the box screws, if an extra ground wire is used.

CONNECTING TO POWER

Disable the power to the junction box from which you plan on taking power by unscrewing the appropriate fuse or tripping the circuit breaker to off. Remove the cover, or drop the fixture if there is one, and locate the black and white wires. Pull these wires toward you to make it easier to work with. Open a knockout hole in the box.

Prepare the end of the cable, with about 8 inches of lead and the last ½ inch or so skinned for splicing. Place a coupler on the cable, bring it into the box, and fasten in place.

Remove the wire-nuts (or tape, if soldered) from the black and white wire splices in the box. Wrap the bared wire of the black lead of the new cable to the splice on the black wires. Resplice with a wire-nut. If the one that was removed is now too small, use a new larger one. Similarly, splice the white wire to the white wires of the junction box. Restore the power at the central control box.

RACEWAYS

Wiring systems that avoid going into the wall, but are attached to the outside (the room side), are called *raceways*. One of two methods is worth considering. Either is fairly simple to install, and can look well in places where a smoothly finished appearance is not necessary. Raceways are suited to workbenches, utility areas, and even in bedrooms where they are concealed by furniture. One system, made by G. E., is called *Flexway Wiring* and consists of metal troughs with covers, which give you a completely protected system. Special curved sections for going around corners are available, and special snap-in outlets are used. Another uses plastic-covered cable that interconnects outlets, switches, and sockets (see Fig. 2-13 in Chapter 2). See "Raceway Outlets for Bedroom" in the last chapter of this book for a description of an installation using the plastic-cable system.

THREE-WAY LIGHT SWITCH CIRCUIT

A three-way light switch circuit permits you to turn a light on or off from either of two positions. A stairway light, for example, may be turned on or off from either downstairs or upstairs. This is a great convenience in the

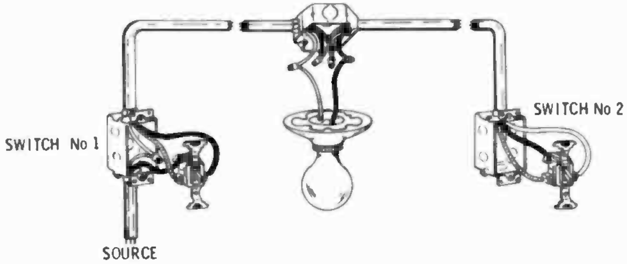


Fig. 4-16. A three-way light circuit allows you to turn a light on and off from either of two switches. Two three-terminal (spdt—single-pole double-throw) switches are used, using 3-conductor cable from the switches to the light. At switch No. 1, splice the white wire from the two-conductor power source cable to the white wire of the three-conductor cable. Connect the black wire from the two-conductor cable to the "common" terminal on the switch. Connect the remaining two wires of the three-conductor cable to either terminal on the sides of the switch. At switch No. 2, connect the black wire to the "common" terminal, and the remaining two wires to the other two terminals. At the light fixture, splice the white wire to the white wire of the cable from switch No. 1, the black fixture wire to black wire of the cable to switch No. 2, the remaining two red wires together and the remaining black and white wires together.

dark. The circuit is called three-way because the switches used have three screw terminals instead of the usual two.

Fig. 4-16 shows how a three-way light circuit is hooked up. It requires three-conductor cable between the two switches. Three-conductor cables are run from the two switch boxes to the ceiling-fixture box. Bring a two-conductor cable into one of the switch boxes from the nearest source of current (call this switch box No. 1). cable to the white wire of the three-conductor cable. Connect the black wire of the two-conductor cable to the "common" screw terminal of three-way switch No. 1. This terminal may be at the top, or to one side of the switch, whereas the other two terminals are one on each side—the same as a regular two-way switch. Frequently the common terminal is darker in color than the other two. Connect the black and red wires of the three-conductor cable to the other two terminals of the switch—one to each terminal.

At the second switch box, connect the red and white wires of the three conductor cable to the two live terminals (not the common terminal). Connect the black wire to the common terminal.

At the light fixture it is just a little tricky, so read this carefully. Using wire-nuts, splice the white wire from the three-conductor cable from switch number one to the white wire of the light fixture. Splice together the red wire from one cable to the red wire of the other cable. Splice together the black wire of the cable from switch No. 1 to the white wire of the other cable. Splice the black wire of the cable from switch No. 2 to the black wire of the light fixture.

CHAPTER 5

OUTDOOR WIRING

Outdoor wiring differs from inside wiring principally because of the precautions that must be taken to guard against the effects of moisture. Other considerations are the effects of weather on overhead wiring, and the effects of ground freezing in the case of cables buried underground. The special weatherproof devices are available everywhere. There is nothing particularly difficult about doing outdoor wiring.

RUNNING WIRES TO THE GARAGE

There are two ways to run wires from the house to the garage. One is overhead, and the other is buried under the ground. Running wires overhead was the easiest and least expensive for years. Before the development of weatherproof plastic cables, requirements for underground cables were pretty strict. Most communities have changed their local electrical codes to agree with the *National Electrical Code,* which permits the use of a heavy-duty plastic cable underground.

Whichever method is used a *grounded* system should be a must on your list. For overhead installations this means the use of three wires, two for the electric service and one that is strictly a ground wire connecting all outlets, boxes, etc., to the grounded system in your house. If the line is placed underground, use the heavy-duty plastic cable with the extra ground wire in it.

If you plan on only installing lights in the garage and perhaps an overhead light or two on the outside, then a two-wire system may be used, *provided* it is an *insulated* system all the way through. This means using plastic-coated cable in the garage, and boxes and covers made of *Bakelite* or similar nonmetallic material. If your plans include some outlets in the garage for a battery charger, or occasional use of an electric drill, for example, then *do* use a grounded system for your own safety.

Overhead wires must be strong enough to carry their own weight, plus possible winter icing, and buffeting by the wind. It may be either copper or aluminum. If it is aluminum, use one wire size larger than for copper because aluminum has higher resistance to current than does copper. Use special outdoor wire with a heavy plastic or rubber insulation. Use No. 10 wire for spans up to 50 feet, if in copper—No. 8, if aluminum is used. The wires must be high enough to clear any equipment that may be run under them. They must not go through trees or near poles that could rub against them when they sway in the wind. Trees are not insulators. If the branches rub the insulation off the wires, current can flow from the wire down through the branches to the ground, causing sparks that could become a fire hazard.

Solid piping or conduit must be used to bring cables from inside the house to the overhead wires, and from wires at the garage into the garage itself. Drill a hole through the foundation into the basement or crawl space. This will be your toughest job. Use a star drill and a heavy hammer. Special concrete drills are made for use with a power drill, but these drills are not large and the hole must be enlarged by chipping away with a star drill. Install a junction box inside with an opened knockout hole centered over the hole made in the foundation. Install a special waterproof right-angle elbow on the outside at the end of a short piece of conduit extending out from the junction box. Install a length of conduit from the elbow up the side of the house to the point where the overhead wires are to be started. Take the rubber-gasketed cover off the elbow at the bottom and fish three No. 14 indoor-type insulated wires (two, if the system is not grounded) from the elbow up to and out at the top. Use one each of white, black, and red wires. Allow about two feet of wire to hang out over the top for making connections to the overhead wires later. The bottom ends of the wires are pushed through the short piece of conduit and through the junction box inside. At the top of the long conduit, thread the wires through a service head and install the service head to the conduit. The service head is designed so that the wires come out slanting downward so water cannot get into the conduit (Fig. 5-1).

Install three strain insulators into the house and three into the garage, one above the other, and each about a foot apart. String three wires between the insulators. If the installation is made in the summer time, allow a slight droop in the middle of each wire. This makes up for contraction of the wire in cold weather. Fig. 5-2 shows how the ends of the wires are brought through the insulators and wrapped around the wires to secure them. Skin the ends of the overhead wires and of the wires that come up from the conduit on the house. Splice them with heavy-duty solderless connectors. Connect the red wire from the conduit to the top overhead wire (the red wire will be your ground wire and will not be connected into the power source), the white wire to the

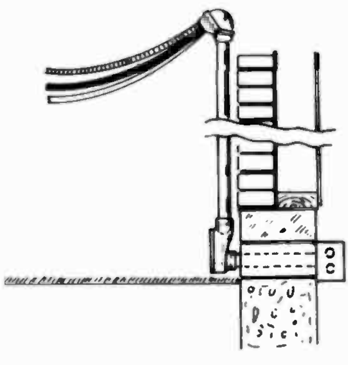


Fig. 5-1. To get power to overhead wires you must install fully enclosed and watertight conduit and fittings. From inside junction box, a short piece of conduit goes through foundation to right angle elbow, through vertical conduit, and out special service head.

