COYNE Electrical School

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ELECTRICAL CONSTRUCTION

AND

WIRING FOR LIGHT AND POWER

Section One

Code, Conductors, Splicing and Soldering

Types of Wiring Systems

ELECTRICAL CONSTRUCTION

Wiring for Light and Power

Electrical construction and wiring offers a tremendous field of opportunity for practical trained men, both in interesting jobs at good salaries with various companies and employers, and also to enter a business of their own.

Naturally, every piece of electrical equipment manufactured and sold each year, must have wiring and circuits to carry the current to it, when it is installed. This includes the billions of dollars worth of electrical machinery and devices made each year, and also the millions of electric lights and lighting fixtures.

Think of it, in old buildings and existing plants, new wires and extensions to the circuits must be run each time additional equipment is installed; and in the new buildings erected, complete new wiring systems must be installed.

Today almost every new home erected in any city or small town, is wired for electric lights and appliances when it is built. Tens of thousands of old houses are being wired, and thousands of others rewired or having improvements and additions made to their wiring, to provide better lighting and more complete use of electrical convenience devices.

Plans are being made to rapidly electrify the last few small towns, which have not yet had electricity, and even the farms are now rapidly electrifying. Nearly one million farms already have their buildings wired, and electric supply from their local power companies' lines, or their own private light plants. Many of our graduates who came from farms, have returned to their own home territories, and made big money wiring houses and farm buildings, installing and servicing farm light plants, radios, refrigerators, lights, and motors.

1. GOOD KNOWLEDGE OF WIRING NEEDED IN MAINTENANCE WORK

Factories and industrial plants throughout this country are over three-fourths electrified at present, and thousands of them employ from one to a dozen or more electrical wiremen, just to take care of their electrical construction and continual expansion.

The few old plants which have been operated by steam or other power, are rapidly changing over to electric power and machines, and modern electric lighting.

Practically every new factory or industrial plant built nowadays, is completely wired and electrified.

These plants keep thousands of trained electrical men constantly employed in interesting and good paying work, maintaining and repairing their electrical machines, lights, and wiring circuits; and installing the new motors, lights and wiring as it is required.

This field of **Electrical Maintenance** work requires men who know the principles and methods of modern wiring thoroughly, so every electrical man should obtain a thorough knowledge of the material covered in this section, whether he intends to specialize in wiring and electrical construction or not.

The electrical maintenance man in any plant will usually have a great variety of interesting work to do, and an opportunity to use every bit of general knowledge he can obtain.

2. VALUE OF GENERAL KNOWLEDGE OF WIRING

The electrician in the small town will also usually be called upon to wire door bells, lights, and power motors; and to shoot trouble and make repairs on everything from a burned out fuse or dead dry cell, to shorts in wiring or faults in power machinery. And even the man who specializes in one line of electrical work, can always use a good general knowledge of electricity, and particularly of methods of wiring.

Many of our graduates make big money in a business of their own in this field, contracting general wiring or specializing in either the wiring of new buildings or old houses.

In addition to wiring contracting, many of them do electrical merchandising, selling lighting fixtures, electrical appliances for the home, radios, etc. The profits from such a business, often started in a very small shop or the basement of their own home, frequently build up a splendid business, paying from $5,000.00 to $20,000.00 per year clear profit.

3. IMPORTANT POINTS IN WIRING

The important things to be considered in any electrical wiring job are: First, the selection of wires of the proper size to carry the amount of current required by the devices, and with the proper insulation according to the voltage of these wires; Second, proper mechanical support and protection for the runs of wire; Third, secure and permanent splices and connections; Fourth, protection and precautions to eliminate all danger of fire or shock.

Each of these features will be covered thoroughly in the following sections. When installing any wiring system these points should be constantly kept in mind, and all work done accordingly.

In years passed a lot of electrical wiring was installed rather carelessly, mainly with the idea of supplying current to the devices requiring it, but without proper consideration for permanence, and safety from fire and shock hazard. As a result many fires originated from defective wiring, causing short circuits, sparks, and flashes, or just overheated wires. In other cases, people received electric shocks or injuries by coming in contact with wires that were not properly insulated.

4. INSPECTION—AN ADVANTAGE TO THE TRAINED MAN

Nowadays there is a general tendency in all electrical construction to follow certain very high standards in the selection of materials, quality of workmanship, and precautions for safety. A great deal of the old wiring is being entirely replaced, and new wiring in most towns and localities must be done according to very strict inspection requirements. This is not at all a handicap, but rather it is a decided advantage for the trained electrical man who knows how to do this work as it should be done, and according to these rules. It makes his services much to be preferred to those of the man who does not know modern methods, or will not recognize the value and importance of safety-first rules in electrical wiring.

5. NATIONAL ELECTRIC CODE

To standardize and simplify these rules and provide some reliable guide for electrical construction men the **National Electric Code** has been provided. This Code was originally prepared in 1897, and is kept frequently revised to meet changing conditions, and improved equipment and materials. It is a result of the best efforts of electrical engineers, manufacturers of electrical equipment, insurance experts, and architects.

This Code book is now published by the National Board of Fire Underwriters, and contains simple specific rules and instructions which, if followed, all tend to make electrical wiring and construction as safe and reliable as possible. Every electrician should have an up-to-date copy of the National Code at all times, and should familiarize himself with the more important rules pertaining to his work, and if he does he will find them of great help in making certain decisions on the job, and performing his work in a manner that will always be a credit to himself and his profession.

6. STATE AND LOCAL CODE RULES

Most states now require that all electrical work be done in accordance with the National Code, and even in the few states where this may not be required throughout, most of the towns and cities do require that all wiring within their limits follow the Code.

Throughout the following pages we shall quote occasionally some rules of the National Code.

The Underwriter's laboratory also tests various electrical materials and supplies, such as wire, switches, fuses, insulations, etc. If these are deemed safe and reliable, and meet the laboratory standards for quality, they carry the underwriters stamp of approval.

This is a good indication for the conscientious electrical man to follow in selecting the best of materials.

Some states have prepared special codes and rules of their own, usually applying to wiring in schools, auditoriums, theatres, and other public buildings, and also to transmission lines, and outdoor construction where the public is involved. These rules, however, all agree with those of the National Code.

A number of towns and cities have their own local code or rules, which in general may be based upon or similar to the National Code, but will have a few specific rules on certain classes of work, which are more rigid than the National Code.

In addition to the National Code and local codes of certain cities, the power companies to whose lines the wiring system may be connected may have some certain rules regarding service wires, meter connections, size and type of devices, and class of equipment connected to their system. So, in starting to do wiring in any town, it is well to familiarize yourself with these local rules if there are any.

In addition to these important rules, if you will also follow the instructions given in the following pages, and apply your knowledge of general principles of electricity, along with good common sense and careful workmanship, you should be able to do most any kind of electrical wiring quite successfully.

Certain things in electrical wiring are done according to what might be termed "standard practice". That is, while there are no set rules for them, experienced electrical men have found that certain ways or methods are generally best, and these have been more or less generally adopted by men on the job.

For example, when installing single pole push button switches, the white button is always placed at the top. Following general rules of this kind simplifies the work a great deal and avoids confusion, both in the wiring, and to the owners of the buildings in which it is installed.

Every electrician should always be on the alert to notice and remember these little details or "wrinkles" of the trade. A number of them will be mentioned in this section.

7. CLASSES OF WIRING SYSTEMS

Wiring systems can be separated into the following classes:

D. C. or A. C. systems, and two wire or three wire systems.

Whether direct or alternating current is to be used depends entirely on which is available from the power companies' lines; or, in the case of a private plant, which type of plant is used.

Direct current is generally used only where it is not to be transmitted over distances greater than one-half mile. It has certain advantages for the operation of special types of variable speed motors, and motors requiring extra heavy starting power for frequent starting and stopping; also where storage batteries are to be charged from the lines, or where arc lamps, and other special D. C. equipment are in use.

Alternating current is equally as good for lighting with incandescent lamps, and much more desirable and economical where the energy has to be transmitted considerable distances. In such cases, it can be transmitted at high voltage for line economy, and then the voltage reduced at the customer's premises by use of step-down transformers.

For power purposes, recently developed alternating current motors will also meet almost every condition that direct current motors formerly were needed for. By far the greater number of wiring jobs which you will encounter will probably be on alternating current systems.

The materials and methods used are just about the same for either D. C. or A. C. systems, except for a few precautions on A. C. circuits which will be covered later.

The simple two wire system is in common use for wiring small homes and buildings where only one voltage and small amounts of power are required. The circuits and connections for such a system are extremely simple, and consist merely of running the two wires to each lamp or device to be used, and of course with the proper fuses and switches. Fig. 1 shows the important parts of a two wire lighting system.

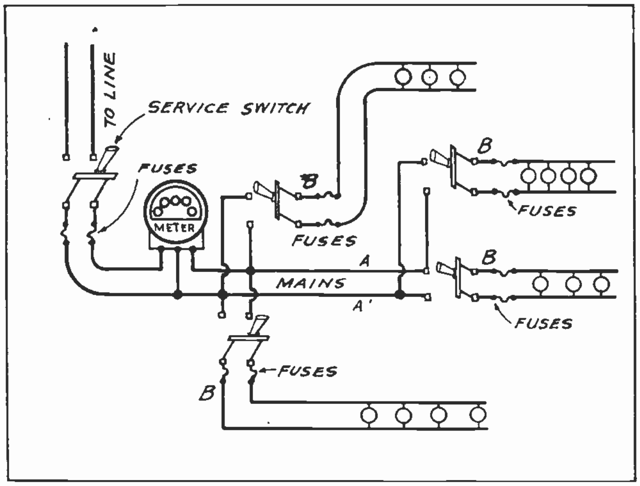


Fig. 1. This sketch shows a simple two-wire system with the service wires, mains and branch circuits.

This system consists of the **Service Wires** which lead to the power supply, **Service Switch** and **Fuses, Meter, Main Wires** or **Feeders**, and **Branch Circuits.** Each branch circuit has its own switch and fuses. The separate light switches are not shown in this diagram. All of the circuits marked "B" are branch circuits, while "A" and "A1" are the main wires which feed the branch circuits. The Watthour meter is connected in the mains, near the service switch, to measure all the energy used in the entire system.

The **Edison Three Wire System** can be applied to either A. C. or D. C. installations. It provides two different voltages, one for lights and one for motors, and also effects a considerable saving in wire size, where used for lighting only. This system will be explained in detail later.

8. WIRING MATERIALS—CONDUCTORS

Before going farther into the methods of wiring it will be well to consider some of the materials used.

Conductors used in wiring for light and power must be somewhat different from those used for low voltage signal wiring, as they usually carry much heavier currents and at higher voltages. They are of course made of copper, as this we know is one of the very best conductors of electric current, and its softness and flexibility make it very desirable for use in inside wiring.

The very low resistance of copper enables it to carry the current with much less loss by voltage drop and heat. So copper wires and cables are used almost entirely for wiring for light and power. Copper wires for interior wiring are usually "annealed" or softened by a heating process as this makes the copper much more flexible and improves its conductivity.

We found that No. 18 or 16 B. & S. (Brown & Sharpe) gauge wires were used for bell wiring, but No. 14 is the smallest sized wire allowed in wiring for light and power. Sizes 14, 12, 10 and 8 are used in solid wires, but when used in conduit the larger sizes are stranded to obtain greater flexibility.

9. INSULATION

Bare conductors can be used in a few places such as on switchboards and distribution panels where they can be rigidly supported and held apart on proper insulators, or insulating panels. For general wiring, however, the wires must be properly insulated to prevent persons from coming in contact with them, and also to prevent short circuits and grounds which would not only interfere with operation of the attached equipment, but also cause fire hazards.

Rubber and braid coverings are the most common forms of insulation. The rubber being of extremely high resistance to electricity provides the best insulation to confine the current to the wires and prevent leakage to the other wires or metal objects. The cotton braid covering is used over the rubber to protect it from mechanical injury. This is called ordinary rubber covered (R.C.) wire, sometimes designated by the letter "R" only.

It is made with both single and double braid coverings, and is very generally used in interior wiring. Fig. 2 shows three forms of rubber and braid insulation on solid wires, and Fig. 3 shows both a solid and a stranded wire with their insulation.

For outdoor use, we have wires with weather proof (W. P.) insulation, consisting of three or

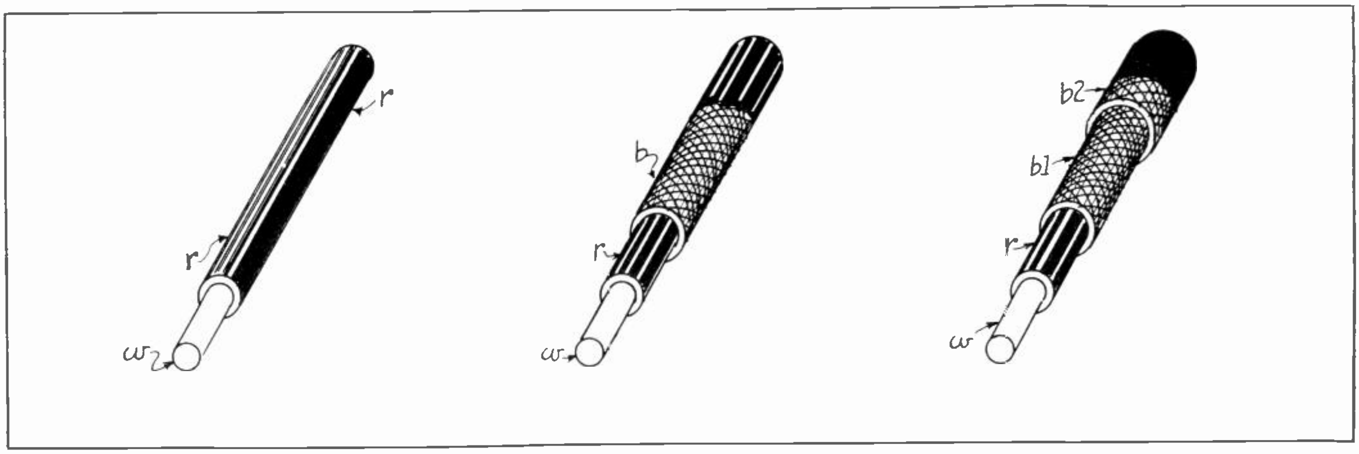


Fig. 2. Three samples of insulated conductors. The wire at the left is covered with rubber only. The one in the center has a layer of rubber and one of cotton braid. The one on the right has one layer of rubber, and two layers of braid. These would be called respectively: Rubber covered (R. C.), Rubber and braid covered, and Rubber and double braid covered.

more layers of braid, soaked or impregnated with moisture resisting compound of a tarry nature.

This kind of insulation is much cheaper than rubber, and is required for outdoor use in many cases, and in some damp locations inside buildings. It should not be used where it is subject to heat or fire, as it is inflammable.

Fig. 4 shows three pieces of wire with weather proof insulation.

For places where the wire is subjected to heat but not moisture, **Slow Burning** (S. B.) insulation with fire resisting braids is used.

Some wires for use in very dry hot places, or for heater cords, are covered with a layer of asbestos fibres for maximum heat and fire resisting insulation.

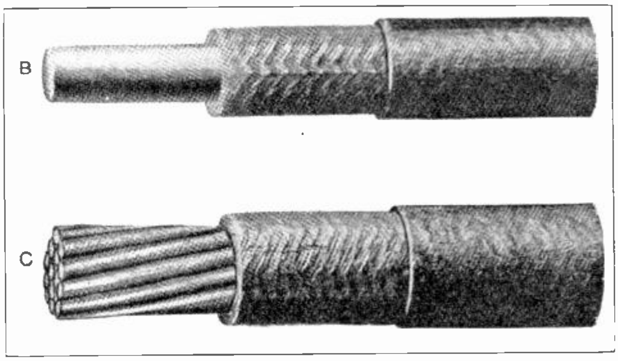


Fig. 3. Examples of solid and stranded conductors with their insulation. The stranded conductors are used in the large sizes because they are more flexible.

Some wires are also prepared with a combination of slow burning and weather proof insulation (S. B. W.). Two such wires are shown in Fig. 5.

Insulated wires are often made up in twisted pairs as shown in Fig. 6, for lamp cords and leads to portable devices. Such wires are usually made of many strands of very fine wires for good flexibility.

The copper wires are usually "tinned" or coated with a thin layer of lead and tin alloy, to prevent corrosion from contact with the chemicals in the rubber, and to make it easier to solder them when splicing.

The outer braid coverings on wires are sometimes made in different colors, particularly black and white, or light gray; or with a colored thread woven into them in order to easily mark or identify certain wires. Reasons for this will be explained later.

For extremely damp places or where wires are to be run under ground, we have wires and cables with a lead sheath over the insulation.

10. WIRE SIZE VERY IMPORTANT

Copper wires can be obtained in almost any desired size and with a variety of insulations for various uses.

It is very important to use wires of the proper size for any wiring job, because if they are too small for the current load they have to carry, they will

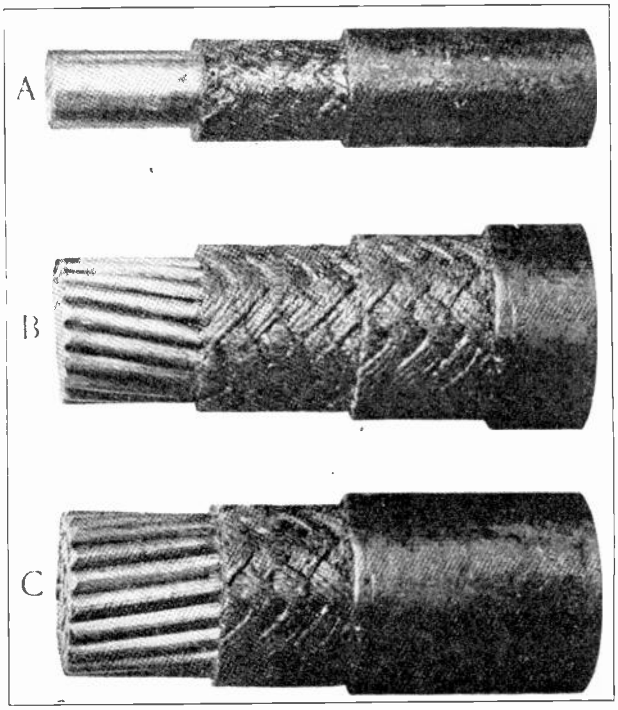


Fig. 4. These wires have what is called "water-proof" insulation, or braid filled with tarry water-proof compound. They are for use outdoors or in damp locations.

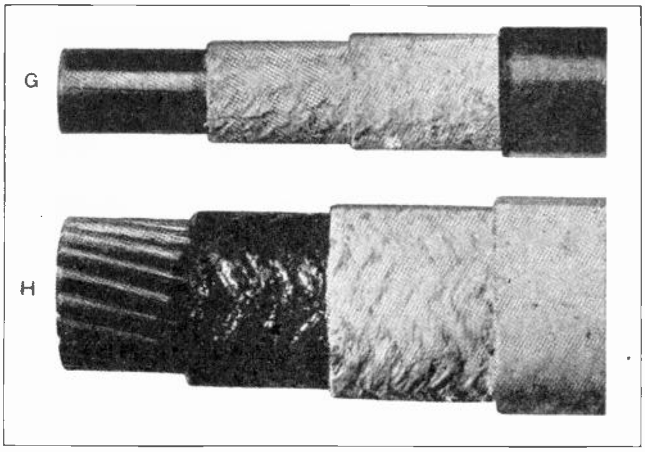


Fig. 5. In this view the upper conductor has a special fire resisting covering known as "slow burning" insulation. The lower conductor has a combination covering of both water-proof and slow burning insulation.

overheat. Excessive heat not only increases the resistance of the wire and creates a greater voltage drop and energy loss, but it also damages the insulation and in some cases results in completely burned out wiring or causes fires.

If wires that are too small are used, the excessive voltage drop causes the lights or equipment to receive less than their rated voltage, which usually results in their unsatisfactory operation. This is particularly true of lighting systems, as a very few volts drop will cause an incandescent lamp to deliver much less than its rated light.

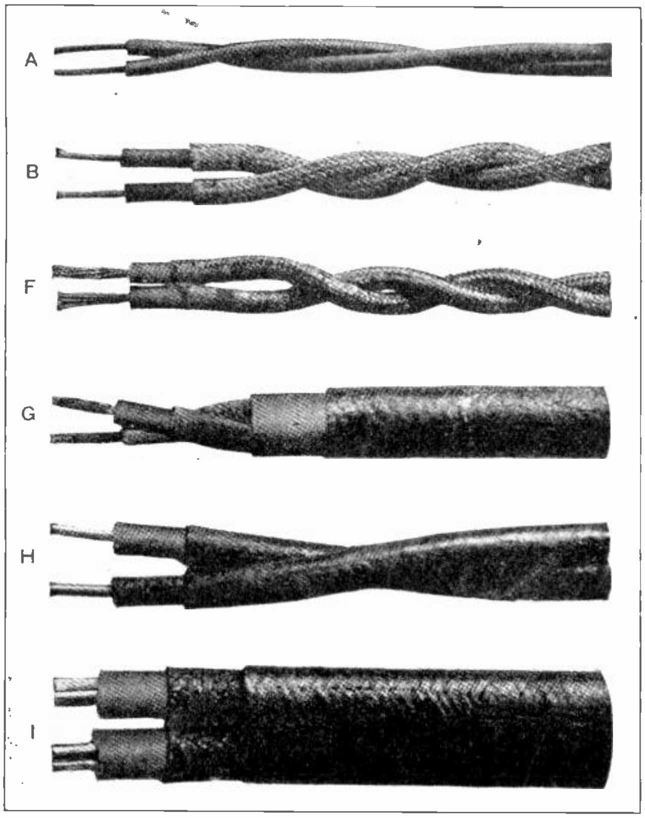


Fig. 6. Conductors are often arranged in pairs for convenience in running two-wire cicuits. Several types of these are shown above.

The National Code specifies the maximum amount of current that shall be allowed on the common sized wires, and this should be followed closely for safe and satisfactory results in any wiring system.

Fig. 7 shows a convenient table which gives the maximum curent capacity of each size of wire from No. 18 up, and for rubber insulation.

If wires are allowed to carry more than these amounts of current for any length of time, they will heat up and the rubber will rapidly lose its insulating quality at these higher temperatures.

B. & S. Gage	Diam. of Solid Wires in Mils.	Area in Circular Mils.	Table A Rubber insulation Amperes
18	40.3	1,624	3
16	50.8	2,583	6
14	64.1	4,107	15
12	80 8	6,530	20
10	101.9	10,380	25
8	128.5	16,510	35
6	162.0	26,250	50
5	181.9	33,100	55
4	204.3	41,740	70
3	229.4	52,630	80
2	257.6	66,370	90
1	289.3	83,690	100
0	325.	105,500	125
00	364.8	133,100	150
000	409.6	167,800	175
		200,000	200
0000	460.	211,600	225
		250,000	250
		300,000	275
		350,000	300
		400,000	325
		500,000	400
		600,000	450
		700,000	500
		800,000	550
		900,000	600
		1,000,000	650
		1,100,000	690
		1,200,000	730
		1,300,000	770
		1,400,000	810
		1,500,000	850
		1,600,000	890
		1,700,000	930
		1,800,000	970
		1,900,000	1,010
		2,000,000	1,050

Fig. 7. This very convenient table gives the current carrying capacity for the various sizes of wire, and also their diameter, and area in circular mils.

For wires with other insulation such as slow burning or weather proof coverings, you can allow from 25 to 50 per cent more current, as these insulations will stand slightly higher temperatures without damage.

Examine the table in Fig. 7 very carefully, and become familiar with its use, as it will be very convenient to you many times from now on.

The first column gives the wire sizes in B. & S. gauge numbers, from 18 to 0000 or "four ought" as it is called. From this size up the larger cables have their sizes given in circular mil area, and can be followed on down the third column to 2,000,000 circular mils.

The second column gives the diameter of the bare wires in mils (thousandths of an inch), and the third column, as before stated, gives the cross sectional area of each size in circular mils. Then in the last column can be found the proper maximum current allowed for any wire.

The term **Circular Mil** means the area of a round wire one thousandth (1/1000) of an inch in diameter. This is the common term for rating and calculating sizes of electrical conductors, and will be covered more fully in a later section on wire calculations.

The longer a wire, the greater is its resistance, and the **Voltage Drop is proportional to both the Resistance and the Current carried.** Therefore, where the wire runs are quite long, we may not wish to allow even the amount of current that the code table does, because the voltage drop would be too great.

In such cases we can determine the exact size of wire to use for any given current load and any desired voltage drop, by use of a simple formula which will also be given and explained in the section on wire calculations.

Referring again to the table in Fig. 7, you will note that the larger the gauge number the smaller the wire. This is a good point to keep in mind so you will not become confused on the sizes and numbers.

Fig. 8 shows a wire gauge often used to determine the exact size of a wire by slipping the bare end of the wire in the slots until one is found that it just fits snugly. The gauge number is marked on the disk at that slot. Be sure to fit the wire to the straight slot and not in the circle at the end of the slot.

Fig. 8. A wire gauge of this type is commonly used to determine the size of wires for various uses.

It often comes in very handy to remember that when you have a wire of any certain size, another wire three sizes larger will have just about double the area; or one three sizes smaller, about one-half the area. For example, a number 3 wire is just about double the area of a number 6; or a number 2 wire just half the area of a number 00.

Another very handy fact to remember is that a number 10 wire has approximately one Ohm resistance per thousand feet, and a number 14 wire has about 2.5 Ohms per thousand feet.

11. SPLICING

In running wires for any electrical system, it is necessary to make numerous splices of various kinds, and a good knowledge of proper methods of splicing and soldering is of the greatest importance for any electrician to have, whether he follows new wiring or merely maintenance and repairs.

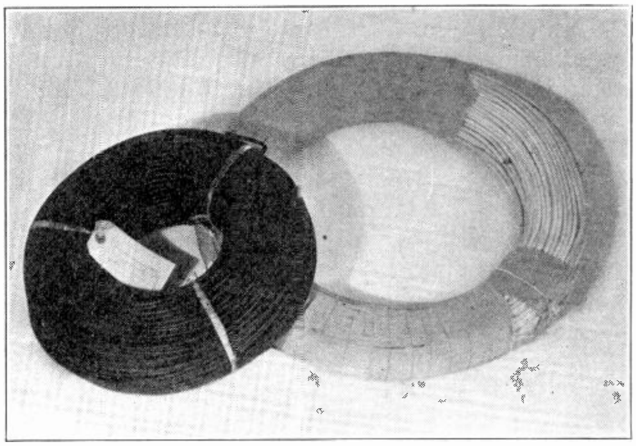


Fig. 9. Two coils of ordinary rubber and braid covered No. 14 wire, such as commonly used in house wiring jobs. The advantage of having the insulation in black and white colors will be explained later.

The old saying that a chain is no stronger than its weakest link, applies in slightly different words; almost as well to a wiring system or, the circuit or system is no better than its splices.

Splices properly made and soldered will last almost as long as the wire or its insulation, but poorly made splices will always be a source of trouble and will overheat, burn off their taping, and cause high resistance circuits and sometimes fires.

A good test of an electrician is in the kind of splices he makes.

The requirements for a good splice are, that it should be **Mechanically and Electrically Secure** before the solder is applied. Solder is then applied, not to strengthen the splice or improve its conductivity, although it does do both to some extent, but for the real purpose of preventing corrosion and oxidization of the copper.

12. COMMON TYPES OF SPLICES

Several of the more commonly used splices are the **Pigtail, Western Union, Tee** or **Tap, Knotted Tap, Fixture Splice,** and **Stranded Cable Splice.** Each of these will be explained in detail.

13. STRIPPING AND CLEANING WIRES

The first very important step in making any splice is to properly strip and prepare the ends of the wire. Stripping means removing the insulation from the wire a proper distance back for the splice to be made. This may range from 1½ inches to 3 or 4 inches for various splices.

The rubber and braid should be removed with a knife, as shown in the upper view in Fig. 10. The knife and wire should be held in a position similar to that used when sharpening a pencil, and the braid and rubber cut through at an angle as shown. Be very careful not to cut or nick the wire, as it reduces the conducting area, and makes it very easy to break at that point.

Never cut the insulation as in the lower view in Fig. 10, as one is almost certain to nick the wire in cutting in this manner, and it makes a more difficult splice to properly tape.

After cutting through the insulation and down to the wire, let the blade slide along the wire, stripping the insulation to the end; keeping the blade almost flat against the wire, so it does not cut into the copper.

After removing the insulation with the knife the wire should be scraped with the back of the blade, to remove all traces of rubber and until the wire is thoroughly clean and bright. If the wire is tinned do not scrape deep enough to remove the tinning, but leave on as much as possible, as it makes soldering easier.

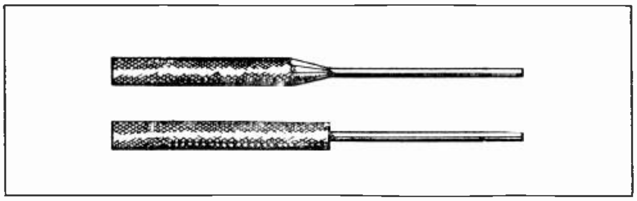


Fig. 10. This sketch shows the proper method of stripping the insulation from a wire in the upper view. The lower view shows the wrong way.

It is impossible to do a good job of soldering if the wires have bits of rubber, dirt, or grease left on them, and as they are very difficult to clean after they are spliced, be sure to do it properly before starting the splice.

A number of wire stripping tools are made and on the market, and some of them are quite fast in operation, but for rubber covered wire and for doing the work right on the job, nothing is much handier than a good sized electricians' knife with a sturdy blade of good steel. A piece of sandpaper can be used to clean the wire if desired.

14. "PIG TAIL" SPLICE

To start a **Pig Tail** splice, strip and clean about two inches on the end of each wire, then hold the wires as in Fig. 11-A, and twist them together a few turns with your fingers; then finish the ends with a pair of pliers. Be sure that both wires twist around each other, and that one does not remain straight while the other wraps around it. They should appear as in Fig. 11-B.

This splice should have at least five good tight turns, and then its end should be bent back as in Fig. 11-C to prevent it from puncturing the tape.

Three or more wires can be connected together by a pig tail splice, and it is commonly used in making splices of wire ends in outlet boxes, and at places where there is no strain on the wires.

In making any splice, always be sure to wrap or twist the turns tightly around each other, as they should not be able to slip or shift upon each other when the splice is complete but not yet soldered. Make the splice itself tight and strong, and don't depend on the solder to do this.

15. WESTERN UNION SPLICE

For splicing straight runs of wire the **Western Union** splice is one of the oldest and most commonly used. It is a very strong splice and will stand considerable pull and strain on the wires. It can be used for splicing large solid conductors and line wires as well as the smaller wires.

In starting a Western Union splice, strip and clean about four inches of the end of each wire.

Hold the ends together tightly with your hand or pliers as in Fig. 12-A, gripping them at the point where they cross. Twist them together a couple of gradual or spiral turns as in Fig. 12-B. These are often called "neck" turns. Then wrap the end of each wire around the other wire in five or six neat, tight turns as in Fig. 12-C. A little practice will be required to get the knack of wrapping these ends tightly and smoothly by hand. If one or two turns do not grip the straight wire tightly, pinch them down carefully with the pliers.

To finish this splice, trim the ends off and pinch them down tight with the pliers, so they will not project and damage the tape later. The splice should then appear as in Fig. 12-D.

Practice making this splice a number of times, as it is one of the most common and important ones used, and every practical man should be able to make it well. Each time you make it examine it carefully and try to improve until it is perfect.

Be careful not to nick or mar wires any more than necessary with the "bite" of your pliers, when gripping them during splicing.

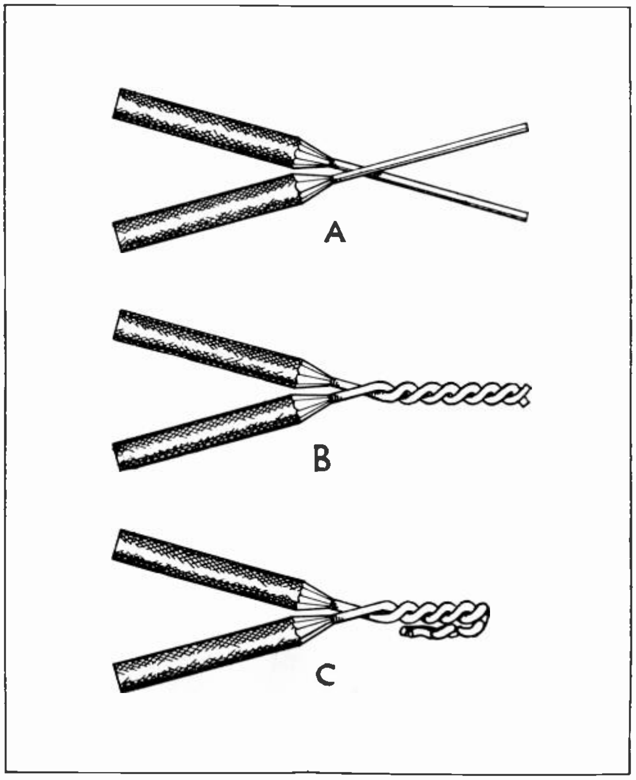


Fig. 11. This diagram shows very clearly the several steps in making a "Pigtail" splice. Examine it very carefully.

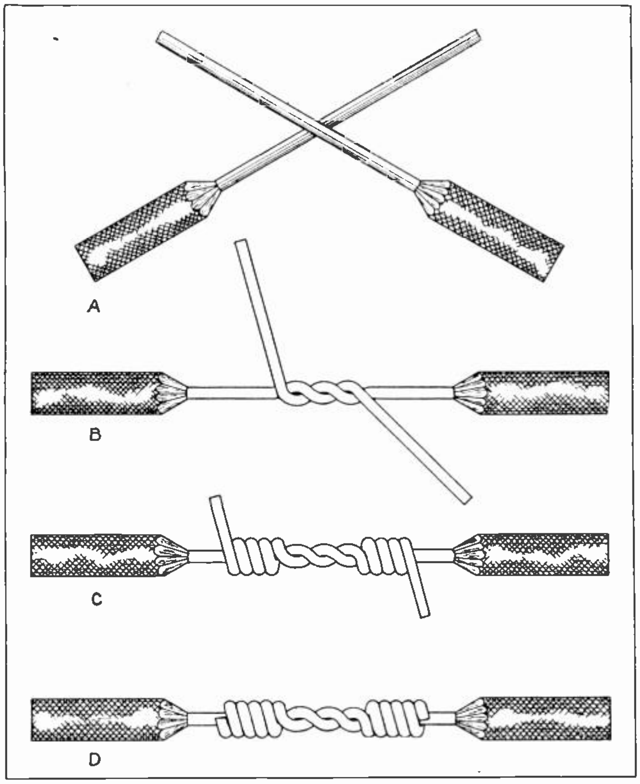


Fig. 12. The above four sketches show the steps and procedure in making a "Western Union" splice.

When making a double Western Union splice in a pair of wires together, always stagger them as shown in Fig. 13, so each splice lies near to undisturbed insulation of the other wire, and so they do not make a large bulge when taped.

Fig. 13-A shows how the ends of the wires should be cut in uneven lengths for such a splice. In 13-B is shown the method of spreading them apart to make the splices, and in 13-C the appearance of the finished splice, before soldering and taping.

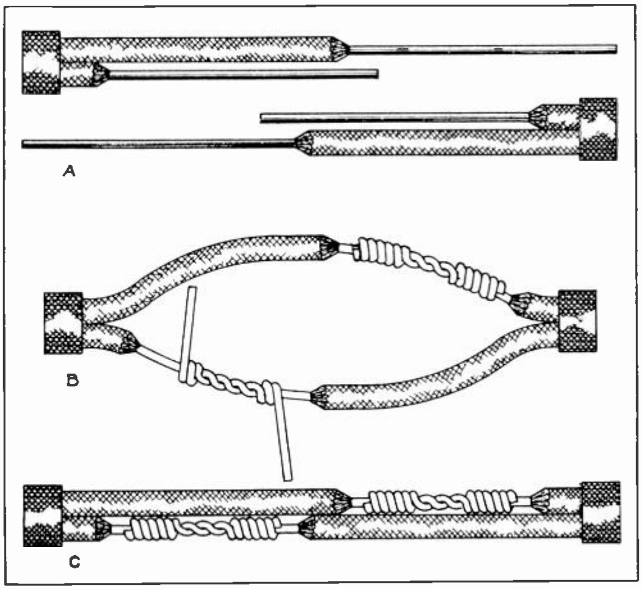


Fig. 13. When making splices in pairs of conductors they should be staggered as shown above so each splice will be near to good insulation on the other wire.

16. TAP OR TEE SPLICE

When a tap or branch is to be connected to a main or "running" wire, we use the **Tap** splice shown in Fig. 14. For this splice, bare about 1 inch on the main wire, and about 3 inches on the end of the tap wire. Then wrap the tap wire tightly about the main wire from five to eight turns, as shown in the figure. The turns should be tight enough so they cannot be slid along the straight wire.

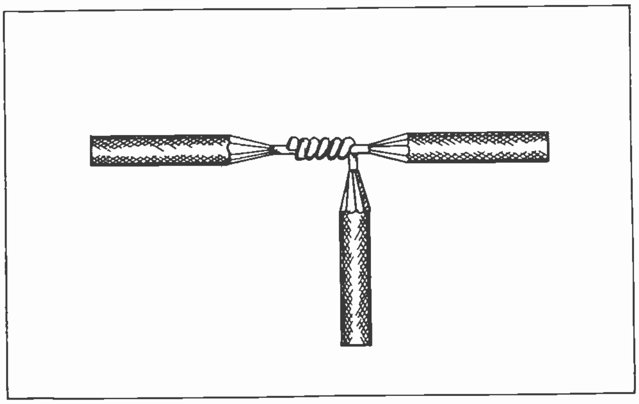


Fig. 14. Simple "Tap" splice used for tapping a "branch" wire to "main" or "running" wires.

17. KNOTTED TAP SPLICE

Where there is a possibility of some pull or strain on the tap wire, we can use the **Knotted Tap** splice which cannot be pulled loose as easily. This splice is shown in Fig. 15, and is very easily made, by simply giving the wire one turn on the side of the tap wire opposite to the side on which the main group is to be, and then doubling back around the tap wire, and winding the balance of the turns in the opposite direction around the main wire. This locks the first turn so it is very secure and hard to pull loose.

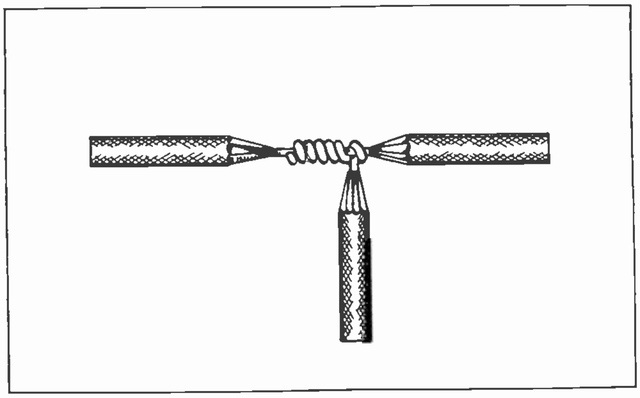


Fig. 15. "Knotted Tap" splice. Note carefully the manner in which the wire is first looped around the branch conductor to lock it securely in place.