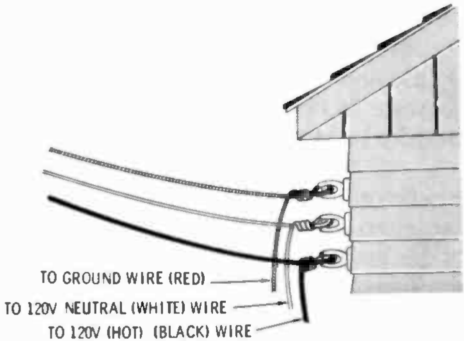


Fig. 5-2. Bring overhead wires through saddle insulator and wrap several times around horizontal portion of wire. The extra ground wire does not carry current, but merely completes the ground system.

middle overhead wire, and the black wire to the bottom wire. Form a drip loop between the wires from the conduit and the overhead wires (Fig. 5-3).

At the garage end, another service head is used to bring power into the garage. It need not go down to the base of the garage; it may go straight in, to a junction box on the inside. Connect the overhead wires to wires coming out of the garage in the same manner that you did at the house.

Wiring inside the garage can be done in the same way as indoor home wiring. If your garage has exposed wall

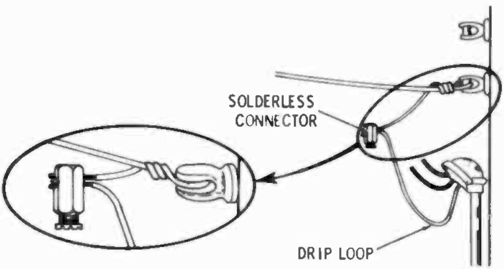


Fig. 5-3. A wire drip loop must be formed when connecting the overhead wires to the wires coming from service head.

studs and rafters, use boxes with brackets attached and install them with wood screws. Use flexible armored cable (BX) exclusively. Do not use the plastic-coated cable. The garage is one place where cable could be subject to mechanical abuse, by heavy tools hanging on the walls, etc.

For underground wires to the garage, first check on the local electrical codes. At one time all underground cable had to be lead sheathed, and run through conduit. Modern plastic cables are impervious to any corrosion that occurs under the ground, and are approved for use underground in most communities today. With either kind, they must be buried deep enough to be below the frost line, and any possible mechanical damage due to gardening or any other work that pierces the soil. See "An Underground System to your Garage" project in the last chapter of this book. It describes a complete installation to the garage, including a three-way light control circuit, for controlling an overhead light installed on the garage from either the house or the garage.

Outlets in the garage should always be of the three-contact safety type. More than that, don't use power equipment in your garage unless it has a three-conductor cord and safety plug.

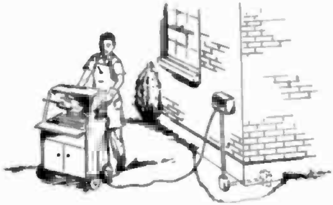
CONVENIENCE OUTLETS

Few things add to the joy of outdoor living more than a source of power to operate a motorized spit on the grill, or for extra lights to read by on a pleasant evening—or even to bring the TV outside. If you use an electric power mower or a hedge cutter, an outdoor power outlet is a necessity.

Again, waterproofing is the only important consideration. See Chapter 2 for a description of the type of box and outlets needed for use outdoors.

Boxes should be installed above the line of highest possible snow fall (including wind-blown drifts) in your area. The lines bringing wires to boxes mounted on the outside must be solid conduit (Fig. 5-4).

Fig. 5-4. Outdoor outlets must be fully watertight. Use special cast metal boxes and gasketed outlet covers. Connections to the power source must be through conduit.



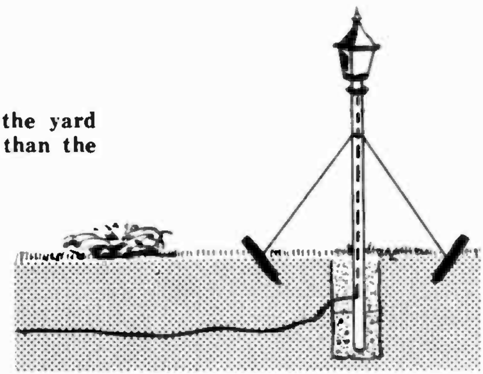
If you have come through brick or concrete for your conduit, be sure to patch up the broken spots afterwards, to keep rain from coming through. In the case of wood, fill in any crevices with plastic wood and, when dry, paint to match the siding.

YARD LIGHTS

A decorative addition to any home is a front yard light about halfway up the entrance walk. These are always fed from underground cable.

Dig a trench from the house to the point on the lawn where the yard light is to be. Make this trench about 18 inches deep (or as deep as necessary to be below the winter freeze level). Dig a hole for the yard light pole deep enough so that the wire entrance hole on the pole is about at the level the cable will be, laid in the trench. Feed a two-conductor cable (two-conductor-plus-ground if the pole is metal) up through the hole and connect to the lamp socket. If a ground wire is used, connect to any

Fig. 5-5. The hole for the yard light should be deeper than the buried cable.



screw that is part of the metal pole. The cable must continue, without splices, all the way from the socket to the house, and into the house. Pour cement into the bottom of the hole and set the light pole into the cement, using temporary stakes and guy wires to hold the pole vertical until the cement sets (Fig. 5-5). At the house end of the cable you will need to go through the foundation again, either straight in, or up through a short length of conduit to a point above the ground level. If above ground, use a weatherproof, capped elbow, as in the case of the overhead garage wiring installation described earlier.

The wiring from the junction box to power, on the inside, is the same as any indoor wiring. Use flexible armored cable to maintain the ground, or the plastic cable, with the extra ground wire if it is fully protected

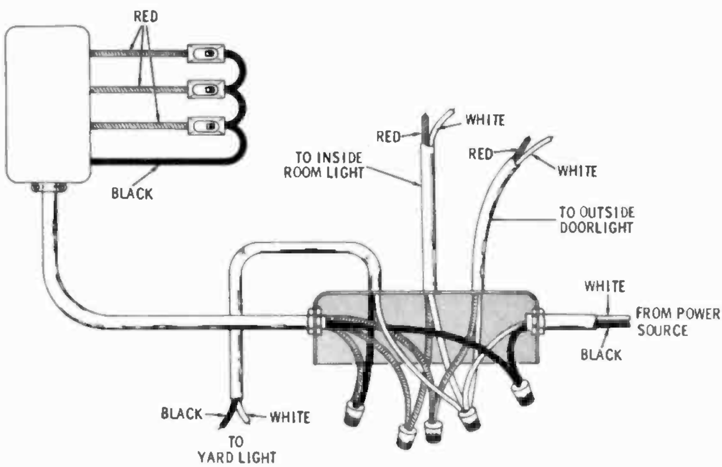


Fig. 5-6. Three switches inside the front door control: (1) front porch or overhead door light, (2) inside light, and (3) new yard light. Connect them up by following the standard color-code system; all white (neutral) wires are spliced together; the black (hot) wire from the source connects to all switches in common; each red wire from a switch connects to each red wire from a light. The cable between the two junction boxes for the yard light will have a white and black conductor. Assume the black conductor to be red.

from damage. A yard light needs a switch. Chances are there is a double switch at your front door—one for the outside light over the front door, or nearby, and the other operating an inside light when you come into the door. Change this to a three-switch unit, with interchangeable devices, as described in Chapter 2. Find the nearest junction box that feeds power to the front door switches and its lights. Connect a cable from the yard light junction to this box. Splice the white wire to the white wire in the box. Go back up to the switch box at the door and unfasten one of the red wires from one of the switches (either one). Tie a stout cord to this wire; go back to the junction box and pull each red wire feeding to the switches. The one that "gives" has the cord tied to it. Pull it down through and out. Tie another red wire to the cord and wire; splice, and pull *both* wires back up into the conduit. Connect the new red wire to the black wire from the yard light. Replace both switches at the door with *three* interchangeable switches. Reconnect two of them the same as the two that were removed. Connect a small jumper wire from the terminal on one of the switches to which the black wire, coming through the conduit, is connected to one of the screw terminals of the third switch. Connect the end of the new red wire to the other terminal. Fig. 5-6 shows the complete wiring. The new, third switch will now control the new yard light.

PROJECT I

WORKBENCH OUTLETS

Because outlets at a workbench will frequently be used to operate power tools, a grounded-type wiring system must be used. This provides the safety of grounding power tools. Also, because some cables are exposed to possible damage, they must be protected.

The object is to install a number of outlets on the front of the workbench, and a fluorescent light over the work space. Fully enclosed metallic raceways may be used for the outlets. The workbench installation described here uses flexible armored cable, or BX.

Begin by finding a nearby junction box from which you can take power. It may be from an overhead light, or from a nearby wall outlet. It is worth considering going back to the control box, if it is easily accessible. Overloads usually occur at workbench outlets more often than at any other outlets. For example, a bench-saw motor will stall if you feed it wood too fast, and the stalled motor will blow a fuse or open a circuit breaker quickly. For reasons like this it is worth considering a separate fuse or circuit breaker in the control box for your workbench. If you don't have an extra unused terminal in the control box, consider tapping on to a circuit where a blown fuse or opened circuit breaker will not interrupt important service to another part of the house. The circuit to the garage is a good one to connect to. You might say that the garage and the workbench are both the domain of the "man of the house," and any interruption of service is an inconvenience only to himself.

If you have chosen a nearby overhead light fixture for your power source, check its box first for the presence of a line that is not controlled by that fixture's switch. Most of the time, but not always, fixture boxes also serve as junction boxes for lines going to other fixtures or outlets on that circuit. At the control box, remove the fuse, or trip the circuit breaker off that controls that circuit. Unscrew the fixture and let it hang by its connecting wires. Look for a black wire in the box coming from one conduit opening and going into another, but *not* connected to the fixture. If you find one, your connections later on will be to that black wire, plus a parallel connection to the white wire going to the fixture. If the box does not have the extra line you will need to be satisfied with your workbench being controlled by that fixture's switch or find another box. If this is the box you decide on, don't make a connection to it yet. Refasten the fixture and turn the circuit back on. Connecting to the power is the last thing to do.

Determine what you want in the way of convenience outlets and overhead lights (if any) at or near your workbench. Use the example of the photos taken for this project. There is an overhead hanging fluorescent light fixture, several a-c outlets at the front of the work space, and a switched outlet at the left end for a power-drill bench adaptor. All outlets are of the three-contact safety type, one of the contacts being grounded to the conduit or

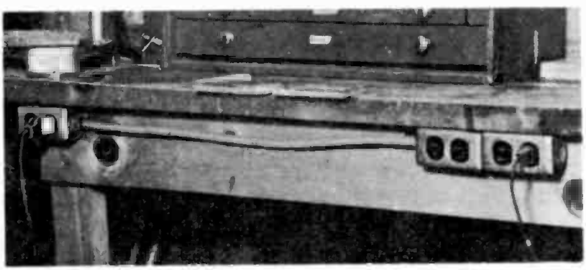


Fig. I-1 Surface-mounted utility boxes are mounted on the front of the workbench. The outlets on the right have grounding terminals, for three-prong safety plugs.

flexible armored cable. Small, 1⅞" × 2⅛" × 4⅛" metal outlet boxes are surfaced-mounted to the front apron of the workbench (Fig. I-2). If you mount two boxes next to each other as shown, allow a ⅛-inch space between them to provide for the overlap of the front plate. In the installation pictured here, the cable supplying the boxes was brought through a hole drilled right through the workbench front apron, behind the right-hand box. These boxes have seven knockouts for bringing cables in: one centered in the back, one at each end, and two on each side. The cable supplying power could come in through any unused knockout. In an installation like this, drill the hole first, and mount the right-hand box over it.

The distance between the two adjacent boxes is too short for armored cable, but you must provide electrical continuity for grounding. For this, cut a 6-inch piece of No. 14 insulated electric wire and scrape the insulation off one half inch of each end, to bare the wire. Loop

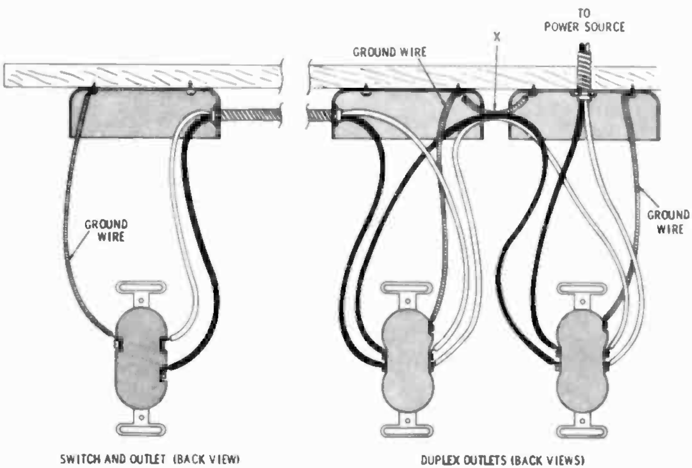


Fig. I-2. Wiring of workbench front outlets. Note ground wire at X. This is the most important one since there is no other bond between the right-hand box and the rest of the front outlets.

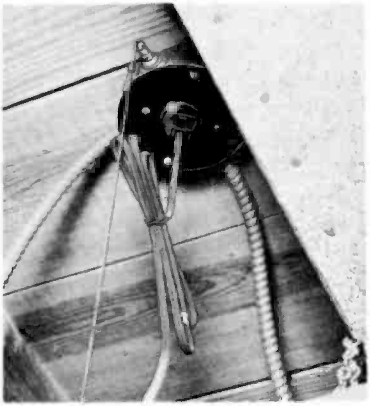


Fig. I-3. A junction box for the workbench is fastened to the underside of the rough flooring of the floor above. The armored cable to the left comes down behind the workbench and feeds the front bench outlets. The cable at lower right brings power to the box. The box cover has an a-c outlet for a fluorescent light hanging over the workbench.

one end around one of the wood screws supporting one box, and loop the other end under a wood screw holding the other adjacent box, running the wire through knockout holes facing each other on the two boxes. Fig. I-2 shows the wiring of the front outlets. Note the ground wires connected under the wood screws in each of the boxes. This is done the same way that you tied the two right-hand boxes together for grounding.

The cable that came through the workbench front apron goes back behind the workbench and up to a ceiling-mounted junction box (Fig. I-3). This is an octagonal box used for ceiling fixtures. Remove as many knockouts as required to bring the cable into the box. The installation pictured includes a supply line to a nearby photographic darkroom, and a pull-cord switch for the fluorescent fixture. Prepare the box before you fasten it to the ceiling boards. If you include the switch, drill a hole of the proper size into one of the sides of the octagonal box and fasten the switch in place. The cover plate includes an a-c socket for plugging the fixture in. Fig. I-4 shows the wiring.

You have completed the installation and you are ready to connect to a source of power at a box. **FIRST, REMOVE THE FUSE OR FLIP THE CIRCUIT BREAKER OFF.** If you have chosen a ceiling fixture box, unfasten the fixture and let it hang, as described before for an inspection of the box. Open one of the knockout holes in the box as described previously. Fasten the cable in place in the open hole. If the box has the black wire mentioned before, splice the black wire from your cable to it. Splice the white wire from your cable to the white

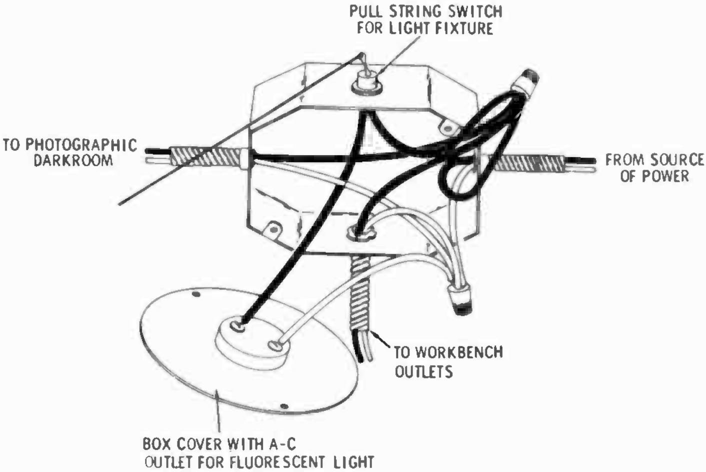


Fig. I-4. Wiring of junction box above workbench. This illustration shows couplers on the flexible armored cable. The switch is installed by drilling a hole of the proper size in one of the knockout forms.

wire connected to the fixture's white wire. Splice by removing the wire-nuts now on the wires, add the new wire with a half turn or so, and replace the wire-nuts. If the splice becomes too bulky to put the original nut back on, use a larger nut. If there was no extra black wire, connect to both the white and black wires connected to the fixture.