18. FIXTURE SPLICE

The **Fixture Splice** which is often used to fasten together two wires of different sizes, is shown in Fig. 16. The various steps in making this splice are as follows: First bare about 5 inches of the end of one wire, and 3 inches on the other wire; then

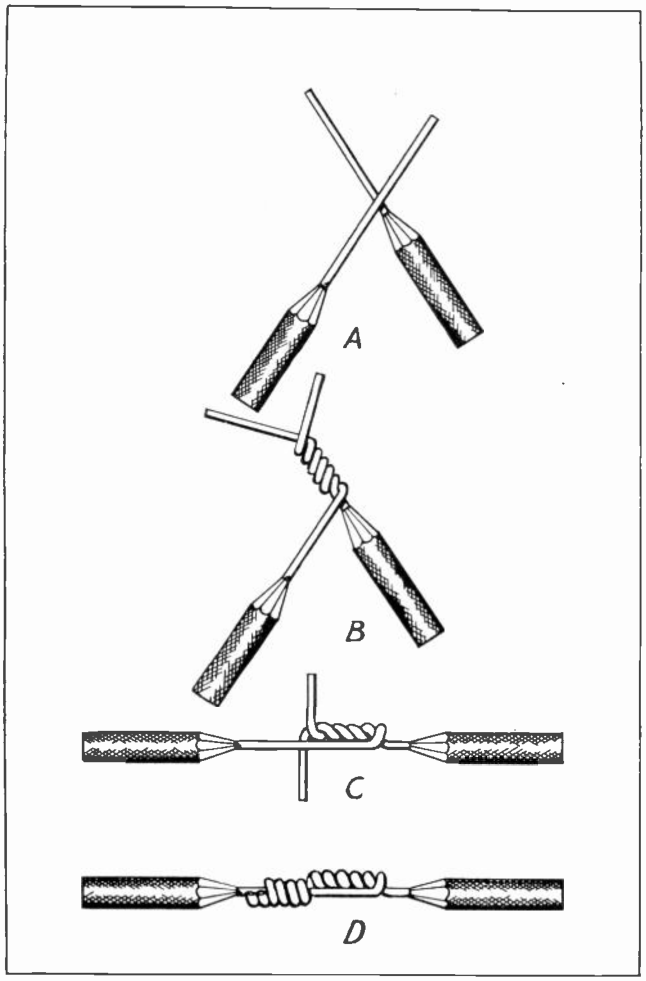


Fig. 16. The above views show the method of making a "Fixture" splice, which is used for connecting together two wires of different sizes.

place them together as shown in Fig. 16-A, with about half the length of the longer bared end crossing the other end, near the insulation. Then twist them both together, as in "B", being sure that they both twist about each other evenly. Then spread the wires apart and bend the twisted ends down tight to the longer remaining bare strip as at "C", and wrap both ends tightly around the wire at this point. The finished splice is shown at "D".

19. CONVENIENT SPLICE FOR LARGE SOLID WIRES

Another splice that is very handy for connecting large solid wires together is the one shown in Fig. 17. This splice is made by simply laying the ends of the two large wires together, overlapping from 2 to 4 inches according to their size, and then wrapping them both with a smaller wire. The smaller wire is much easier to bend, and can be quickly and tightly wound around the large ones. In addition to winding the small wire around both the large ones where they overlap, also wind it a few turns around each one at the end of the splice, as shown in the figure. The ends of the large wire should be slightly bent outward to hold the smaller wire wrapping in place, and prevent the large ones from being pulled out; but be careful not to bend them out far enough to puncture the tape. This splice when well soldered makes one of good conductivity, because of the great area of contact between the small wire turns and the two large ones.

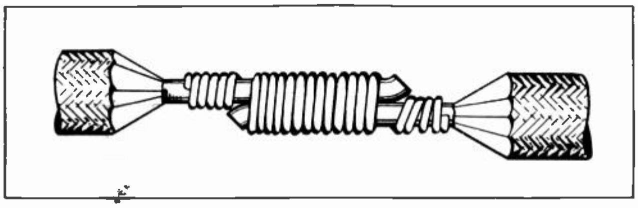


Fig. 17. A very convenient splice to use on large solid conductors. By wrapping them in this manner with the smaller wire we don't have to bend or twist the stiff heavy wires.

20. STRANDED CABLE SPLICE

There are a number of methods used in splicing stranded cables, but the most important points to keep in mind are to be sure to secure enough good contact area between the two groups of wires to carry without overheating the same load of current that the cable will, and to keep the diameter of the splice down as much as possible.

The wires should be stripped back about ten or twelve times the cable diameter, and each strand separately cleaned. Then spread the strands of each cable out fan-wise, as in Fig. 18-A, and butt the cable ends together. Sometimes it is well to cut off

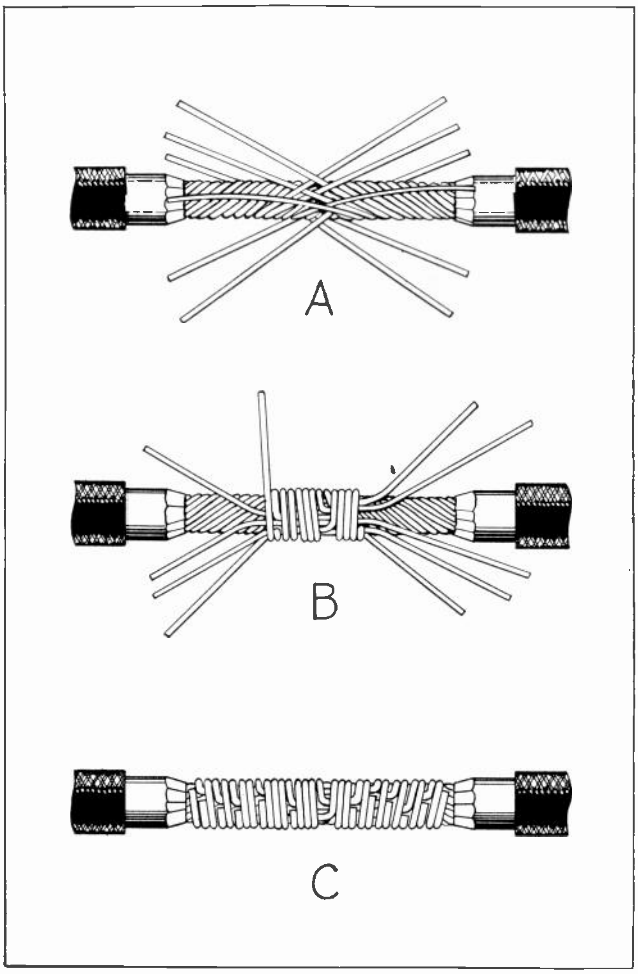


Fig. 18. Examine this diagram very closely and it will be a great help to you in making neat and efficient cable splices.

the ends of a few of the center strands at the point where they butt together, in order to reduce the diameter of the finished splice. A few less than half of the strands can be removed without reducing the current carrying capacity of the joint below that of the cable. This is because the wires of each cable overlap each other, maintaining an area equal to that of the cable anyway.

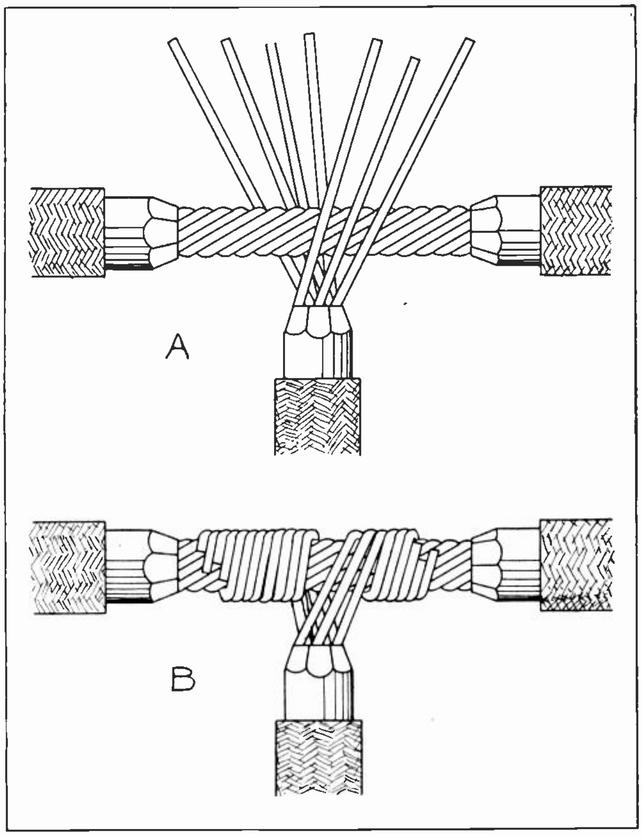


Fig. 19. Method of making a "tap" splice with stranded cables. Note how the wires of the "tap" cable are divided and each group wrapped in opposite directions around the "running" cable.

Next wrap one strand at a time around the cable, starting with strands from the outer surface of the cable, and wind these over the others which are laid tight along the cable. See Fig. 18-B. When one strand is all wound up, start with the next tight to the finish of the first, but continuing to wrap them all in one layer if possible.

The finished splice should appear neat and compact as in Fig. 18-C.

In making a tap splice with cables, bare several inches of the main cable and thoroughly clean all the outer strands, removing all rubber from the grooves with a wire brush or pointed tool or knife. Then spread the cleaned strands of the tap cable, dividing them in half and butt them against the main cable in the center of the bare spot as in Fig. 19-A. Then wrap them in opposite directions around the main cable in one layer or as few layers as possible, as in Fig. 19-B, which shows the completed splice.

21. SOLDERING SPLICES

All splices made in permanent wiring should be carefully soldered, to **Preserve** the quality and conductivity of the splice.

We have already mentioned that the main reason for soldering is not for the purpose of improving the strength or conductivity of the splice, but to prevent corrosion or oxidization from spoiling the good contact of the wires.

22. COPPER OXIDE AND ITS EFFECT ON JOINT RESISTANCE

Copper rapidly oxidizes or "rusts" when exposed to air or moisture, and also corrodes very quickly if any chemicals or chemical vapors come in contact with it.

A bright copper wire soon forms a thin brownish film of oxide on its surface if it is not tinned or covered in an air tight and moisture-proof manner. This film will even form between the wires where they are in contact with each other. Copper oxide is of a very high resistance to electric current flow, and a very small amount of it which may be almost unnoticeable, greatly increases the resistance of a splice. This would be likely to cause serious heating of the joint, after a period of possibly a few weeks or months from the time it was made, even though the splice was practically perfect when new.

A very thin layer of solder, properly applied so that it actually unites or alloys with the clean copper surface, will prevent this oxidization or corrosion, and maintain almost indefinitely, the original low resistance of the splice.

In order to obtain this proper bond between the solder and the copper, the copper must be absolutely clean, then treated with a **Flux** which makes the solder flow freely; and the solder and copper must both be well heated.

If these rules are all kept in mind and carefully followed, you can easily do a good job of soldering that will be a credit and source of pride to you on every job.

23. SOLDERING COPPERS

To heat the splice and melt the solder we use a **Soldering Copper** of the proper size, and which must be kept well cleaned, tinned, and heated. These tools are often called "soldering irons", but they are made of good copper because copper can be readily tinned so the solder will adhere to it and also flow over its surface or point; and also because copper will quickly absorb heat from a torch or flame, and easily give up its heat to the splice and solder. **Copper is an Excellent Conductor of Heat,** as well as electricity, and if you keep in mind that the function of the soldering copper is to impart its heat to the splice, as well as to melt the solder, you will find it much easier to understand soldering and will make a much better job of it. Fig. 20 shows a common soldering copper of the type that is heated in the flame of a blow torch or gas soldering furnace. Such coppers must be reheated frequently, and where much soldering is to

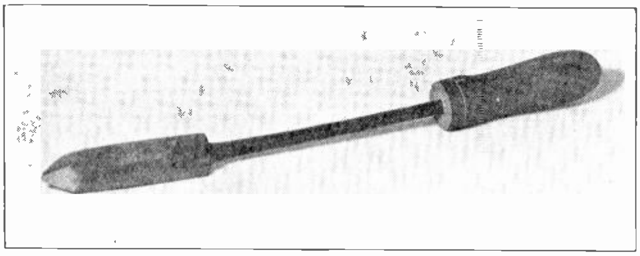


Fig. 20. An ordinary soldering copper of the type commonly used in electrical work.

be done, it is often well to use two of them so one can be heating while the other is in use. Fig. 21 shows a blow torch in use for heating an "iron".

Soldering coppers can be obtained in various sizes, the smaller ones being more convenient for some classes of work, and the large ones holding the heat longer. A half pound copper and a one pound size are generally very good for ordinary wiring.

Wherever electricity is available an electric soldering "iron" can be used very conveniently, as they remain hot while in continual use. They are made in different sizes and with various sized and shaped tips for use on different sized splices and various types of work. Two of these electric "irons" are shown in Fig. 22.

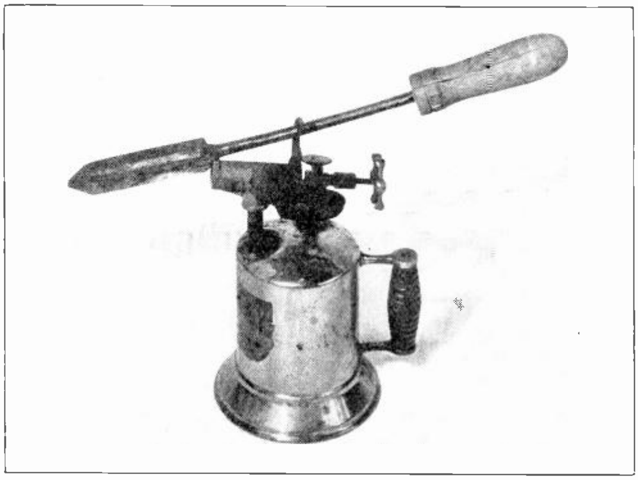


Fig. 21. This photo shows a gasoline blow torch such as commonly used for heating soldering coppers, and splices in electrical conductors.

24. CLEANING AND TINNING

The point of any soldering "iron" must be kept bright and clean and well **tinned,** or it will not "flow" the solder properly or convey its heat readily to the splice.

When very dirty or covered with a heavy scale, or pitted, they should be smoothed and cleaned with a file. When in use on the job they require occasional "brightening up". It can be done by rubbing the point on a block of salammoniac which is obtainable from electric shops and hardware stores in small cakes for this purpose. See Fig. 23.

Rub the heated point on the block and immediately apply a little solder to it in an even thin coating. This is called "tinning" the "iron". Or when a small hole is worn in the block, place a little solder in this hole or pocket and melt it with the "iron", while rubbing it in the solder and against the salammoniac at the same time.

Dipping the point of the hot soldering copper into the flux occasionally, helps to keep the tinning bright.

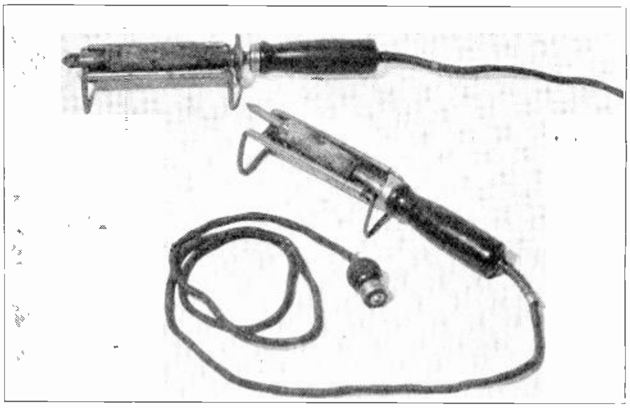


Fig. 22. Electric soldering irons are very convenient where electric current is already available.

25 SUFFICIENT HEAT IS IMPORTANT

Never try to solder a splice without a well tinned, well heated "iron" as it will only waste time and result in a poor job.

If the iron is not hot enough the solder will melt very slowly and become pasty, instead of flowing freely as it should. The iron should be hot enough so the solder will melt almost instantly when touched to its point.

When heating an iron with a blow torch or gas furnace, be sure the flame is blue and clean, otherwise it will blacken and dirty the iron.

26. SOLDER FOR ELECTRICAL USE

Solder as used for electrical work is usually made of about half lead and half tin. It can be bought in the form of long bars, solid wire solder, and "resin core" wire solder.

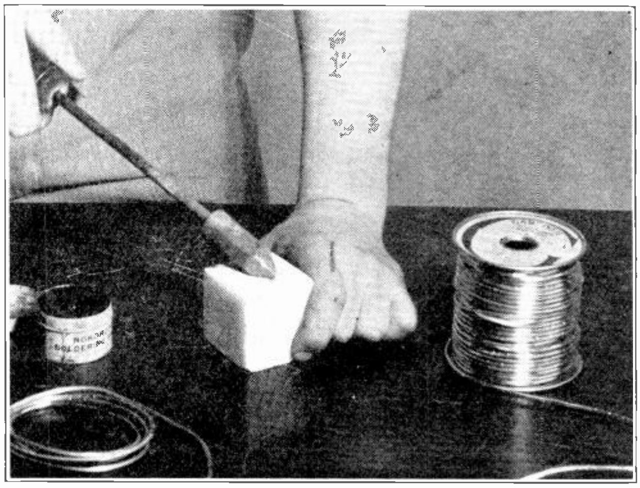


Fig. 23. This photo shows the method of cleaning and tinning a soldering copper with a block of salammoniac.

The wire solder is most commonly used for applying to small splices, and the bar solder for large cable splices and for melting in a solder pot.

The resin core solder is very convenient as the resin carried in the hollow wire acts as a flux, automatically applied as the solder is melted.

27. SOLDERING FLUX

Flux should always be used on any splice before applying the solder, as it dissolves the oxide on the metal and causes the solder to flow and unite with the metal much more readily.

Resin is a very good flux and can be used in bar form or powder, and melted on the hot splice. Muriatic acid was formerly used, and while it is a very active and effective flux, it should not be used on electrical work, as it causes corrosion of the wires later. No acid flux should be used on electrical splices.

Several kinds of good flux are prepared in paste form which is very convenient to apply.

These fluxes should be applied to the splice and melted on it with a good hot iron. Excessive flux should not be used, and none should be allowed to remain in the splice, as resin and some of the other fluxes act as insulators if they are not well melted out or "boiled out" of the solder with plenty of heat.

28. PROPER METHOD OF APPLYING SOLDER TO SPLICE

When the splice is "fluxed" the solder should be evenly applied and well melted so it runs into the crevices between the wires. It should not be dripped on the splice by melting it above with the iron. Instead the splice should be hot enough to melt the solder when it is rubbed on top of the turns.

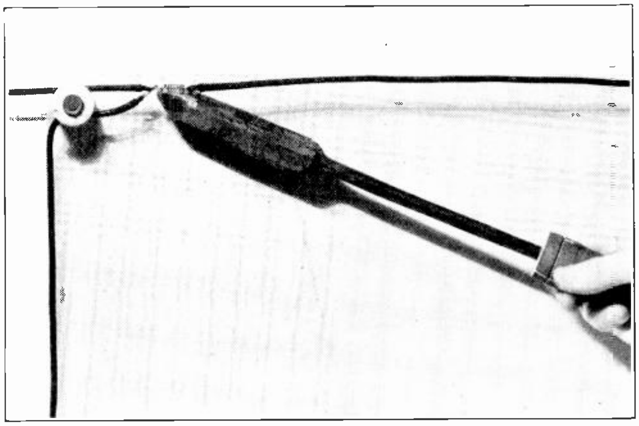


Fig. 24. Soldering copper should always be applied to the under side of the splice, as the splice can be heated much quicker in this manner. A drop of solder should be placed on the tip of the iron and pushed against the under side of the splice. This helps to conduct the heat into the splice very rapidly.

The proper place for the soldering copper is **underneath the splice,** as heat naturally goes up, and this will heat the splice much quicker. See Fig. 24.

Many beginners have a great deal of difficulty heating a medium sized splice before the copper becomes cold, because they do not understand the principle of **heat transfer** from the copper to the splice.

29. CONDUCTING THE HEAT TO THE SPLICE

Always remember that heat will travel or flow through metals much easier than through air, and while copper is an excellent conductor of heat, there is very little actual contact area between the soldering copper and the rounded turns of the splice.

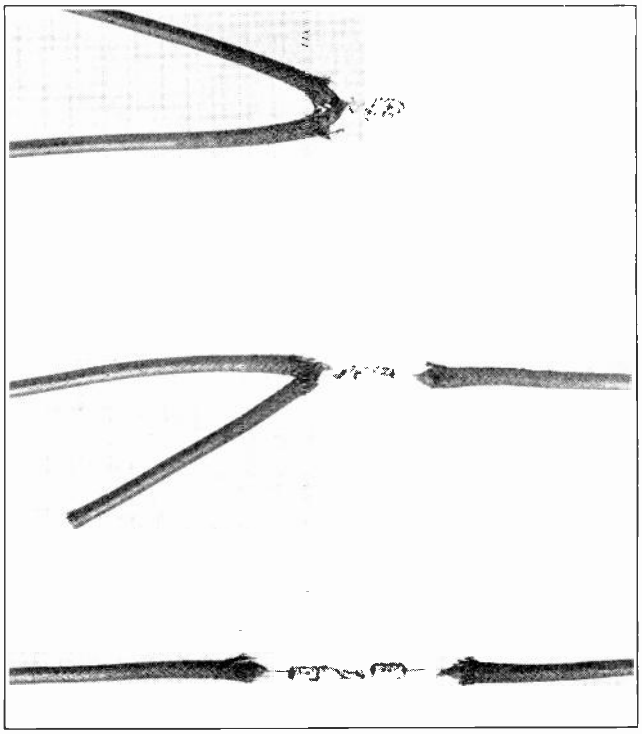


Fig. 24-B. The above three views show soldered splices of the Pigtail type and Western Union type. Note how the solder thoroughly covers and adheres to the entire splice.

Here is a simple little trick of the trade which, once you have tried it, you will never forget, and you will be surprised to see how much it speeds up any soldering job on a splice. Place the heated copper under the splice with one of the flat faces of the tip held fairly level and in contact with the turns of the splice. Then melt or "puddle" a little drop of solder on the copper, by pushing the solder wire in between the copper and the splice. This drop should melt almost instantly, and will provide a much greater area of metal-to-metal contact between the copper and the splice, and **the heat will flow into the splice many times faster,** heating it well in a very few seconds.

Then, while still keeping the good contact of the soldering copper on the bottom of the splice, run the solder on the top, allowing it to run down through the turns. Examine Fig. 24 again, and you will note the drop or puddle of solder on the iron, and the correct method of applying the solder to the splice.

Do not leave a large bulge of solder on any splice, but melt it off so that just a good coating remains on all turns.

Pigtail splices can be quickly and easily soldered by dipping them in a small ladle of molten solder.

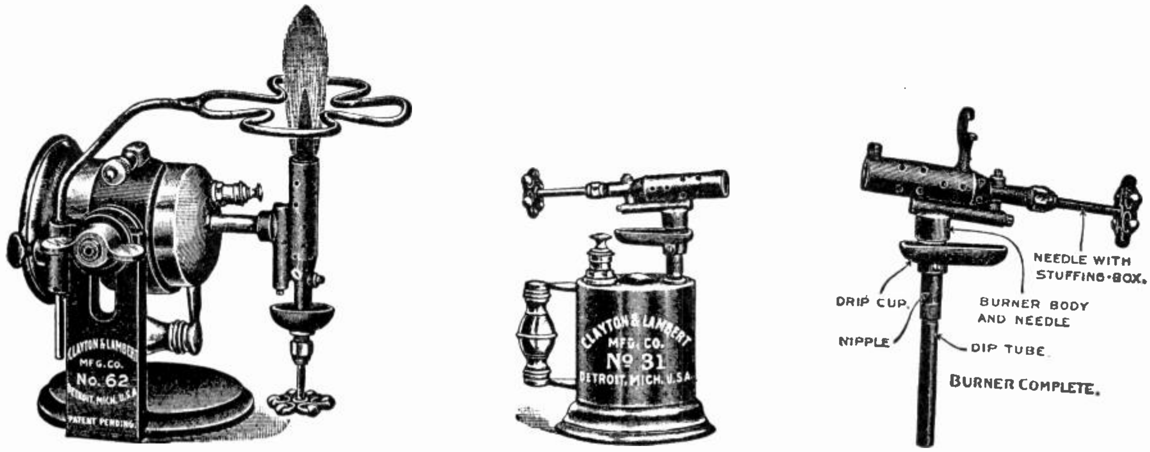


Fig. 25. This view shows the important parts of a blow torch on the right, and at the left the method of using a blow torch in a special stand for heating a lead melting pot.

Convenient small ladles or pots with long handles are made for this use.

30. SOLDERING LARGE SPLICES

When soldering cable splices, it is often difficult to get the entire splice hot enough before the soldering copper gets cold. The copper of the splice, also being a good conductor of heat, carries it away along the cable nearly as fast as the soldering copper can supply it.

For soldering the larger cable splices, a blow torch is used to heat them, or they are dipped in hot solder, or have the molten solder poured over them and the excess caught in a pan below the splice.

If the insulation near the splice gets too hot, it should be kept cool by wrapping a wet rag around it while soldering.

In using a blow torch care should be taken not to overheat or burn the copper strands, as it weakens them greatly, and also makes a poorer job of soldering.

31. BLOW TORCHES

Fig. 25 shows a common gasoline blow torch in the center view, and its burner and valve in a larger view at the right.

To start such a torch, a small amount of gasoline should be run into the drip cup and lighted with a match. This flame heats the burner nozzle directly above, and as soon as it is hot the valve can be opened allowing a fine jet of gasoline to spray into the nozzle, where it immediately vaporizes and burns with a clean blue flame of very high temperature.

If the flame is white and unsteady, the burner is not yet heated enough.

These torches have a small air pump built in the gasoline can, and the air pressure thus supplied forces the liquid up to the burner in a spray.

The valve is of the needle type and should not be closed too tightly or it will damage the needle and valve seat. After extinguishing the torch it is well to loosen the valve just a little so it will not stick when the metals become cold.

The left view in Fig. 25 shows a torch mounted in a bracket and stand for heating a lead pot.

Fig. 26 shows a regular gasoline lead pot, used for melting larger quantities of lead for large cable work.

32. CABLE LUGS

For attaching stranded cables to the terminals of machines or switchboards, and also for splicing where the splice may need to be disconnected occasionally, we use copper cable lugs as shown in Fig. 27.

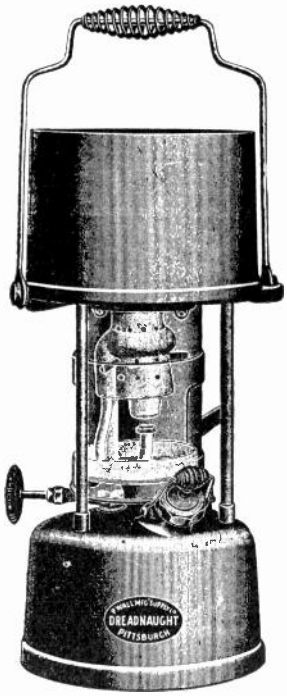


Fig. 26. Gasoline lead melting pot for use in soldering large cables, and cable sheaths.

These lugs are made in different shapes, and for single cables or a number of cables as shown. They have a hollow cup on one end for attaching to the cable, and the other end is flattened and has a hole through it, so it can be securely bolted to a terminal or another lug.

33. ATTACHING AND SOLDERING LUGS TO CABLE

To attach a lug to a cable, first strip just enough of the insulation from the end of the cable to allow the bare end to go fully down into the cup. Do not remove too much insulation, as it should cover the cable close to the end of the lug when it is attached.

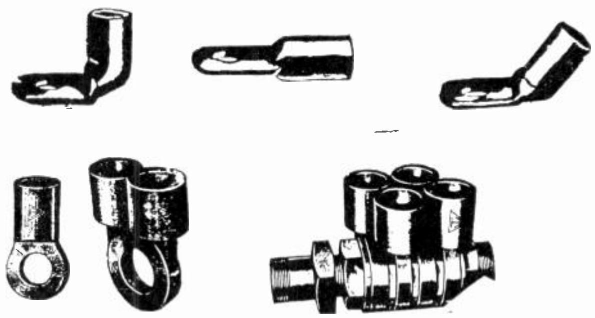


Fig. 27. Several types of soldering lugs used for connecting cable ends together or to the terminal of electrical equipment.

Clean the bared end well, and also **make sure the lug cup is clean.** Then **flux and tin** the cable tip and inside of the cup, and melt enough solder in the cup to half fill it. The lug can be held in the flame of a torch until hot and then melt the solder in it. Be careful not to burn your pliers when heating lugs, as it destroys the temper of the steel if the pliers are held in the edge of the flame. The lug can easily be held in the flame with a wire hook, and then taken in the pliers when heated and ready to melt the solder in it.

When the cup is heated and half full of molten solder, push the cable tip down in it, and hold it there while the lug can be cooled with a wet rag, causing the solder to harden quickly. Do not move the cable while the solder is hardening.

34. SOLDERLESS CONNECTORS

Solderless connectors such as shown in Figs. 28 and 29 are sometimes used for connecting cables. These devices have a sort of sleeve or clamp that is squeezed by the threaded nuts causing them to grip the cable very securely. These are much quicker to use and very good for temporary connections, but are not allowed for permanent connections in some places.

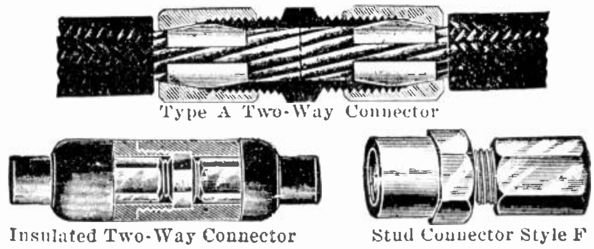


Fig. 29. Several other types of solderless connectors, showing a sectional view of the upper one which illustrates the method in which it grips the cable.

Solderless connectors can also be obtained in several very good forms for smaller wires, and are great time savers on jobs where they can be used.

Another method of splicing solid wires is by the use of the tubes shown in Fig. 30. The wires are slipped into these tubes and then the whole thing twisted into a splice.

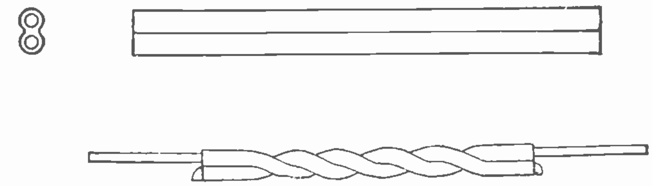


Fig. 30. Twin metal tubes of the above type are often used for splicing large solid conductors.

35. LEAD COVERED CABLE SPLICING

When splicing large lead sheath cables, the lead is split back from 10 to 36 inches according to the cable size, and a large lead sleeve slipped over one of the cable ends for use in covering the splice when it is finished. The one or more conductors in the cable are then spliced and taped.

If paper insulation is used on the conductors the moisture is boiled out of them by pouring hot molten paraffin over them. See Fig. 31.

When the splice in the conductors is finished the lead sleeve is slid over it, and its ends are joined to the cable sheath by pouring hot lead over them and "wiping" it on with a pad as it cools. This

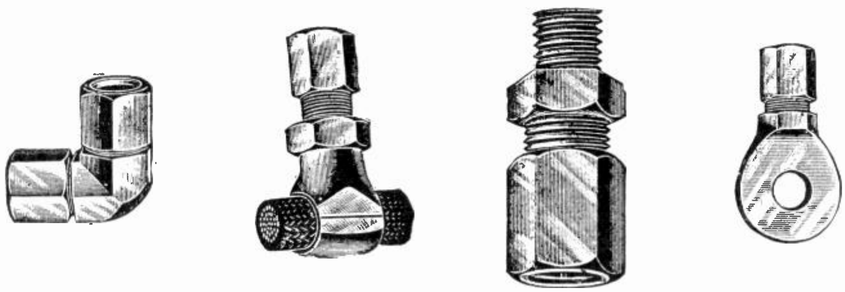


Fig. 28. Several styles of solderless connectors usde for splicing cables. These connectors grip the cable very securely when their nuts are tightened with a wrench.

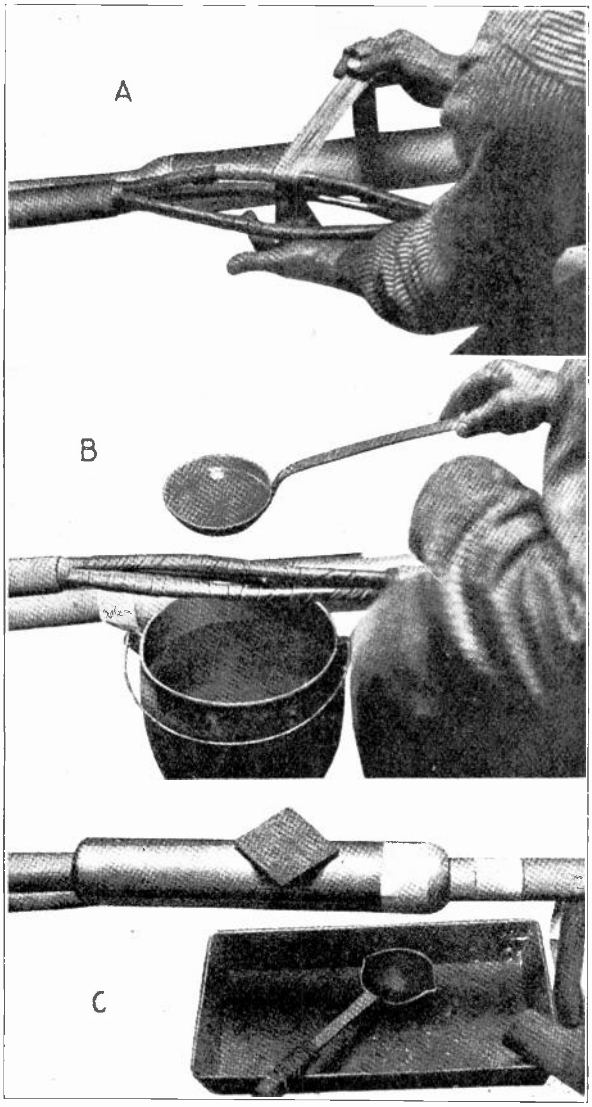


Fig. 31. This view shows several of the important steps in splicing lead covered cables.

is a very critical job and one that requires a lot of practice to get the lead on smoothly and obtain a tight junction, without melting the sheath. The whole joint is then poured full of hot paraffin or insulating compound, through a small drilled hole in the sleeve. Then this hole is plugged tight to exclude all air and moisture.

Fig. 32 shows some of the steps in making such a splice.

36. TAPING OF SPLICES

All splices on wires with ordinary rubber and braid insulation should be taped carefully to provide the same quality of insulation over the splice as over the rest of the wires.

Two kinds of tape are used for this, one a soft gum **Rubber Tape,** and the other known as **Friction Tape,** which consists of cloth filled with sticky insulating compound.

The rubber tape is applied to the splice first to provide air and moisture tight insulation of high dielectric strength, and equal to the rubber which was removed. The friction tape is then wrapped over the rubber tape to provide mechanical protection similar to that of the braid which was removed.

In applying rubber tape, cut from 2 to 4 inches from the roll and peel off the cloth or paper strip which separates it in the roll. Then start the end of this strip at one end of the splice, tight to, or slightly overlapping, the rubber on the wires. Stretch it slightly while winding it on spirally. Press or pinch the end down tightly onto the last turn to make it stick in place. See Fig. 33.

A short time after this tape is applied, it becomes very tightly stuck together in almost a continuous mass, so it cannot be unwound, but would need to be cut or torn off. This is ideal for proper insulation.

The friction tape is "peeled" from the roll and applied in a spiral winding of two or more layers.

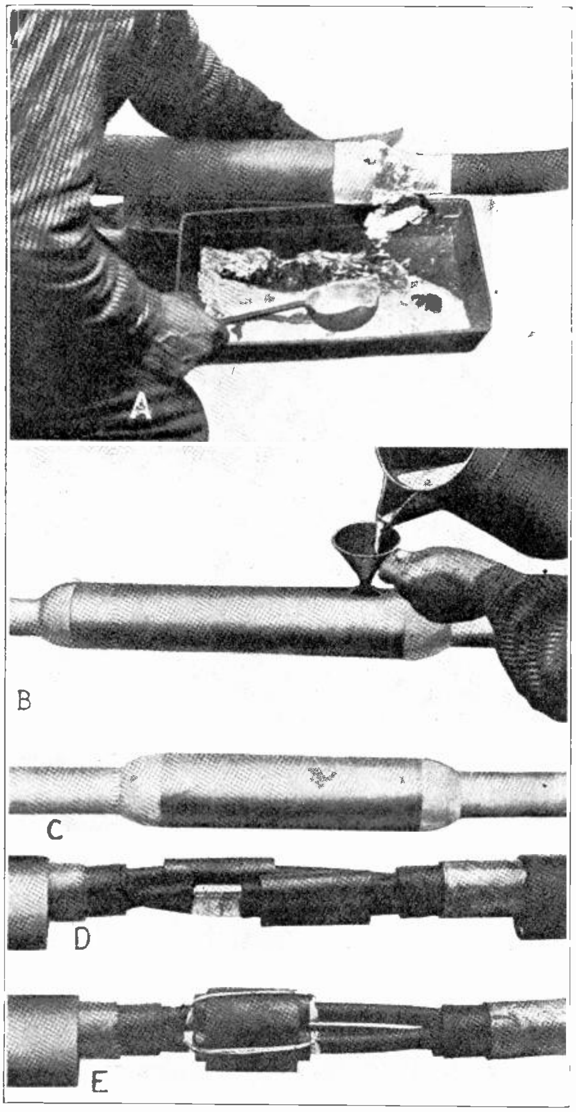


Fig. 32. "A" shows method of "wiping" the joint between the sleeve and sheath of a lead covered cable. "B", Pouring the finished splice full of hot insulating compound. "C", Finished splice with sleeve in place. "D" and "E", Small inner sleeves of insulating material are often used to separately insulate the several conductors.

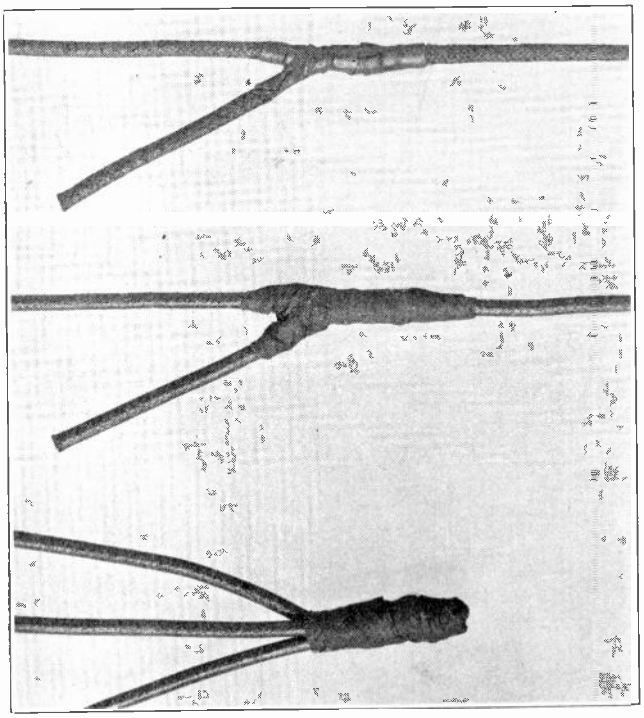


Fig. 33. The upper view shows a "tap" splice covered with rubber tape. The center and lower views show "tap" and "pigtail" splices completely taped with both rubber and friction tape.

Each turn should lap well over the preceding one. Sometimes where one has working room to allow it, the friction tape can be started on the splice without tearing it from the roll, and the roll then passed around the wire, allowing the tape needed to unwind as it is wrapped on the splice.

Friction tape can be torn off the roll, or it can be split in narrower strips by simply tearing it.

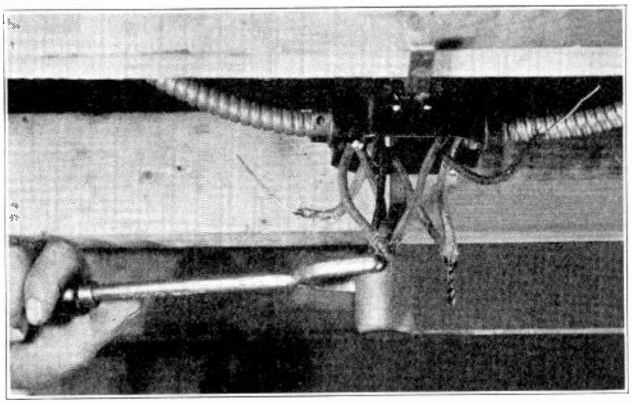


Fig. 34. Pigtail splices can be quickly and conveniently soldered by dipping in molten solder as shown.

TYPES OF WIRING SYSTEMS

While we have found that the conductors for light and power wiring have good insulation on them, we can also see that this insulation is not sufficient to protect the wires from the mechanical injury and damage they would receive if they were just run loosely and carelessly about the buildings.

For this reason and also for the sake of appearance, all wiring must be run on proper supports, and with proper additional protection to its insulation where necessary. It should be located where it cannot be bumped with moving objects, and out of the way as much as possible.

In addition to the several general classes of wiring systems we have already mentioned, this work is also divided into several types of systems according to the method of installation, and kind of materials used.

Two general divisions are: **Open** or **Exposed Wiring**, and **Concealed Wiring.**

In open wiring systems the wires are run on the surfaces of the walls, ceilings, columns and partitions, where they are in view and readily accessible.