If your power takeoff is at an outlet box, make parallel connections to the screws of the outlet sockets. Match wires, black to black, and white to white. Reassemble the devices into their boxes, turn on the power at the control box, and you are in business.

Don't take lightly the earlier suggestion for installing the newer three-contact a-c safety sockets. Most power tools today are being supplied with a three-conductor cable and a three-prong plug. One of the wires in the cable is connected to the metal housing of the tool at one end and the round ground terminal at the plug end. This provides grounding protection in case something goes bad in the tool and one of the hot a-c wires makes contact with the housing. Without this protection, you could get a dangerous shock when handling the tool while standing on a cement or damp floor, or otherwise coming in contact with "ground." If your present power tools have two-conductor cables and plugs you should change them to the three-conductor type. In making the replacement, two of the three wires connect to the same places as the two that were removed, and the third wire (usually green in color) is connected under the head of any screw that fastens to the metal housing or case. Remember that the three-contact type of outlet sockets will still accept the standard two-prong plug, so you have not restricted yourself to the use of the three-contact plugs by installing them.

INSTALLING A CEILING DROP LIGHT

A popular addition to the modern home is an offset ceiling drop light. Some are designed to be merely hung from the ceiling and supplied with power by an external drop cord to plug into a nearby outlet. The cord is sometimes camouflaged with a gold-finished chain. A better-looking job is to install a junction box in the ceiling, and conceal the lines that supply the fixture by running them through the ceiling and wall. Fig. II-1 shows this kind of light.

Fig. II-1. A modern three-lamp drop-ceiling fixture. Concealed wiring is in the ceiling and wall, with switch at bottom of the wall.

While installing a junction box in a concealed ceiling is not easy, it can be done, with patience and perseverance, and with the instructions given here. It is made easier by using plastic-covered two-conductor cable instead of armored cable or conduit for the wires. This cable is easier to fish through spaces between the studs in the wall and joists in the ceiling, and through a hole in the header (explained later).

Most local electrical codes permit the use of plastic cable when installed in places where it is not subject to mechanical abuse. There is no need to have a grounded system in this installation, as there would be in a workbench outlet installation, for example.

First, consider the dimensions of the room. Ceiling joists are laid between the sides of the shortest dimensions, or width, of the room. You must consider this in deciding on a location for the fixture and the box for its switch—the cables in the ceiling must be run between the joists, and therefore parallel with them. The exception to this, of course, is the home with an attic above the ceiling.

If you locate the fixture at a point just above an outlet on an inside wall, the total work required is reduced. If the nearest outlet is elsewhere, the complexity is increased. Pick the spot that is esthetically best, because you will be living with it for a long time. Let us use the fixture installation pictured here.

Fig. II-2 is a cutaway illustration of the entire installation. The nearest outlet was three feet to the right of the spot decided on for the fixture. Since a switch must be installed to turn the fixture lights on and off, and the nearest outlet was behind a couch, another outlet box was installed just below the fixture, at the same height above the floor as the existing outlet.

Cut a one-inch-wide channel in the plaster from the existing outlet to the spot *near* where the new box for the switch is to go. Cut the channel to three or four inches beyond the last wall stud. This leaves a plaster area all around the new switch box, needed for mounting it. Cut

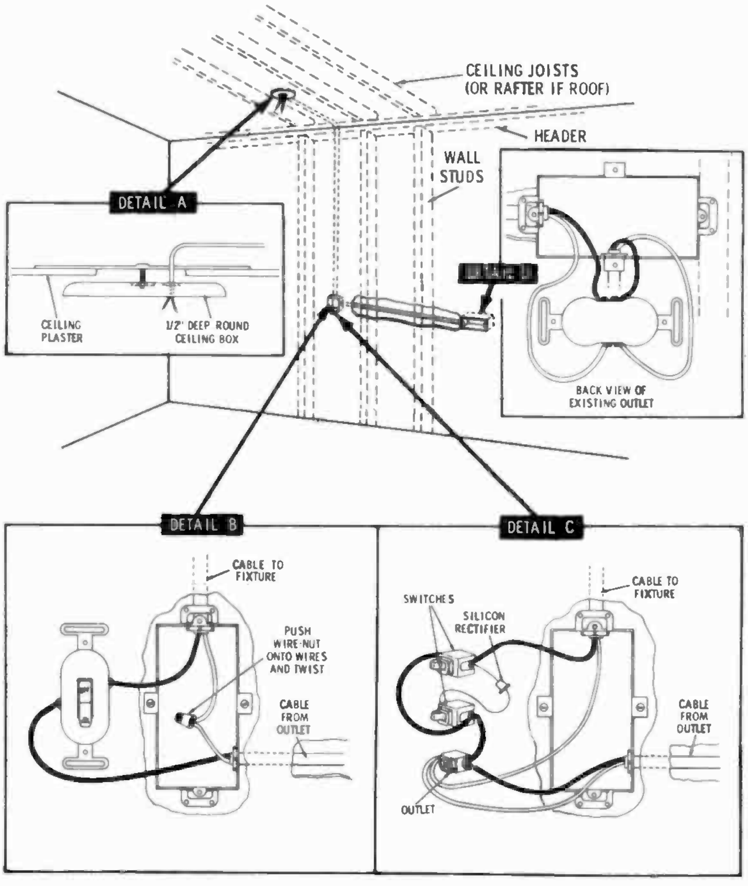


Fig. II-2. How to install a ceiling box and switch box for a drop-light ceiling fixture with concealed wiring. The cable must go through a hole in the "header." Detail *A* is a ½-inch deep ceiling box below the plaster and held in place by a long bar behind the plaster with a nipple at the center. Detail *B* shows the wiring of a single switch. Install the box as shown in the step-by-step illustrations shown previously. Detail *C* is an alternate switch arrangement, using "universal"-type devices. It provides an extra outlet and two switches: one is the "bright" switch, and the other, with a silicon rectifier in series, is a "dim" switch. Detail *D* shows how to make a parallel connection to the existing outlet.

one-inch-wide slots in the wood of the wall studs between the existing outlet box and the new box, using a large crosscut saw. A power saber saw will save you a lot of energy, if you have one or can borrow one. Knock out the wood between the cuts in the 2 × 4's with a chisel. These slots will hold the cable which is to be run between the two boxes.

Cut the plaster with a hand-keyhole or power saber saw. Drill a hole large enough to start the point of the keyhole saw first. Power saber saws start their own slot by their jabbing action.

Use the type of box that supports itself to the plaster. The new switch box cutout in the plaster should be nearly centered between two of the wall studs. Cut an opening in the plaster for the box following the outline supplied with it, or follow the step-by-step illustrations given previously in this book.

Locate the spot in the ceiling where you want the fixture to hang. This should be in line with the location of the new box. In this way, you are pretty sure of finding a spot that is *between* ceiling joists, and not *on* one. To be absolutely sure of this, drill a one-inch hole in the ceiling and explore behind this hole with a stiff wire. Make sure there is about three inches of space all around the hole behind the plaster. If everything is clear, cut out a round hole a little smaller than a shallow ceiling-fixture box.

The toughest job is drilling a hole through the header at a point in line with the ceiling-outlet hole and the new switch-box hole, through which the cable will pass from one box to the other. The header is the horizontal board that was nailed across the tops of the vertical wall studs, and to which the ceiling joists were nailed when your house was built. If yours is a one-story house with an unfloored attic the job is easy. If you have two floors, or a flat roofed one-story house, it requires more work.

If you have an attic, go up into it and locate the spot where you made the cutout for the fixture junction box. In line with this, drill a ⅝- to ¾-inch hole through the header. Cut a piece of plastic-coated two-conductor cable the measured length from the ceiling box to the switch box below. Allow a couple of inches for inaccuracy in measurement, plus 14 to 16 inches for individual leads at the ends. Feed the cable through the hole in the header from the attic down, so that the ends come out through both plaster cutouts.