Concealed wiring systems have all wires run inside of walls and partitions, and within the ceilings and floors, where they are out of view and not easily reached.

Open wiring is often used in mills, factories, warehouses, and old buildings, where appearance is not important, and where it may often be desirable to make changes in the wiring. One of its advantages is that it is always easy to inspect or repair.

Concealed wiring is generally used in all new buildings for homes, offices, stores, etc.; and also for many modern factories. It is much to be preferred where good appearance is important.

Another way of dividing wiring systems is based on whether the wires are run in metal or not.

NON-METAL SYSTEMS

1. **Knob and Tube Work,** where the wires are supported by porcelain knobs and tubes. This system may be either open or concealed, and is a very low cost system.

2. **Cleat Work,** where wires are supported by cleats and knobs. This system is also very low in cost but cannot be concealed.

3. **Non-Metallic Sheathed Cable.** This is one of the latest systems to be permitted by the Code, is reasonable in cost, very convenient to install, and can be run concealed or open.

4. **Wood Moulding,** where wires are run in grooves in wood strips. This is a very old system and is rapidly becoming obsolete.

METAL SYSTEMS

5. **Rigid Conduit.** Wires are run in iron pipes. This system is somewhat higher in cost, but is considered the best of all systems, and can be either open or concealed.

6. **Flexible Conduit.** Wires are run in flexible steel tubes. A very reliable system and very convenient to install in certain places. Can be either concealed or open work.

Both of the above are considered as one system by the National Code.

7. **Electrical Metallic Tubing.** Wires run in steel tubes, lighter in weight than regular conduit, and equipped with special threadless fittings. A very good system, and very convenient to install, but has certain code restrictions. Can be used only for open work.

8. **Armored Cable (B. X.).** Wires are encased permanently in a flexible steel casing at the factory, and bought this way. A very reliable system and very convenient to install. May be run either open or concealed.

9. **Surface Metal Raceways.** (Often called metal moulding.) Wires are run in thin flat or oval metal tubes, or split casings. Low in cost, but can only be used for open work.

10. **Underfloor Raceways.** Wires run in metal casings or ducts under floors. Used in factories and offices, but under certain Code restrictions.

This list of the various types of wiring systems will also give you a good general idea of their applications and the materials used. We will now cover each system in detail, with its materials, advantages, and methods of installation.

37. KNOB AND TUBE WIRING

The Knob and Tube system is one of the oldest and simplest forms of wiring, and while not as reliable as conduit, it is allowed by the National Code, and is still used to some extent in small towns and rural homes. If carefully installed it will give very good service and at very low cost of installation.

The principal materials required for a wiring job of this type, are the **Porcelain Knobs, Porcelain Tubes,** and flexible non-metallic tubing known as **"Loom".**

The knobs are used to support the wires along surfaces or joists of the building. The tubes are to protect the wires where they run through holes in joists or walls, and the loom to protect the wires through holes, or where they enter outlet boxes or run close together.

38. KNOBS

Fig. 35 shows an excellent view of a split knob of the type commonly used, and also a porcelain tube in the lower view.

You will note that the knob has grooves on each side, with ridges in them to grip the insulation on the wire. The wire can be run in either groove, but do not run two wires of opposite polarity on one knob.

The nail has a leather washer under its head to prevent splitting the knob caps when driving it tight. Care should be used, however, as it is possible to split the knob cap if it is tightened too much.

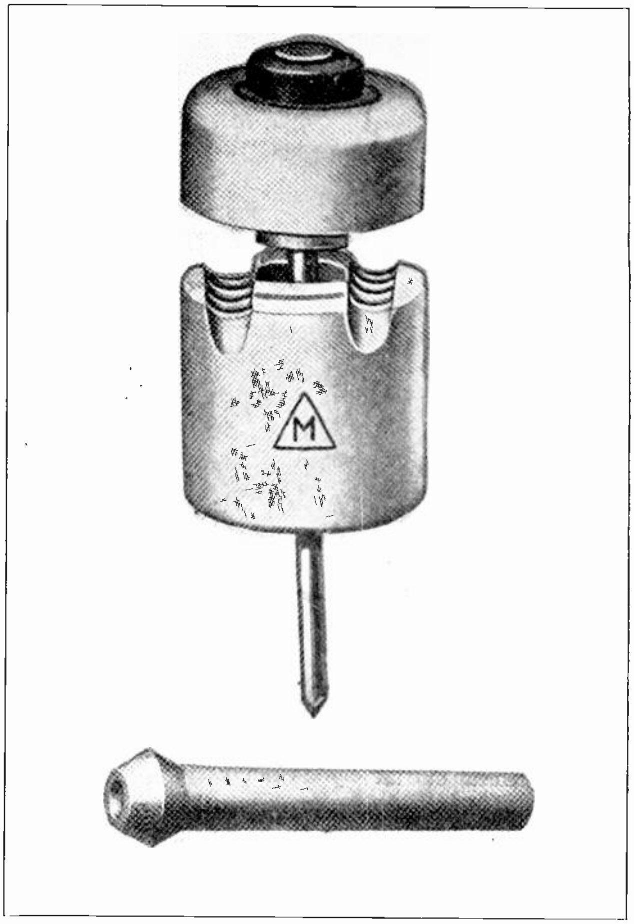


Fig. 35. The upper view shows a common type of split knob with the nail and leather washers which are used with them. Below is a porcelain tube of the type used in Knob and Tube wiring.

Knobs should be placed along the wire not farther than 4½ feet apart, and in some cases should be more frequent to provide proper support.

Before tightening the knobs, the wires should be drawn up tight so they will not sag and touch the wood, or present a bad apearance.

Wires of opposite polarity supported on knobs, must be spaced five inches or more apart.

Knobs can be used to support either horizontal or vertical wires, as long as the wires are drawn up tight.

Fig. 36 shows several styles and sizes of knobs, and also some porcelain cleats, and both a solid and a split porcelain tube.

The one piece knobs with the grooves around them must have the wires tied to them with a short piece of wire of the same size and insulation as the running wire.

Knobs must hold the wires at least an inch away from the surface wired over.

Sometimes knobs are fastened with screws instead of nails, and the ordinary split knob, such as shown in Fig. 35. would require 2½" or 3" No. 10 flat head wood screws.

39. TUBES

Wherever the wires are to run through holes in joists or walls, the porcelain tubes must be used to prevent damage to the insulation by rubbing or vibration.

The standard tube is 3″ in length and about ⅝″ in diameter and has a bulge or head on one end. Where the tube must run at a slant, the head should always be placed upwards to prevent the tube from dropping out of the hole. An exception to this is where wires enter an outlet box and the tube is held in place by the wire being bent back toward the nearest knob. The head should then be on the end which will prevent the angle of the wire from pushing it out of the hole.

Either a ⅝″ or 11/16″ wood bit can be used for boring the holes for standard porcelain tubes, and it is well to bore them with a little slant so the tubes will not tend to work out of the holes.

Other tubes can be obtained, both longer and larger than the common 3″ size.

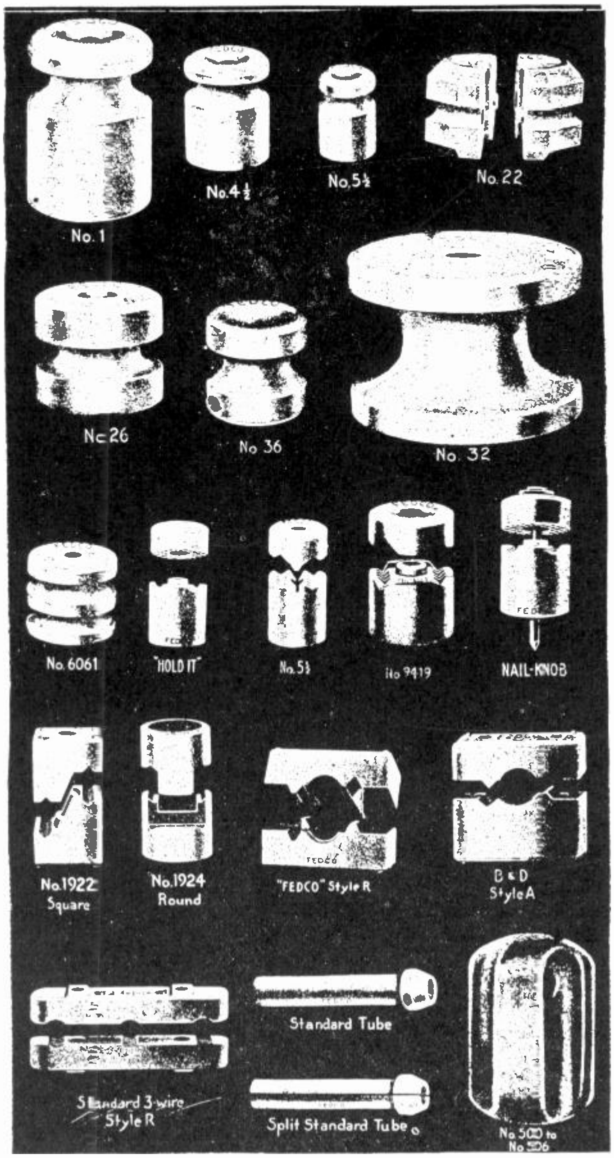


Fig. 36. Several different types of solid and split knobs, cleats and tubes.

40. LOOM

Fig. 37 shows a piece of the flexible "loom", and Fig. 38 shows a larger view of a small piece, in which you can see the inside construction of this woven insulation.

Fig. 37. A piece of "loom" or flexible insulation used to protect wires in certain places in Knob and Tube wiring.

Wherever wires enter an outlet box for a switch or lamp, a piece of loom must cover the wires from within the outlet box to the nearest knob outside the box. Fig. 39 shows a metal clamp used for fastening the end of the loom into the box. This clamp grips the loom with small teeth and wedges it tightly in the hole to prevent it from ever slipping out.

Where wires must be closer than 5 inches apart or where they must be run inside a wall, ceiling, or floor, for more than four and a half feet without knobs, they must be completely covered with loom. By protecting the wires in this manner they can be fished through difficult places in old house wiring, where knobs cannot be placed.

Fig. 38. Enlarged view showing the fabric and construction of a piece of "loom".

Some electricians occasionally try to cheat the Code and the customer by placing short pieces of loom only at each end of such a wire run, and not clear through. But when caught by a careful inspector, or when it causes a fire, such work as this costs the electrician far more than the extra loom for a good job would have cost.

In some places even in new house wiring it may be desired to run five or six wires or more between the same two joists. This cannot be done with knobs and still keep them all five inches apart. It can be done, however, by covering the wires with loom and running them all between two joists, or by grouping them all on one joist under loom straps if desired.

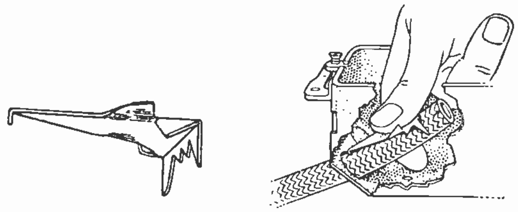
Where one wire crosses another, or crosses a pipe of any kind, if it cannot be supported well away by a knob, a porcelain tube or piece of loom five or six inches long can be slid on the wire and taped in place at its ends, to hold it directly over the wire or pipe to be crossed.

Wherever wires are attached to switches or enter outlet boxes, or where a tap is taken from a wire, a knob should be located close to this point to take all possible strain off from the splice or switch, or edge of the outlet box. See Fig. 40-A, which shows how a knob can be used both to support the running wire and to secure the tap wire and keep any strain off the splice.

Fig. 40-B shows how an extra knob should be placed near the point where a splice is made to a running wire which is not supported at this point by a knob.

Fig. 41 shows a section of a knob and tube wiring system in which you can observe a number of the parts and methods which we have mentioned for this type of work.

Examine this photo closely and note the important points shown.



The Clip Placing Clip in Box

Fig. 39. "Loom" can be fastened securely in the outlet box with clips as shown above.

41. RUNNING THE WIRES

When wiring a new building with a knob and tube system, it is quite easy to install the wiring between the joists in walls and ceilings before the lath and plaster are put on.

The wires should be run for the mains and branch circuits, and the outlet boxes for switches and lights should be installed. The boxes should be set so their edges will be about flush with the plaster surface, or a little beneath it. They should not be "recessed" or set in, more than ¼ inch at the most. These outlet boxes will be explained later.

When running wires in old buildings, advantage can usually be taken of unused attics or basement ceilings, making it quite simple to run the wires in these places. Where the wires are likely to be disturbed or injured, if run on protruding knobs, it is well to protect them by running a board along

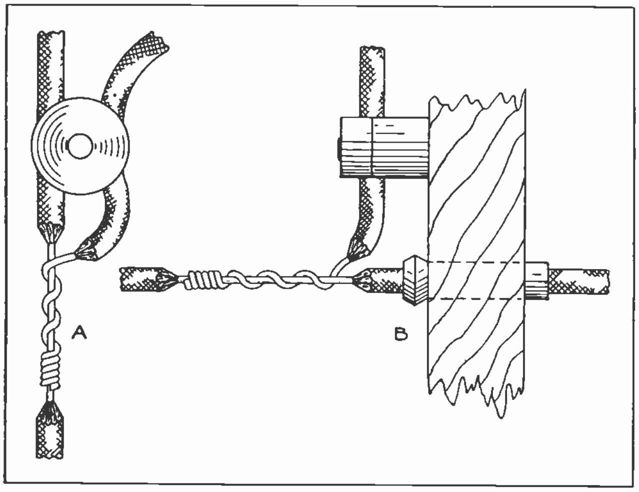


Fig. 40-A. Sketch showing a Knob used both to support the "running" wire and to keep the "tap" wire from putting any strain on the splice.

Fig. 40-B. When no Knob is near on the "running" wire an extra one should be placed on the "tap" wire close to the splice in the manner here shown.

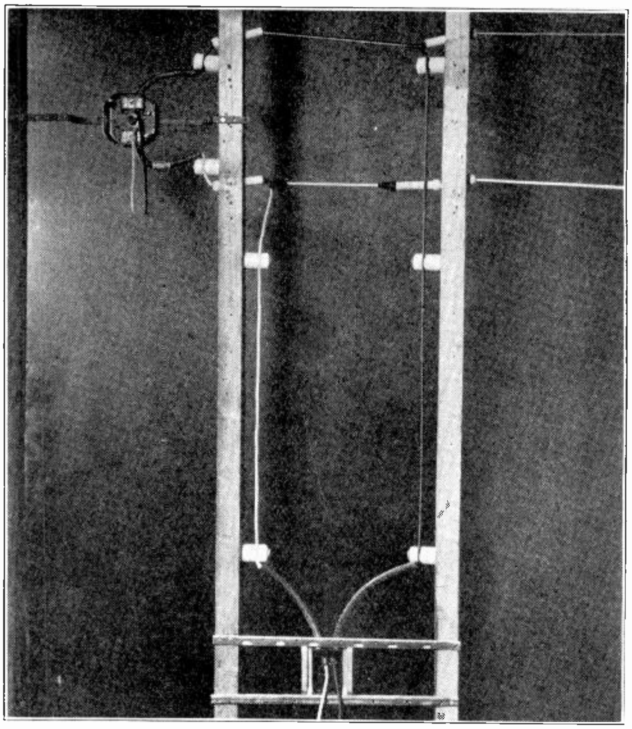


Fig. 41. This photo shows several of the most important features in a Knob and Tube wiring system. Note particularly the manner in which the "loom" extends from the outlet box, the use of the porcelain tube where the wires cross, and position of tubes in the joists when they are near to knobs as shown.

them, or by running the wires through the joists in tubes.

Where the wires are run through walls to switch boxes or wall light outlets, they can usually be pushed up or dropped down between the vertical joists and pulled out through the outlet opening.

A "mouse" and string, as formerly described in the section on signal wiring, can be used to good advantage to pull the wires through vertical walls.

Where they must be run horizontally through hollow floors or ceilings, a steel fish tape can be pushed through first, and used to pull in the wires. These fish tapes are long, thin, flat pieces of springy steel and obtainable in different sizes and lengths. They can be pushed and wiggled quite a distance through spaces between joists, and even around corners and obstructions to quite an extent. They are also used for pulling wires in conduit, as will be explained later.

Fig. 42 shows a piece of fish tape rolled in a coil for convenient carrying.

An ordinary jointed steel fishing rod, or a long thin stick with an eye in the end, can often be used very well to push wires into difficult places, or to push a string through and use it to pull the wires in with.

42. OUTLET BOXES

Where wires are attached to switches or fixtures, proper outlet boxes should be used. Fig. 43 shows a common type of outlet box for use with switches or convenience outlet receptacles. This box is made of thin steel and in sections, so it can be made wider to hold several switches or receptacles if desired.

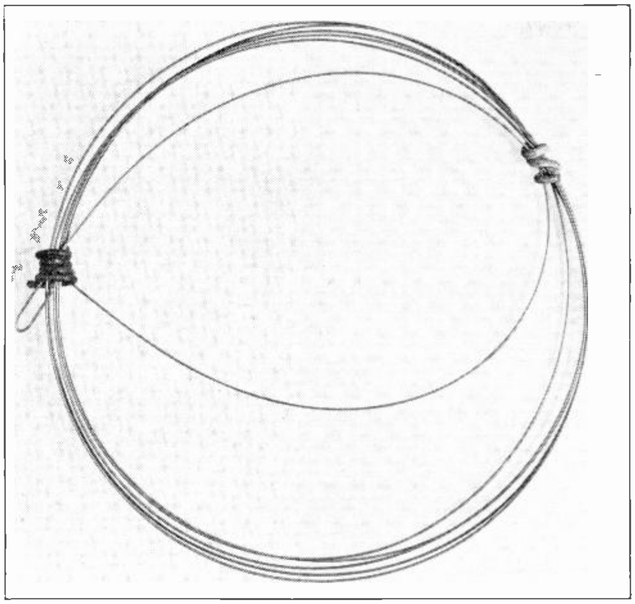


Fig. 42. A coil of steel fish tape, such as used for pulling wires into difficult places in a building, or through conduit.

The small detachable "ears" on each outer end are to fasten the box to the lath or wall, and they are adjustable so the box can be set out farther by merely loosening the screws in the "ear". These boxes have "knockout" pieces or round sections cut nearly through the metal, so they can be punched or knocked out with a hammer. These openings are for the loom and wires to enter the box for connecting the switch.

Such outlet boxes provide a rigid support for the switches or receptacles, and a protection around the back of the devices where the wires are connected.

The center and lower views in Fig. 43 show a clamping plate and screw inside the box with special shaped notches for gripping the loom or flexible conductor sheath where it enters. Note that the notches in this plate come directly over two knockout slugs.

Outlet or knockout boxes of this type can be obtained with the small knockouts to fit loom, or with larger ones for conduit, but the boxes are standard size to fit all push button or lever switches.

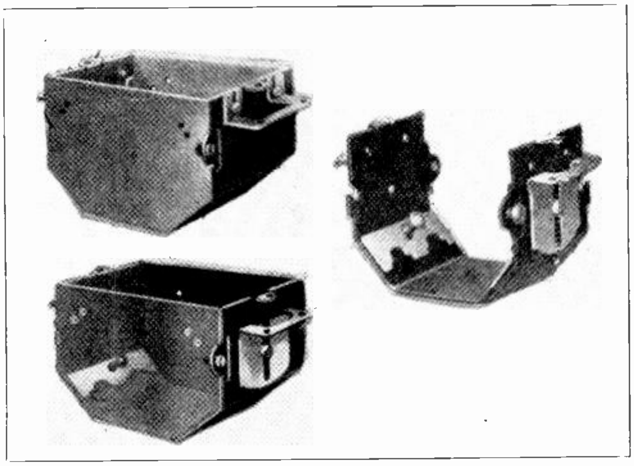


Fig. 43. Several views of a sectional outlet box of the type used for mounting switches and receptacles.

Fig. 44 shows a double outlet box for two switches or receptacles. The screws in the small "lips" at the center of each end are for fastening the switches or receptacles in the box.

Fig. 45 shows a type of ceiling outlet box, used to attach wires to lighting fixtures, and also to support the fixture. Deeper boxes of this type are often used for ceiling outlets.

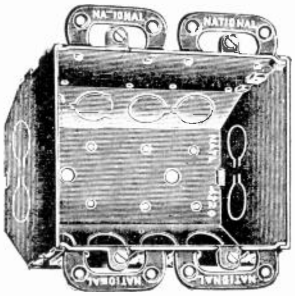


Fig. 44. Double outlet box for mounting two switches, two receptacles, or a switch and receptacle.

Fig. 46 shows some of the various types of outlet boxes and covers available. You will note that some of these have both small and large knockouts, so they can be used either with loom and knob and tube wiring, or with conduit.

Fig. 47 shows an outlet box with bar hanger used to support it between joists, and you can also note the fixture stud in the center of the box for attaching a lighting fixture. This box also contains two new style loom clamps.

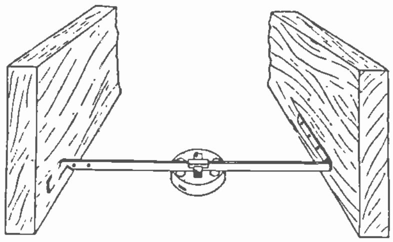


Fig. 45. A metal bar or hanger is used to support outlet boxes between the joists.

Fig. 48 shows how large solid knobs are often mounted on racks to support various numbers of power cables.

43. CLEAT WORK

In cleat wiring systems the wires are run in pairs and supported in grooves in the ends of porcelain cleats such as shown in Fig. 49. This view shows a two-wire cleat, but they are also made for three wires.

These cleats are fastened to the walls or ceilings with two screws through the holes shown. They must support the wires at least ½" from the surface wired over, and keep them at least 2½" apart.

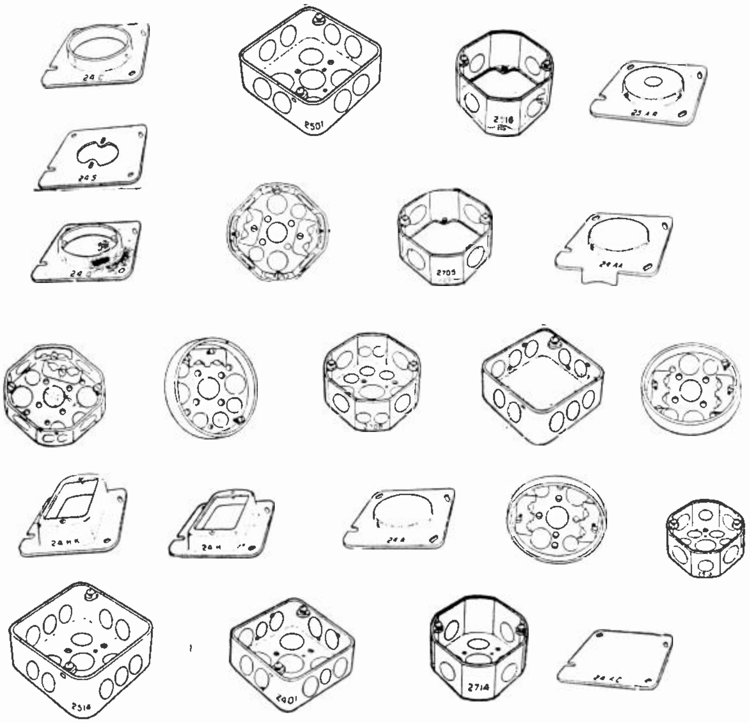


Fig. 46. Several types of outlet boxes and covers. Note the arrangement and size of the "knock-out" openings.

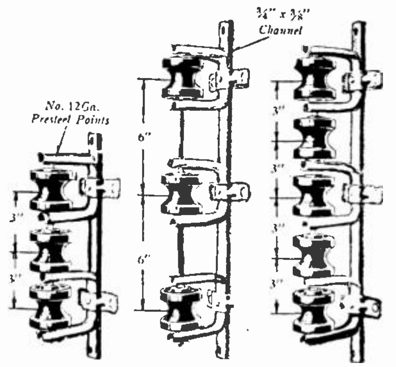


Fig. 48. Large solid knobs on special brackets of the type shown above are often used to support runs of several large wires or cables. Open wiring systems in factories and industrial plants often make use of knobs or cable racks of this type. They are very convenient to install, and the knobs can be removed by withdrawing the rod which runs through them, thus making it easy to place the wires on the inside of the knobs if desired, or in other cases they are tied to the outside of the groove with a tie wire.

Cleats should not be placed farther apart than 4½ feet along the wires, and in many places should be closer.

Cleat wiring may be used as part of a knob and tube or other system, but must always be run exposed.

Tubes or loom must also be used where the wires pass through walls or partitions.

44. CLEAT FITTINGS

To attach fixtures to a cleat wiring system we can use an outlet box that fastens to the ceiling or wall with screws and is covered by the canopy of the fixture. Loom must be used where the wires enter the box.

For installing plain lamps with reflectors only, cleat receptacles or rosettes, such as shown in Fig. 49-B. are used. The two in the upper row are to be mounted on the same surface the cleats are on, and

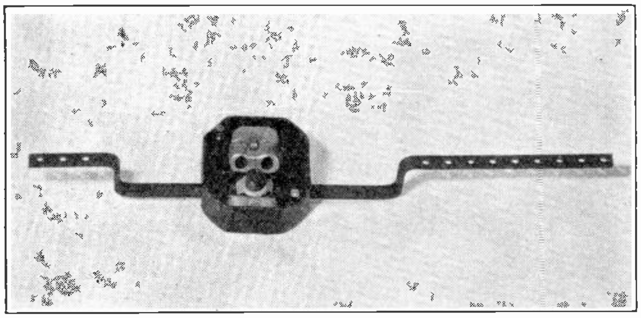


Fig. 47. This photo shows the inside of a common outlet box with fixture stud and "loom" clamps in place, and also the bar used for mounting the box.

the wires should be attached directly to the terminals of the receptacles. Lamp bulbs can be screwed into the openings shown. The two in the center row are called "rosettes" and are used to suspend lamps on drop cords. The two below are other types of drop cord rosettes, and the one at the left can be used either with cleat or moulding work.

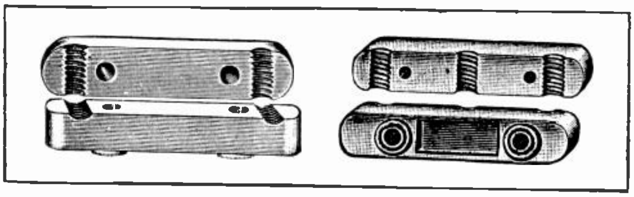


Fig. 49. Porcelain cleats of the type used for holding two or three wires in cleat wiring systems.

Surface type snap switches are generally used in cleat work, and a porcelain **Switch Back** is used to hold the switch base and wires ½ inch away from the mounting surface.

The same general rules are followed in cleat work, as were given in knob and tube work, for protecting wires where they may cross pipes or each other. We should also use cleats near splices or connections to devices, as we do with knobs, to remove any possible strain from the splices.

45. NON-METALLIC SHEATHED CABLE

This is one of the newer systems of wiring, and consists of wires encased in a covering of protective fabric. Fig. 50 is a sketch of a piece of this cable of the two-wire type, and shows the extra insulation

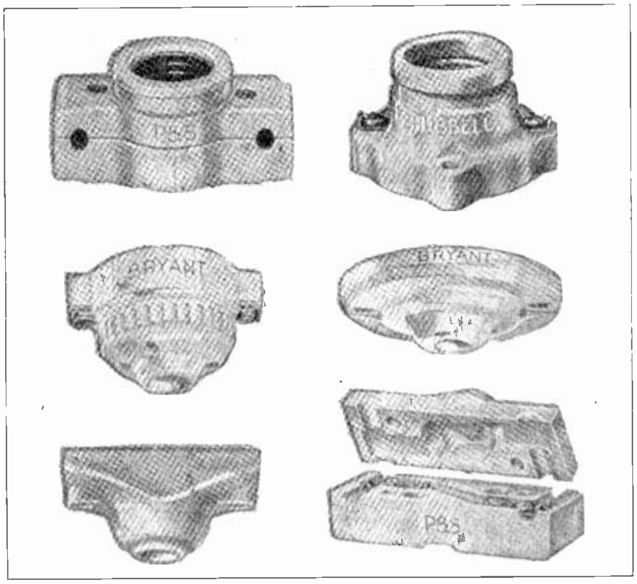


Fig. 49-B. Several types of porcelain receptacles used for attaching lamps or drop cords to a cleat wiring system.

on the wires as well as the outer covering, which is somewhat similar to loom.

This material is very commonly known as "Romex", and can be obtained in either two-wire or three-wire cables. Fig. 51 shows a piece of each kind, and the method of fastening them to the walls or partitions with metal straps.

This type of cable is very flexible and very easy to install and, as before mentioned, it can be run either exposed or concealed. In concealed wiring it can be run between joists or through holes without any additional protection, and simply fastened in place by the small metal straps, such as shown in Fig. 51.

46. INSTALLING ROMEX

These straps must not be spaced farther apart than three feet, and the cable should always be run tight to some supporting surface such as along a joist, wall, or ceiling. When run across joists or open spaces it should be supported by a board. When it is being run concealed in new buildings the straps can be placed 4½ feet apart, and in old buildings, where it is impractical to support the cable with straps, it can be fished from one outlet to another, similarly to wires covered with loom.

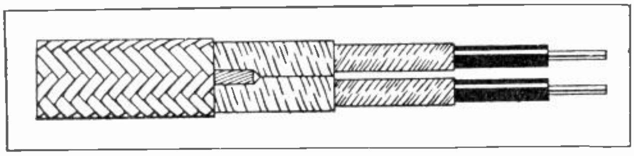


Fig. 50. This sketch shows the construction of a piece of non-metallic sheathed cable or "RomeX". Note the heavy layers of extra insulation on the wires, and also the strong outer braid covering.

Even though the original cost of this material is somewhat higher than that of the same number of feet of wire with knobs and tubes, the ease with which it can be installed makes the finished system very reasonable in cost.

In making bends in such cable runs it should be carefully done so as not to injure the covering and insulation of the cable, and the bends should have a radius of not less than five times the diameter of the cable.

Regular outlet boxes of the type already covered are used where switches and fixtures are to be installed. All cable runs must be continuous and without splices from one outlet box to the next.

Where the cable comes through the floor, or is run along a partition within six inches of a floor, it should be protected by running it through rigid conduit or pipe.

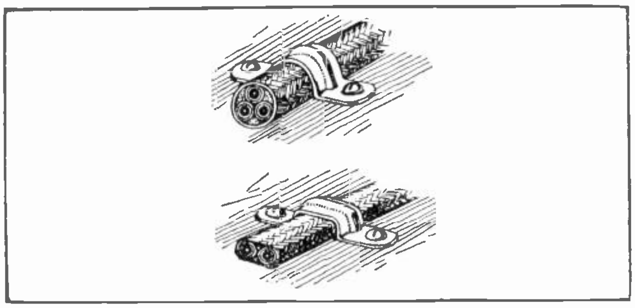


Fig. 51. This view shows a piece of three-wire and one of two-wire non-metallic sheathed cable, and also the method of attaching this cable to a surface with metal straps and screws.

47. GROUND WIRES AND FITTINGS

The newest form of this sheathed cable has a bare copper wire run under the outer covering, parallel to the insulated wires. This wire is used for grounding the various outlet boxes and fixtures, and it should be securely grounded at the service switch, or entrance to the building.

Fig. 52 shows several methods of attaching the

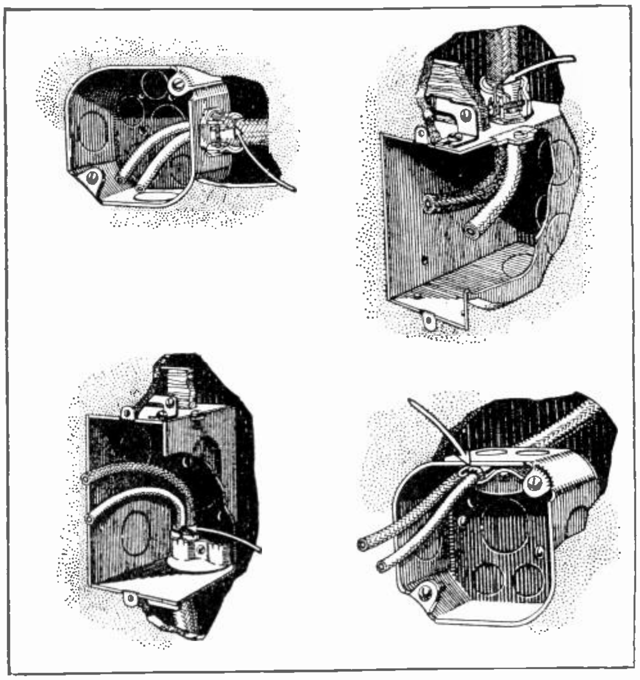


Fig. 52. The four views above show methods of attaching RomeX to outlet boxes with special clamps for this purpose. Note the ends of the wires, which are stripped back to allow the splicing or connection.

cable to common outlet boxes. The two upper views show the use of a "squeeze" clamp, which is attached to the outlet box with a lock-nut, and into which the cable is inserted and then gripped by tightening the screw of this clamp. The two lower views show another type of clamp similar to those used for fastening loom.

The ground wires should be stripped back six or eight inches through the outer covering of the cable to allow the wires to be stripped for connections in the box, and then this ground wire is attached to the cable clamp, as in Fig. 53, thus effectively grounding the outlet box. The ground wire must not in any case be left inside the box.

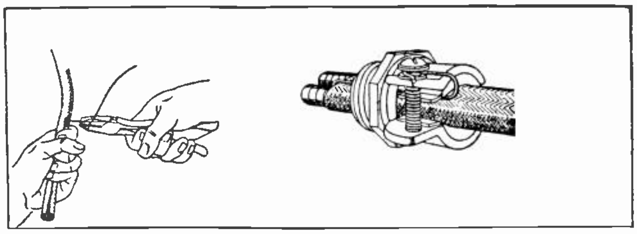


Fig. 53. This sketch shows the method of stripping back the extra ground wire in non-metallic sheathed cable, and also the manner in which it is attached to the outlet box clamp.

Fig. 54 shows a method of installing non-metallic cable in the joists of a new house, and Fig. 55 shows how it can be installed in the attic of either a new or old building.

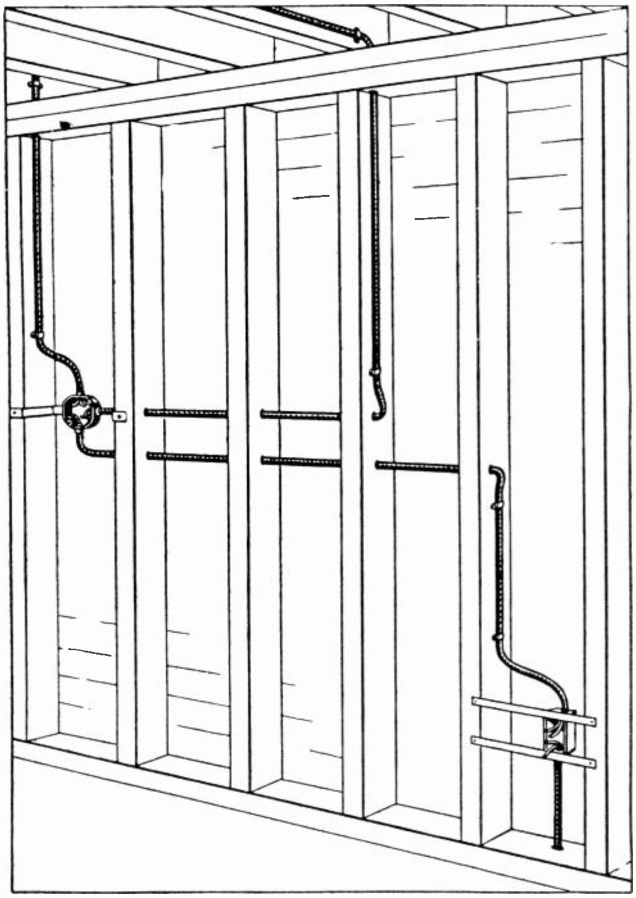


Fig. 54. A section of an installation of RomeX, showing how it is run through and along joists of a building.

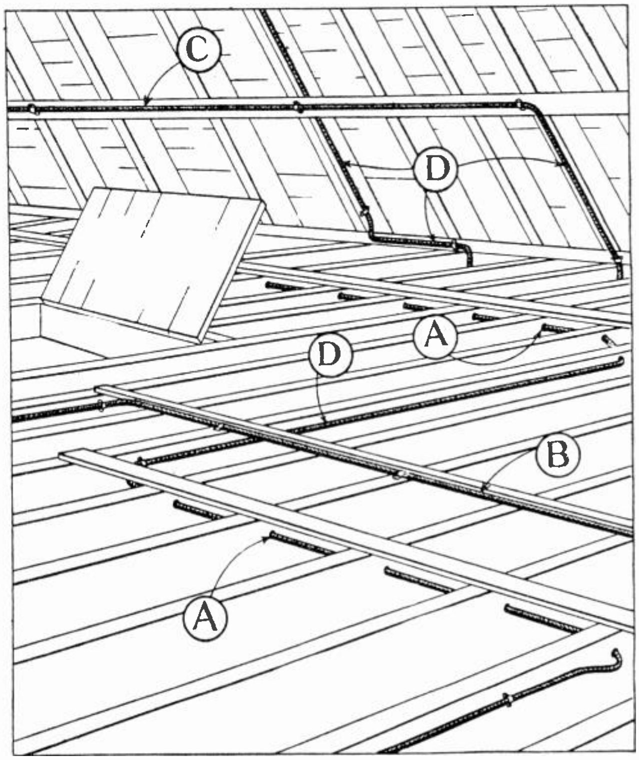


Fig. 55. RomeX is a very convenient type of wiring to install in the attics and walls of finished buildings.

In general, the installation of non-metallic cable is very similar to that of armored cable, or B.X., which is covered in a later section.

48. WOOD MOULDING

As previously mentioned, this system of wiring is not used much any more, but you will probably still find some installations of it, where an extension in the same type of wiring might be desired. Even then, it would probably be better to install metal moulding or raceway, unless the other system had to be matched exactly.

Fig. 56 shows a sketch of a piece of this moulding, and the manner in which the wires are run in the grooves, and the wood cap placed over them.

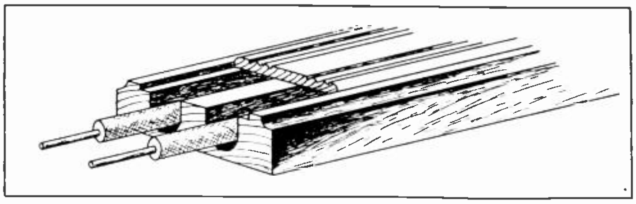


Fig. 56. A piece of wood moulding of the type sometimes used in making additions to old systems of this type.

Where switches or fixtures are installed with this type of system, the moulding is either cut to allow the mounting of a special porcelain block or fitting to which the wires are attached, or in some cases direct to the switches, which can be mounted flush with the surface of the moulding. A special fitting is also required where tap splices are made to running wires.

We would not advise using this type of wiring in any case, except where absolutely necessary to match some existing system. So it is not advisable to spend very much space or time on it here. In many old systems of this type the wiring can be made a great deal safer and more dependable if it is entirely removed and replaced with a more modern system.

RIGID CONDUIT WIRING

While this system is a little more expensive to install, it is usually by far the safest and most satisfactory type of wiring, and in this system the wiring is enclosed throughout in rigid steel pipe, which can be run either exposed or concealed in wood building partitions, or even embedded in the concrete or masonry of modern fire-proof buildings.

Concealed conduit must, of course, be installed in either frame or masonry buildings while they are being erected, although short runs may be worked in, in certain places in a finished building. When it is installed in finished buildings the system is usually exposed, however.

49. ADVANTAGES OF CONDUIT WIRING.

With the conduit system grounded as required by Code rules, there is practically no chance of fire or personal injury, due to any defects in the wire or insulation, because in such cases the wire becomes grounded to the pipe, and will immediately blow the fuse and open the circuit as soon as the fault occurs. In case of any momentary grounds or short circuits in such systems, the fact that the wires are enclosed in metal pipe makes it almost impossible to start any fires.

Some of the general advantages of conduit wiring are as follows:

1. The wiring is much more compact, and takes up less space than when strung out on knobs.

2. The grounded metal conduit shields the conductors magnetically, and prevents them from setting up external magnetic and electro-static fields that would otherwise interfere with telephones or radio equipment.

3. Conduit forms an absolutely rigid support for the wires without placing any strain on them, and also affords excellent protection from any mechanical damage or injury to the conductors.

4. It provides a very convenient method of grounding the circuit at any desired point.

5. It is suitable for both low voltage and high voltage wiring, depending upon the insulation of the wires or cable used; while the other systems mentioned can be used only for voltages under 600, and several of them under 300.

In addition to the above advantages, rigid conduit can be made absolutely water-proof, and is, therefore, suitable for wiring in damp locations.

In wiring new homes the slight extra cost is well worth while, because a conduit system will certainly be the most dependable and permanently satisfactory one obtainable. Many of the larger cities require that all new homes have conduit wiring installed. Practically all modern apartment buildings, offices, hotels, and department stores use conduit wiring exclusively, and industrial plants and buildings of fire-proof construction use it very generally. Many towns require the use of conduit for the entrance of service wires to the buildings, even though the building itself may use some other form of wiring.

Conduit pipe is very much like ordinary gas or water pipe in general appearance, except that it is somewhat softer, so it can be more easily bent for making turns and offsets in the runs.

Fig. 57 shows a piece of rigid conduit, and a sectional view of the end, as well as the threads on the right hand end.

Fig. 57. Piece of rigid conduit or pipe, in which wires are run in conduit systems.

Conduit is made in standard sizes from ½-inch to 6-inch inside diameter. These standard sizes are ½-inch, ¾-inch, 1-inch, 1¼-inch, 1½-inch, 2-inch, 2½-inch, 3-inch, 4-inch, 4½-inch, 5-inch, and 6-inch. These dimensions are approximately the actual inside diameter, usually being a little larger in each case. The ½-inch size is the one most commonly used for ordinary house wiring, and ¾-inch is used on some of the main runs.

The inside surface of conduit piping is smoothed by the manufacturers, so it will have no rough spots that might cut or damage the insulation on the wires. It is also enameled to prevent rusting.

The outside surface is usually coated with waterproof enamel, or galvanized. One process for treating both inside and outside is called "Sherardizing", and is a process whereby zinc is applied to the surface while hot, in such a manner that it actually alloys with the pipe.

50. CONDUIT FITTINGS AND METHODS OF INSTALLING

Conduit is made in ten-foot lengths for convenient handling and installation. Where longer runs are required between outlets, it is necessary to couple the ends of the pipe together by threading them with a die, and using a pipe coupling. Such joints should be thoroughly tightened to make them water-tight and to provide a good electrical circuit, as the Code requires that the entire conduit system be continuous, for the purpose of having a complete ground circuit.

Fig. 58 shows the method of using a die to thread the end of a piece of conduit, and the proper position to hold the die stock handles.

Fig. 59 shows a sketch of a pipe coupling at the left as it would be used to attach two straight lengths of conduit together. The view at the right shows a coupling used with a nipple to attach runs of conduit to an outlet box.

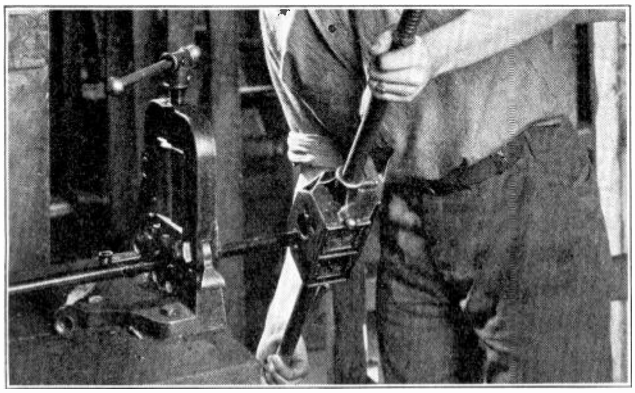


Fig. 58. Threading the ends of rigid conduit. Note the method of holding and operating the die.

Standard outlet boxes of the type already shown and described, and with knockouts of the proper size, are used with conduit systems.

The common method of attaching the conduit to the outlet box is to thread the pipe end and screw a lock-nut well back on the threads. Then insert the threaded end in the box and screw on the end bushing. By tightening the lock-nut on the outside, the conduit is then securely fastened to the box. The box also becomes a part of the complete grounded circuit, and for this reason the lock-nuts should be well tightened with a wrench, to insure good connections.

Fig. 60 shows a conduit bushing on the left, and a lock-nut in the center view.

The bushing not only helps to secure the pipe to the box, but also has a smooth rounded end to protect the wires from damage against the edges of the conduit.

Never attach a small conduit to a hole that is too large in the outlet box, without using proper reducers or washers to get a secure connection.

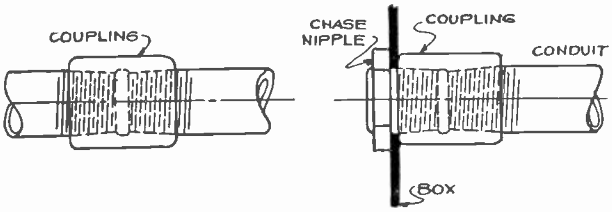


Fig. 59. Threaded couplings are used to connect lengths of conduit together, and in some cases to connect them to outlet boxes with a special nipple.

51. REAMING, CUTTING AND BENDING OF CONDUIT

The ends of all lengths of conduit are reamed at the factory to eliminate sharp corners that might otherwise damage the insulation on the wires. When you cut shorter lengths they should be reamed, as shown in Fig. 61, before coupling them together, or attaching them to outlet boxes. This removes any possible sharp edges on the inner corners, and protects the insulation of the wires from damage when drawing them in.

When a piece of conduit shorter than ten feet is required, it can easily be cut to the desired length with a hack-saw, as shown in Fig. 62. Considerable care should be taken in measuring the length of conduit runs, so that the piece will be cut the proper length to fit the location of the outlet box, and avoid mistakes that will spoil lengths of conduit.

Where a conduit run must turn a corner or go around some obstruction, the smaller sizes can be easily bent with a device called a "hickey".

Fig. 63 shows the method of bending a piece of ½-inch conduit with one of these hickeys. The conduit can either be laid on the floor, as shown in this view, or fastened in a pipe vise securely mounted on a bench or truck. Special stands with pipe legs for attaching to floor are also obtainable for conduit bending and cutting. Fig. 63-B shows two types of hickeys or grips without the pipe handles in them.

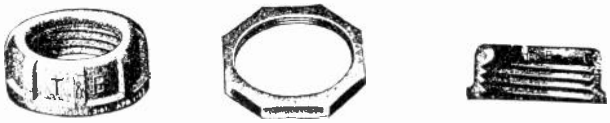


Fig. 60. A bushing and lock nut of the type most commonly used in attaching conduit to outlet boxes.

52. SIZES AND TYPES OF BENDS, AND NUMBER ALLOWED

In making conduit bends care should be used not to bend them too sharply and cause the pipe to flatten, as this will reduce the inside opening, and make it difficult or impossible to draw the wires through it. The inside radius of any bend should not be less than six times the rated diameter of the conduit. This means that the bend would form part of a circle with a radius six times the conduit diameter.

Thus, if we were bending ½-inch conduit, the inner radius of any bend should not be less than three inches, which would mean that the curve of the pipe should conform to, or fit the outer edge of a circle six inches in diameter.

Fig. 64 shows several of the more common bends made in conduit, and the names by which they are called. Not more than four right angle bends are allowed in any single run of conduit between outlet boxes. This is because the greater the number of

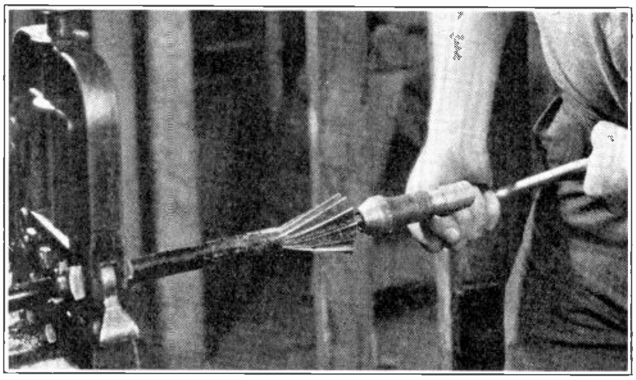


Fig. 61. Reaming the end of a piece of conduit after cutting to remove sharp edges, which might damage the insulation on the wire.

bends the harder it is to pull the wires through the pipe.

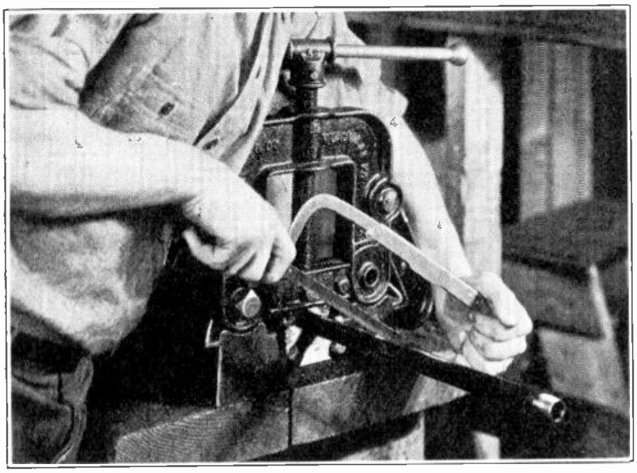


Fig. 62. Cutting a piece of rigid conduit with a hack saw. It should always be cut squarely as otherwise it is difficult to properly ream and thread it.

53. CONDUIT FITTINGS

While the sizes from ½-inch to 1-inch can be quite easily bent, on the larger sizes it is quite customary to buy manufactured elbows. However, the larger conduits can be bent on the job with power bending equipment, or by use of block and tackle, and some secure anchorage for the pipe. Sharp turns in conduit can be made by the use of fittings commonly known as **condulets** and **unilets.** These fittings are also made for attaching one length of conduit into another, and for crossing conduits, and for practically every need that can arise in a conduit installation.

Fig. 63. Smaller sizes of conduit can be easily bent into the required curves and shapes with a bending "hickey", in the manner shown here.

Fig. 65 shows a number of these fittings with their proper letters, by which they are marked and called when buying. Examine these fittings and note their various applications carefully. The letter L denotes an elbow or fitting used to make a right angle turn. An L.R. fitting is one that is used to make a turn to the right, while an L.L. fitting is one used to make a turn to the left.

These directions are determined by holding the condulets up with the opening toward you, and the short L. on the lower end. Then, if this short extension points to the right, it is an L.R., or if it points to the left it is an L.L. fitting.

An L.B. is one with an opening in the back. An L.F., one that opens to the front.

There are also **Tee** fittings with a tap opening on the back or either side desired, and cross fittings with openings on both sides, as well as the ends. The fittings here mentioned are the ones more commonly used and, along with the special fittings made, will fill almost every need that can arise.

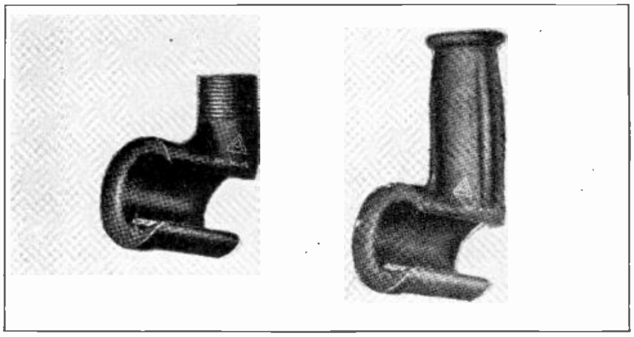


Fig. 63-B. These views show two types of grips or "hickeys" used with a pipe handle for bending conduit.

54. PULL BOXES AND JUNCTION BOXES.

In addition to these fittings, and the regular outlet boxes used for mounting switches and fixtures, there are also pull boxes, which are used at various points in long runs of conduit to make it easier to pull in the wires in shorter sections at a time.

Sometimes the run of conduit is so long, or has so great a number of bends, that it is impossible to pull the wires through the whole distance at once without running the risk of breaking them or damaging the insulation. In such cases the wires can be pulled through as far as the first pull box along the run, and then looped back, and pulled through the following section.

In other cases boxes are used where there are junctions in the wiring system and a number of splices must be made. These are called "Junction"

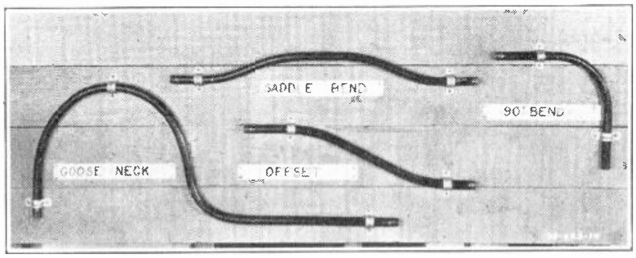


Fig. 64. This photo shows several of the more common bends frequently made in conduit. Note the names given to each. The saddle bend can, of course, be made much deeper in the form of a "U" when required.

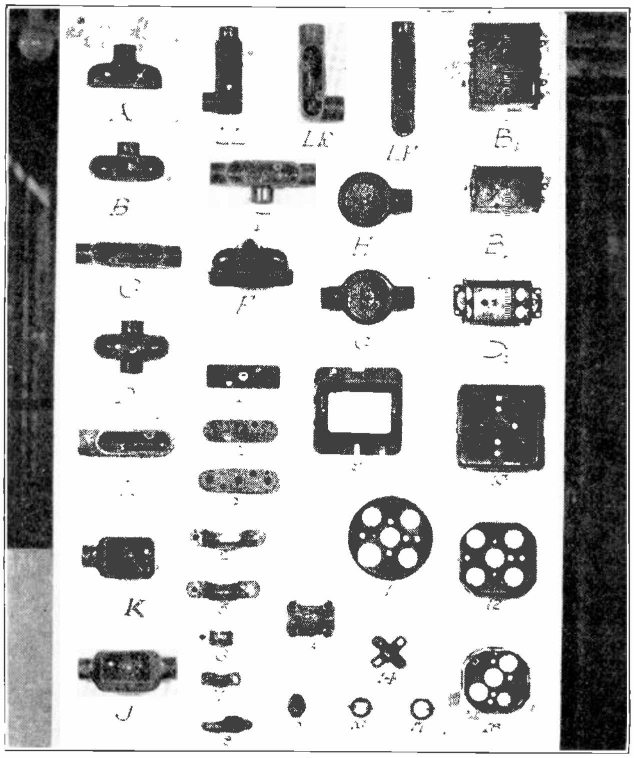


Fig. 65. This photo shows a number of the more common types of conduit fittings and outlet boxes, also porcelain covers for the fittings, conduit straps, fixture stud and lock nuts.

boxes. Several of the more common types of outlet boxes are shown in Fig. 65. There are many types of special boxes for almost every possible requirement, but those shown and mentioned here will fill the need in 95 per cent or more of the cases in ordinary wiring jobs. Fig. 65-B shows a number of the covers used on these boxes. Some are blank for merely closing the boxes, and others have openings and screws for attaching switches or receptacles, or for leading out wires to terminals of devices or other systems.

55. SUPPORTS FOR CONDUIT

Conduit is supported and fastened with pipe straps, which may have either two holes for nails or screws, or a single hole. Fig. 65 shows several different types and sizes.

When these straps must be attached to brick or masonry it is necessary to first drill holes in the masonry with a star drill, such as shown in Fig. 66. These drills can be obtained in different sizes, and are used to make holes of any desired depth by simply tapping them with a hammer and gradually rotating them in the hole. Those of the larger size can be used to make openings clear through a wall for the conduit to pass through.

When holes are made for conduit fasteners a wooden plug can be driven tightly into these holes to receive wood screws or nails; or a more desirable method is to use expansion bolts, similar to those shown in Fig. 67. For expansion bolts the star drill holes must be made the proper size to fit the bolt, and when the expansion shell is inserted, and the bolt screwed into it, it causes the shell to spread and grip the sides of the hole very tightly.

For fastening conduit or wiring materials to tile, a toggle bolt such as shown in Fig. 68 is used. These bolts have a hinge bar or cross-piece, which can be folded against the side of the bolt so they can be pushed into a small hole in the tile. Then, by turning the bar crosswise, the ends of this bar catch on the inner side of the hole, making a very secure anchorage.

In buildings of concrete or masonry construction the pipe is embedded in the cement, brick, or tile and requires no supports, except to hold it in place temporarily while the concrete is being poured, or the masonry erected around it.

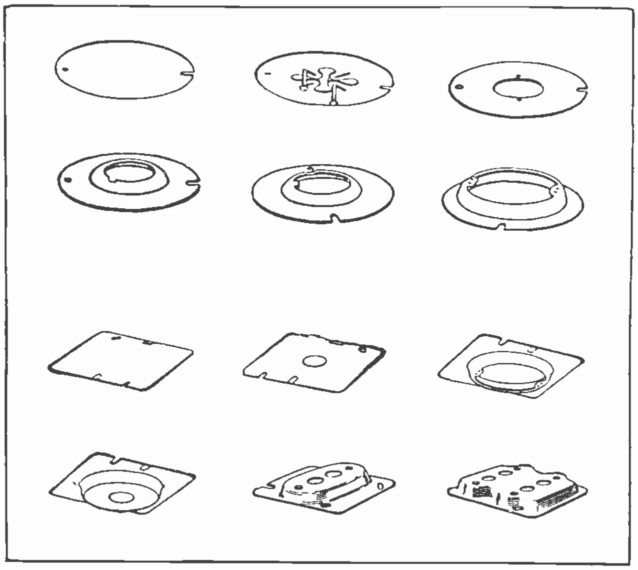


Fig. 65-B. Various types of covers can be obtained for outlet boxes and for mounting switches, lamp receptacles, etc.

The Code requires that in all conduit installations the pipe and fittings must be installed complete before any wiring is put in, and the wires should not be run until all mechanical construction work around the building is finished. This rule is made to avoid the possibility of the wires being damaged.

Ordinary rubber covered wire, with either single or double braid, can be used in conduit systems; but double braid must be used on wires larger than No. 8. In special locations where it is particularly dry and hot, wire with slowburning insulation can be used.

For use in conduit, wires No. 6 and larger must be stranded for better flexibility and ease in pulling them in.

Fig. 66. This view shows the cutting nose of a star drill, such as used for drilling holes in masonry for attaching or running conduit in buildings of masonry construction.

56. PULLING WIRES INTO CONDUIT

To pull wires into a conduit system we first push a steel "fish tape" through the pipe. This can be forced through the allowed number of bends quite easily, as a rule. The wires are then attached to the end of the fish tape and pulled in the conduit. All the wires in any one run should be pulled in at one time. It is very difficult and impractical to draw wires into pipe that already has several in it, because of the friction of the sticky insulation of the moving wires rubbing against the stationary ones.

This same rule applies when repairing or replacing wires in conduit. You may wish to replace only one or two wires, but it will be better to remove the entire group, and then pull the new ones in with the old wires.

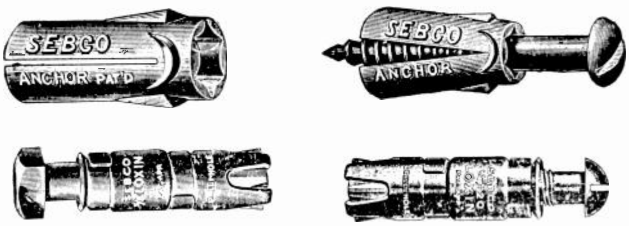


Fig. 67. Several types of expansion bolts and shells used for fastening conduit strips to holes and masonry.

No splices are allowed in wires in the conduit, or at any place except in the proper fittings or outlet boxes.

If we were to attempt to pull wires with splices into a run of conduit, the taping might be pulled off at some bend or corner, leaving the bare splice to cause a ground or short circuit.

As each section of the wiring is pulled into the runs of conduit, the ends can be cut off at the outlet box, always allowing enough to make the necessary splices and connections. It is much better to allow a couple of inches extra and cut these off when installing the switches and fixtures, than to have the wires too short, and have to replace them or draw them up in a manner that places a strain on them.

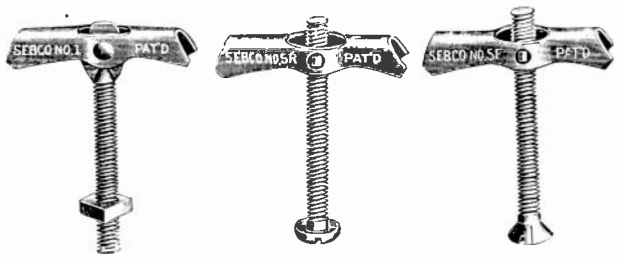


Fig. 68. Toggle bolts of the type used to attach conduit to tile walls or ceilings.

Sometimes considerable difficulty is experienced in pulling wires into long runs with a number of bends, but a great deal of this can be eliminated by the proper care. If a large number of wires are to be pulled into any conduit, or if they have been started and don't come through easily, it is well to withdraw them and blow some powdered soap stone, or even powdered soap, into the conduit. This lubricates the wires, and eliminates a great deal of the friction, without doing any damage to their insulation. This is particularly useful when pulling in large cables.

Never use oil or grease of any kind on the wires, as it is very injurious to the insulation.

While pulling on the wires from one end, it is a very good idea to have someone feed them carefully in to the point where they are drawn in. Keeping the wires straight and free from kinks and twists will help considerably to make them pull in with the least possible friction.

Sometimes in vertical runs of conduit, instead of using a steel fish tape, a "mouse" consisting of a small steel ball or piece of steel chain, is dropped through the pipe with a string attached, and this cord can then be used to pull in the wires; or a large rope which in turn can be attached to the wires.

Wires in long vertical runs of conduit in high buildings should be supported at various intervals,

WIRES IN CONDUIT

Size of Wire	Number of Wires in One Conduit								
	1	2	3	4	5	6	7	8	9
	Minimum Size of Conduit in Inches								
14	½	½	½	*¾	¾	1	*1	1	1
12	½	½	*¾	¾	¾	1	1	1	1¼
10	½	¾	¾	*1	1	1	1¼	1¼	1¼
8	½	¾	*1	1	1	1¼	1¼	1¼	1¼
6	½	1	1¼	1¼	1½	1½	2	2	2
5	¾	1¼	1¼	1¼	1½	2	2	2	2
4	¾	1¼	1¼	1½	2	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1½	1½	2	2	2½	2½	2½
1	¾	1½	1½	2	2	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	2½	3	3	3½	3½	4
200000C.M	1¼	2	2½	2½	3	3	3½	3½	4
225000	1¼	2½	2½	3	3	3½			
250000	1¼	2½	2½	3	3	3½			
300000	1¼	2½	3	3	3½	3½			
350000	1¼	2½	3	3½	3½	4			
400000	1¼	3	3	3½	4	4			
450000	1½	3	3	3½	4	4½			
500000	1½	3	3	3½	4	4½			
550000	1½	3	3½	4	4½	5			
600000	2	3	3½	4	4½	5			
650000	2	3½	3½	4					
700000	2	3½	3½	4½					
750000	2	3½	3½	4½					
800000	2	3½	4	4½					
850000	2	3½	4	4½					
900000	2	3½	4	4½					
950000	2	4	4	5					
1000000	2	4	4	5					
1100000	2½	4	4½	6					
1200000	2½	4½	4½	6					
1250000	2½	4½	4½	6					
1300000	2½	4½	5	6					
1400000	2½	4½	5	6					
1500000	2½	4½	5	6					
1600000	2½	5	5	6					
1700000	3	5	5	6					
1750000	3	5	5	6					
1800000	3	5	6	6					
1900000	3	5	6						
2000000	3	5	6						

*Where single conductor, single braid, solid wires only, are used, four No. 14 wires may be installed in a ½ inch conduit and up to seven No. 14 wires in a ¾ inch conduit. Three No. 12 wires may be installed in a ½ inch conduit, four No. 10 wires in ¾ inch conduit and three No. 8 wires in a ¾ inch conduit.

Fig. 69. This table gives the proper number of wires of different sizes which can be allowed in various conduits. It is very convenient to use in selecting the proper size of conduit for certain number of wires of any desired size.

either by driving wood wedges into the pipes at outlet boxes, or by looping the wires around strain insulators in special boxes. This is done to remove from the wires near the top the strain of the weight of a long vertical run.

57. NUMBER OF CIRCUITS AND WIRES ALLOWED IN ONE CONDUIT

Wires of different voltages, such as bell wires and wires for light or power, must never be run in the same conduits.

When running wires for alternating current systems, the two wires of a single phase, or three wires of the three phase system, must all be run in the same conduit; otherwise, they will set up magnetically induced currents in the iron pipe, which will cause it to overheat.

Running all the wires of the same circuit through the one pipe causes their magnetic flux to be neutralized, because the currents flow in different directions through the different wires.

Fig. 69 shows a table which gives the proper number of wires that can be allowed in conduit of any given size; or, in other words, this table can be used to determine the sizes of conduit required for any number of wires of a certain size.

For example, from 1 to 3 No. 14 wires will require ½-inch conduit, while 4 or 5 can be run in ¾-inch conduit, and from 6 to 9 in 1-inch conduit. To run 4 number 10 wires requires 1-inch conduit, or to run 3 number 6 wires requires 1¼-inch conduit.

These figures are for double braid insulation. For single braid, see note under table in Fig. 69.

RUBBER-COVERED WIRE.—OUTSIDE DIAMETERS.

Size Wire	Diam. of Bare Copper, Inches	Diameter Outside Insulation		Circumference, Inches	Size Wire	Diam. of Bare Copper, Inches	Diameter Outside Insulation		Circumference, Inches
		Inches	Nearest 64th				Inches	Nearest 64th	
14*	.064	.19	12/64	.....	250,000	.575	.89	57/64	2 51/64
12*	.080	.21	14/64	.....	300,000	.630	.94	60/64	2 62/64
10*	.102	.24	15/64	.....	350,000	.681	.99	1	3 8/64
8*	.128	.27	17/64	.....	400,000	.728	1.03	1 2/64	3 15/64
6	.184	.40	26/64	1 17/64	450,000	.772	1.08	1 5/64	3 24/64
5	.206	.42	27/64	1 21/64	500,000	.814	1.12	1 8/64	3 33/64
4	.232	.45	29/64	1 27/64	550,000	.855	1.18	1 12/64	3 46/64
3	.260	.48	31/64	1 33/64	600,000	.893	1.23	1 15/64	3 55/64
2	.292	.51	33/64	1 39/64	650,000	.929	1.27	1 17/64	3 63/64
1	.332	.58	37/64	1 53/64	700,000	.964	1.30	1 19/64	4 5/64
0	.373	.62	40/64	1 61/64	750,000	.998	1.33	1 21/64	4 12/64
00	.418	.67	43/64	2 7/64	800,000	1.031	1.36	1 23/64	4 17/64
000	.470	.72	46/64	2 17/64	850,000	1.062	1.40	1 26/64	4 26/64
0000	.528	.78	50/64	2 29/64	900,000	1.093	1.44	1 28/64	4 33/64
					950,000	1.123	1.47	1 30/64	4 40/64
					1,000,000	1.152	1.50	1 32/64	4 46/64
					1,250,000	1.322	1.68	1 44/64	5 18/64
					1,500,000	1.412	1.78	1 50/64	5 37/64
					1,750,000	1.552	1.92	1 59/64	6 3/64
					2,000,000	1.631	2.00	2	6 18/64

Fig. 70. This table gives the diameter of various sized wires in inches and fractions. These diameters are given both for bare and insulated wires.

This table is very easy to read and use, by simply noting the sizes of the wire in the left-hand column and the number of wires desired in the row across the top, and then reading down under this number to the line for that size of wire, where the proper size of conduit will be found.

Examine this table carefully and become familiar with its use because it will prove very convenient.

For wire groups and combinations not shown in the table, it is recommended that the sum of the cross sectional areas of the wires to be run in any conduit should not be more than 40 per cent of the area of the opening or bore in the conduit.

Under such conditions, however, it is usually well to consult the Inspection Department before going ahead with the work.

Dimensions of Rubber-Covered Wire.

Wire	Area	Wire	Area	Wire	Area
14	.028	225,000 C.M.	.55	1,000,000 C.M.	1.74
12	.035	250,000 C.M.	.58	1,100,000 C.M.	2.04
10	.045	300,000 C.M.	.69	1,200,000 C.M.	2.16
8	.057	350,000 C.M.	.77	1,250,000 C.M.	2.22
6	.13	400,000 C.M.	.83	1,300,000 C.M.	2.27
5	.15	450,000 C.M.	.92	1,400,000 C.M.	2.40
4	.17	500,000 C.M.	.99	1,500,000 C.M.	2.52
3	.19	550,000 C.M.	1.11	1,600,000 C.M.	2.63
2	.21	600,000 C.M.	1.19	1,700,000 C.M.	2.78
1	.27	650,000 C.M.	1.27	1,750,000 C.M.	2.85
0	.31	700,000 C.M.	1.33	1,800,000 C.M.	2.89
00	.36	750,000 C.M.	1.39	1,900,000 C.M.	3.05
000	.42	800,000 C.M.	1.45	2,000,000 C.M.	3.14
0000	.49	850,000 C.M.	1.54		
		900,000 C.M.	1.60		
		950,000 C.M.	1.68		

Fig. 71. Table of areas of various wires and cables in square inches. These figures are very convenient when calculating the area of a number of conductors to go in conduit. Areas given include insulation.

The table in Fig. 70 gives the diameter in fractions of an inch for the different sized wires, both bare and with insulation, while table 71 gives the area in thousandths of a sq. inch of the more common sized wires. These tables will make it easy to determine the total area of a number of wires of any size that you might desire to run in conduit. Then it will be easy to tell whether this is more than 40 per cent of the size of the conduit, by referring to table 72, which gives the area in sq. inches of the different standard sizes of conduit.

DIMENSIONS OF CONDUIT

Conduit	Area	40% of Area	Conduit	Area	40% of Area
½	.306	.122	3	7.34	2.93
¾	.516	.206	3½	9.94	3.97
1	.848	.339	4	12.7	5.08
1¼	1.49	.596	4½	15.9	6.36
1½	2.03	.812	5	19.9	7.96
2	3.32	1.328	6	28.8	11.52
2½	4.75	1.9			

Fig. 72. This table gives both the total area of the inside opening in conduit, and 40% of the area of the different sizes, which is the amount that can be occupied by the conductors.

This latter table also shows in two of the columns, 40 per cent of the area of each size conduit, which makes it a very handy table. As an example of its use, if we were required to run six number 6 wires and four number 2 wires all rubber covered, we would multiply the area of a number 6 wire, which is .13, by 6; or .13 × 6 = .78. Then also multiply the area of a number 2 wire which is .21, by 4; or .21 × 4 = .84. Then .78 plus .84 equals 1.62 square inches, total area for all the wires.

Now in the column headed "40 per cent of the area" it will be found that a 2½-inch conduit will be required, as it is the next larger, and 40 per cent of its area will be 1.90 square inches.

Ordinarily the Code doesn't permit more than nine wires of any size in one conduit. Sometimes it is not advisable to allow even this many, not only because of the difficulty in pulling them in but also because if one wire breaks down or develops a short or ground, the arc is likely to damage the insulation of all the others and cause trouble in other circuits as well.

Where lead covered conductors are to be run in conduit, the table in Fig. 73 will be very convenient for determining the proper size of conduit for any number of lead covered wires of a given size.

SIZE OF CONDUIT FOR THE INSTALLATION OF WIRES AND CABLES

Lead Covered Wires (0-600 Volts) (Single Conductors)

Size of Wire	Outside Diam. 64th	Diam. Dec. Equiv.	Number of Conductors in One Conduit — Minimum Size of Conduit in Inches: 1	2	3	4
14	16	.25	½	½	¾	¾
12	18	.27	½	¾	¾	1
10	21	.32	½	¾	1	1
8	23	.35	½	1	1	1¼
6	30	.47	¾	1¼	1¼	1½
5	32	.50	¾	1¼	1¼	1½
4	33	.51	¾	1¼	1½	2
3	35	.55	¾	1½	1½	2
2	37	.58	1	1½	2	2
1	41	.64	1	2	2	2½
1/0	44	.68	1	2	2	2½
2/0	47	.73	1	2	2	2½
3/0	50	.78	1¼	2	2½	3
4/0	54	.84	1¼	2½	2½	3
250,000	62	.97	1¼	3	3	3½
300,000	65	1.01	1½	3	3	3½
350,000	68	1.06	1½	3	3	3½
400,000	71	1.11	1½	3	3½	4
450,000	74	1.15	1½	3	3½	4
500,000	78	1.21	2	3½	3½	4
550,000	86	1.34	2	3½	4	4½
600,000	88	1.37	2	3½	4	4½
650,000	90	1.40	2	4	4	5
700,000	92	1.43	2	4	4	5
750,000	94	1.47	2	4	4	5
800,000	96	1.50	2½	4	4½	5
850,000	99	1.55	2½	4	4½	5
900,000	100	1.56	2½	4	4½	5
950,000	102	1.59	2½	4½	4½	6
1,000,000	105	1.64	2½	4½	4½	6
1,250,000	116	1.81	3	5	5	6
1,500,000	126	1.97	3	5	6	
1,750,000	136	2.12	3	6	6	
2,000,000	142	2.21	3	6	6	

Note.—Nos. 14 to 8, solid wires, all other stranded. Outside diameters are given as wires of different makes vary in the outside diameters of similar sizes. This table is based on runs of fifty feet and not more than two standard right angle elbows. Where there are no elbows, or where manufactured bends of a radius greater than the standard elbow are used, special permission in writing may be granted for a deviation from the above table.

Fig. 73. This table gives the number of lead covered wires of different sizes that can be contained in various sized conduits.

58. GROUNDING CONDUIT SYSTEMS

When the entire conduit system is installed complete from the service switch and meter throughout the entire building, it must be thoroughly grounded as near to the source of current supply as possible. This ground connection should be made at a waterpipe whenever available. If no piping systems are in the building which can be depended upon for a good ground connection, then a good ground rod or piece of pipe can be driven into the ground eight feet deep to make sure that it is always in contact with moist earth, or a large plate of metal can be buried several feet in the earth, and covered with charcoal and salt as well as earth.

All conduit systems are required to be grounded, whether any part of the wiring within them is grounded or not. These ground connections from the conduit to the waterpipe or ground rod should be as short as possible, and always accessible for inspection, as they must be maintained in good, unbroken condition at all times.

Where the wiring system is not polarized and none of its wires are required to be grounded, the conduit can be grounded by use of copper ground strips, as shown in Fig. 74, or by extending a piece of conduit from the regular conduit system to the waterpipe and attaching its ends to both of them by special clamps.

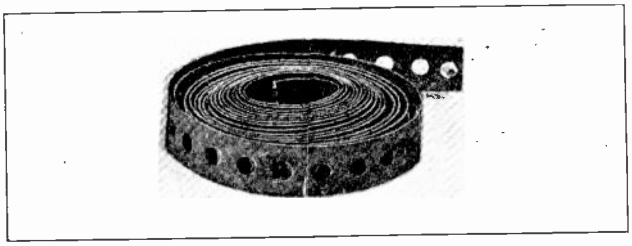


Fig. 74. Copper grounding strip of the type shown above is often used to ground conduit systems to the waterpipes or earth grounds.

Where wires are used for grounding, the wire should not be smaller than a No. 8, and should be attached to the waterpipe with a special grounding clamp, two styles of which are shown in Fig. 75.

Fig. 76 shows three styles of grounding clamps, the upper one of which is equipped with a cable lug, into which the heavy ground wire or cable should be securely soldered. The lower view shows two clamps that are used to attach both the ground wire and a piece of conduit to the waterpipe.

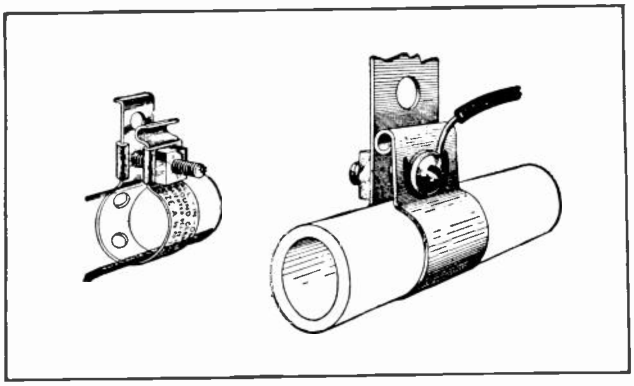


Fig. 75. Two types of grounding clamps used to securely attach ground wires to waterpipes.

These are used for polarized wiring systems, which will be explained later, and in which it is required to ground the neutral wire of the system with a ground wire, which is run through a short piece of conduit that is also connected to the waterpipe. This conduit not only acts as a ground for the conduit system, but also as protection for the ground

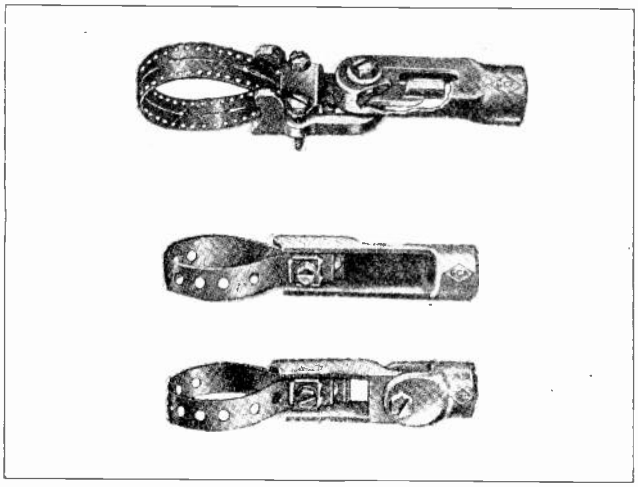


Fig. 76. Several approved type ground clamps used to attach both the conduit and ground wire to waterpipes.

wire of the electrical system. Always scrape all paint or rust from any pipe before attaching the ground clamp.

This thorough grounding, as previously mentioned, is an essential requirement for maximum safety from fire and shock hazard in a wiring system, and should be done with the greatest of care by the electrician when installing such systems.

Fig. 77 shows what is called an isometric view or phantom view of a house in which a conduit system has been installed. This view shows the service and meter box in the basement, and the various runs of conduit to baseboard, convenience outlets and wall switches, wall and ceiling light fixture outlets on both the above floors, as well as a light in the attic.

59. ELECTRICAL METALLIC TUBING

This is a lightweight pipe, much like rigid conduit, which has recently been approved by the Fire Underwriters. It is made with very thin walls, so thin in fact that we are not permitted to thread it. This means that threadless fittings are used, which saves considerable labor.

Fig. 78 shows one of the fittings in a sectional view which shows the manner in which the tapered split sleeves are drawn in by the threads to grip the pipe.

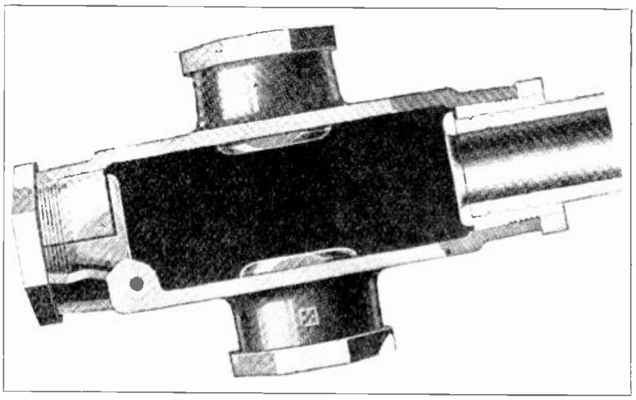


Fig. 78. Sectional view of a fitting for threadless conduit, showing the special gripping sleeves inside its ends.