If the drop fixture is being installed on the first floor of a two-story house, you must remove a section of baseboard in the room above where the cable is to go through the header. Fig. II-3 shows how to drill a hole from the position of the baseboard diagonally down through the floor board and through the header board. Go back down into the room where the fixture is to be installed, and cut a 4″ × 5″ rectangular hole in the plaster about a foot below the ceiling, directly above the switch-box cutout. The easy way to do this is to scribe a 4″ × 5″ rectangle

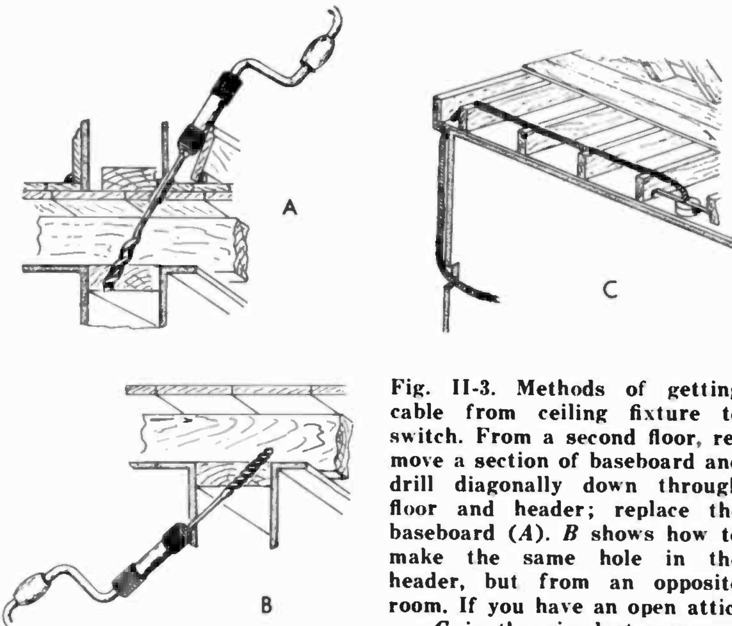


Fig. II-3. Methods of getting cable from ceiling fixture to switch. From a second floor, remove a section of baseboard and drill diagonally down through floor and header; replace the baseboard (*A*). *B* shows how to make the same hole in the header, but from an opposite room. If you have an open attic, *C* is the simplest way.

on the wall, drill two half-inch holes (one in each diagonally opposite corner) and use a keyhole saw to cut along the lines from the holes out. Save the piece of plaster you cut out. You will use it to patch up the hole later.

In a one-story house with a flat roof, the hole is made diagonally upward from the next room behind the wall. This means patching and repainting that hole later, of course.

You will need two pieces of fish tape, one at least four feet long and one at least eight to ten feet long, depending on how far from the wall the ceiling outlet is. Fish tape is flat flexible spring steel with the ends bent over to form a hook. It can be purchased at all electrical supply stores. Push the shorter piece through the header hole from the floor above, working it down to where you can reach it from the rectangular cutout you made below. You will be going through two holes: one you made going through the floor boards just beyond the baseboard line from the second floor, and the other, the hole in the header. Pass the other fish tape laterally through from the ceiling cutout, and try to catch the end of the first fish tape with the end of the second. Then, pull on the shorter fish tape from below to draw the longer fish tape through the header hole and into the room (Fig. II-4). Fasten the end of the cable to the far end of the longer fish tape, and pull the cable through the header hole until you can reach it from the rectangular cutout in the wall.

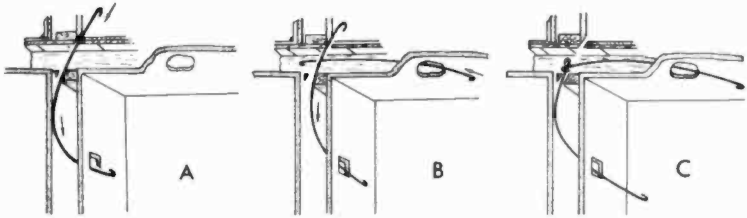


Fig. II-4. "Snake" a short fish line down through the floor board hole and header hole from the second floor, and bring the end out at the 4″ × 5″ plaster cutout, as shown at *A*. Push a longer fish line through the ceiling hole and hook the first one, as in *B*. Draw the short fish line down, and pull the long one through, into the room (*C*).

You will then be able to wiggle the cable down to the switchbox cutout.

Knock out the appropriate holes in all three boxes, and connect the cable to the boxes. Install a switch box of the type designed to hold to plaster. Install a shallow ceiling box with a long strap.

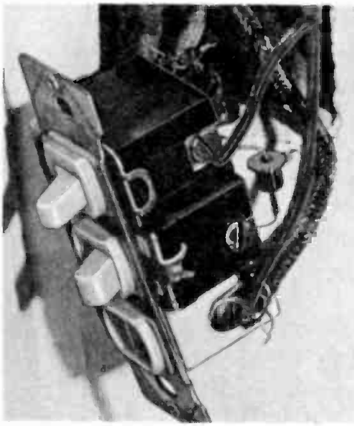


Fig. II-5. Photo shows the "top hat" silicon rectifier used to dim the fixture lights.

At the switch box you have a choice: You may settle for a switch alone, or for some means for dimming the lights. A description of universal devices is found in earlier chapters. The half-bright condition is obtained by connecting a silicon rectifier between two of the switches. It may be seen in the photograph of Fig. II-5. These are available from radio-parts supply companies. They are known as *top hat* silicon rectifiers, and have a rating of 750 milliamperes at 400 volts PIV. It is not important to know what the figures mean, but you will need to use them to make the purchase. These rectifiers dim the lights by rectifier action. They are installed in series with one switch. As rectifiers, current will flow through them in only one direction. Since only half the normal current goes to the lights, they burn at somewhat less than half their normal brightness.

Install the ends of the plastic-sheathed cable in the two boxes as shown in previous chapters. Splice the ends of the cables at the fixture to the fixture wires, using wire-nuts. Hang the fixture in one of the three ways shown previously, depending on the construction of the fixture.

Make connections to the switch box as shown in one of the detailed drawings earlier in this book.

REMOVE THE FUSE OR OPEN THE CIRCUIT BREAKER AT THE MAIN CONTROL BOX. Connect the cable to parallel screws on the original outlet box (Fig. II-2), matching the wire colors—white to white and black to black.

Now the job is done, except for patchup, cleanup, and paintup. Use patching plaster or *Spackle* to replaster the long cut from the original outlet box to the new switch-box. Make a stiff mixture so that it does not run. You will probably find that it requires two applications: the first for general fill-in; and the second, after the first dries to put a smooth finishing touch to the job. Use patching plaster to cement the rectangular piece cut out of the wall below the ceiling. Here, too, it will probably take two applications.

PROJECT III

ADDING SURFACE WIRING TO A BEDROOM

This business of piling up your duplex outlets with cube taps, in order to handle more appliances, is a tangle of wires, it looks messy, and it can be dangerous. At the head of twin beds was a single outlet box with a duplex socket. Object: Connect two twin-size electric blankets, two reading lamps, and an electric clock; five appliances connected to an outlet designed for two. The original mess is shown in Fig. III-1.

How do you best provide five outlets for five appliances? Adding in-wall outlets with boxes and through-the-wall

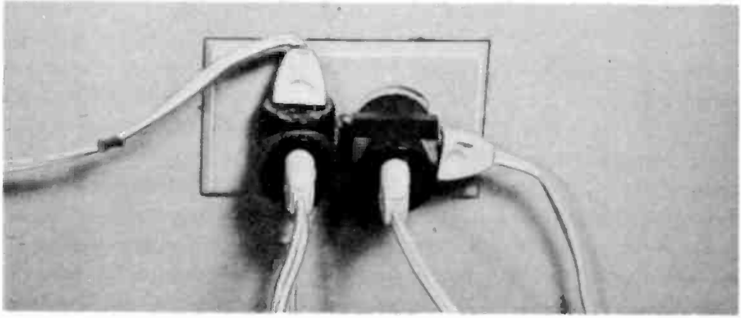


Fig. III-1. A duplex outlet trying to handle five appliances through the use of cube taps. It is hazardous and should be replaced with more outlets.

cables would be a lot of work—chiseling plaster and fishing cable—especially since all five outlets are to be within a five-foot space. The answer is in *surface wiring.* As the name implies, this is wiring on the surface, or outside the wall.

Surface wiring comes in two basic styles: a covered, metallic trough in which regular electrical cable or wires connect from source or input to the outlets; and heavy, plastic-enclosed cables to which special outlets are wired. The metal-enclosed surface wiring (sometimes called *raceways*) is recommended for areas such as workbenches where some mechanical abuse may be encountered. The plastic-cable system is adequate for places where the wiring is somewhat protected (as is the case of the bedroom project described here). It can be used for most inside outlet wiring.

Plastic-cable surface wiring also comes in two general forms: one uses the standard plastic cable, the same kind that is used for in-wall wiring; the other is specially fabricated of plastic, in which the conductors are molded into the form in such a way they plug into special fittings to change direction, and outlets snap into place along the molded strip. Fig. III-2 is a photograph of the parts used in the latter system.