Fig. 79 shows how easily the fittings can be placed on or removed from the pipe, by slipping the lock-nuts on the pipe and the grip-nuts inside

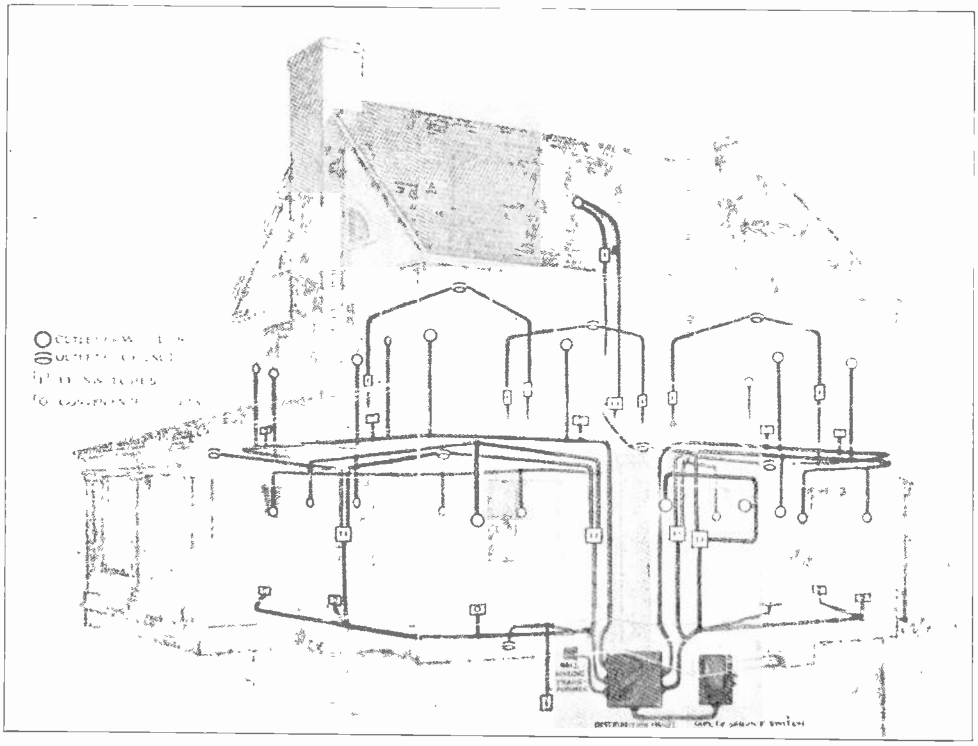


Fig. 77. Isometric or phantom view of a house in which conduit is installed. Note the arrangement of conduit in walls and ceilings, and the locations of various outlets.

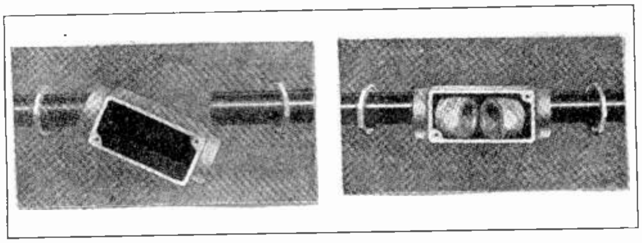


Fig. 79. This view shows the convenient manner in which threadless fittings can be installed with conduit.

the fitting. This tubing is lighter and easier to handle than regular conduit and is lower in price. It can be bent with less effort, and the cost of installation, due to the saving of time, is also less. Special couplings and fittings of all types are supplied for this tubing, similar to conduit fittings but with the grips for threadless pipe. Fig. 80 shows a coupling used for threadless tubing.

Split bushings are also made for use of standard conduit fittings with metallic tubing.

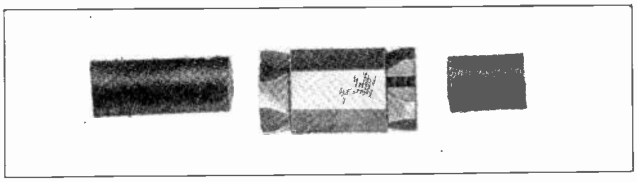


Fig. 80. Special coupling used for connecting together lengths of threadless conduit or electric metallic tubing.

With a few exceptions, the same rules apply to this metallic tubing as to the standard conduit, but it cannot be run concealed. This tubing and its special fittings must be so finished that it will never be mistaken for rigid conduit. It may be finished in either enamel or zinc and in standard sizes is approved in only ½" or ¾" and 1". Its use is restricted to voltages of 300 volts or less, to No. 8 wire or smaller, and no circuit therein shall be fused for over 30 amperes. Furthermore, it can only be used in exposed dry places where it cannot be subjected to mechanical injury or corrosive vapors.

Even with all these restrictions, its advantages, as noted above, make it a desirable system when put to its intended use. Fig. 81 shows a section of an installation of threadless tubing.

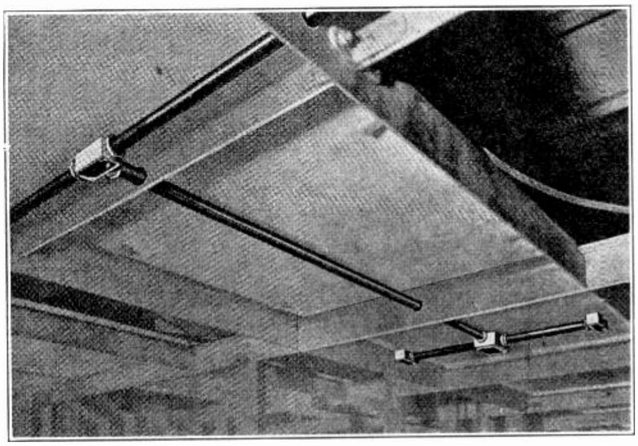
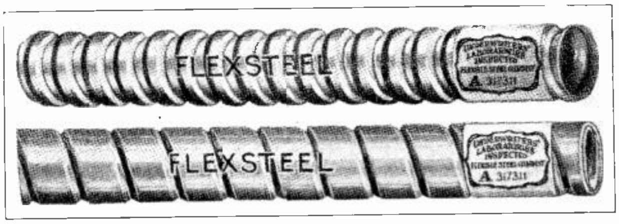


Fig. 81. Section of an installation of electric metallic tubing with threadless fittings.

60. FLEXIBLE CONDUIT

Flexible conduit is used very much the same as rigid conduit, except that its flexibility permits it to be fished into walls and partitions in old buildings, where rigid conduit cannot be conveniently installed.

As mentioned before, flexible conduit consists of tubing made of spirally wound steel strips, the turns of which are securely locked together to form a continuous metal casing in which the wires are run. Figs. 82 and 83 show pieces of flexible conduit of different types, which will give you a general idea of its construction.



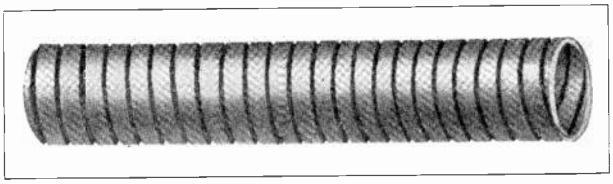


Fig. 82 & Fig. 83. Pieces of several types of flexible conduit, showing how it is constructed of narrow steel strips wound spirally.

Like rigid conduit, this system must be run continuously from one outlet to the next, and the entire system grounded.

Fig. 84 shows several types of couplings used in connecting lengths of flexible conduit together, and also to attach it to outlet boxes. The upper left view shows an ordinary straight coupling and the grooves which enable it to grip the turns of the conduit when it is bolted on. The lower left view shows a fitting for making sharp turns with flexible conduit, where it attaches to an outlet box. The upper right hand view shows a coupling that can be used for attaching flexible to rigid conduit, or for attaching flexible conduit to an outlet box, with an added nipple. The lower right view shows a very common connector used for attaching either flexible conduit or armored cable to outlet boxes.

Flexible conduit is not as waterproof as rigid conduit is, and should not be used in very damp places, unless rubber covered wires with lead sheaths are used, and it should not be imbedded in concrete.

Its particular advantages are for wiring old buildings, getting through difficult places with a number of bends, and for running flexible leads from rigid conduit to motors or other electrical machines.

Fig. 85 shows a photograph of a motor connected up with flexible conduit. This is one of its very definite advantages as it allows a motor to be moved slightly to tighten belts, etc.

The same type of outlet boxes, conduit straps, and many of the same general rules for rigid conduit are also used for flexible conduit.

The more important points of conduit wiring systems have been carefully covered in this section, and it will be well for you to get a good general understanding of this system, as it is one of the most important of all and is in very extensive use.

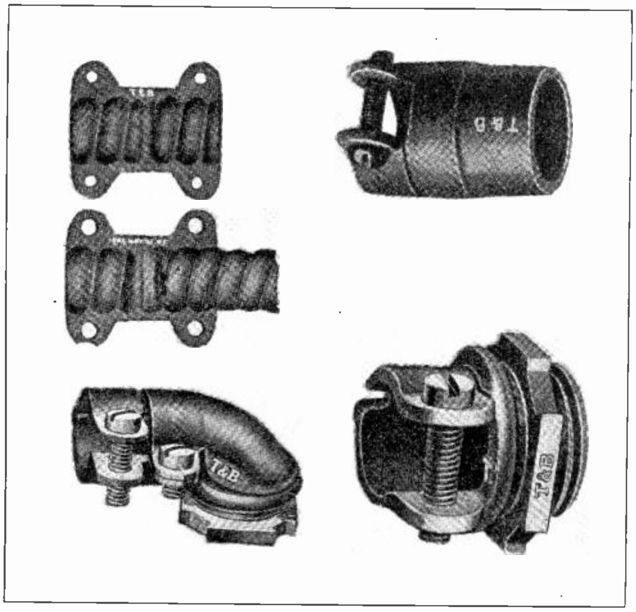


Fig. 84. Several types of couplings used for connecting flexible conduit together or to outlet boxes.

61. ARMORED CABLE

On the outside, armored cable looks much like flexible conduit. But there is this difference; while the latter has the wire pulled in after it has been installed, armored cable has the wires already in when purchased. It is made in two types and is frequently known as BX or BXL. The former consists of one, two, three or four conductors with rubber insulation and heavy waxed braid, and then an addition of an armor of steel ribbon.

Fig. 86 shows a piece of 3-wire BX and one with two wires. Note the color markings of the wires and the extra twin braid over each group.

BXL is made in a similar way but has the addition of a lead sheath just under the steel armor. This makes it waterproof and permits it to be used where there is moisture, or where it is exposed to the weather. BX may be obtained with wires from No. 4 to No. 14.

62. ADVANTAGES OF ARMORED CABLE WIRING

Armored cable wiring is a very popular system for all wood construction buildings. While rigid conduit is usually used for concrete work, and sometimes used for other types of buildings, it is occasionally found too expensive for certain jobs. The use of armored cable or BX gives us a first class job at low cost, can be installed almost as cheaply, and is much better than Knob and Tube

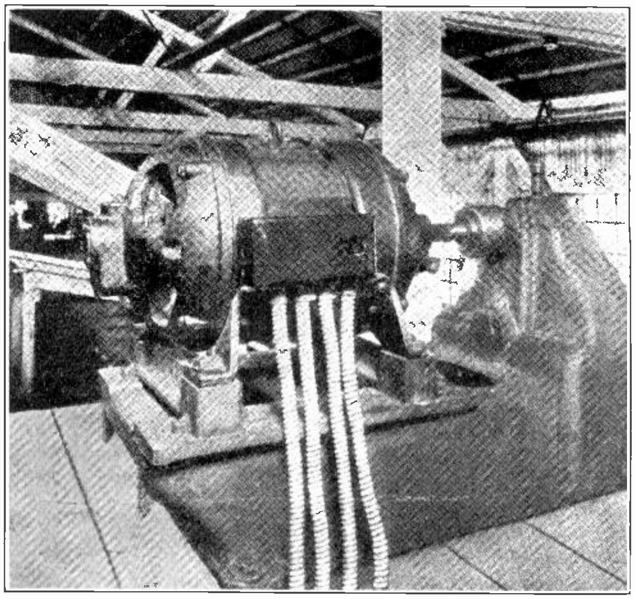


Fig. 85. Flexible conduit is very convenient for motor connections, as it allows some movement of the motor for belt tightening, etc.

work. It makes a good job on all new work, and is absolutely the best system for old house wiring. It is very convenient and economical to install because its flexibility makes it easy to run in difficult places and because, when BX is installed, the wires are in also and do not have to be pulled in later.

The same outlet and switch boxes are used for BX as for conduit, and are installed with BX fittings made for the purpose and clamped securely to the BX armor, and then fastened to the boxes with a lock-nut. Fittings are also made so that BX can be used in conjunction with the other systems of wiring. Several of these fittings are shown in Fig. 87.

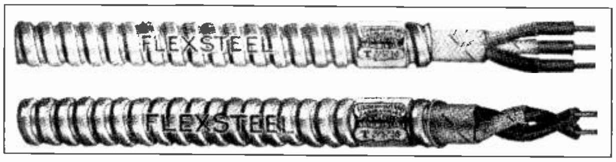


Fig. 86. Pieces of two different types of two-wire and three-wire armored cable. This material is supplied with the wires already in the armor.

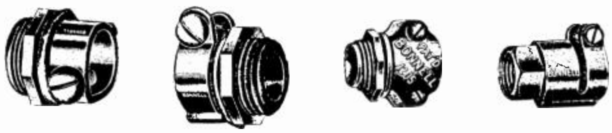


Fig. 87. Several types of fittings used for attaching armored cable to outlet boxes or rigid conduit.

Where possible BX should be fastened to the surface wired over with the proper size pipe straps. BX must be continuous from outlet to outlet. A violation of this would mean that you would have splices outside the outlet boxes, which is against the rule for metal systems, and then besides, you would increase the chance of not having a perfect ground throughout the system. The braids over the insulation of the different wires have different colors so the wireman can trace the "hot" or grounded wires, as will be explained later.

BX can be bought in rolls of 250 ft. or less, and then cut into the desired lengths with a hack saw. Fig. 88 shows a coil of BX as it would be bought.

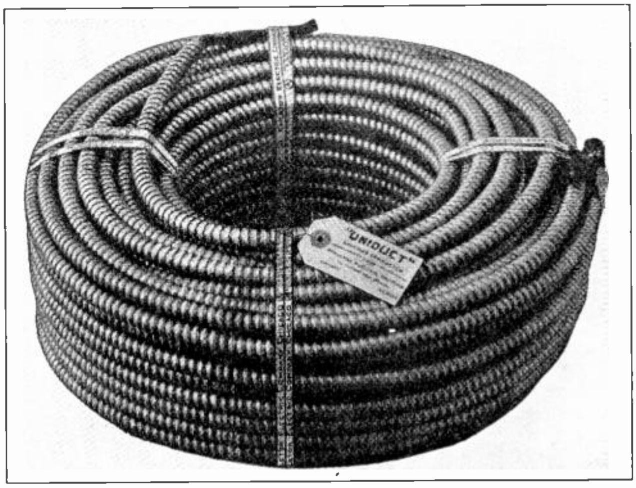


Fig. 88. A coil of armored cable or "BX" showing its convenient flexibility, which is one of the decided advantages of this material for wiring systems.

63. CUTTING AND STRIPPING BX

To cut BX, simply hold it firmly in a vise or against your knee or a piece of wood, and cut across one turn of the spiral steel wrapping, being sure to cut clear through one turn or strip of this steel, but do not cut into the insulation of the wire underneath.

To cut clear through the one turn it is necessary to cut into the turn next to it a little. Practice this cutting and you will soon find just the proper angle

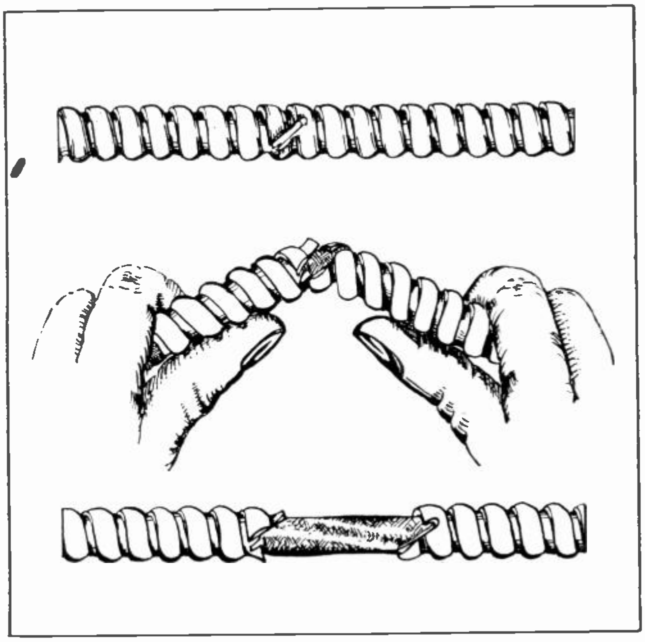


Fig. 88-B. The top view shows the proper method of cutting BX armor with a hack saw. The center view shows how it can then be broken apart without damaging the conductors or insulation inside. A short section of the armor can then be pulled off the end of the cable as shown in the lower view.

to hold the hack saw, and it will become very easy to make a neat cut. See Fig. 88-B.

When the armor strip is cut through, bend the BX to open the cut and the armor will separate, and then the wires can be cut through squarely and easily with the hack saw.

To attach BX to an outlet box make the cut as described about 6 inches from the end, but only through the metal. Then bend the BX at the cut and separate the armor, and the short length can be easily pulled off from the ends of the wires. This leaves them ready to split the outer braid and strip the insulation for splicing. Fig 89 shows a piece prepared in this manner.

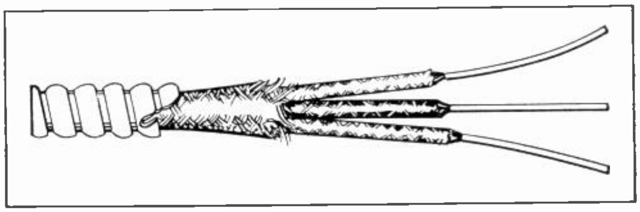


Fig. 89. This sketch shows how the ends of conductors in armored cable can be stripped for connections and splicing.

64. USE OF BXL

BXL or lead sheath BX is a very good system to use in underground work, running from one building to another, such as from a residence to a garage in the back end of the house-lot. A ditch of the proper depth, say 2 ft., can be dug. As the cable is flexible, this ditch does not necessarily have to be absolutely straight, but may be around any obstacle that might be in the way. Where galvanized rigid conduit is used more care has to be taken, and the joints where the lengths of conduit are coupled together must be leaded to keep out moisture. Great care should be taken in handling BXL, so as not to crack the lead. This precaution, of course, should be taken with all lead covered cables, but it is very necessary with BXL, as damage to the lead cannot be detected by inspection, and will only show up possibly weeks afterwards when moisture has time to leak through and cause a short.

65. METAL RACEWAYS OR MOLDING

Metal Raceways or metal molding is one of the exposed wiring systems that is quite extensively used. Although it does not afford such rugged and safe protection for the wires as conduit and armored cable do, it is a very economical and quite dependable system, and is very convenient to install in finished buildings where new wiring or extensions to the old are to be installed. One of the advantages of metal molding is its neat appearance where wiring must be run on the surface of walls or ceilings in offices, stores, etc.

It must never be run concealed or in damp places.

Two of the leading manufacturers of metal raceway materials call their products respectively, **wire mold** and **metal molding**, and they are quite commonly known by these names.

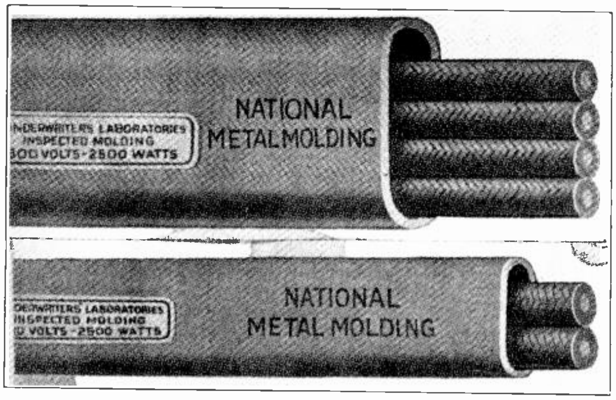


Fig. 90. Two pieces of metal molding of a very neat appearing type for exposed wiring systems.

Fig. 90 shows two pieces of one style of molding called "Ovalduct", and in which the wires are drawn after it is installed, similarly to conduit.

Fig. 91 shows another style that comes in two strips. The back strip is installed and then the wires are laid in it and the cap snapped in place over them.

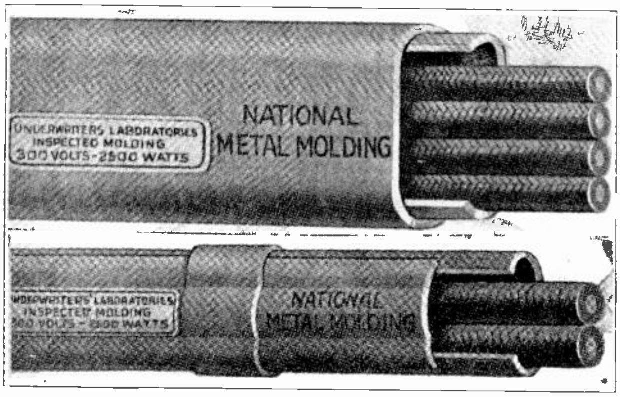


Fig. 91. Another type of metal molding with a removable cap or cover strip, which can be placed on after the wires are insulated.

Various types of fittings for couplings, corner turns, elbows, outlets, etc., are provided to fit these moldings. Fig. 92 shows a number of these fittings, and Fig. 93 shows a closer view of a common elbow fitting.

Many of the rules for BX systems apply also to metal raceways, such as: it must be continuous from outlet to outlet, must be grounded, and all wires of an A.C. circuit must be in one raceway, etc.

You will note from the Figures 90 and 91 that metal raceways are made in two sizes for either two or four wires. Another size is available now for 10 wires, but is to be used only in certain places as allowed by the Code or local authorities. Wires sizes No. 14 to No. 8 can be used with these moldings, and the wire must be rubber and braid covered, and installed with no splices except at proper boxes or fittings.

Fig. 94 shows a fitting that can be used as a junction box and for splices, or for an outlet box when a cover is used with an opening as shown.

Fig. 95 shows several sizes of boxes to be used with metal raceways, for mounting switches and receptacles. Note the wall plates which are to be attached to the surface wired over, and have slots in their edges for the molding to be slipped under

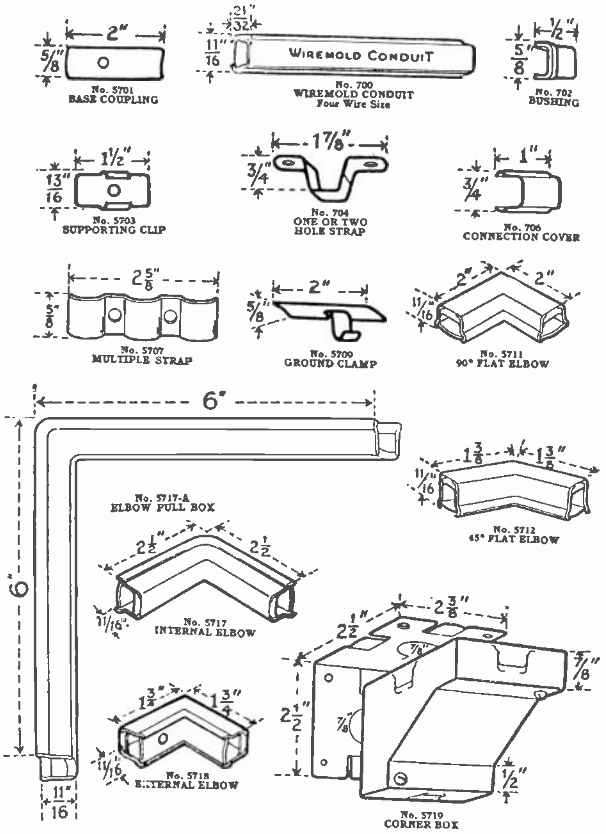


Fig. 92. A number of various types of fittings are provided for use with metal molding in making turns in the corners of walls and ceilings.

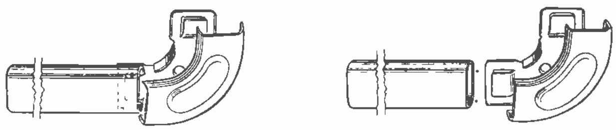


Fig. 93. A common form of elbow used with metal raceways or moldings.

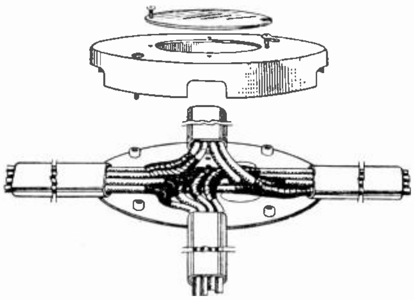


Fig. 94. This view illustrates the use of a junction box in which splices can be made, and various runs of metal raceway attached together. We can also attach lights or receptacles to the smaller opening in the cover of this box.

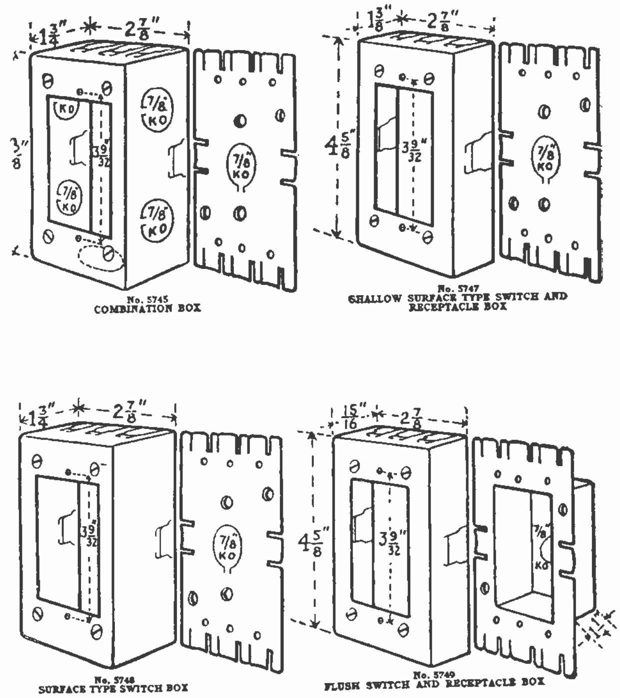
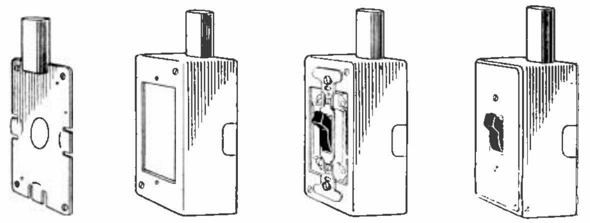


Fig. 95. Several styles and sizes of outlet box for use with metal molding and in which switches or receptacles can be installed.



Back plate and Molding Installed on Surface. — Box mounted. — Toggle Switch Installed in Box. — Installation Completed with Flush Device Plate No. 491.

Fig. 96. These views show the various steps in installing a switch in the outlet box of a metal raceway system.

to anchor it to them. Fig. 96 shows how these boxes are installed and the switches mounted in them.

Fig. 97 shows a number of other fittings for various uses as their descriptions indicate.

Metal molding can also be bent to fit or go around various corners or obstructions. For this purpose a bending tool, such as shown in Fig. 98, is used. This device has a rounded fitting on its handle, to make the molding bend in a neat curve of the proper size and without flattening. Molding is easy to bend because of its thin walls.

66. NEAT APPEARANCE

Fig. 99 shows the neat appearance of a run of metal molding to two ceiling light fixtures. This view shows that it is one of the best appearing of all exposed systems of wiring.

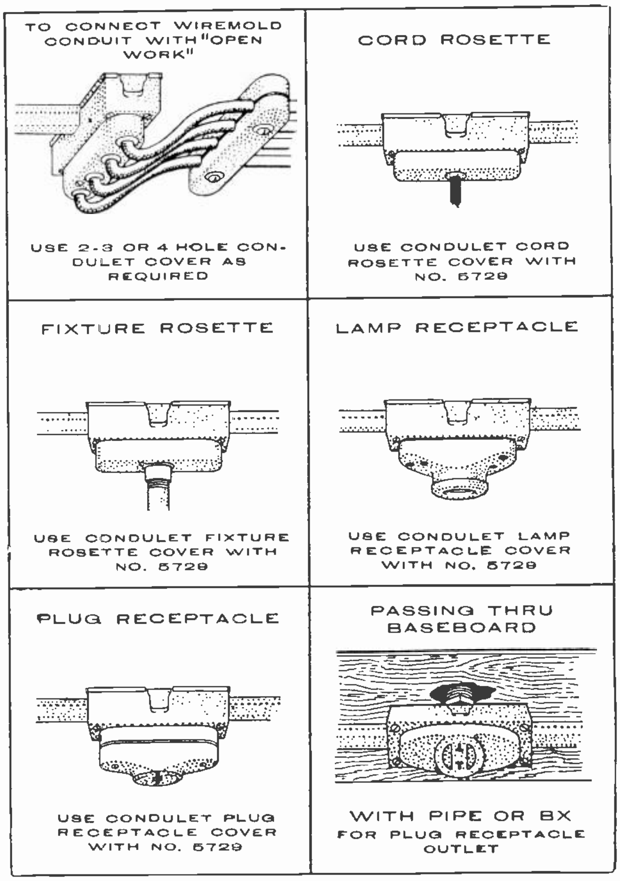


Fig. 97. Above are shown a number of fittings used with metal molding and an explanation of the use of each.

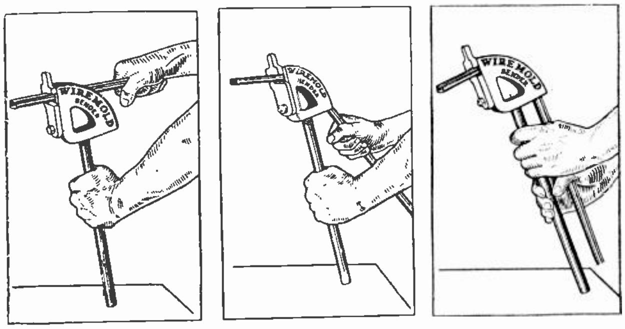


Fig. 98. This view shows a bending tool, and the method in which metal molding can be bent into different shapes for turns and corners.

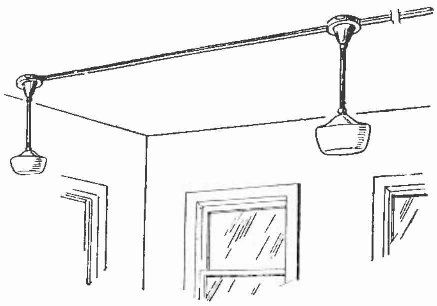


Fig. 99. Section of a metal raceway wiring system with two light fixtures attached. Note the neat appearance of this type of wiring for exposed work.

The method of attaching a fixture canopy to the ceiling plate and fixture stud, is shown in Fig. 100, and Fig. 101 shows how connections are made to the running wires, for drop cords and light fixtures. Note the porcelain connector block used to attach the fixture wires to the running wires by terminal screws instead of splices.

Fig. 102 shows the installation of a convenience outlet and the method of attaching a piece of BX to the same box, to run to a wall light fixture.

67. UNDERFLOOR RACEWAYS

These are runways considerably larger than metallic tubing, and are restricted about the same way, including the voltage, size of wire, and fuse limits. In addition, not more than 10 wires can be placed in any one raceway and the combined cross-sectional area of all conductors must not exceed 30% of the interior cross-sectional area of the raceway. These raceways may be either rounded or rectangular, and may be run exposed or embedded in concrete floors, provided the structure is not weakened by their use. The upper surface of flat top ducts cannot be over 4" wide. They may be either open-bottom or closed-bottom types, and all joints and edges must be filled with a water-proof cement. The usual requirements of other metal systems, that there be an electrical continuity of the raceway throughout and that it be grounded, must be strictly observed.

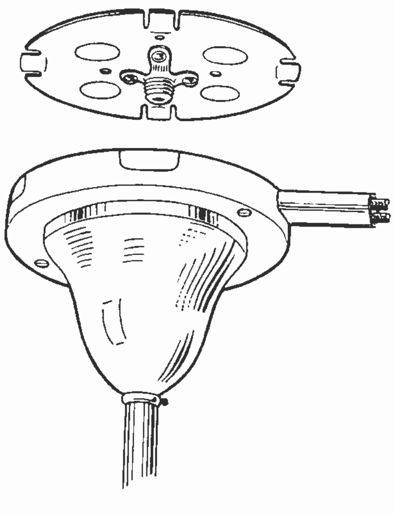


Fig. 100. This sketch shows the ceiling plate and fixture stud to which the light fixture and canopy are attached, and also the slots for attaching the molding to this plate.

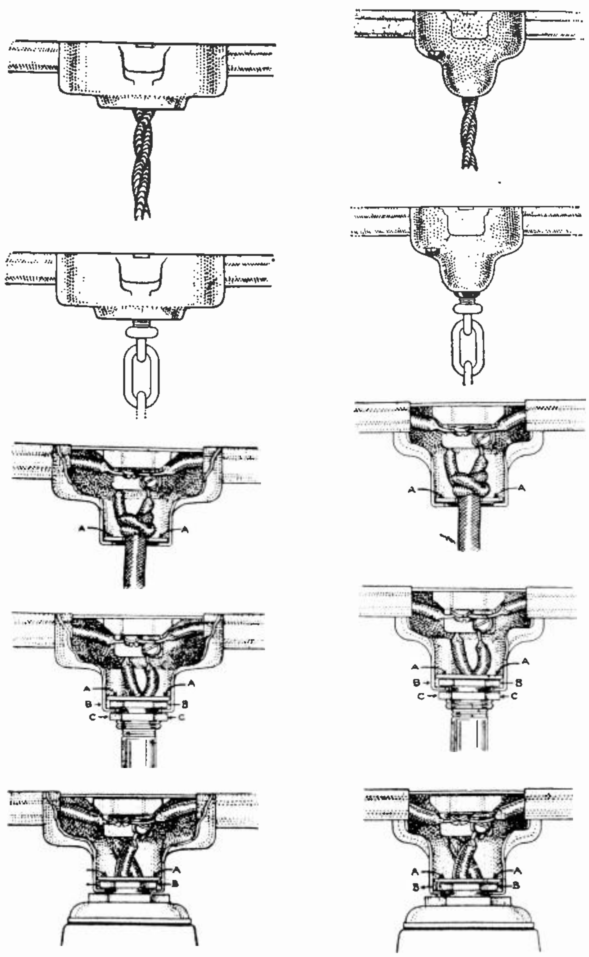


Fig. 101. The above views show a number of styles of fittings used with metal molding and the method of making connections for fixtures. Note the connector blocks used for attaching fixture wires to the running wires.

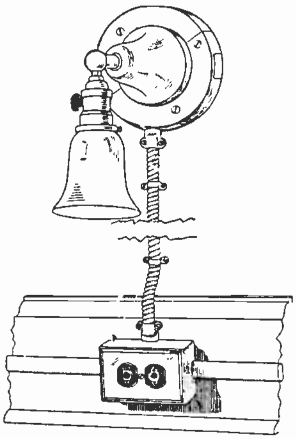


Fig. 102. Convenience receptacle and box on a metal molding system, showing BX attached for a branch circuit to a light.

COYNE
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ESTABLISHED 1899

ELECTRICAL CONSTRUCTION
AND
WIRING FOR LIGHT AND POWER

Section Two

Fuses and Switches
Three-Wire Systems, Polarized Wiring
Wire Calculations, Installation Methods
Business Methods and Estimating
Trouble Shooting

FUSES AND SWITCHES

68. FUSES

Every wiring system, no matter what type it may be, must be properly fused. This is a strict requirement of the National Code, and an absolute necessity, both to protect the wiring and equipment on the circuits as well as persons who might handle them.

Fuses in electrical circuits are similar in purpose to safety valves on steam boilers. With a boiler, whenever the steam pressure rises so high that it is unsafe and more than the strength of the boiler should stand, the safety valve opens and relieves this pressure. In electrical circuits, whenever the current load becomes more than the wires can stand without overheating and burning their insulation, the fuse blows and disconnects the circuit. So we can readily see the great importance of having in every electrical system fuses of the proper size and type.

Fuses are made in many different styles and sizes for different voltages and current loads, but they all operate on the same general principle, that is, opening the circuit by melting a piece of soft metal which becomes overheated when excessive current flows through it.

The temperature rise which melts a fuse depends upon the amount of excess current, the duration of excess current, and the ease with which heat escapes from the fuse.

69. LEAD LINK FUSES

Early types of fuses were simply a piece of lead wire connected in the circuit, through which current flowed to the lines and devices to be protected. This lead wire, being soft and easy to melt, would blow out as soon as the current load in amperes went above a certain amount. These pieces of wire were kept short and fastened securely under terminal screws, so that their resistance would not be high enough to cause much voltage drop in the circuit. By selecting the proper size of lead wire they could be made to open the circuit at almost any desired current load. This type of **Link** or lead wire fuse is not very safe or dependable. Such fuses have a tendency to oxidize and corrode, and become quite inaccurate after being in service a while. In addition to this, when they do blow out, the molten metal spatters over equipment, and is likely to injure persons if they are nearby.

70. CARTRIDGE FUSES

You will still find lead link fuses in use in some places, but in general they have been replaced by the modern **Cartridge Fuses** on all circuits of over 30 amperes capacity, and some of less; and by the **Plug Fuse** on circuits with under 30 amperes load.

Fig. 103 shows two types of cartridge fuses and the renewable fuse link used with them. This type of fuse consists of a hard fibre cylinder in which the fuse strip of soft metal is contained. This strip is gripped tightly by the brass ferrules on the end of the fuse chamber, so the entire cartridge can be conveniently mounted in a **Fuse Block.** Several types of these are shown in Fig. 104.

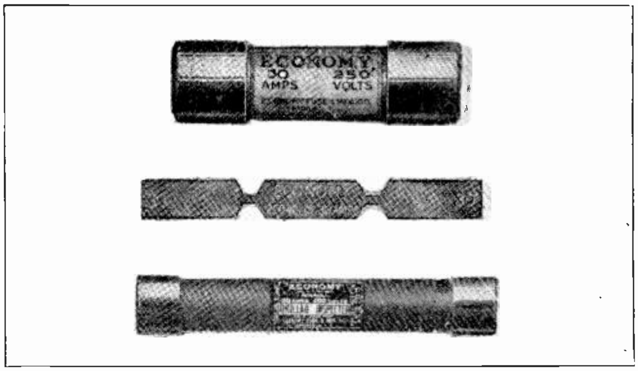


Fig. 103 The above view shows two types of cartridge fuses and one of the fusible lead links which are used inside these cartridges.

The fuses are held in the blocks by spring clips which grip the metal ferrule at the end of the cartridge. This makes them very easy and quick to renew when one blows out. The cartridge fuse is much more reliable and accurate because the fuse link is enclosed in the cartridge, and its temperature is not affected by air currents as is the open fuse link.

With a cartridge fuse, when the link blows out the arc or flame and molten metal are all confined within the cartridge, except in very rare cases when a heavy short circuit may cause the cartridge to explode.

Most cartridge fuses are of the renewable type in which the burned out link can be quickly replaced by unscrewing the ferrules or caps at the ends. The burned piece can then be removed and a new link inserted, the ends being folded over and securely gripped by the caps when they are screwed back on, or held under bolts on the knife blade type. The cost of this renewal link is very small, and as the cartridge very seldom needs to be replaced, the proper fusing of circuits is of very small expense compared with its protection value.

Fig. 104. These porcelain fuse blocks are equipped with spring clips in which the cartridge fuses are held.

71. "CUT-OUT" BLOCKS AND KNIFE BLADE FUSES

The porcelain blocks for holding the fuses are often called **Cut-Out Blocks.** The smaller fuses are used in circuits up to 60 amperes and are made in the ferrule type, or with the round end caps. Large sizes for from 65 to 600 amperes are made in the knife-blade type, with short flat blades attached to the end caps. These blades fit into clips on the fuse block, which are similar to regular knife switch clips. This type of construction is used on the heavier sizes because it gives a greater area of contact surface at the clips for heavy currents to flow through. Fig. 105 shows two knife-blade type cartridge fuses.

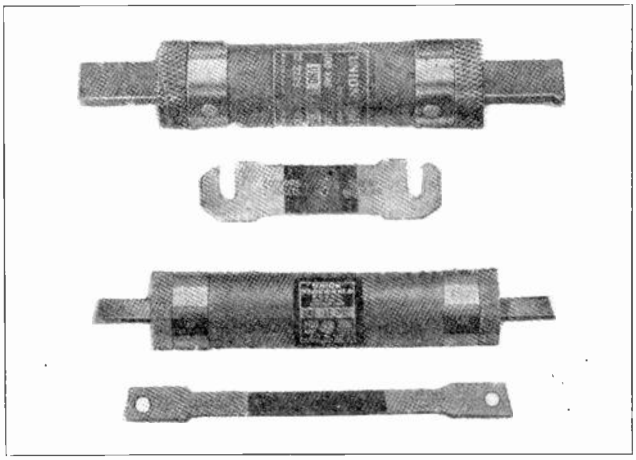


Fig. 105. For the heavier loads of current, knife blade type cartridge fuses of the above type are used.

Ferrule type fuses for voltages from 250 to 600 are commonly made in the following ampere ratings: 3, 5, 6, 10, 20, 25, 30, 35, 40, 50, and 60.