Electrostrip is the brand name of the surface wiring used in this bedroom project. (It is made by I-T-E Circuit Breaker Co., Detroit 32.) Fig. III-3 is a closeup view of the plastic molded strip, with an outlet in place. The two round wires projecting from the edges carry the current to the outlets. The center flat strip is the "grounding" conductor (note that the outlets are the 3-contact safety type). The center strip is exposed, which is all right because it is not carrying live voltage. Actually the two round conductors are partially exposed between the curled-over lips of the edge of the strip. The outlets make contact by means of fingers that reach under those edges and grip the wires. The ground terminal of the socket (the D-shaped hole in the center) contacts the center strip.

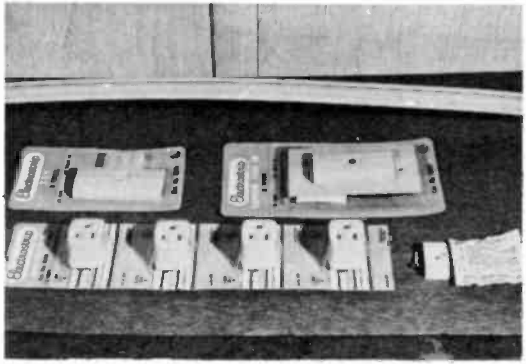


Fig. III-2. Parts used in the surface-wiring project. At top is the plastic strip with wires molded in. The center pieces are a "tee" and a "feed-in." The stripped ends of the cable plug into these fittings. The "feed-in" makes connection to the wires in your outlet box. Bottom row shows snap-on outlets and end-cable finishing pieces at right.

Fig. III-4 shows the end of the strip about to be plugged into the "tee" conductor. Nearly the whole system is a plug-in system, with the exception of the final splicing

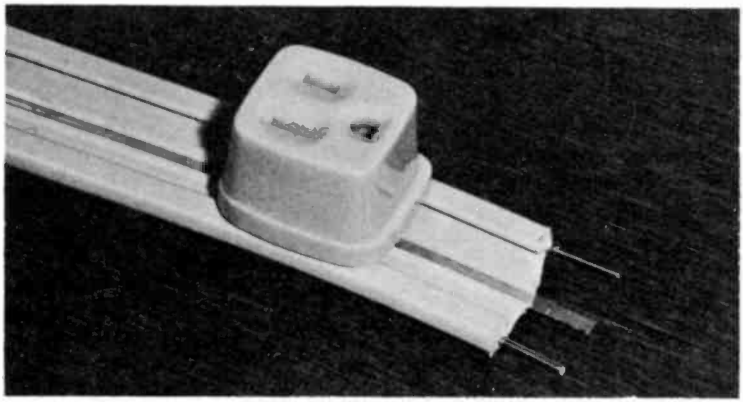


Fig. III-3. Detail of "Electrostrip" surface-wiring cable. Center ribbon is "ground" strip. Outlet twists into grooves and contacts current-carrying wires and ground strip.

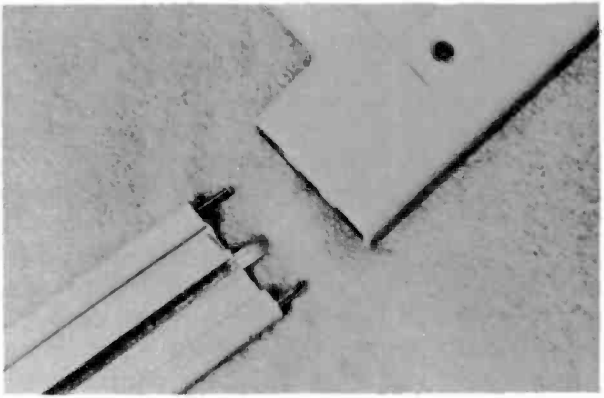


Fig. III-4. The bared cable ends of the surface wiring strip "plugs in" to "tee," "ell," or "feed-in" connectors.

to the wires in the outlet box. This is one of the few systems providing a finished, clean way of coming out of the outlet box.

First, determine your needs and purchase the equipment. The plastic wiring strip is available in almost any length. Include two end pieces. These are the same color plastic, and they put a finished touch to the far ends of the cable. You will need one "tee," a three-wire "feed-in" for making connection to the wires in the existing box, and any number of outlets to meet your requirements.

This project required five outlets spaced over a five-foot length. A six-foot piece of cable strip was purchased, from which a one-foot piece was cut for the vertical portion. Cutting the cable is tough. Use a hacksaw, since the plastic is hard and wires heavy. Three-eighths inch of plastic insulation must be cut away from the ends that plug into the "tee" and "feed-in." In this case a hand-held high-speed grinder with a small emery wheel was used to cut a deep groove around the plastic, ⅜ inch from the ends. Don't cut into the metal wires or center strip. The cut piece can then be forced off the end, by the squeezing action of a pair of diagonal cutters, leaving the two wires and center strip exposed, as shown in the photos. Use a small file to round off the ends of the two outer wires, so that they will start into the spring-grip terminals of the "tee" and "feed-in" more easily.

The molded strip is marked for screw holes to be drilled for mounting to the baseboard. Use a No. 27 drill, and mount it to the baseboard with ½ inch No. 6 wood screws.

Start by placing the "tee" directly underneath the existing a-c outlet. Set the "feed-in" plate over the present duplex outlet and cut the vertical section of the cable strip to the proper length between the two. The backs of the "tee" and "feed-in" have templates to show how far up into these pieces the cable plugs go.

Disable the current to the outlet box by removing the fuse or opening the circuit breaker at the central control box. Take the cover off the outlet; unscrew the duplex outlet itself, and pull it out toward you to bring the wires out for handling (Fig. III-5). Unscrew the terminals and remove the wires. The ends of the wires are hooked from behind under the screw heads. Straighten them and cut off all but ½ inch of the bare ends.

You now have two wires—a black and a white wire. These will carry the current. But you will also need a third wire, for grounding. Cut an 8-inch piece of any kind of wire and fasten one end inside the outlet box to any screw you find there. If you don't find a small screw, loosen the knurled locknut holding the conduit, place the bare end of the wire under it, and retighten the locknut. You now have three wires out of the box.

Splice the three wires of the "feed-in" plate to the three wires coming out of the outlet box—black to black, white to white, and red to the ground wire you installed. Use wire-nuts to make the splices (Fig. III-6). Plug the short vertical section of cable into the mating junction of the "feed-in" device. Screw the large cover plate in place over the box with the screws that are supplied. Plug this cable into the "tee" and position the assembly with the "tee" at the bottom. Screw the "tee" to the

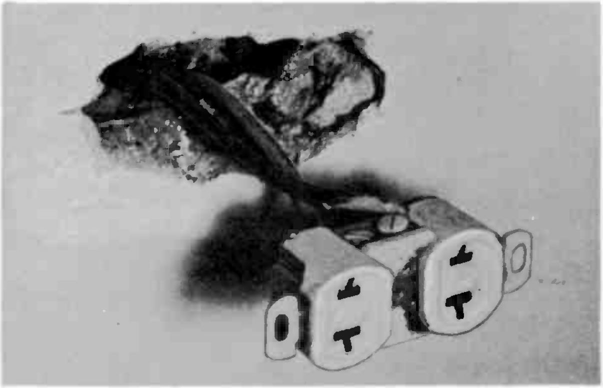


Fig. III-5. Unscrew duplex outlet and pull towards you to bring out the wires.

baseboard. Plug the horizontal sections of molded cable into the "tee," one into each side. If you are not going out in two directions as is done here, but in one direction only, you can buy an "ell" for the connection to the vertical piece of molded cable.

Fasten the cable to the baseboard with No. 6 wood screws. If you are going into the plaster above the base-

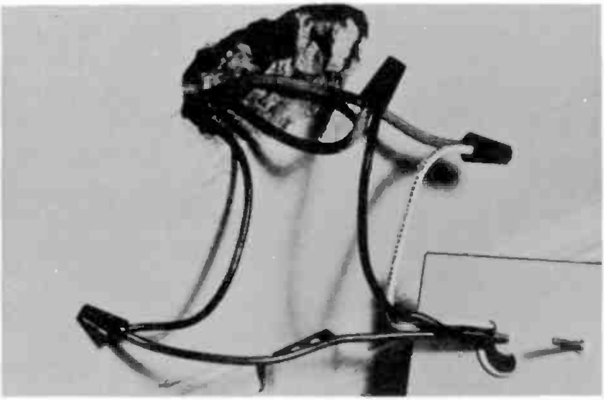


Fig. III-6. A third wire is fastened to the outlet box for grounding. Splice the wires to the "feed-in" cables with wire-nuts.

board, you should install small plastic anchors into the plaster wall first. Wood screws do not hold well in plaster. For going neatly into wood, drill a pilot hole with a No. 31 or $^{3}/_{32}$-inch drill.

Fasten the finishing end pieces in place on the cable ends. Cut a "V" notch into the ends of the molded-plastic cable strip, to clear the wood screws for the end pieces.

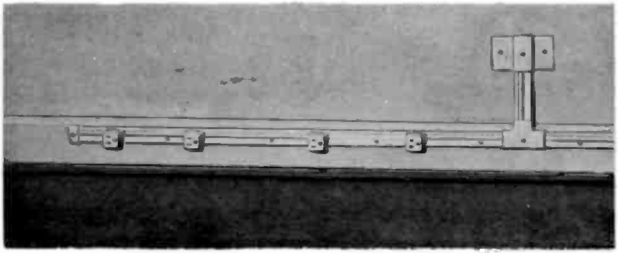


Fig. III-7. The finished surface wiring installations. Additional outlets are easy to add; they snap into place anywhere along the cable strip.

Install the outlets where you want them. Fit them into the grooves of the molded cable strip and give them a one-third turn clockwise. Instructions are on the cards on which they come mounted. Don't install the outlets where the wood screws are.

Reconnect the service at the control box. Now you have a neat surface wiring installation. Any time you wish you can add outlets, or remove those you put in and relocate them on the molded cable. Fig. III-7 shows the finished job.

PROJECT IV

INSTALLING A YARD FLOODLIGHT

This is a back-yard floodlight installed high at the second-floor level, and using the cone-shaped and silvered floodlight bulb. Obviously, the light may be installed on one-story homes, but get the light up as high as possible for best coverage.

As with all outdoor installations, that part of the system exposed to the weather outdoors must be fully weatherproof. This means using thin-wall conduit to carry the wires to the outlet, and using a special weatherproof socket and mounting for the bulb.

The project begins with a study of the optional locations for meeting three objectives: location of the light; location of a convenient switch indoors; ease of installing connecting wires from the first to the second. These three requirements are easily met when there is a back door to the yard that you want to illuminate.

Fig. IV-1 shows the light installation and the conduit carrying the wires to the light socket. Fig. IV-2 is a photo of a small hall leading to the back door. Originally a single switch controlled the overhead hall light. Now you see three switches: one is for the hall light, one for the outdoor floodlight described here, and the bottom one is a three-way switch for the yard light on the garage (described elsewhere).

Fig. IV-1. It is important that wiring to an outside light be fully weatherproof. The use of thin-wall conduit to carry the wires is a must.

The only part of this job that was a little difficult was providing a means for the conduit to come through the brick wall to the switch box inside. If yours is a frame house the job is much easier. In order to keep the bend

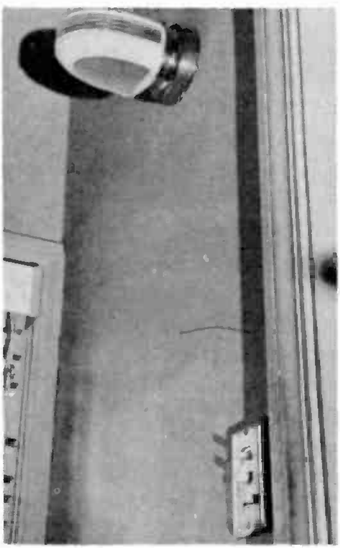


Fig. IV-2. A back-hall single-light switch was changed to three switches: one for the original hall light; one for the outside floodlight; and a three-way switch for the garage.

on the conduit at as small an angle as possible, it was decided to come into the switch box instead of the closer hall light junction box. Carefully figure the point of entry from the outside to a convenient box inside. Use a star drill and a heavy hammer (or a short-handled sledge hammer) and pound a hole diagonally down through the brick. An electric drill and carbide-tipped drill bit will do the job faster and easier. In the case of a frame house with wood siding it is merely necessary to drill a hole of the proper size (usually ⅝ inch) with an electrician's drill bit and a hand brace.

Fig. IV-3 is a diagram of the method of entry for this project. A hole was drilled through the two courses of brick, using a carbide-tipped bit, then enlarged with a star drill and hammer. The spot selected for entry was to emerge into the wall space between the back hall and the kitchen. Behind the brick was a 2 × 4 wall stud. A hole through the stud was made with a long, ⅝-inch electrician's drill.

Use a single length of conduit from the location of the floodlight to the box. This may involve a little tricky bending. It is made fairly easy by using a conduit bender, as described in Chapters 2 and 7. At this point a decision must be made on the method of "grounding" the conduit to the box. Three choices are open: fit a coupler to the box end of the thin-wall, which requires that the hole made in the wall be large enough to pass the coupler; cut out a square of plaster near the switch box, through

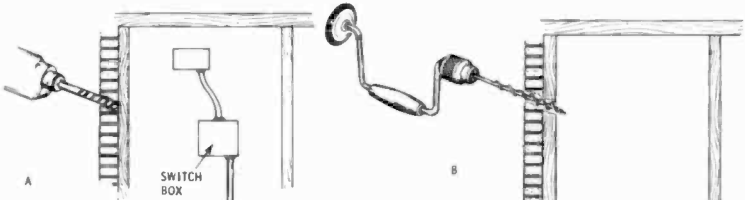


Fig. IV-3. If you must go through brick for bringing in the thin-wall conduit, use a carbide-tipped drill bit and electric drill to start (A). Use a ⅝-inch electrician's wood bit and hand brace for wood(B).

which you can reach to put a coupler on the conduit after it has been passed through the wall; or no coupler, but provide an electrical ground by soldering a piece of heavy wire to the box end of the conduit and fastening the other end of the wire to the box.

Cut off the electric current to the box by removing the fuse or tripping the circuit breaker to off at the control box. Remove the existing switch from the switch box. Remove a knockout slug from the side or top of the box. This is done by prying the slug from the inside of the box to bend the slug, then twisting it off with pliers.

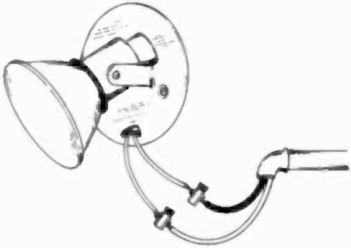
Put the conduit through the wall until it just emerges through the knockout hole in the box. Fasten the conduit in place on the outside wall with conduit brackets. If it is to be fastened to brick, you can obtain special nails made for driving into the mortar between the bricks.

Special outdoor sockets are made for one, two, or three floodbulbs. These use porcelain sockets which are capable of taking the high heat of the bulbs, and they are enclosed in a rubber jacket to make them weatherproof. If it is to be fastened to brick, it is best to mount it with a wood board. Cut out an 8″ × 8″ board of ½-inch plywood; thoroughly paint it to protect it from the weather; and fasten it to the brick first. Then mount the socket to the board. If the socket is mounted to wood siding, the board is not necessary.

Fish two insulated wires through the conduit, one black and one white, leaving about 8 inches extra in the box and about 10 or 12 inches out the top on the outside. Install a two-wire service head on the top of the conduit. This provides a moistureproof entrance for the wires. Splice the leads from the socket to the wires at the top using solderless connectors, and leaving a *drip loop* of wire for each lead (Fig. IV-4).

If your conduit entered into a switch box, you will need to replace the single switch with two switches. A dual-switch device can be purchased to fit the same box. If you plan on more than two switches, go to the universal devices described in Chapter 2.

Fig. IV-4. Form a drip loop where you connect to the floodlight leads, and use solderless connectors for the splices.



The box must have a black and a white wire coming into it for a source of power. Splice the white wire from the conduit you installed to the white wire in the box. The black lead from the conduit connects to one side of the new switch installed. The other terminal of the switch is "jumpered" to the terminal of the other switch to which the black wire already in the box is connected. Install the second switch to the same wires removed from the original switch (Fig. IV-5).

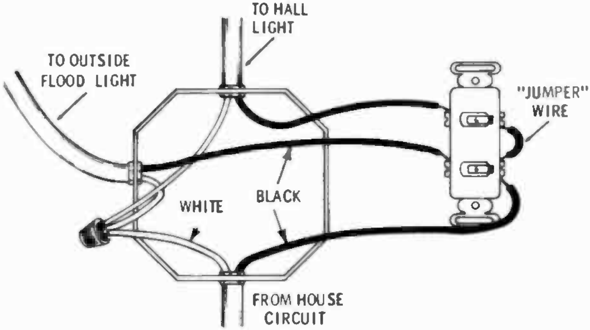


Fig. IV-5. Change a single switch to two switches: one for the original inside light, and the other for the new floodlight.