Knife-blade type fuses for the same voltages are made with current ratings of 65, 70, 75, 80, 90, 100, 130, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 550, and 600.

72. PLUG FUSES

Plug fuses are made with ampere ratings as follows: 3, 6, 10, 12, 15, 20, 25, 30. These plug fuses are the type most commonly used for fusing branch circuits in house wiring systems. They are made with a threaded base to screw into a socket in the cut-out block, similar to lamp sockets. Several types of plug fuses are shown in Fig. 106. Those in the top row are ordinary fuses with a small mica window, so it is easy to see when they have been blown. The fuse shown below with an extra element is of the renewable plug type. These fuses when blown can be taken apart and the small link replaced similarly to the renewal of the cartridge fuses.

Fig. 107 shows several types of cut-out blocks for plug fuses.

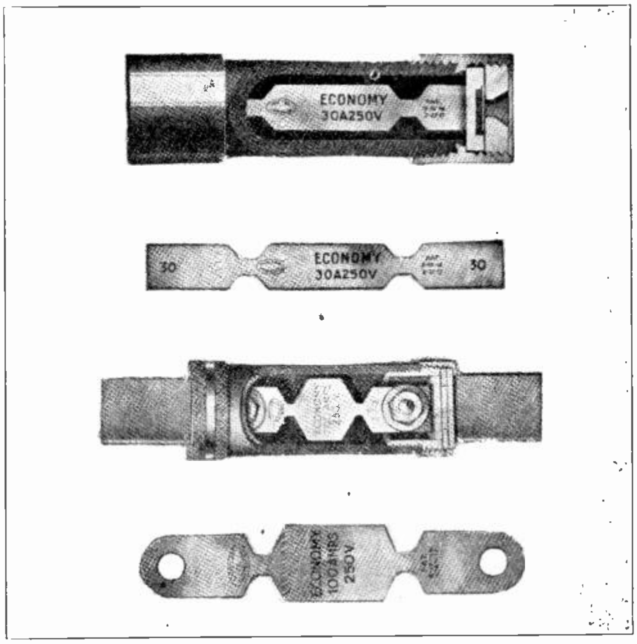


Fig. 105-B. These sectional views show the construction and arrangement of cartridge fuses and the manner in which the fuse strips are fastened in them. Note the difference in the mounting of this strip in the upper and lower cartridges.

When any circuit is overloaded a small amount beyond the capacity of its wires and fuses, the fuses gradually become warmer and warmer, until the link melts out and opens the circuit. When a circuit becomes severely overloaded or a short circuit occurs, the fuse blows instantly, and sometimes with considerable flash. This is as it should be because, if fuses didn't blow at once, a short circuit would very quickly ruin the insulation of the wires with the intense heat of the great rush of current.

73. NATIONAL CODE RULES ON FUSES

In general, every electrical circuit and system should be protected by fuses of the proper size connected in series with its lines, and care should be used never to allow fuses to be replaced with others that are too large. The National Code is very strict in the matter of fusing circuits and a few of the most important rules are as follows:

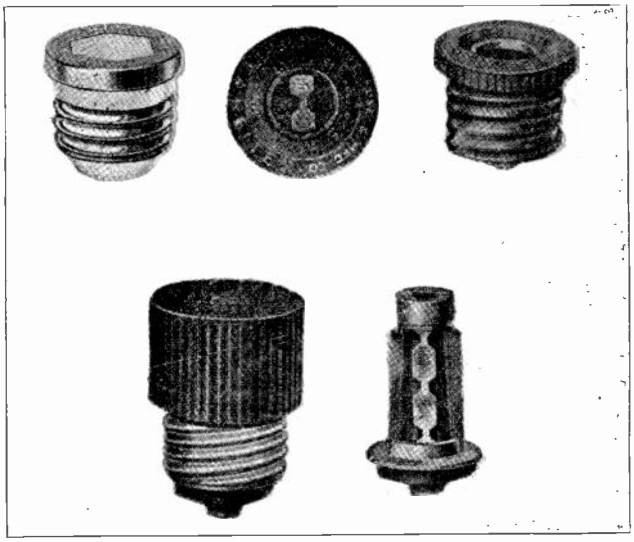


Fig. 106. The three fuses in the upper row are of the ordinary plug type with fusible windows to show when the link is blown out. The lower view shows a refillable plug fuse and one of its refill elements.

1. Fuses must be provided at every point where the wires of a system change in size, except when fuses closer to the service are small enough to protect these wires.

2. Fuses on fused switches must be placed on the dead side of the switch when it is open.

3. Every ungrounded service conductor should be provided with a fuse, except the neutral wire of a three-wire system, which must never be fused at any point.

4. All ungrounded wires of branch circuits should be protected by fuses.

5. Two-wire branch circuits on ungrounded systems must have both wires protected by a fuse in each wire.

6. Ordinary branch circuits must be protected by fuses not larger than 15 amperes at 125 volts, or 10 amperes at 250 volts.

Sometimes, when a fuse blows, some person who doesn't understand the function and safety value of a fuse may replace it with a piece of copper wire or in some cases even put pennies behind plug fuses. This is exceedingly dangerous practice and should never be used under any circumstances, as it is practically treating the wires of an electrical system, as if the safety valve of a boiler were locked.

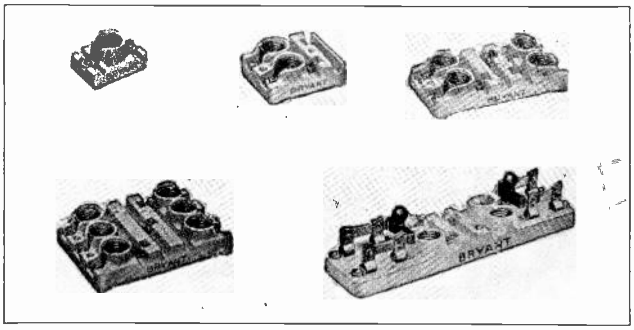


Fig. 107. Several types of "cut-out" blocks or fuse blocks for plug fuses are shown above.

When the size of fuses for any certain circuit is not specified by the Code, it can easily be determined by the use of your Watts law formula. If we know the voltage of any circuit and the load rating in watts of the equipment on this circuit, we can easily find the current in amperes by dividing the watts by the volts. This will indicate the proper size of fuses, providing we are also sure that the size of the wires is large enough to carry this load.

The table previously given, showing the current capacity of rubber covered wires, will also be a convenient guide to the selection of proper fuses. More about fuse troubles and maintenance will be covered in a later section on trouble shooting, and in the advanced sections on motors and power machinery, additional information will be given on the proper sizes of fuses for machines of different horse-power ratings.

74. PANEL BOARDS AND FUSE CABINETS

In small house-wiring systems, the fuses are usually placed at the place where the supply wires enter the house and near the service switch and meter.

In some small homes there may be only one circuit and one pair of fuses, and in larger homes or those better equipped with complete electric wiring there may be from 2 to 6 or more branch circuits and fuses. Fig. 108 shows two types of fuse blocks and safety switches in metal boxes. This is the modern and approved way to install them.

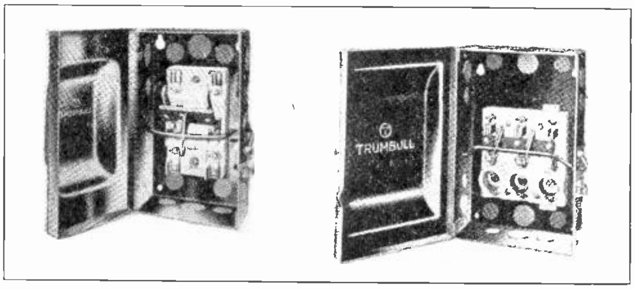


Fig. 108. Fuse blocks of either the cartridge or plug fuse type are commonly mounted with a safety switch in metal boxes.

In larger buildings—such as apartment houses, stores, and offices—there may be from a dozen to a hundred or more branch circuits, all requiring separate fusing.

In such cases it is common practice to install in one central cabinet all the fuses for a large group of circuits. Fig. 109 shows two such cabinets, one for a two-wire system and one for three wires. Both have main service switches which disconnect the entire cabinet and all circuits from the supply wires, and also separate switches and fuses for each circuit. The branch circuit switches in these cabinets are enclosed under safety panels through which only the handles protrude.

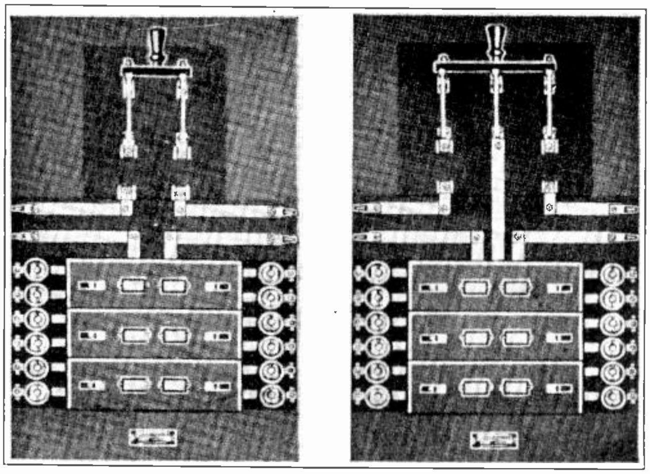


Fig. 109. On the left is shown a two-wire "cut-out" panel, and on the right one for three-wire circuits. Note the arrangement of the safety switch, plug fuses, and branch circuit switches.

Fig. 110 shows a modern fuse cabinet and metal panel of the type used in many large apartment buildings and offices, and Fig 111 shows a connection diagram for an entire cabinet of this type, including the meters.

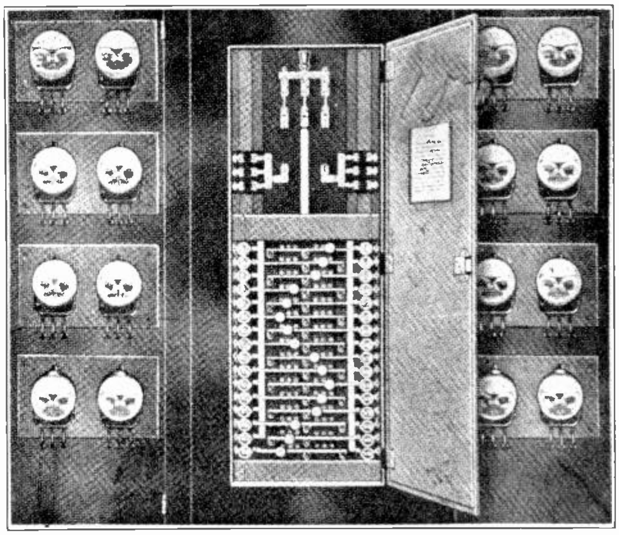


Fig. 110. This is a modern fuse and meter panel for large buildings which have a great number of branch circuits.

75. SWITCHES.

There are numerous types of switches used in electrical wiring. It is very important to select the proper types for various applications and to properly understand their use, operation and care.

The purpose of any switch is to conveniently and safely make and break an electrical circuit and start or stop the flow of current, thereby controlling the operation of the devices on that circuit.

76. KNIFE SWITCHES

Knife Switches are one of the most common types and are used for opening and closing the heavier circuits, such as main service wires in light and power wiring systems, and also branch circuits to motors and equipment using large amounts of current.

Knife switches consist simply of one or more copper blades hinged at one end and with clips at the other, and proper terminals for connecting the wires to them. Fig. 112 shows three common types of knife switches. One is called a **Single Pole,** one a **Double Pole,** and one a **Three Pole** switch. The number of poles indicates the number of blades, or the number of wires the switch can open. They are also made with 4 poles or more, and **Single** or **Double Throw.** Those shown in the figure are all single throw. Double throw switches have two sets of clips, one at each end, so the blades can be thrown either way into either set of clips, thus shifting from one circuit to another.

Knife switches are made with or without fuse clips as desired. The three pole switch in Fig. 112 is of the fusible type, while the other two switches are not.

When installing knife switches, they should be mounted so that the blades when opened cannot fall closed by gravity, and they should be connected so that when opened the blades as well as any fuse that may be on them will be dead. The blades of knife switches should always be enclosed, except when the switches are mounted on approved switch boards or panel boards.

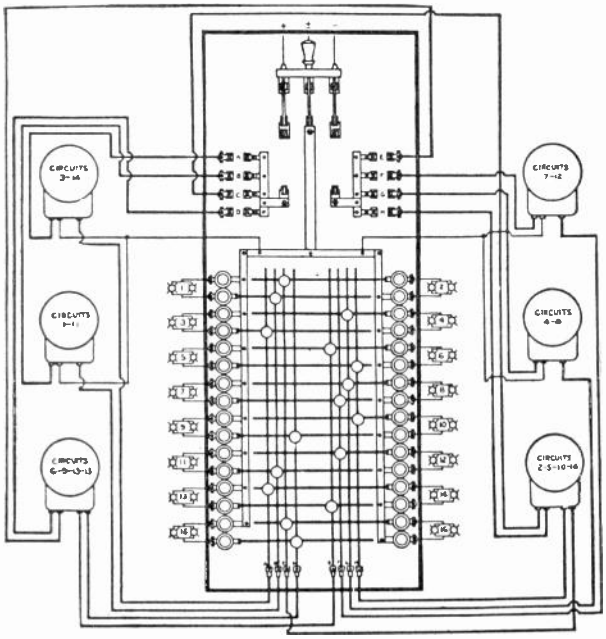


Fig. 111. Wiring diagram for modern fuse and meter cabinet.

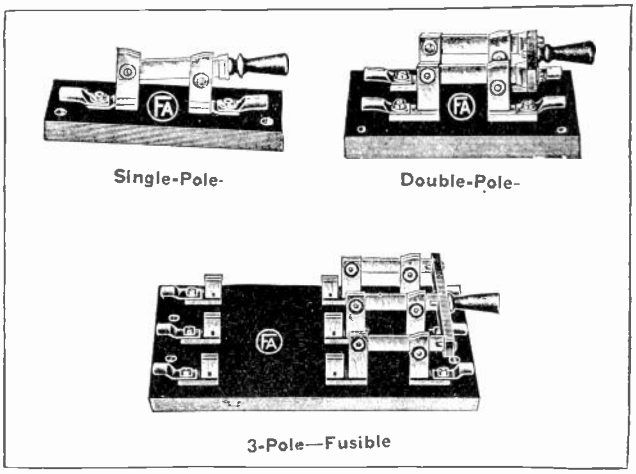


Fig. 112. Three common types of knife switches. The lower one is equipped for knife blade type fuses. Note the lugs which are used for attaching large wires or cables to these switch terminals.

Knife switches that are enclosed in a safety box and used for service switches in wiring systems should have a handle on the outside of the box, so the switches can be opened or closed without opening the door, and some indication or marks should be on the box to show when the handle is in the open or closed position.

Switches used for motor circuits should have a current capacity or continuous duty rating of 125% of the motor blade current rating.

It is very important that the clips of knife switches be kept properly fitted to the blades, so as to secure proper contact and prevent overheating of the switch due to high resistance.

77. SNAP SWITCHES

For the control of lights and branch circuits the **Snap Switch** is commonly used. There are several types of snap switches made, and their name comes from the quick snapping action with which they break the circuit. This action is obtained by a small spring and is a very important feature of such small switches, as the speed and suddenness with which it opens the circuit extinguishes the arc much more rapidly and effectively, thus to a great extent eliminating fire hazard and preventing burning of the switch contact.

Snap switches are made in **Single Pole, Double Pole, Three Way, Four Way,** and **Electrolier** types. Each of these types will be explained.

78. SURFACE TYPE SNAP SWITCHES

One of the very common and simple types of these switches is the **Surface Type Snap Switch.** Fig. 113 shows two switches of this type, one of them having the cover removed to show the working parts.

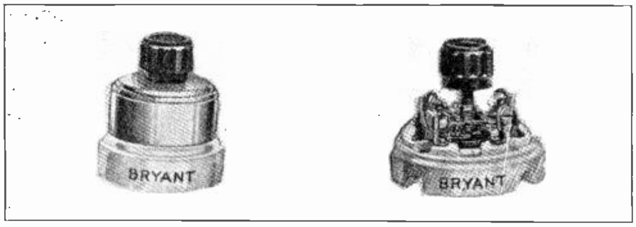


Fig. 113. Above is shown an ordinary surface type snap switch. The view on the right shows the cover removed.

These switches have a small rotating blade that is snapped in or out of stationary clips set on the porcelain base. When the button is turned it first winds a small coil spring on its shaft, and as it is turned farther this spring snaps the rotating blade in or out of the stationary clips.

For convenient connection of the wires, terminal screws are provided. These screws are of soft brass. While they should be tightened enough to hold the wires securely, they should not be forced too tight or their threads are likely to be stripped.

Fig. 114 shows several types of surface type snap-switches.

Surface type **Toggle** or **Tumbler** switches are being installed in preference to rotary button snap switches in many places today. Fig. 115 shows a surface type toggle switch on the left and two of the tumbler type on the right. These switches are more convenient to operate, as it is only necessary to push their levers up or down, instead of twisting a button as on the rotary snap switch.

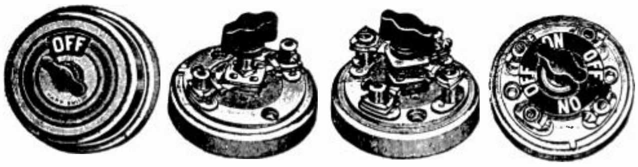


Fig. 114. Several types of snap switches. Note the "off" and "on" markings used on indicating switches.

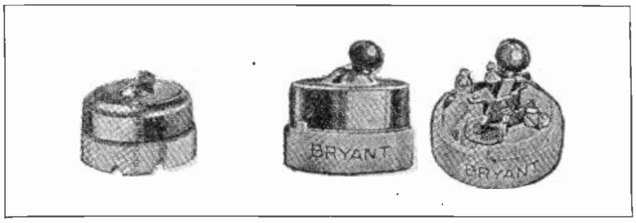


Fig. 115. Toggle and tumbler switches of the above type are very commonly used for surface mounting.

79. FLUSH TYPE SWITCHES

The snap switches mentioned so far are called "surface" type, because they are made to mount right on the surface of the wall. This is often not as desirable in appearance as the **Flush Type** switch, which mounts in an opening cut in the wall, has a neat flush cover plate, and is a very popular type. Fig. 116 shows two views of a **Push Button** type switch. The left view shows an open side view and the manner in which the two buttons are used to rock a small blade back and forth. The right view shows the top of a switch of this type.

Fig. 116. These two views show the construction and mechanism of push button type snap switches.

Fig. 117 shows another type of push button switch on the left, and a toggle switch on the right. The metal extensions or "lips" on these switches are used to fasten them in the switch box, which is mounted in a hole cut in the lath and plaster. Then the switch plates, or covers, are placed over them and fastened in place with small screws, presenting a finished appearance as in Fig. 118.

Where it is desired to control a separate light by means of a switch on the ceiling near that light, a ceiling pull-cord switch, such as shown in the left view in Fig. 119, is used. The one on the left

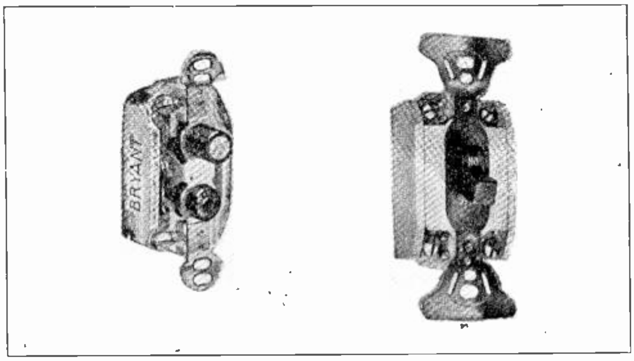


Fig. 117. Above are shown a push button switch on the left and a toggle switch on the right. Both are for flush mounting in switch outlet boxes.

is made to mount right on the surface of the ceiling, while the one on the right is made to mount in the side of the outlet box or fixture canopy and is called a Levolier switch.

There are also small snap switches which are enclosed in lamp sockets called **Key Sockets** or **Pull Chain Sockets.** Fig. 120 shows a key socket on the left and a pull chain socket in the center.

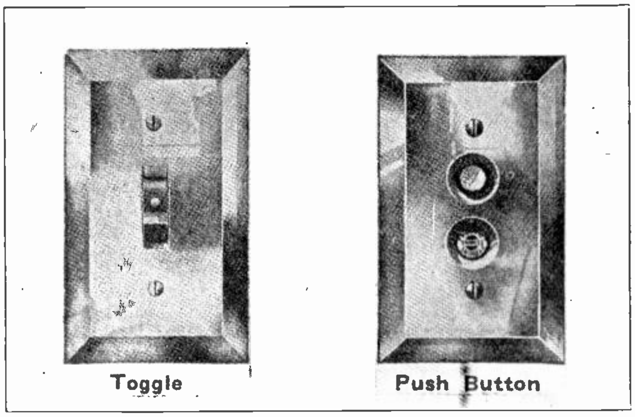


Fig. 118. This shows the finished appearance of properly mounted flush type switches with the covers placed over the outlet boxes.

80. SINGLE POLE SWITCHES

Single Pole Snap Switches are used to break only one wire of a circuit, and **must always be connected in the ungrounded wire.** They are used to control a light from one place only, and are the most commonly used of all switches in residence lighting systems. Single pole switches can always be easily distinguished from the others because they have only two terminals for the wires, and only one blade.

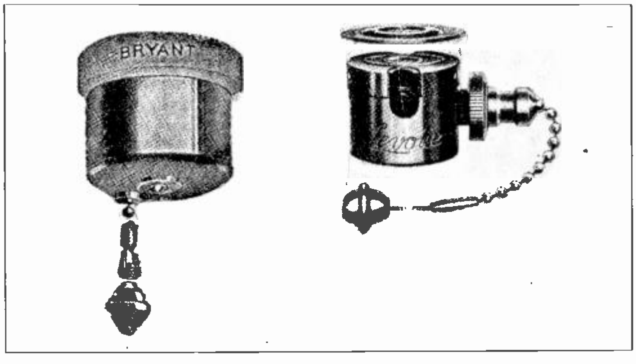


Fig. 119. Two types of pull cord switches for ceiling mounting and used to control individual lights.

81. DOUBLE POLE SWITCHES

Double Pole Switches are used to open both wires to a light or device, and thus break all connections from it to the line. Opening both sides of the circuit at once also more quickly extinguishes the arcs at the switch points. A double-pole surface-type switch always has four terminals and two blades. These blades are mounted one above the other on the shaft, and are insulated from each other. On this type of switch, never connect the line wires to opposite terminals, but always to terminals on the same side of the switch.

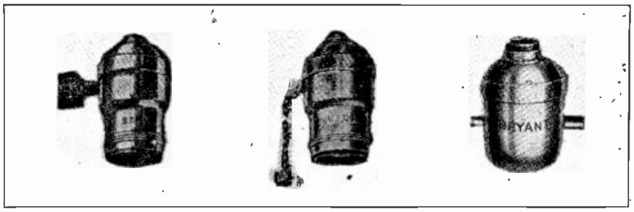


Fig. 120. On the left is a key socket or switch for controlling lights on drop cords. The center view shows a pull-chain socket, and on the right is a push button switch that can be mounted on the end of a suspended pair of wires.

Fig. 121 shows some of the symbols used for common surface-type snap switches, so you will be able to recognize them in the following connection diagrams.

Fig. 122 shows the connections of a single pole switch and a double pole switch for controlling the lamps, "L" and "L".

82. THREE-WAY SWITCHES

Three-Way Switches are used to control a light or group of lights from two different places, so they can be turned on or off at either switch. This is a connection very commonly used in all modern homes for lights in halls, on stairways, and other places. It is also very convenient for controlling garage, barn, or yard lights, as the lights outside can be turned on at the house and off again at the garage or barn. Or the lights can be turned on at the outer buildings and turned off at the house.

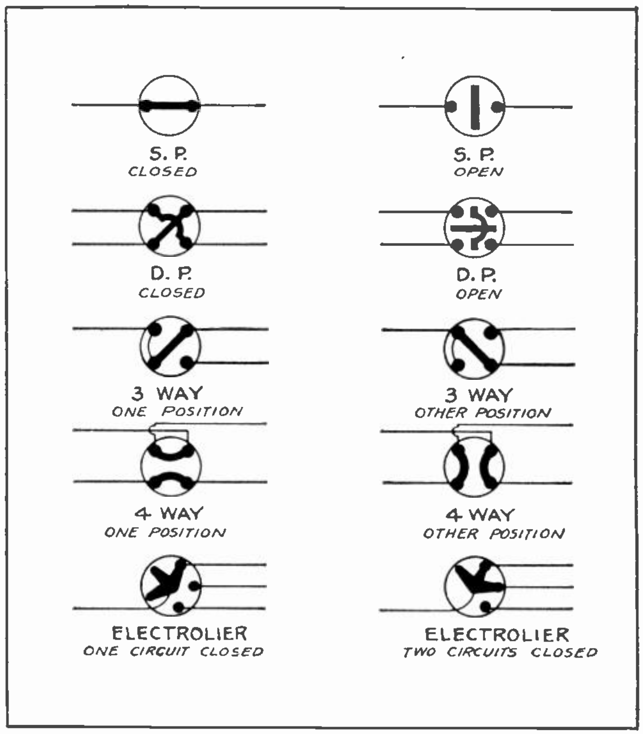


Fig. 121. The above symbols will be used to represent various types of switches in the following connection diagrams. Close examination of these symbols will also help you obtain a better understanding of each of these switches.

Three-way surface-type switches have four terminals and usually one blade. Sometimes there are two blades in one line. Two of the terminals are permanently connected together in the switch with

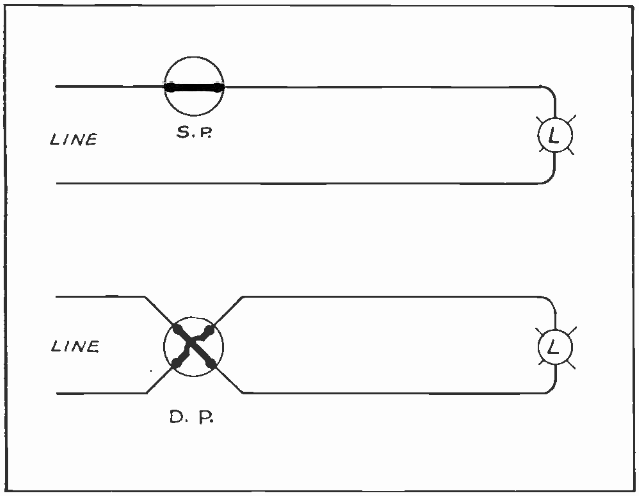


Fig. 122. The top diagram shows a simple single-pole switch connected to control one light. The lower diagram shows a double-pole switch connected to break both sides of the circuit to a light.

a shunt wire. Usually these terminals can be located by a strip of sealing wax in a groove between them on the base of the switch. This wax covers the shunt wire. This construction is one means of telling a three-way switch from other types of surface snap switches. On flush type switches, the three-way is the only one which has just three terminals.

Fig. 123 shows the connection diagram for two three-way switches used to control a light from two different points. Note that the **line always connects to the shunt terminal of one switch and the lamp to the shunt of the other switch.** The other two terminals of each switch are connected together as shown. This is a good rule to remember in connecting up three-way switches. Trace this diagram carefully and you will find the circuit to the lamp is closed. Shifting either switch blade will open it, and again shifting either one will close it once more.

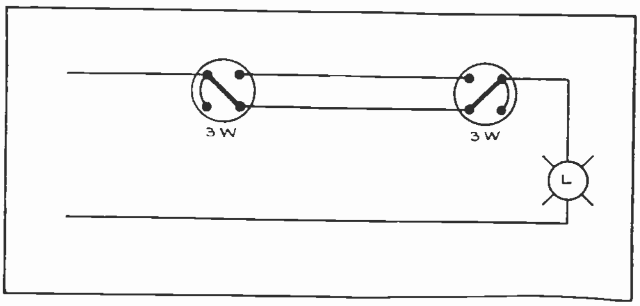


Fig. 123. Two three-way switches used for controlling a light fron two different places. Note carefully the manner of connection.

Fig. 124 shows another method of connecting three-way switches, known as the Cartweis system. This method is not approved by the Code as it places line wires of opposite polarity on adjacent terminals of the switch. This is in contradiction to the rule given for the common approved connection and is not considered as safe.

However, this method is sometimes used on 32 volt systems and saves one wire where both switches are to be located near the line wires, as in a case where a live line is run from a house to the garage or barn to operate other devices there in addition to the light.

The first system should always be followed in interior wiring in houses with 110 volt circuits.

83. FOUR-WAY SWITCHES

Four-way switches are used where it is desired to control a light or group of lights from more than two places. By their use in combination with three-way switches, we can control a light from as many places as desired.

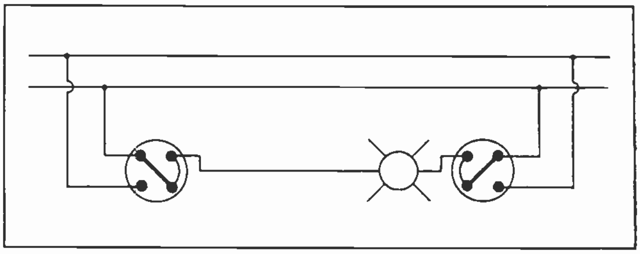


Fig. 124. This sketch shows the Cartweis system of connecting three-way switches. This method should not be used on 110-volt circuits in interior wiring.

The four-way surface-type switch has four terminals and two blades, and can be quite easily distinguished from the other switches because its blades always connect to adjacent terminals on the sides of the switch. No matter which position the switch is in, the blades always connect together one or the other set of adjacent terminals.

Fig. 125 shows a method of connecting two three-way switches and two four-ways to control a light from four different places.

The important points to note in this connection are as follows: The two three-way switches are always connected at the ends of the control group, with their shunts to the line and lamp, as before mentioned. Any number of four-way switches can then be connected in between them as shown. With surface-type snap switches, the one wire connecting the three-way and four-way switches together should **always be crossed at each switch** as shown, but the other one just connected straight through from terminal to terminal on the same side of the switches as shown. With some flush-type switches it is not necessary to cross the wires on one side of the four-ways, as they are already crossed inside the switches.

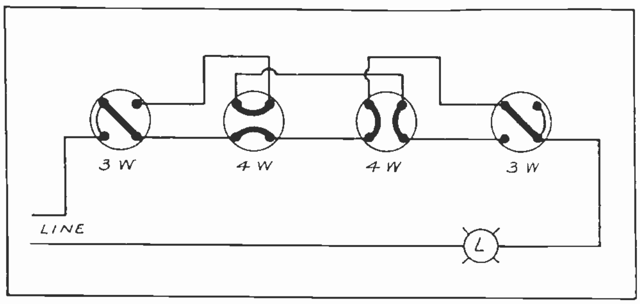


Fig. 125. This diagram shows two three-way and two four-way switches connected to control a light from four different places. Note carefully the connection and arrangement of the three-way switches at the ends, and the manner in which the wires to one side of the four-way switches are crossed.

Trace the diagram in Fig. 125 very carefully and you will find that, with the switch blades in their present position, the circuit to the lamp is closed. Moving any one of the switch blades into its other position will open the circuit, and moving any other one will close it again.

This type of connection is a very valuable one to know, and you will find it much easier to understand and remember the rules for its connection if you try drawing several combinations with different numbers of switches and tracing them out to see if they give the desired results.

A very important rule to remember in installing three-way and four-way switches is that they **must all be connected to the ungrounded wire** of the line, and never to the grounded wire. This is a Code rule, as it is with single pole switches, to make sure that the "hot" or ungrounded wire to the light is always open when the switch is turned off.

84. SUBSTITUTING VARIOUS SWITCHES

Sometimes in emergencies you may not have the proper switches on hand and certain others can be substituted temporarily if desired. For example, you can use either a three-way or four-way switch in place of a single pole switch. To use a three-way in place of a single pole, connect the line wire to the shunt terminal and the lamp wire to either of the separate terminals, as in the upper view in Fig. 126.

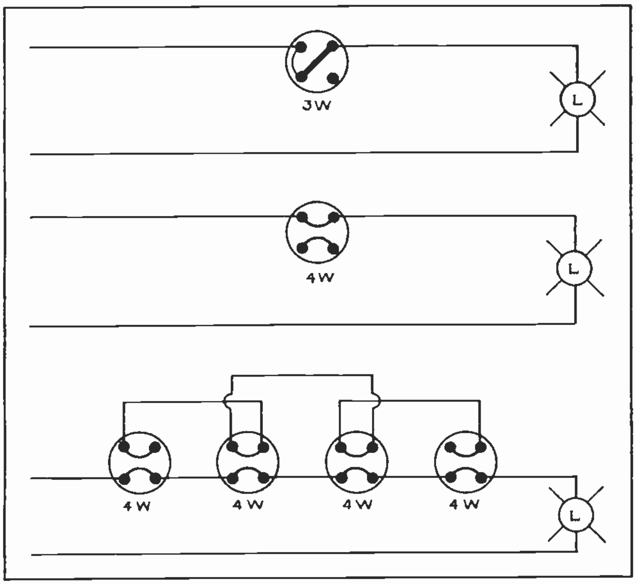


Fig. 126. The above three diagrams show methods of substituting various switches when the proper ones are not available. The top and center connections show the use of three-way and four-way switches in place of single-pole switches. The lower connection shows four-way switches used in place of three-way switches at the ends of the group.

To use a four-way switch in place of a single pole, connect the line and lamp wires to any two adjacent terminals, as in the center view in Fig. 126.

To use four-way switches in place of the usual three-ways at the ends of a group for controlling a light from several places, connect them as shown in the lower view in Fig. 126.

Some of these switches will cost more than the proper ones for which they are substituted—for example, three-way and four-way switches cost much more than single pole switches—so these substitutions should only be made in emergencies.

85. ELECTROLIER SWITCHES

Electrolier Switches are used to control one or more circuits, such as several lights on a chandelier, or the several sections of a heater element in an electric range, etc. These switches are obtainable with two or three circuits. Fig. 127 shows a method of connecting a three-circuit electrolier switch to turn on one, two, or all three of the lamps; or turn them all off if desired. In the upper view all lamps are out, in the center view only one lamp is on, and in the lower view two lamps are on. If the rotating element of the switch were turned one more point to the right all three lamps would be on.

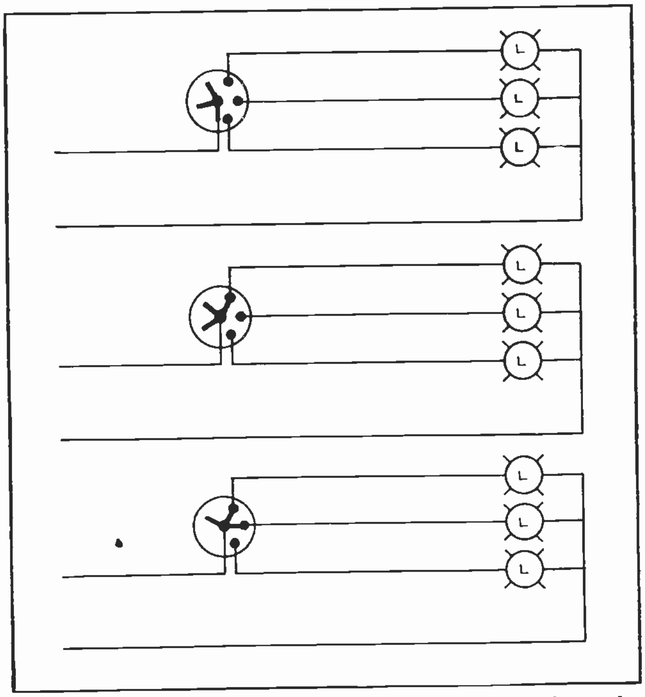


Fig. 127. These three diagrams show the manner in which an electrolier switch can be used to turn on one or more lights at a time.

These switches are very commonly used on electric ranges and heaters, to get low, medium, or high heat.

Fig. 128 shows several of the connections for push button and toggle-type flush switches. The sketch at "A" shows the terminal location and connections of a single-pole push button switch connected to control one lamp. "B" shows the terminals and connections of another type of flush single-pole switch. "C" shows a double-pole switch connected to control one lamp. "D" shows two flush-type, three-way switches connected so that either one can turn the light on or off. "E" shows two three-way switches and one four-way switch connected to control a light from three places. The wires are crossed at the four-way switch, as is necessary with some types of flush four-ways. "F" shows the connection of two three-ways and one four-way, using the type of four-way switch that has its terminal connections crossed inside, so the wires are run straight through. "G" shows a flush-type two-circuit electrolier switch with connections made to its marked terminals for turning on first one light, then both lights, then both off. "H" shows a two-circuit electrolier switch connected to first turn on one light, then turn it off; next turn on the second light, and then turn it off. "I" shows a three-circuit electrolier switch connected to first turn on one light, next turn on two lights, next all three lights on; then all off.

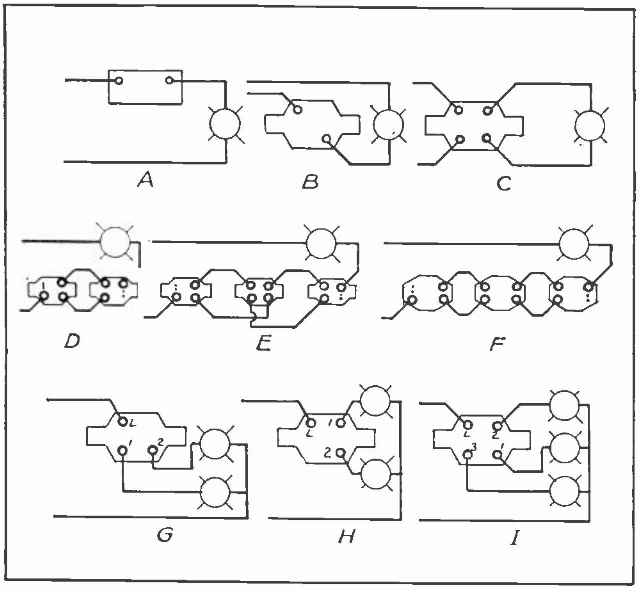


Fig. 128. The above sketches show methods of connecting flush type switches as represented by manufacturers' symbols. Check each connection with its explanation in the accompanying paragraphs.

A great many types of special switches are made for different applications. However, with a good understanding of these more common types, and a careful examination of the blades, terminals, and parts of any switches you may encounter, you should be able to understand them quite easily.

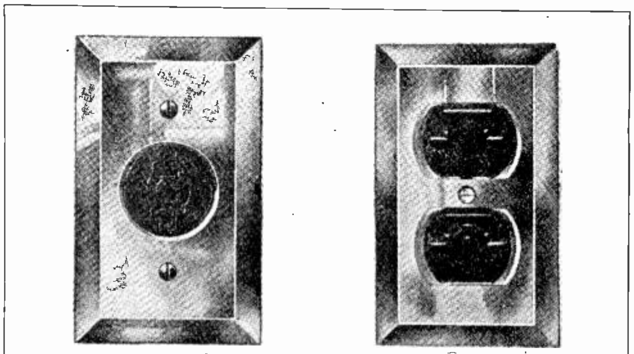
Sometimes the small copper blades and clips of snap switches become badly burned from the arcing when the circuit is interrupted or flamed, because they don't fit properly and make good contact with each other.

Snap switches are made in different current ratings according to the load they are supposed to control, and they should never be placed in circuits where they have to carry more current than they are rated for, because this will overheat them, burning and softening the blades and clips until they are useless. Any snap switch that arcs badly or sticks frequently is usually an indication of a defect in the switch or an overload on it.

86. CONVENIENCE OUTLETS AND RECEPTACLES

In the preceding pages we have occasionally mentioned outlet boxes for convenience receptacles. A modern house-wiring system is not merely to supply proper lights and convenient control for them, but should also include in all rooms a sufficient number of convenience outlets for the attachment of portable household electrical devices, such as fans, heaters, curling irons, dusters, sewing machines, vacuum cleaner, and the many other electrical devices used in the home today. These convenience outlets are usually installed in the baseboard, although sometimes they are mounted higher up in the walls, or even in the box with the switches.

The same outlet boxes can be used as are used for flush-type switches, and either a single or double plug receptacle can be installed. Fig. 129 shows both a single and a double receptacle of this type, with the cover plates which fit over the outlet boxes.



Single Receptacle | Duplex Receptacle

Fig. 129. Every home that is wired for electricity should have a sufficient number of convenience outlets or receptacles of the types shown above.