If you have terminated your conduit in a box you have installed for it, of course you will need to provide power and switching. This is done in the same way as for any indoor installation to a new light fixture, and you may use either flexible armored cable, or three-wire plastic-covered cable. The third wire of the three-wire cable will be used for grounding.

PROJECT V

INSTALLING LIGHTS AND POWER FOR THE GARAGE

This project covers the job of providing power to outlets in an unattached garage, and includes a three-way switch control of lights on and in the garage. Lights can be turned on or off from the garage, or from the house.

To provide for all of this (plus a ground for safety) it will be necessary to run five wires between the house and the garage. Two of the wires will carry continuous service to the outlets. One will be the ground wire. Two wires are needed between the three-way switch in the house and the three-way switch in the garage.

Because of its neater appearance and ease of installation use heavy-duty plastic-covered cable, buried in the ground. Be sure to check your local electrical code to determine whether or not they permit the use of this cable in this manner; most codes do. Two lengths of cable, one with three conductors and one with two, will be needed.

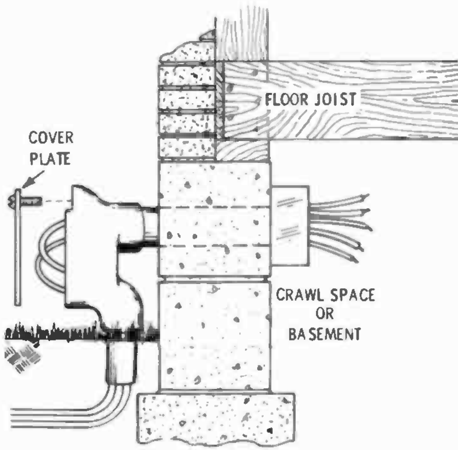
Begin by providing an access hole through the house for a short length of thin-wall conduit between a junction box inside and a waterproof elbow on the outside. Fig. V-1 shows one installed through a brick wall. A length of thin-wall conduit must also be fitted to the elbow to go down into the ground about 18 inches. Make a similar installation at the garage for the cable entrance.

Fig. V-1. A waterproof elbow outside the house and garage joins sections of thin-wall conduit for underground cable entrances. The back plate is removable for handling the cable for a right-angle bend.

Dig a ditch at least 18 inches deep between the two conduit sections going into the ground, between the house and the garage. The minimum depth required by electrical codes is usually 18 inches. It must be below the frost line and deep enough so that gardening tools will never damage the cable buried in the ditch. It is usually best to follow along an installed fence. You are less likely to dig any deep holes along the fence in the future, and it identifies the location of the cable.

Remove the weatherproof cover plates from the elbows. Lay the cable in the ground, and bring them up through

Fig. V-2. How to bring cable into house. With cover off elbow, cables can be made to take the right-angle turn.



the vertical sections of the thin-wall conduit and out through the elbows. Make the bend at the bottom of the thin-wall sections as gradual as you can to prevent the edges of the conduit from cutting into the plastic. At the entrance elbows, bend the cable and push them through into the house at one end, and into the garage at the other end (Fig. V-2). Leave enough cable out the junction boxes to work with. Put the covers back on the elbows. Push the dirt back into the ditch and tamp it down.

From the house junction box (whether it is installed in the basement, a crawl space, or higher up such as in an enclosed porch) run two flexible armored cables (or plastic cables if located where they cannot be damaged). Use one with two conductors for the three-way switch, and one with three conductors for ground and power service. The wiring circuit for the project described here

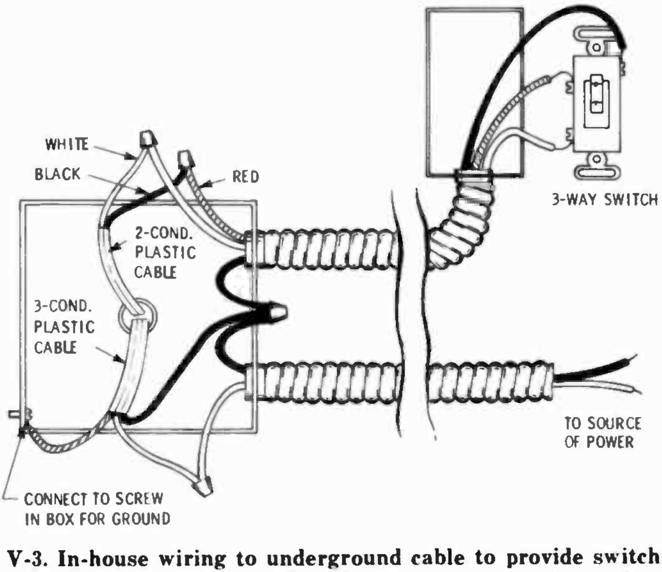


Fig. V-3. In-house wiring to underground cable to provide switching of lights from house to garage, plus separate power for outlets in garage.

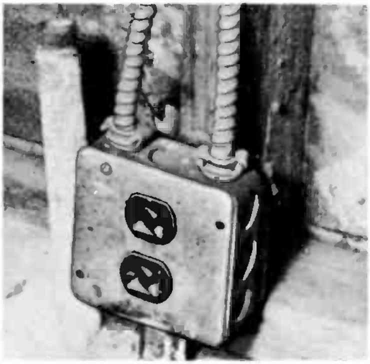


Fig. V-4. The four-inch junction at the entrance of the cable to the garage.

is shown in Fig. V-3. Obviously you can alter this to suit your own needs.

At the garage bring the cables into a 4-inch junction box. Fig. V-4 is a photograph of one. In this case a thin-wall conduit pipe was put in place at the time the cement for the garage floor was poured. (The pipe to the left of the junction box in the photo was installed for water

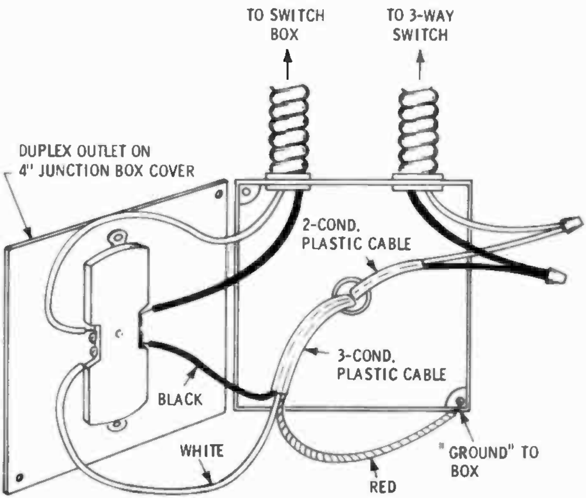


Fig. V-5. Connections at garage cable input. It includes a duplex outlet at the entrance junction box.

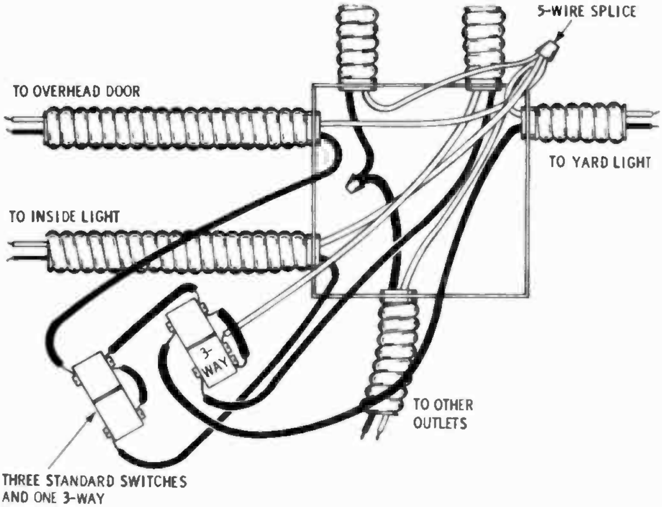


Fig. V-6. Distribution junction box with three-way switch plus three individual light switches.

but never used.) If the garage is already up, you would, of course, use the entrance method described previously.

Install two two-conductor flexible armored cables to the box and run them up to the ceiling line and across to the side entrance door. Fig. V-5 shows the wiring at the entrance junction box. Note the matching of wire colors as in Fig. V-3.

The 4-inch junction box just inside the side door of the garage is the point of distribution to all services in the garage. The cover plate on the box has four openings for four switches: one is the three-way switch; the other three are standard switches, for an outside yard light on the garage, an outside light over the car entrance sliding door, and an inside light. In addition to individual switches for each of these lights, they are also all controlled by the three-way switch. Thus, any or all may be turned on or off from either the house or the garage. Fig. V-6 shows the wiring of this central box and the four switches.

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