Fig. 130 shows the receptacles without covers and ready to be installed in the outlet boxes. The metal "lips" on the ends of each one are for attaching them to the outlet boxes with screws. These receptacles are connected to wires that are always live and are not controlled by switches. All that is necessary to obtain from them current for portable devices is to push the prongs of the plug, which is on the end of the cord, into the slots in the receptacle, where they are gripped by spring contacts inside.

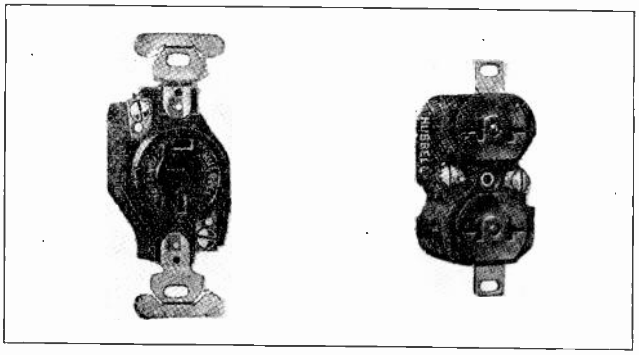


Fig. 130. These receptacle units are mounted in ordinary outlet boxes similar to those used for flush type switches. Note the terminal screws for connection of the wires to the receptacle, and also the metal "ears" for attaching the receptacle to the outlet box.

86-A. ATTACHMENT PLUGS

Small receptacle plugs can be obtained for screwing into threaded lamp sockets, and to them we can then attach the regular cord plug. These are commonly known as attachment plugs. Fig. 131 shows both sections of an attachment plug; close together in the left view, and separated at the right. The upper or male cap section in the right-hand view has two connection screws on its prongs, and can be quickly and easily attached to the cord of a portable device.

For certain portable tools requiring three and more wires, special plugs can be obtained. Some of them also have an extra wire for grounding the portable tool to the conduit system for safety to the operator.

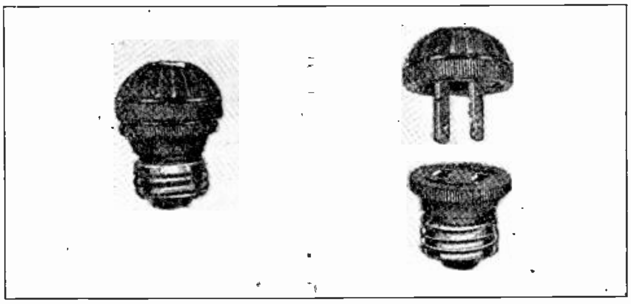


Fig. 131. Two views of an attachment plug of the type which can be screwed into a socket. The male element with the two brass prongs is attached to the cords of portable devices, and can then be plugged into any receptacle of this type

THREE-WIRE SYSTEMS

86-B. TWO-WIRE AND THREE-WIRE SYSTEMS

We have already mentioned that wiring systems can be either two-wire or three-wire systems.

The two-wire system does not need very much explanation as its connections and principles are very simple. They are the ones commonly used in small homes, and consist of the two main wires brought into the building from the power company's lines, and properly equipped with service switch, fuses, and meter.

From this point several branch circuits with two wires each can be run to the various groups of lights or outlets about the house. Two-wire lighting circuits are usually of 110 volts or about that, and two-wire D. C. or A. C. power circuits are usually of 220 volts.

It is a very simple matter to connect lights or motors to these circuits, with the proper switches and fuses where needed. The load devices are all connected in parallel, and while usually we need pay no attention to positive or negative polarity, we do need to know which wire is the grounded one and which the ungrounded. This will be explained a little later.

87. EDISON THREE-WIRE SYSTEM

The three-wire system is used extensively by power companies on their lines to the customers' buildings, and in most all of the larger homes and modern office buildings, hotels, stores, and factories.

This system is often thought to be somewhat complicated but in reality it is very simple to understand for anyone with a knowledge of the principles of electric circuits, such as you have already obtained.

The Edison three-wire system gets its name from the fact that it was originally used by Thomas Edison, who connected two 110 volt D. C. generators in series to obtain 220 volts between two outside wires, and 110 volts between each outside wire and the center or **neutral** wire. See Fig. 132.

You will recall that when any two generators or sources of current supply are connected in series, it adds their voltages; so it is easy to see how the two different voltages are obtained in this system

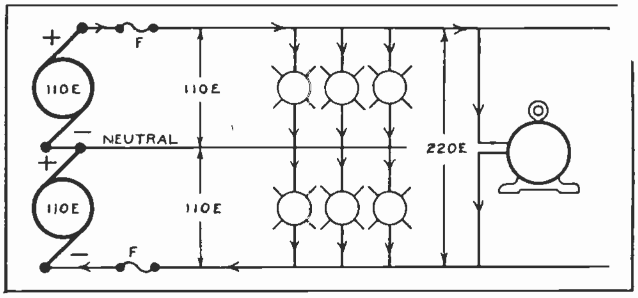


Fig. 132. This diagram shows the arrangement of two generators in series to supply an Edison three-wire system. Note that this arrangement provides both 110 volts for lamp circuits and 220 volts for motor circuits.

The advantages of the three-wire system are that it provides 110 volts for lights and 220 volts for motors, with only three wires, and it effects a great saving in the size of conductors and copper costs even when used for lighting alone. This is because when there is an equal number of lights on each side of the system, they all really operate on 220 volts, with two groups of lamps in series across the outside wires.

The current tends to flow through both generators in series and through both groups of lamps in series, and no current will flow in the neutral wire, as long as the number and size of lamps is equal on each side of the system.

88. SAVING IN COPPER BY USE OF THREE-WIRE SYSTEM

With the lamps operating at 220 volts and two in series, they require only one-half as much current in amperes to supply their rated voltage, as they would if they were operated on 110 volts. Therefore, smaller wires can be used and we find that this system saves over 50 per cent of the wire cost, except on certain small circuits where the Code requires a certain minimum size of wire.

The simple sketch and problem in Fig. 133 will illustrate how this reduction of current is obtained. We will use even figures of 100 volts and 200 volts to make them easy to follow. In "A" we have six 100 volt lamps of 200 watts each. The total wattage of the six lamps will be 6 x 200 or 1200 watts. The current required for this wattage will be W ÷ E or 1200 ÷ 100 = 12 amperes, which will be the load on the wires. In "B" the lamps are connected two in series and each of these pairs connected across the 200 volt wires.

The total wattage of the lamps remains the same, or 1200 watts, and now the current will be W ÷ E again or 1200 ÷ 200 = 6 amperes. So with this connection the wires only need to carry one-half as much current.

This can also be checked in another way as follows: We know that the current required by each 100 volt, 200 watt lamp will be 200 ÷ 100 or 2 aperes. So when they are all connected in parallel will require 12 amperes to operate them. But ien they are connected as at "B", the same two nperes which lights the upper lamps must pass a through the lower one as well, so it now requires only 3 × 2 or 6 amperes, at 200 volts.

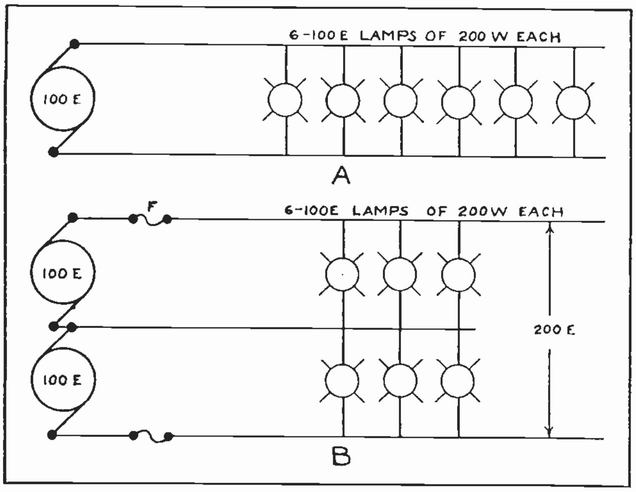


Fig. 133. By the use of Watts law determine the current required for the six lamps on 100 volts in the upper circuit; then determine the current required on the three-wire system below with the lamps apart on 200 volts and in groups of two in series. This will show the reason for considerable saving in the size of the wires on three-wire systems.

89. UNBALANCED SYSTEMS

So far we have considered only a balanced load condition where no current flows in the neutral wire. Now let's see what will happen if the load is unbalanced or if one of the lamps is turned out on the upper side of the system in Fig. 133-B. We will illustrate this separately. In this case the lower side will require 6 amperes and the upper side only 4 amperes. Two amperes will now flow out along the neutral wire from the lower generator, to make up this shortage. The upper generator supplies 4 amperes which flow through both groups of lamps and through the lower generator as well; and the lower generator supplies 6 amperes, four of which still flow through the outer wires and both groups of lamps, and two of which flow through the neutral and lower wires and lower groups of lamps only. The generators automatically assume their proper share of load whenever the load balance changes. Note the size of the current arrows which show this division of current. This is due to the fact that the resistance and the voltage drop of each group of lamps vary with their number.

For example, if the lamps in Fig. 134 are all 100 volt, 200 watt lamps their resistance will be 50 Ohms each. Then, according to our rule for finding the total resistance of a parallel group, that of the two upper lamps will be 50 ÷ 2 = 25 Ohms resistance between wires "A" and "B". The total resistance of the three lower lamps in parallel will be 50 ÷ 3 or 16⅔ Ohms between wires "B" and "C".

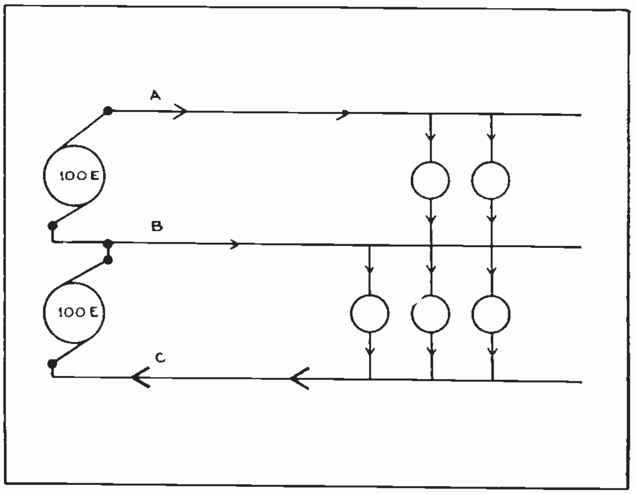


Fig. 134. This sketch shows an unbalanced three-wire system. Note carefully the division of current between the two generators and circuits and the direction of current flow in the neutral wire.

Each generator delivers 100 volts, so that is the voltage applied to each group of lamps. The current through the upper group will be E ÷ R or 100 ÷ 25 = 4 amperes. The current through the lower group will be 100 ÷ 16⅔ = 6 amperes. So we find that a simple application of Ohms law explains why the generators will each automatically supply their proper share of the current load.

The amount of current flowing in the neutral wire will always be in proportion to the amount of unbalanced load, and it may be in either direction according to which side of the system is the more heavily loaded.

90. "SOLID NEUTRAL" FOR THREE-WIRE SYSTEMS

The ideal condition for a three-wire system is to have no current flowing through the neutral, so we should always try to keep the load as evenly balanced as possible when connecting up the two-wire branch circuits to the three-wire mains.

Of course, it is impossible to keep such a system perfectly balanced at all times, because of lights and devices on the different circuits being turned on and off. This is the reason we need the neutral wire, and also one of the reasons the Code requires that on the modern polarized system the neutral must **not have in it any fuse**, which might open it at any time. This is the reason it is often termed a **Solid Neutral.** Many of the older non-polarized systems, however, have fuses and switches in the neutral.

91. EFFECTS OF OPEN NEUTRAL AND UNBALANCED LOAD

Now let's see what will happen in such a system if the neutral were fused and this fuse blew out while the load was unbalanced. In Fig. 135 we normally have a balanced load of eight lamps when all are turned on, but at present two in the upper group are turned off and the fuse in the neutral is blown.

Assume that the lamps are each of 100 Ohms resistance, and let's find out how much current will be flowing through the six lamps with 200 volts applied by the two generators in series, and their neutral open.

The resistance of the upper and lower groups of lamps being unequal, we must first figure that of each group separately and then, as the two groups are in series, we will add them to obtain the total resistance of all the operating lamps.

The resistance of the upper two lamps in parallel will be 100 ÷ 2 or 50 Ohms. That of the lower four in parallel will be 100 ÷ 4 or 25 Ohms. Then 50 + 25 = 75 Ohms, total resistance.

Now, according to Ohms law, we find that with 200 volts applied the current will be 200 ÷ 75 or 2⅔ amperes. This current will all flow through the upper two lamps, and then divide out through the lower four, so the upper lamps will burn much brighter than the lower ones.

The reason for this can also be checked by our knowledge of Ohms law and voltage drop principles. We know that the voltage drop across any device or group of devices in parallel is proportional to the resistance of the devices and the current flowing through them, or E d = I × R. Then, with a current of 2⅔ amperes flowing through the upper two lamps, which have a combined resistance of 50 Ohms, we find we have 2⅔ × 50, or 133⅓ volts drop across them, which accounts for their burning much too bright. On the lower group with the same current flowing through a resistance of 25 Ohms, we will have 2⅔ × 25, or 66⅔ volts drop across the lamps, which accounts for their burning very dim.

This over voltage applied to the upper group will cause their filaments to be severely overheated, and possibly burned out if they are left long in this condition.

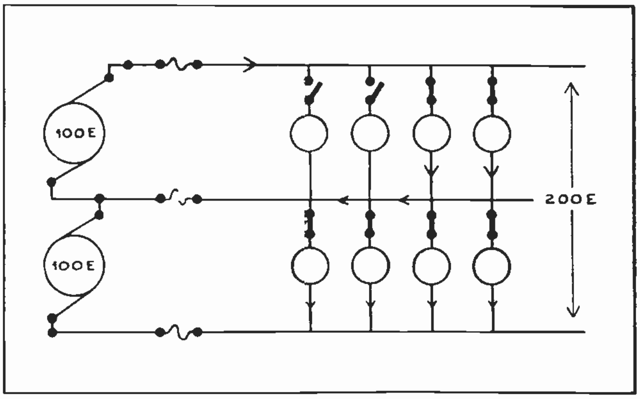


Fig. 135. This diagram illustrates what would happen if the neutral wire was to become opened on an unbalanced three-wire system. The upper two lamps would then burn excessively bright, and the lower four would burn very dimly.

From this we see what a common indication of a blown neutral fuse or a non-polarized three-wire system would be when part of the lamps burn excessively bright and others burn very dim.

This cannot happen on the modern polarized system where the neutral has no fuse and is always closed, allowing the generators to balance up the load by applying 100 volts at all times to each side of the circuit. If this had been the case in Fig. 135, the lamps would have remained at normal brilliancy, as 100 E ÷ 50 R of the upper group would cause just two amperes, or one ampere for each lamp, to flow through them; while 100 E ÷ 25 R of the lower group would cause four amperes, or one ampere for each lamp, to flow through them. The neutral wire would carry the difference.

While it is not likely that the neutral will often have to carry as much current as the outer wires, on a properly balanced three-wire system, it is possible for it to happen occasionally, so the Code requires that the neutral wire be the same size as the others, except on loads over 200 amperes, where we can reduce the size of the neutral 30%. This reduction is allowed either from the maximum connected load, or by applying what is known as a **Maximum Demand Factor,** which will be explained later.

We have illustrated the principles of the three-wire system with two D. C. generators as the source of the two different voltages, because it is easy to understand and was the first method of obtaining this system. In a number of places this method is still in use, where 110 and 220 volts D. C. are used. In other cases a special three-wire generator is used, having a connection to a center point in its armature winding to obtain the neutral or half voltage wire.

This system can also be used just as readily on A. C., by using two transformers connected in series, or merely a center tap from the 220 volt secondary winding of one transformer, as shown in Fig. 136. This is by far the most common type of three-wire system in use today, and is applied to power systems at 220 or 440 volts A. C., as well as to house wiring systems.

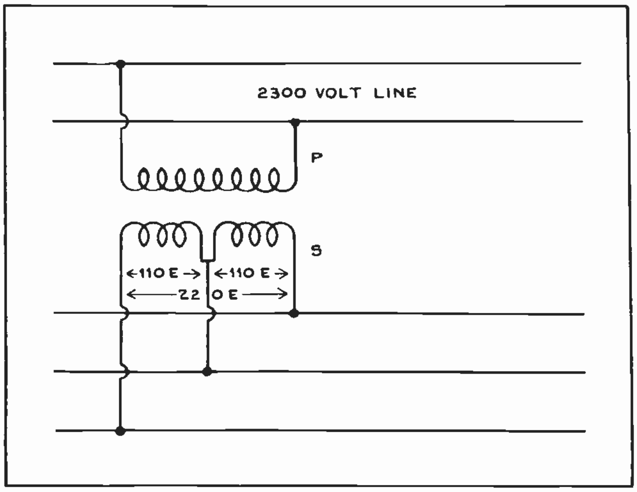


Fig. 136. Three-wire A.C. systems can be conveniently obtained by the use of a center connection to transformer windings as shown above.

92. POLARIZED WIRING SYSTEMS

This system has been mentioned several times so far, particularly with reference to the grounding of various circuits and devices. The term polarized in this case refers to the grounding and marking or identification of the neutral wire.

The modern polarized wiring system is one that has the neutral wire thoroughly grounded at the service switch, and this grounded wire distinguished throughout the entire system by a different color from the "hot" or ungrounded wire.

Generally, we use a wire with black or red insulation for the ungrounded wire, and one with white or light gray insulating braid for the grounded wire. This applies to wires from 14 to 6 in size. On larger wires and cables, other methods of marking the grounded wire are used. Its ends can be coated with white paint or tagged, or at the service entrance the ends left for the power company's man to connect his wires to, can have the insulation stripped off the grounded wire for a short distance. The identification of the grounded wire should be carried on through every branch circuit, fixture wire, etc., right up to the device using the current.

The other very important rule for a polarized system, as previously mentioned, is that the neutral or grounded wire must not have any fuse in it at any point, but must always be complete and unbroken from the service box to the very tip of light sockets or devices to which it is attached. Or, in other words, it must be what is called a **Solid Neutral.**

93. SAFETY FEATURES AND ADVANTAGES OF POLARIZED WIRING

The principle advantage of maintaining this unbroken grounded wire, and having it plainly marked, is so that it can always be connected to the threaded or outer element of lamp sockets and receptacles; while the "hot" or ungrounded wire must always be connected to the inner or center terminal of such sockets. This eliminates practically all danger of anyone getting a shock by touching this device, even if the insulation of the outer element failed, allowing it to touch the shell or casing.

You will find the terminal screws of the latter type sockets, receptacles, and switches are also identified by one screw having a yellow or brass color, and the other a white or silvery color.

The grounded wire should, of course, attach to the lighter colored screw, and the "hot" wire to the brass colored screw.

When using BX we must make an exception to the rule on connection of the black and white wires together.

This is because we must have one black wire and one white one coming out of the outlet for connection to the light fixture, as in Fig. 136-B. In order to do this, we must connect the white wire of the BX, which runs to the switch, to the black wire in the ceiling outlet.

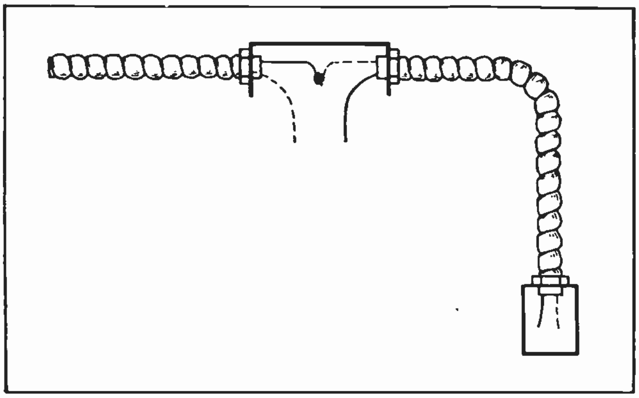


Fig. 136-B. This sketch shows the manner in which the white and black wires in a polarized system are connected at the outlet boxes for ceiling lights and wall switches.

We should then remember that the white wire at the switch is the "hot" one, and the black wire at the ceiling outlet is the return wire from the switch, and it should be connected as usual to the yellow screw on the fixture.

In order to make this protection positive and dependable, you can readily see that the grounded wire must always be complete clear back to the transformer, and we should never place any switch in this side of the circuit, unless it also opens the ungrounded wire at the same time it opens the grounded one. Double pole snap switches, for example, open both wires at the same time. Single pole switches must always be placed in the ungrounded wire.

Having this neutral wire grounded, as well as the conduit, gives us added protection against fire or shock hazard from the conduit system.

In case the insulation of the "hot" wire becomes defective, and allows it to touch the conduit, this causes a short circuit and immediately blows the fuse, indicating a defect on the circuit, which can be repaired at once. Using this system with a solid neutral also eliminates the possibility of having an open neutral and burned out lamps or devices on one side of the system from an unbalanced load.

94. GROUNDING NEUTRAL WIRE OF POLARIZED SYSTEMS

At the transformers you will always find three wires coming from the secondary winding. The center one of these is the neutral, and is grounded by the power company. The ground inside the building at the service switch should be heavy copper wire not smaller than No. 8, as previously mentioned, and this wire should be protected from possible breakage by being run inside the piece of conduit to the waterpipe, where it is attached by use of a ground clamp, previously described.

The end of this ground wire at the service box is usually connected to the "neutral strap" in the switch box, and also to a brass grounding screw that will be found in the modern steel switch cabinet.

We do not ground the service switch or any part of an interior D. C. wiring system, but one wire of the D. C. line is grounded at the power plant.

On all alternating current systems, however, this additional grounding of the neutral wire as well as the conduit, and the identification of this wire throughout the system are great safety features and advantages, and make the Edison three-wire system a very desirable one to use.

95. PARTS OF WIRING SYSTEMS

Every wiring job consists of at least two, and sometimes three, important parts. They are the **Service, Feeders,** and **Branch Circuits.** All jobs must have the service and branch circuits, and on the larger installations the main circuits feeding from the service to the branch circuit panels are called feeders.

The service can be divided into two parts also. One part is the running of the wires from the transformer or line to the building service entrance, which would be the **Drip Loops** or weather cap on the building. The other part is the running of the wires from the drip loop into the service switch.

96. SERVICE WIRES

The service wires from the pole are usually run by the power company from whom the power is to be purchased. These wires should have weatherproof insulation, and be attached to insulators at the house in a manner to keep all strain off from the drip loop and weather cap.

See Fig. 137, which shows how these wires would be attached to the building, and also a method of bracing a porch, or part of a building, to stand the strain that long heavy service wires might place upon it.

The **Drip Loop,** or slack loops of wire from the insulators to the weather cap, are used to prevent water from running down the wires into the conduit.

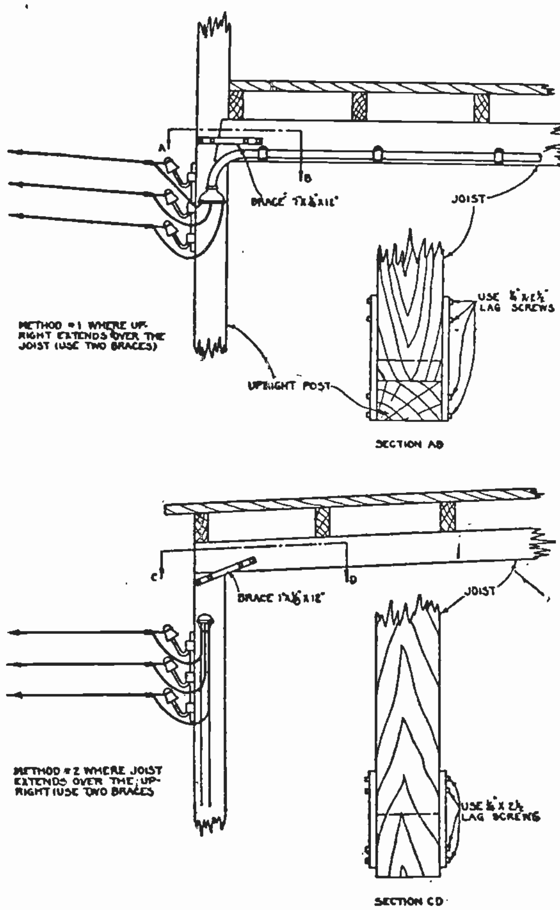


Fig. 137. The above two sketches show the method of arranging the connections of service wires to a building with strain insulators, drip loops, and weather heads. Also note the method of bracing a porch or corner of a building to stand the strain of a long run of service wires.

The electrician wiring the house can use either conduit or knob and tube work for running the service on in to the service switch. The Code recommends the use of conduit, and it is much the best.

The service wires must be at least No. 8 and rubber covered. This requires ¾" conduit, which can be run from a point near the outside insulators, either up or down the outside wall, or along horizontally, to a convenient place for entrance to the service switch inside. The wires and conduit should be larger if the load requires.

This conduit should always be equipped with a **Weather Cap,** such as one of the types shown in Fig. 138, so the wires enter from the under side and no water can enter the conduit.

In some cases a "B" condulet fitting can be used, or the upper end of the conduit bent in an inverted "U", and an "A" condulet used to form the weather protection. The strain insulators and weather cap should be located 15 to 18 feet from the ground if possible.

If knob and tube work is used for the service, the wires should also enter the building high up, to be out of reach from the ground outside. They should also pass through properly sloped tubes where they enter the wall.

Service wires should enter the building at a point as near as possible to the service switch, and this switch should be located near a door or window if possible. This location of the switch is to make it more easily accessible in case of fire.

Fig. 138. Weather head fittings of the types shown above are used on the end of conduit at the service entrance to prevent water from entering the conduit.

97. FEEDERS

On larger jobs, such as apartment buildings, stores, and offices, cut-out blocks, or fuse cabinets are often located on the various floors or in various sections or apartments. The **feeders** are run from the service switch to these branch circuit panels, and the wires must be of the proper size according to the load in amperes which they are to carry.

Sometimes several buildings are connected together by feeders, in which case there must be a suitable **Feeder Control** switch at one end or the other, to separate the systems in each building when necessary.

Service or feeder wires when passing over any buildings must clear the roofs 8 ft. at their nearest point.

98. BRANCH CIRCUITS

Practically all wiring systems have **Branch Circuits,** which may be referred to as the **wires beyond the last set of fuses.**

Most branch circuits are two-wire circuits, although some are three-wire. On all ordinary two-wire branch circuits of under 125 volts, we must use at least No. 14 wire, and fuses of not over 15 ampere size as a rule.

In addition to lamps, we may connect appliances of not over 660 watts or 6 amperes each to these branch circuits.

99. TYPES OF BRANCH CIRCUITS

Branch circuits are sub-divided into:

Lighting Branch Circuits, which are intended to supply energy to lighting outlets only, and are governed by the rules just given.

Combination Lighting and Appliance Branch Circuit, which as its name implies is a combination of lighting and power outlets with limits as shown above.

Appliance Branch Circuits, which supply energy to permanently wired appliances or to attachment plug receptacles.

Appliance Branch circuits are further sub-divided into:

Ordinary Appliance Branch Circuits, using as a rule receptacles and plugs rated at not over 15 amperes at 125 volts, using at least No. 14 wire and fused for not to exceed 15 amperes. On these circuits we may use appliances rated at not over 1320 watts.

Medium Duty Appliance Branch Circuits, wired with No. 10 wire, and fused for 25 amperes, where we may use appliances rated not to exceed 15 amperes or 1650 watts each.

Heavy-Duty Appliance Branch Circuits, wired and fused as above, for appliances between 15 and 20 amperes.

Appliances using over 20 amperes should be supplied by individual circuits.

100. LOADS ON WIRING SYSTEMS, AND SIZE OF SERVICE WIRES

The total connected load on any wiring system can easily be calculated by adding up the rating in watts of all the lamps and devices connected to the system.

Then, by dividing this wattage by the voltage of the system, we can determine the current in amperes which would flow if all the devices were ever operated at once. This would be called the maximum load.

In the ordinary building there is almost never a time when all lights or devices are turned on at once. However, careful tests and measurements on various classes of buildings show certain average loads which represent the usual case. In various types of buildings these loads vary from 25 per cent to 85 per cent of the connected load.

Until 1928 the National Code required the installation of service wires and feeders large enough to take care of the **Maximum Connected Load.** If there was a total connected load of 500 amperes in the building, the service wires had to be large enough for this load, even though there was practically no chance of 500 amperes ever being used at any one time.

101. DEMAND FACTOR

The Code now permits us, under certain conditions, to consider the **Maximum Demand** instead of the **Maximum Connected Load,** when figuring the size of service and feeder wires. To do this we use what is called the **Demand Factor.** This figure is obtained from the ratio of the maximum demand to the connected load of the type of system we are considering. It is based on the area, as determined by the outside dimensions of the building and the number of floors; and it may be applied to interior wiring systems supplying both lights and appliances. This demand factor also varies with the use to which the building is put.

Let us consider an example for an ordinary single-family dwelling. If the house is 40′ x 70′ and two stories high (not counting unoccupied basements or unfinished attics or porches) then its area will be 40′ × 70′ × 2 = 5600 sq. ft .

For the first 2000 sq. ft. of such buildings, we allow one watt per sq. ft. or 2000 watts; and for the balance .60 watts per sq. ft. The balance in this case is 5600 — 2000, or 3600 sq. ft.

With this balance we can use the demand factor, which is .60 for this type of building. Then .60 × 3600 = 2160. We must always add an extra 1000 watts for appliances.

The total load, or maximum demand, will then be 2000 + 2160 + 1000 or 5160 watts. If this is to be on a balanced three-wire system we can divide the watts by 220 volts, or 5160 ÷ 220 = 23.4+ amperes, to allow for on the service wires. If it is to be a 110 volt system then 5160 ÷ 110 = 46.9+ amperes. (Note—Wherever the + sign is used after an answer figure, it indicates this figure is approximate and not carried out to long decimal fractions.)

In residence buildings of the apartment type, for from two to ten families, we use .70 as the demand factor, and add 1000 watts for each apartment for appliances. The demand factor can also be applied to the total allowance for appliances.

In stores, including department stores, we allow two watts per sq. ft., except for display cases and show windows. For counter display cases, allow 25 watts per linear ft. (per ft. of length); for wall and standing cases, 50 watts per linear foot; and for show windows, 200 watts per linear ft. In such buildings 1.00 is used as a demand factor.

In garages, allow ½ watt per sq. ft., and use 1.00 as the demand factor.

In industrial plants and commercial buildings, the service wires are calculated for the specified load of the equipment. This takes into consideration the average load factor, which will be covered in a later section on motors.

Other kinds of installations are covered in the Code and can easily be referred to when required.

Keep in mind that the demand factor applies only to services and feeders, and not to branch circuits.

WIRE CALCULATIONS

102. WIRE CALCULATIONS

A great deal of valuable information on the size of copper wires, their resistance, and current carrying capacity can be obtained from convenient tables; and they should be used whenever possible as they are great time savers.

There are certain cases, however, when tables are not available or do not give just the needed information, and a knowledge of simple wire calculations is then very important.

For example, the table in the National Code which gives the allowable current carrying capacities is based on the heating of the wires and does not consider voltage drop due to resistance of long runs or lines. Both of these considerations are very important and should always be kept in mind when planning any electrical wiring system.

The wires must not be allowed to heat enough to damage their insulation, or to a point where there will be any chance of igniting nearby materials. If wires are allowed to heat excessively, it may cause the solder at joints to soften and destroy the quality of the splices; and in other cases it may result in expansion of the wires and resulting damage. Heat is also objectionable because it increases the resistance of the wires, thereby increasing the voltage drop for any given load.

103. VOLTAGE DROP

Whether or not the wires heat noticeably, the resistance and voltage drop on long runs may be great enough to seriously interfere with the efficient operation of the connected equipment. Incandescent lamps are particularly critical in this respect and a drop of just a very few volts below the voltage for which they are rated, greatly reduces their light and efficiency. In the case of lighting circuits, the current reduces when the voltage at the lamps is below normal.

Motors are not affected by small voltage variations quite as much as lamps are, but they will not give their rated horsepower if the voltage is below that at which they are rated. When loaded motors are operated at reduced voltage, the current flow actually increases, as it requires more amperes to produce a given wattage and horsepower at low voltage than at the normal voltage. This current increase is also caused by the fact that the opposition of the motor windings to current flow reduces as their speed reduces. The reason for this will be explained later.

From the foregoing we can see that it is very important to have all wires of the proper size, to avoid excessive heating and voltage drop; and that, in the case of long runs, it is necessary to determine the wire size by consideration of resistance and voltage drop, rather than by the heating effect or tables alone.

To solve the ordinary problems requires only a knowledge of a few simple facts about the areas and resistance of copper conductors and the application of the simplest of arithmetic.

104. GAUGE NUMBERS BASED ON RESISTANCE

You have already learned that wire sizes are commonly specified in B. & S. gauge numbers. This system was originated by the Brown & Sharpe Company, well known manufacturers of machine tools. The B. & S. gauge is commonly called the American Wire Gauge, and is standard in the United States for all round solid electrical wires.

These gauge numbers are arranged according to the resistance of the wires, the larger numbers being for the wires of greatest resistance and smallest area. This is a great convenience, and a very handy rule to remember is that **increasing the gauge by three numbers gives a wire of approximately twice the area and half the resistance.** As an example—if we increase the gauge from No. 3, which has .1931 Ohms per 1000 ft., to No. 6, we find it has .3872 Ohms per 1000 ft., or almost double.

Brown & Sharpe gauge numbers range from 0000 (four ought), down in size to number 60. The 0000 wire is nearly ½ inch in diameter and the number 60 is as fine as a small hair.

The most common sizes used for light and power wiring are from the 0000 down to No. 14; and also, of course, the Nos. 16 and 18, which are used only for fixture wiring.

105. CIRCULAR MIL, UNIT OF CONDUCTOR AREA

In addition to the gauge numbers, we have a very convenient unit called the **Mil**, for measuring the diameter and area of the wires. The mil is equal to 1/1000 of an inch, so it is small enough to measure and express these sizes very accurately. It is much more convenient to use the mil than thousandths or decimal fractions of an inch. For example, instead of saying a wire has a diameter of .055", or fifty-five thousandths of an inch, we can simply say or write 55 Mils. So a wire of 250 Mils diameter is also .250", or ¼ inch, in diameter.

As the resistance and current-carrying capacity of conductors both depend on their cross-sectional area, we must also have convenient small units for expressing this area. For square conductors such as bus bars we use the **Square Mil,** which is simply a square 1/1000 of an inch on each side. For round conductors we use the **Circular Mil,** which is the area of a circle with a diameter of 1/1000 of an inch. The abbreviation commonly used for circular mil is C.M.

These units simplify our calculations considerably, as all we need to do to get the area of a square conductor in **Square Mils,** is to multiply one side by the other, measuring them in mils or thousandths of an inch.

To get the area of a round conductor in **Circular Mils,** we only need to square its diameter in mils or thousandths of an inch.

106. CONVERSION OF SQUARE MILS TO CIRCULAR MILS

In comparing round and square conductors, however, we must remember that the square mil and circular mil are not quite the same size units of area. For a comparison see Fig. 139. At "B" we have shown a circle within a square. While the circle has the same diameter as the square, the corners of the square make it the larger in area. So just remember this little illustration, and it will be easy to recall that the area of one **Circular Mil** is less than that of one **Square Mil.** The actual ratio

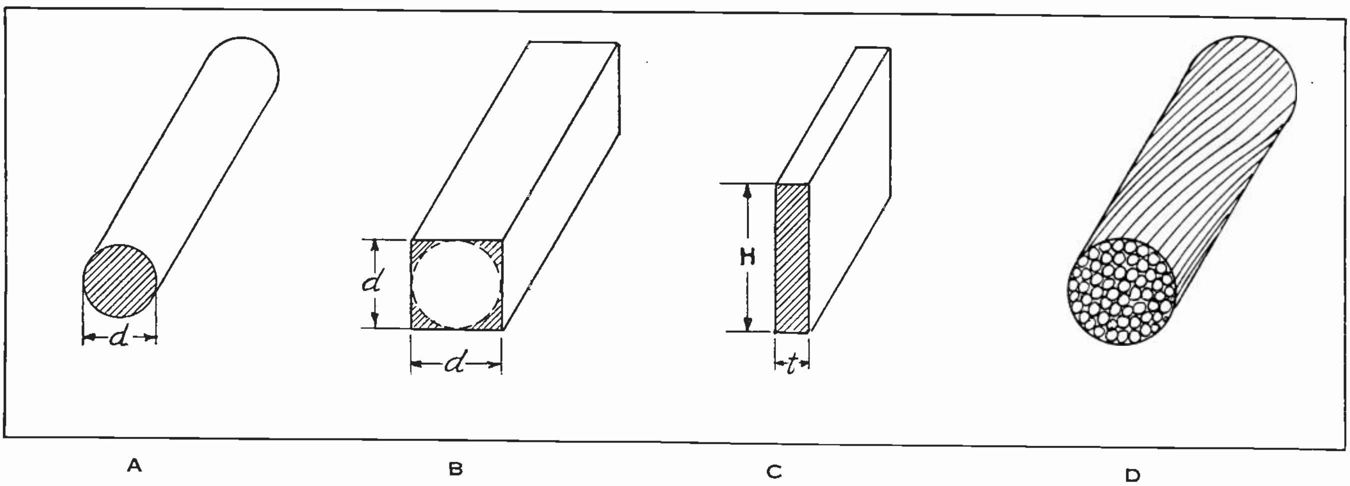


Fig. 139. Electrical conductors are commonly made in the several shapes shown above. Note particularly the comparative areas of round and square conductors as shown at "B", and refer to these illustrations when making the calculations explained in the accompanying paragraphs.

between them is .7854, or the circle has only .7854 of the area of a square of the same diameter.

Then if we wish to **find the Circular Mil Area from the number of Square Mils, we divide the Square Mils by .7854.** If we wish to **find the Square Mil Area from Circular Mils, multiply the Circular Mils by .7854.**

For example, if the conductor at "A" in Fig. 139 is a No. 0000 and has a diameter of 460 mils, what is its area both in circular mils and in square mils? The C.M. area is 460 × 460 = 211,600 C.M. Then the sq. mil area is 211,600 × .7854 = 166,190.64 sq. mils.

If the bus bar at "C", in Fig. 139, is 1½ inches high and ¼ inch thick, what is its area in square mils, and what size of round conductor would be necessary to carry the same current that this bus bar would? First, the dimensions of a ¼" x 1½" bus bar, stated in mils, are 250 mils × 1500 mils. Then the area in sq. mils is 250 × 1500 = 375,000 sq. mils.

To find what this area would be in circular mils we divide 375,000 by .7854, and find it would be 477,463.7 C.M. The nearest size to this in a round conductor is the 500,000 C.M. size, which we would use in this case.

Bus bars of the shape shown at "C" in Fig. 139 are commonly used in wiring power plant or large distribution switchboards. These bars ordinarily range in thickness from .250" to .375"; and in height, from 1" to 12". On voltages under 600 they can be used bare, when properly mounted on switchboard panels. On higher voltages they are usually taped to avoid shock hazard.

It is quite common practice to allow about 1000 amperes per sq. inch on such busses when they are located in well ventilated places. This is a very convenient figure and should be remembered.

When heavier currents than one of the thin bars can carry, are to be handled on a switchboard, several bars are usually mounted in parallel with small spaces between them for air circulation and cooling.

Stranded conductors, such as shown in Fig. 139-D, are used on all sizes larger than 0000. As stranded conductors are not solid throughout, we cannot determine their area accurately by squaring their diameter. This diameter also varies somewhat with the twist or "lay" of the strands.

To determine the cross-sectional area of such conductors, we get the area of each strand, either from a wire table or by calculation from its diameter, and then multiply this by the number of strands, to get the total area of the cable in C.M.

The following wire table gives some very convenient data and information on the common sizes of conductors, and will be very convenient for future reference as well as during your study of this section.

WIRE TABLE. (Bare Solid Copper)
B & S Gauge

Size B&S Gauge	Diameter in Mils	Area in Circular Mils	Lbs. per 1000 feet Bare Wire	Resistance (Ohms) per 1000 feet at 60° F.
		Solid Wire		
26	15.94	254.1	.77	40.75
25	17.90	320.4	.97	32.21
24	20.10	404.01	1.22	25.60
23	22.57	509.5	1.54	20.30
22	25.35	642.4	1.95	16.12
21	28.46	810.1	2.45	12.78
20	31.96	1022.	3.10	10.14
19	35.89	1288.	3.90	8.04
		Solid Strand		
18	40.30	1624.	4.917	6.374
16	50.82	2583.	7.818	3.936
14	64.08	4107.	12.43	2.475
12	80.81	6530.	19.77	1.557
10	101.9	10380.	31.43	.9792
9	114.4	13090.	39.63	.7765
8	128.5	16510.	49.98	.6158
7	144.3	20820.	63.02	.4883
6	162.	26250.	79.46	.3872
5	181.9	33100.	100.2	.3071
4	204.3	41740.	126.4	.2436
3	229.4	52630.	159.3	.1931
2	257.6	66370.	200.9	.1532
1	289.3	83690.	253.3	.1215
0	324.9	105500.	319.5	.09633
00	364.8	133100.	402.8	.07639
000	409.6	167800.	508.	.06058
0000	460.	211600.	640.5	.04804
		Stranded Cable—Circular Mil Sizes		
	Approximate Diameters			
	500.	250000.	756.8	.04147
	547.7	300000.	908.1	.03457
	591.6	350000.	1059.	.02963
	632.5	400000.	1211.	.02592
	707.1	500000.	1514.	.02074
	774.6	600000.	1816.	.01729
	836.7	700000.	2119.	.01481
	866.	750000.	2270.	.01382
	894.4	800000.	2422.	.01296
	948.7	900000.	2724.	.01153
	1000.	1000000.	3027.	.01036
	1118.	1250000.	3784.	.00839
	1225.	1500000.	4540.	.00692
	1323.	1750000.	5297.	.00593
	1414.	2000000.	6054.	.00518

The above table of diameters, areas, weights, and resistance of copper wires will be very convenient whenever you have a problem of wire sizes or calculations.

107. RESISTANCE OF CONDUCTORS

As previously mentioned, it is often necessary to determine the exact resistance of a conductor of a certain length, in order to calculate the voltage drop it will have at a certain current load.

The resistance per 1000 ft. of various wires can be obtained from the accompanying wire table, and from these figures it is easy to calculate the resistance of smaller or greater lengths.

Suppose you wish to find the total resistance of a two-wire run of No. 10 conductors 150 ft. long. First multiply by 2, to get the entire length of both wires; or 2 × 150 = 300 ft. Then, from the table, we find that the resistance of No. 10 wire is .9792 Ohms per 1000 ft. Our circuit is less than 1000 ft.; or 300/1000 × .9742 = .29226 Ohms; or approximately .29, which would be accurate enough for the ordinary job.

In another case, we wish to run a short outdoor line between two buildings, a distance of 1650 ft., and using No. 1 wire. What would its total resistance be? The total length of both wires will be 2 × 1650 = 3300 ft. From the table, we find the resistance of No. 1 wire is .1215 Ohms per 1000 ft. Then as 3300 ft. is 3.3 times 1000, we multiply 3.3 × .1215 = .40095 or approximately .4 Ohms.

The National Code table for carrying capacities of wires, allows 100 amperes for No. 1 R.C. wire. We find, however, that if we have this much current flowing through our line, the voltage drop (Ed) will be I × R or 100 × .4 = 40 volts. This is too much to be practical, because even if we applied 120 volts to one end of the line, the lamps or devices at the other end would receive only 120 — 40, or 80 volts. The watts loss in the line would be I × Ed, or 100 × 40 = 4000 watts, or 4 KW.

So we find that the practical load for such a line would be about 25 amperes, which would give a voltage drop of 25 × .4 or 10 volts. If we now apply 120 volts to the line, the equipment at the far end will receive 110 volts, and the loss will only be 25 × 10 or 250 watts.

108. RESISTANCE OF COPPER PER MIL FOOT

In many cases we may need to calculate the resistance of a certain length of wire or bus bar of a given size.

This can be done very easily if we know the unit resistance of copper. For this we use the very convenient unit called the **Mil Foot:** This represents a piece of round wire 1 mil in diameter and 1 ft. in length, and is a small enough unit to be very accurate for all practical calculations. A round wire of 1 mil diameter has an area of just 1 circular mil, as the diameter multiplied by itself or "squared", is 1 × 1 = 1 circular mil area.

The resistance of ordinary copper is 10.79 Ohms per Mil Foot, but we usually use the figure 10.8 as sufficiently accurate. This figure or "constant" is important and should be remembered.

Suppose we wish to determine the resistance of a piece of No. 12 wire, 50 ft. long. We know that the resistance of any conductor increases as its length increases, and decreases as its area increases. So, for a wire 50 ft. long, we first multiply, and get 50 × 10.8 = 540, which would be the resistance of a wire 1 C.M. in area and 50 ft. long. Then we find in the table that the area of a No. 12 wire is 6530 C.M., which will reduce the resistance in proportion. So we now divide: 540 ÷ 6530 = .0826+ Ohms.

In another case we wish to find the resistance of 3000 ft. of No. 20 wire, for a coil winding perhaps. Then, 3000 × 10.8 = 32,400; and, as the area of No. 20 wire is 1022 C.M., we divide: 32,400 ÷ 1022 = 31.7+ Ohms.

Checking this with the table, we find the table gives for No. 20 wire a resistance of 10.14 Ohms per 1000 ft. Then for 3000 ft. we get 3 × 10.14 = 30.42 Ohms. The small difference in this figure and the one obtained by the first calculation, is caused by using approximate figures instead of lengthy complete fractions.

We can use the mil ft. unit and its resistance of 10.8 to calculate the resistance of square bus bars, by simply using the figure .7854 to change from sq. mils to C.M.

Suppose we wish to find the resistance of a square bus bar ¼" x 2", and 100 ft. long. The dimensions in mils will be 250 × 2000, or 500,000 sq. mils area. Then, to find the circular mil area, we divide 500,000 by .7854 and get 636,618+ C.M. area. Then, 100 ft. × 10.8 = 1080 Ohms, or the resistance of 100 ft. of copper 1 mil in area. As the area of this bar is 636,618 C.M., we divide: 1080 ÷ 636,618 = .001,696+ Ohm, total resistance. According to the allowance of 1000 amperes per sq. inch, such a bus bar could carry 500 amperes, as it is ¼" × 2" = ½ sq. inch area. With a 500 ampere load, the voltage drop would be I × R, or 500 × .001696 = .848, or approximately .85 volts drop.

The following table gives the allowable current carrying capacities of wires with rubber insulation; also those with varnished cloth and other insulations, such as slow burning, etc. This table gives the current allowed by the National Code.

ALLOWABLE CURRENT CARRYING CAPACITY OF WIRES

B. & S. Gauge Number	Area in Circular Mils	Allowable Current in Amperes Rubber Insulation	Varn. Cloth Insulation	Other Types Insulation
18	1,624	3	....	5
16	2,583	6	....	10
14	4,107	15	18	20
12	6,530	20	25	25
10	10,380	25	30	30
8	16,510	35	40	50
6	26,250	50	60	70
5	33,100	55	65	80
4	41,740	70	85	90
3	52,630	80	95	100
2	66,370	90	110	125
1	83,690	100	120	150
0	105,500	125	150	200
00	133,100	150	180	225
000	167,800	175	210	275
	200,000	200	240	300
0000	211,600	225	270	325
	250,000	250	300	350
	300,000	275	330	400
	350,000	300	360	450
	400,000	325	390	500
	500,000	400	480	600
	600,000	450	540	680
	800,000	550	660	840
	1,000,000	650	780	1,000
	1,500,000	850	1,020	1,360

The capacities above are based on copper having 98 per cent of the conductivity of pure copper wire. For insulated aluminum wire the capacity will be taken as 84 per cent of the values given in the table. Wires can be connected in parallel for greater capacity only by the consent of the inspection department of the National Board of Fire Underwriters.

109. ALLOWABLE VOLTAGE DROP

We must remember, however, that this table does not take into consideration the length of the wires or voltage drop. For this reason we may often wish to use larger wires than the table requires.

In lighting installations, we should never use wires so small that there will be over 2 per cent drop on branch circuits, or 3 per cent drop on feeder circuits. Generally the voltage drop should not be more than 1 to 2 per cent. On power wiring installations, there should usually not be over 5 per cent drop. This means that on a 110 volt branch circuit we should not have over .02 × 110 or about 2.2 volts drop; on 220 volt feeder circuits, not over .03 × 220 or 6.6 volts drop; and on 440 volt power circuits, not over .05 × 440 or 22 volts drop, etc.

110. SIMPLE FORMULA FOR CONDUCTOR AREA

For selecting the proper size of conductor for any known load in amperes, and to keep the voltage drop within the desired practical limit, we have a very simple formula that will tell us the circular mil area of the conductor to use.

This formula must, of course, consider the resistance of copper, the total length of the line, and the current load in amperes. It is as follows:

$$\text{C.M.} = \frac{10.8 \times L \times 2 \times I}{Ed}$$

In which:

C.M. = Circular mil area of conductor.
10.8 = Resistance of copper per mil ft.
L = Length of line in feet.
2 = Is to multiply by to obtain total length of both wires.
I = Load in amperes.
Ed = Allowable voltage drop in volts. (Not in per cent.)

(Note: The figure 2 is also used for Edison three-wire systems, as the current never has to flow through more than the resistance of two wires.)

Now let's see how we would use this handy formula for choosing the size of wire on a certain job. Suppose we wish to run a feeder 200 ft. long to a branch panel on which the load consists of: Twenty-six 60 watt, 110 volt lamps; ten 200 watt, 110 volt lamps; and one 10 h.p., 220 volt motor.

First, we will find the total load in watts. Twenty-six 60 watt lamps will use 26 × 60, or 1560 watts. Ten 200 watt lamps will use 10 × 200, or 2000 watts. As there are 746 watts in 1 h. p., the 10 h. p. motor will use 10 × 746 or 7460 watts. (Assuming 100% efficiency.)

Then 1560 + 2000 + 7460 = 11,020 watts. Assuming this load to be balanced, the current will all flow over the two outside feeder wires at 220 volts. So to find the current we use the formula W ÷ E = I, or 11,020 ÷ 220 = 50+ amperes.

We will allow 6 volts drop on the feeders, and, using the wire size formula, we will substitute the values we have found, as follows:

$$\text{C.M.} = \frac{10.8 \times 200 \times 2 \times 50}{6}$$

Working this out, we find we get 36,000 C.M. area for the wire. Looking this up in the table we find that the next size larger is No. 4 wire, which has 41,740 C.M. area. As the Code table allows 70 amperes for this wire with rubber insulation, we find we are quite safe in using it from this standpoint.

Try out the foregoing formula on some imaginary problems of your own, until you can use it easily because it is very commonly used in electrical layouts and estimating.

111. VOLTAGE DROP FORMULA

If we wish to determine what the voltage drop will be on a certain installation already made, or on the wires proposed for a job, we can simply transpose the formula we have just used, interchanging voltage drop for C.M. area, as follows:

$$Ed = \frac{10.8 \times L \times 2 \times I}{\text{C.M.}}$$

Suppose we have a two-wire, 110 volt installation where the load is 25 amperes and the feeder is 120 feet long, and only supplied with 110 volts.

The Code allows us to use a No. 10 wire for 25 amperes, and the area of No. 10 wire is 10,380 C.M. Then, substituting these values in the formula, we have

$$Ed = \frac{10.8 \times 120 \times 2 \times 25,}{10,380} \text{ or } 6.05 \text{ volts,}$$

whereas we should not have more than 3% of 110, or about 3.3 volts drop.

In another case, suppose an electrician used No. 14 wire for a 110 volt branch circuit in a factory and this circuit had twelve 100 watt lamps and two 60 watt lamps connected to it, and was 90 ft. long. The total watts in this case would be 1320 and at 110 volts, this would be a load of 12 amperes. It would be quite natural to use No. 14 wire, as the Code allows 15 amperes for this size, and it is the size so commonly used. But checking it with our formula we find that No. 14 wire has an area of 4107 C.M., and that

$$Ed = \frac{10.8 \times 90 \times 2 \times 12,}{4,107} \text{ or } 5.6+ \text{ volts drop,}$$

which would certainly not be satisfactory.

Using the other formula again, we can easily determine the size of wire that should have been used on this job to keep within the normal 2 volts drop.

$$C.M. = \frac{10.8 \times 90 \times 2 \times 12,}{2} \text{ or } 11{,}664 \text{ C.M. Area}$$

As the next larger wire is No. 8, this should have been used; or as a No. 10 wire has 10,380 C.M. area, it could be used, with slightly over 2 volts drop.

So we find that it is very important to be able to do these simple wire calculations on certain jobs, and you will find this material of great value, both in learning how to use the formulas, and in using them and the tables for future reference.

The following table of voltage drop per 1000 ft., per ampere, with various sized conductors is also very convenient, and the wire table on the next page gives a lot of very valuable data on copper conductors, that will often prove very useful.

TABLE OF VOLTAGE DROP

Size B. & S. Gauge	Volts drop per 1000 feet per ampere	Size B. & S. Gauge	Volts drop per 1000 feet per ampere
18	6.374	250,000.	.04147
16	3.936	300,000.	.03457
14	2.475	350,000.	.02963
12	1.557	400,000.	.02592
10	.9792	500,000.	.02074
9	.7765	600,000.	.01729
8	.6158	700,000.	.01481
7	.4883	750,000.	.01382
6	.3872	800,000.	.01296
5	.3071	900,000.	.01153
4	.2436	1,000,000.	.01036
3	.1931	1,250,000.	.00829
2	.1532	1,500,000.	.00692
1	.1215	1,750,000.	.00593
0	.09633	2,000,000.	.00518
00	.07639		
000	.06058		
0000	.04804		

Volts Lost Per 1000 Feet per Ampere.

Gauge Equivalents with Weights and Resistances of Standard Annealed Copper Wire

B. & S. American Wire Gauge No.	Diameter In Inches	Area Circular Mils	Ohms at 68 deg. Fah.			Feet		Pounds			B. & S. American Wire Gauge No.
			Per 1,000 Ft.	Per Mile	Per Pound	Per Pound	Per Ohm	Per 1,000 Ft.	Per Ohm	Per Mile	
0000	0.460	211600.	0.04906	0.25903	0.000077	1.56122	20497.7	640.51	12987.	3380.	0000
000	0.40964	167805.	0.06186	0.32664	0.00012	1.9687	16255.27	507.95	8333.	2680.	000
00	0.3648	133079.	0.07801	0.41187	0.00019	2.4824	12891.37	402.83	5263.	2130.	00
0	0.32486	105534.	0.09831	0.51909	0.00031	3.1303	10223.08	319.45	3225.	1680.	0
1	0.2893	83694.	0.12404	0.65490	0.00049	3.94714	8107.49	253.34	2041.	1340.	1
2	0.25763	66373.	0.1563	0.8258	0.00078	4.97722	6429.58	200.91	1282.	1060.	2
3	0.22942	52634.	0.19723	1.0414	0.00125	6.2765	5098.61	159.32	800.	840.	3
4	0.20431	41743.	0.24869	1.313	0.00198	7.9141	4043.6	126.35	505.	665.	4
5	0.18194	33102.	0.31361	1.655	0.00314	9.97983	3206.61	100.20	318.	528.	5
6	0.16202	26251.	0.39546	2.088	0.00499	12.5847	2542.89	79.462	200.	420.	6
7	0.14428	20817.	0.49871	2.633	0.00797	15.8696	2015.51	63.013	126.	333.	7
8	0.12849	16510.	0.6529	3.3	0.0125	20.0097	1599.3	49.976	80.	264.	8
9	0.11443	13094.	0.7892	4.1	0.0197	25.229	1268.44	39.636	50.	209.	9
10	0.10189	10382.	0.8441	4.4	0.0270	31.8212	1055.66	31.426	37.	166.	10
11	0.090742	8234.	1.254	6.4	0.0501	40.1202	797.649	24.924	20.	132.	11
12	0.080808	6530.	1.580	8.3	0.079	50.5906	632.555	19.766	12.65	105.	12
13	0.071961	5178.	1.995	10.4	0.127	63.7948	501.63	15.574	7.87	82.9	13
14	0.064084	4107.	2.504	13.2	0.200	80.4415	397.822	12.435	5.00	65.5	14
15	0.057068	3257.	3.172	16.7	0.320	101.4365	315.482	9.859	3.12	52.1	15
16	0.05082	2583.	4.001	23.	0.512	127.12	250.184	7.819	1.95	41.3	16
17	0.045257	2048.	5.04	26.	0.811	161.22	198.409	6.199	1.23	32.7	17
18	0.040303	1624.	6.36	33.	1.29	203.374	157.35	4.916	0.775	26.0	18
19	0.03589	1288.	8.25	43.	2.11	256.468	124.777	3.899	0.473	20.6	19
20	0.031961	1021.	10.12	53.	3.27	323.399	98.9533	3.094	0.305	16.3	20
21	0.028462	810.	12.76	68.	5.20	407.815	78.473	2.452	0.192	12.9	21
22	0.025347	642.	16.25	85.	8.35	514.193	62.236	1.945	0.119	10.24	22
23	0.022571	509.	20.30	108.	13.3	648.452	49.3504	1.542	0.075	8.13	23
24	0.0201	404.	25.60	135.	20.9	817.688	39.1365	1.223	0.047	6.44	24
25	0.0179	326.	32.2	170.	33.2	1031.038	31.0381	0.9699	0.030	5.12	25
26	0.01594	254.	40.7	214.	52.9	1300.180	24.6131	0.7692	0.0187	4.06	26
27	0.014195	201.	51.3	270.	84.2	1639.49	19.5191	0.6099	0.0118	3.22	27
28	0.012641	159.8	64.8	343.	134.	2067.364	15.4793	0.4837	0.0074	2.56	28
29	0.011257	126.7	81.6	432.	213.	2606.959	12.2854	0.3835	0.0047	2.03	29
30	0.010025	100.5	103.	538.	338.	3287.084	9.7355	0.3002	0.0029	1.61	30
31	0.008928	79.7	130.	685.	539.	4414.49	7.72143	0.2413	0.0018	1.27	31
32	0.00795	63.	164.	865.	856.	5226.915	6.12243	0.1913	0.0011	1.01	32
33	0.00708	50.1	206.	1033.	1357.	6590.41	4.85575	0.1517	0.00076	0.803	33
34	0.006304	39.74	260.	1389.	2166.	8312.8	3.84966	0.1204	0.00046	0.634	34
35	0.005614	31.5	328.	1820.	3521.	10481.77	3.05305	0.0956	0.00028	0.504	35
36	0.005	25.	414.	2200.	5469.	13214.16	2.4217	0.0757	0.00018	0.400	36
37	0.004453	19.8	523.	2765.	8742.	16659.97	1.92086	0.06003	0.00011	0.317	37
38	0.003965	15.72	660.	3486.	13772.	21013.25	1.52292	0.04758	0.00007	0.251	38
39	0.003531	12.47	832.	4395.	21896.	26496.237	1.20777	0.03755	0.00004	0.199	39
40	0.003144	9.88	1049.	5542.	34823.	33420.63	0.97984	0.02992	0.000029	0.158	40

No. 140. This very complete table of data for copper conductors will often save you a great amount of time if you become familiar with its use, and refer to it for the information it contains. It will be a good plan to compare the sizes, areas and resistance of a number of the more common sized wires given in this table. This will help you to understand the gauge numbers and in making selections of proper conductors for various jobs in the future.

INSTALLATION METHODS

112. LAYOUTS AND PLANS

In starting any wiring job, whether you are working for a contractor or in business for yourself, there are certain general steps to be followed. Regarding simple knob and tube installations, it is not necessary to say much more about the details of this work than has been previously covered. However, remember that before running any wires, one should have the location of all outlets well in mind, and preferably sketched on a plan; and then marked on the frame work of the new building, if it is such; or upon the walls and ceilings of an old building in which the wiring is being installed after the house has been built.

113. LOCATION OF LIGHT AND SWITCH OUTLETS

Ceiling outlets for lighting fixtures should be carefully located and centered to give a balanced appearance in the room, and to afford the best distribution of light.

Wall light outlets should be placed about the walls with proper regard for locations of doors, windows, and large permanent pieces of furniture. Outlets for wall bracket lights should be approximately 66 inches from the floor, if the fixture turns upward from the outlet. If it is of the type that hangs downward, the outlet should be about 72 to 74 inches from the floor. These heights, of course, will depend somewhat upon the ceiling height in various rooms, and the scheme of decoration used. Outlets for wall switches should be about 52 inches from the floor to the bottom of the outlet box, and their locations should be carefully chosen to give the greatest convenience in control of the lights. For example—it is common practice to have the control switches for one or more lights near the front door or entrance to the house, so they can be turned on as soon as the person comes inside at night. In other rooms of the house, switches can be placed either near doors, or in the most convenient locations, to save as many steps as possible. The owner of the building should of course be consulted on such matters, in order to give the best possible satisfaction in the finished job.

After the outlets have all been located, the shortest and most direct runs should be chosen for the various wires to fixtures and switches. Then if there is no blue print already provided for the job, a complete wiring diagram of each floor should be laid out on paper to be sure to get the proper circuits and control of lights and equipment with the fewest possible wires.

114. KNOB AND TUBE INSTALLATION

If knob and tube wiring is being installed in a new building, the holes for the porcelain tubes can be drilled through the center of the joists, as these holes are not large enough to materially weaken the woodwork. Knobs can be placed along the joists for circuits to be run in the walls, and also along the joists in unfinished attics and basements. Before determining the location of the meter and service switch, we should locate the probable point at which the power company will bring the wires from their pole line into the building, and the service switch and meter should be located near this point if possible.

In knob and tube installation in new buildings, the wiring should, of course, all be installed before the lath and plaster are put on the walls. The thickness of lath and plaster that are to be used should be carefully considered, so that the edges of the outlet boxes will be about flush with or about an eighth of an inch under this surface.

115. MAKING CONNECTIONS TO SWITCHES AND FIXTURES

When the wires are attached, and the ends brought out in the box, it is well to plug the outlet box with a wad of newspaper to keep the wire ends from becoming damaged or the box clogged with plaster. After the plaster is on and has hardened, the fixtures can be hung and connections made to them and the switches.

In making all such connections, be sure to strip enough of the end of the wires to make a good hook, or one complete turn under the terminal screws, but don't strip an excessive amount so there would be more bare wire than necessary around the switch terminals for fixture connections. See that these wires are bright and clean before placing them under the screws, and always bend the hook in the end of the wire to the right, that is, clockwise or in the same direction the screw head turns. This causes the screw to wrap the wire hook tight around it; while if the hook is made in the opposite direction it often opens up and works out from under the screw head when it is tightened. Don't twist these screws too tight, because they are usually of soft brass and the threads can be easily stripped.

116. BX AND NON-METALLIC CABLE INSTALLATION

The same general rules apply to wiring a new building with BX or non-metallic sheathed cable. Either of these materials can be run along the joists and through holes in the framework as required. Before cutting the various lengths of wire, BX, or cable for any run, be sure to measure them accurately and allow a few inches extra for stripping the ends and making splices and connections. It is always much better to allow a few inches over and trim this off when making the final connections, rather than to find the wires or cable too short and then have to replace them. Always tighten BX and cable clamps securely in the outlet box openings.

When wiring old buildings, great care should be used not to damage the plaster or decorations, and not to make any unnecessary dirt or mess around the building. When cutting holes in the plaster on walls or ceilings to locate outlet boxes, a cloth or paper should be spread underneath to catch all plaster dust. Sometimes an old umbrella can be opened and hung or held up side down under the place in the ceiling where the hole is being made, so it will catch all of this dirt and keep it off from rugs and furniture.

117. LOCATING AND CUTTING OUTLET BOX OPENINGS

Be careful not to cut any of these holes so large that the fixture canopies or switch plates will not cover them neatly. In case the plaster cracks or a mistake is made so that the hole cannot be completely covered, it should be filled with plaster of paris, or some such material, to make a neat appearance again.

Outlet box holes can be cut through the plaster with a chisel. The size of the holes should be carefully marked by drawing a pencil around the outlet box, held against the plaster. In locating the exact spot to cut these openings in the plaster, it is well to first cut a very small hole in the center of the spot where the larger one is to be made, using this to locate the cracks between the lath. Then it is possible to shift the mark for the larger hole up or down a little so the lath can be cut properly, to leave a place in the wood for the screws which fasten the box to the wall. If this method is not followed, sometimes two complete laths are cut away, and the metal ears on the box, which have the screw holes in them, will not reach from one remaining lath to the other.

On wall outlet openings we should always try to cut clear through one lath and a short distance into two adjacent ones. Fig. 141-A shows the wrong way that laths are sometimes cut, and "B" shows the proper way in which they should be cut.

For cutting round holes a regular plaster cutter can be obtained, which fits into an ordinary brace and can be rotated the same as a drill.

For ceiling outlets never cut the lath any more than necessary to bring the wires or BX through.

118. RUNNING WIRES AND BX INTO DIFFICULT PLACES

A number of methods have already been described for pulling and fishing wires, cable, and BX into walls and openings in finished buildings; so that, with a little ingenuity and careful thought, you will be able to solve almost any problem of this kind that you may encounter.

In pulling wires into spaces between the joists in walls, a flashlight placed in the outlet box hole is often a great help in feeding the wires in, or in catching them with a hook to draw them out of the outlet opening.

Where it is necessary to remove floor boards, it should be done with the greatest of care, so as not to split the edges and make a bad appearing job when the boards are replaced. A special saw can be obtained for cutting into floors without drilling holes to start the saw. Then, if the beading or tongue is split off with a thin sharp chisel driven down in the crack between the boards, the board from which the tongue has been removed can be pried up carefully without damaging the rest of the floor.

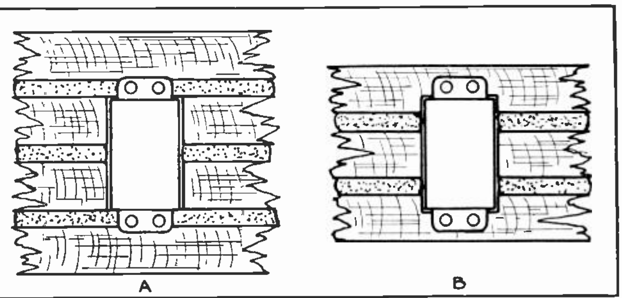


Fig. 141. The view at "A" shows the wrong method of cutting lath to install an outlet box for switches. Note that the metal "ears" do not reach over the lath to provide any anchorage for the screws. At "B" is shown the correct method of cutting the lath to make a secure mounting for boxes of this type.

If it is necessary to run wires or BX crosswise through a number of floor or ceiling joists, it can usually be done by boring the holes through them at a slight angle, and then working the wires or cable through. Where tubes are used, be sure to place the heads up in these slanting holes, so the tubes cannot work out.

Sometimes it is necessary to remove baseboards and cut holes behind these, to aid in fishing the wires or cable up or down through floors and into the walls at this point. In other cases, a channel can be cut in the plaster behind the baseboard, and BX or non-metallic sheathed cable run in this channel, and the baseboard replaced to cover it.

Whenever removing baseboards in this manner, be very careful not to split the "quarter-round" wood strips or trimming that is often fastened along the edges of the baseboard. A broad putty knife is a very good tool to use in removing these strips.

A key-hole saw is very useful in cutting through laths to make outlet openings. Let's emphasize once again that in installing old house wiring, thoughtfulness, care, and neatness are the greatest essentials in leaving the customer satisfied.

119. CONDUIT INSTALLATION

When installing conduit wiring systems in new buildings, the entire plan should be carefully gone over first, to make sure that proper number of wires for each circuit and the proper sizes of conduit have been selected. A great deal of time and money can be saved by planning these things in advance and thereby avoiding costly mistakes.

After the outlets have been located and the boxes carefully installed on their proper supports and hangers, the lengths of conduit can be cut, bent, and fitted in place.

In running conduit in wood frame buildings, care must be taken not to damage or weaken the building structure. In some cases a conduit run cannot be made in the shortest and most direct line, because it would necessitate the notching of joists at some distance from any support. This should not be done, as it is likely to weaken them too much. Instead, it is better to run the conduit along between the joists for some distance and then make the cross run near a wall or partition support, so the notches in the joists can be near their ends where the strain is not so great.

Fig. 142 is a view looking down on a group of ceiling joists, and which illustrates the proper method of running conduit in such cases.

In certain types of frame-building construction, finished floors are laid on strips an inch or more thick over the soft-wood floors. In such cases, with the permission of the contractor or architect, the conduit can often be run between these floors, thus saving considerable labor and materials.

All lengths of conduit should be screwed into their couplings as tightly as possible, to make the conduit ground circuit complete and the entire system secure and tight.

In attaching the conduit to outlet boxes, screw the lock-nut well back on the threads, insert the threaded end of the pipe in the knock-out opening, and screw the bushing on this end as far as it will go. Then tighten the lock-nut securely with a wrench.

120. SPECIAL PRECAUTIONS FOR CONDUIT IN CONCRETE BUILDINGS

When installing conduit in concrete buildings, there are sometimes fewer problems than with wood construction, but there are a number of different details which must be observed. In this type of building, conduit generally runs directly by the shortest path from one box to the next; and when the concrete is poured around it, the conduit, instead of weakening the structure, has a tendency to strengthen it.

Just as soon as the wood forms for a certain section of the building are set up, the electrician must be on the job to install the conduit and outlet boxes. In some cases he must be on hand practically all the time these forms are going up, as there are certain places where it is necessary to install the boxes or conduit as the carpenters are placing the wood forms.

The locations of outlet boxes, particularly those for ceiling lights, should be lined up carefully and straight, so the fixtures will present a neat appearance when they are installed. If these boxes are carelessly located, it is almost impossible, and certainly a mighty costly job, to correct them after the concrete is poured.

After the locations for the outlets have been carefully marked on the boards, the conduit can be cut to the proper lengths, reamed, threaded, and fitted to the outlet boxes.

Before the boxes are nailed in place, the ends of all conduits should be tightly plugged, either with wood plugs or with special disks which are held in place by the bushings. These plugs are to keep soft concrete from running into the pipes. Then the outlet boxes themselves should be packed tightly with newspaper, so that there is no possibility of their filling up with wet concrete. Then the boxes should be nailed securely in place so that there is no chance of their being moved before or during the time the concrete is being poured. If these precautions of plugging conduit and outlet boxes are not observed, you will often encounter a very difficult and expensive job of drilling hard concrete out of the boxes or pipes.

The installation of the complete conduit system is what we term "roughing in." None of the wires should be pulled in until all mechanical work on the building is completed. Sometimes on big buildings this requires weeks or months after the conduit has been installed, so you can see how important it is to have complete and accurate sketches and plans of the whole electrical system.

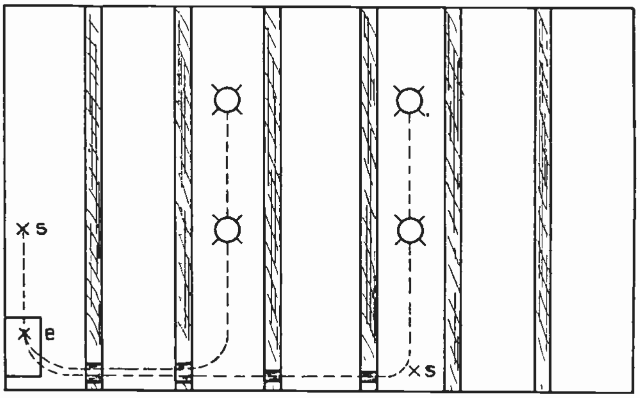


Fig. 142. Ceiling joists should not be notched in their centers in order to run conduit by the shortest path to outlets. Instead the joists should be notched near walls or supports, and the conduit bent to run through these notches, and then back between the joists to the outlets as shown in this diagram.

121. PULLING IN THE WIRES

When we are ready to pull the wires into the conduit, the outlet boxes should be cleaned out and all plugs removed from the ends of the pipe.

On very short runs, the ends of the wires can sometimes be twisted together and the group simply pushed through from one outlet to the next. More often, however, we will need to push the steel fish tape through first, and then pull the wires through with it, as previously described. This is usually a job for two men, one to feed the wires into the conduit straight and even, without allowing them to cross or kink, and the other man to pull on the fish tape.

We should not forget to use powdered soap stone to lubricate the wires when necessary on long runs.

On short runs where the wires pull in rather easily, it may only be necessary to hook them through the loop in the fish tape and twist them together a few times. On more difficult runs, it is sometimes necessary to solder these twisted loops so there will be no chance of their pulling loose from the fish tape.

122. FINAL TESTS

When the wires are all pulled in and the ends cut off at the outlet box, allowing the extra length for splices and connections, these ends can then be stripped and cleaned. Before any connections are made, all wires should be thoroughly tested with a dry cell and buzzer or magneto and bell, to make sure there are no shorts or grounds which might have occurred through damaging the insulation when the wires were pulled in.

After the splices are made, it is a good idea to make another thorough test before they are soldered, to see that all connections are proper and that no faults have developed.

The soldering should then be done immediately, before the bare copper has time to oxidize or corrode. Then all splices should be thoroughly and carefully taped, both with rubber and friction tape. Never slight this part of the job because, if you do, shorts or grounds are likely to develop when the poorly taped splices are pressed back into the outlet boxes.

In hanging fixtures care should be taken to make a neat job of it, and not to dirty the light-colored ceiling by rubbing hands or black materials against it. In some cases the fixture splices are soldered, while in others solderless connectors can be used. These connectors are especially desirable in buildings where no smoke or soot from the soldering operation can be allowed.

After all wiring is complete and all devices connected up, make a final test at the fuse box to be sure there are no shorts or grounds on the "hot" wire. If the system tests clear, then insert the fuses if the service has been connected to the power line, close the switch and test all switches and lights for satisfactory operation.

BUSINESS METHODS AND ESTIMATING

123. SALESMANSHIP

For the man who may plan to enter a business of his own sooner or later, the following common sense principles of salesmanship and business methods, as well as the simple practical tips on estimating, should be very useful.

In most towns, whether they are small villages or medium-sized or larger cities, there are opportunities for a wide-awake electrical contractor who knows his business and gives first-class, up-to-date service.

Even in the small towns or localities, where there seems to be considerable competition already existing, an aggressive man can often build up a splendid business with certain classes of work that are overlooked by the present organizations; and in some cases, where the existing prices charged for this work are high, the man starting in on a small scale with low overhead expense can often do first-class work at a more reasonable price, and thereby build up a good business and reputation for himself.

This, of course, cannot be done by merely locating in a place, and waiting for the business to come to you. It requires active salesmanship and some advertising to get established and build up a business of this nature.

A great many men have the ability and qualifications necessary, and with training of the kind covered in the course, should be able to make a real success, and certainly should not overlook these opportunities.

124. NOT MUCH CAPITAL REQUIRED TO START

As mentioned in an earlier section, a great number of our graduates have started splendid businesses of their own with a few small jobs to begin with, doing the work in their own basements or homes, on such repair jobs as were taken in. Of course, the smaller wiring jobs for various customers are done on their premises, and do not require at the beginning an elaborate outlay of tools and materials. As the business grows, one can acquire more tools and materials, some of which should be kept on hand. Later he may rent a shop or building for a store and place to repair electrical equipment.

The very fact that you have had training at an institution of this kind often makes a prospective customer more inclined to try your work and ability, and if you uphold your reputation from the start by putting your knowledge into practice and doing first-class work on every job, your success will be quite certain.

125. PERSONAL CONTACT WITH CUSTOMERS VERY IMPORTANT

Very often the easiest way to secure the first jobs is by personal contact and salesmanship. Wherever new buildings are being erected there are possible customers for wiring jobs, whether these buildings are small private garages, complete homes, stores, factories, or office buildings.

Even where there is very little construction taking place, there are usually homes or buildings with old style and very incomplete wiring systems. Their owners can often be easily convinced that the addition of convenience outlets, more lights, and better lighting fixtures would be a convenience or actual saving of time in the home that would well repay the small cost of installation.

In approaching a customer with a suggestion of this kind, it is often a great help in interesting them, to carry along a few good-looking pictures of homes properly wired, illustrating the great improvement in appearance and the many conveniences thus obtained. A Foot Candle Meter to test the light and fixtures in a home will often interest a customer a great deal from the very moment you call. Their interest at first may be almost entirely in the instrument, but if you can get them to go about the house with you, and see the actual readings, and the evidence which the meter gives of poor lighting, then they can usually be interested in the greater comfort and reduced eye-strain, as well as the much better appearance of the home where proper lighting is installed.

It may be necessary to make even twenty or thirty calls of this kind to secure one job, but this should not be allowed to discourage one, because it doesn't take so much time to make these calls, and even if a great number are made without results at that particular time, many of them will result in business in the near future.

If you can succeed in leaving a good impression of yourself, your knowledge of the subject, and your sincerity and desire to be of service, many of these persons will call you back later, perhaps to do some small job; or will recommend you to their friends who may have wiring or repairs to do. Of course, you should always leave some small card or folder with your name, address, and telephone number, so they can conveniently get in touch with you later.

126. MODERN METHODS AND INSTRUMENTS TO SECURE INTEREST AND CONFIDENCE OF CUSTOMER

Some instrument, such as the Foot Candle Meter mentioned, or perhaps a volt meter for testing the voltage at the outlets and lamp sockets, will tend to leave the impression that you are up-to-date and well qualified to do good work whenever they may need you.

A free inspection of the wiring and electrical appliances in a home is often a very good method of approach. If conditions are found in the wiring which are likely to be hazardous from the fire or shock standpoint, this can be called to the attention of the owner in a diplomatic and pleasant manner, and a recommendation made that they be fixed or changed at the first opportunity.

Minor repairs on plugs or cords of appliances, defective light switches or sockets, and things of this kind can often be made in a few minutes time, and with almost no cost to the electrician. They will, however, usually create a great amount of good will, and be the cause of securing future business.

A few weeks of "missionary work" of this nature will usually be required to get things started and begin to bring in the jobs, but remember that any business organization or experienced business-man expects to do these things when starting out in any locality.

It is well to keep in mind that one's personal appearance is important in making calls on home owners or prospective customers. A neat, business-like appearance tends to create confidence and respect.

127. ESTIMATING—TIME AND MATERIAL BASIS

When it comes to giving a price on a job, there are several ways in which this can be handled. The time and material basis is ideal for the electrician, and can usually be made satisfactory to the customer. When a job is done in this manner, the customer pays you by the hour for the work of installing the system, and also pays you for the material, which you may buy wholesale and sell to him at retail prices, thus making a reasonable profit in addition to your wages.

If you merely make fair wages on the first several jobs this should be quite satisfactory, for you will be obtaining experience, not only in doing the actual work and gaining confidence in your knowledge and ability, but also in the time required for each type of work, and the costs of various items. You should keep a very careful record of these things, as they will be of great assistance in making accurate estimates on future jobs.

128. COST PER OUTLET

Totaling the entire expense of any job of a certain class of wiring and then dividing this by the number of outlets, will give you a basis on which to estimate jobs of this type in the future. After experience on several installations, you can quote prices at so much per outlet on jobs of any type, such as knob and tube, BX, or conduit wiring. These different classes of wiring are, of course, to be done at different prices per outlet.

Before giving such an estimate, however, you should always look over the building or plans very carefully, to make sure that you are not running into certain difficulties in the installation that will run the expense considerably higher than you expected. In certain types of construction, or where certain special requirements have to be met to please the customer or to satisfy the local inspector, it will be necessary in making your estimate to add a certain amount to the usual price per outlet.

It is well to emphasize here that you should not discuss with your customers the basis or method by which these figures are obtained, because in some cases they may use this as a wedge to force a competitor to cut his prices below yours.

129. OVERHEAD EXPENSE AND PROFIT

After you obtain a start and are doing larger jobs, a certain percentage should be added to the cost of materials and labor for overhead expense and profit. These things may sometimes need to be explained to customers, so they do not get the impression that you are overcharging them for certain items.

There is always certain to be some **overhead expense** or **cost of doing business,** regardless of whether you have a shop or merely operate your business from your home. This overhead consists of certain small items of expense which you cannot charge directly to the customer, but should properly proportion over the charges for each job.

Some of these items are as follows:

- Telephone Bills
- Electric Light and Water Bills
- Rent; or Taxes, if you own a building
- Insurance, both Fire and Liability
- Non-Productive Labor
- Advertising
- Truck and hauling expenses
- Depreciation of stock and materials you may carry on hand
- Bad or uncollectable bills
- Bookkeeper, or any office help
- General office and shop expense

The item of profit on medium and large sized jobs is one that you are justly entitled to. If you buy your supplies and materials from a large dealer at wholesale prices and charge the customer the regular retail price, this is one source of profit, and a certain reasonable percentage can be added to your wage allowance on any job to complete your per cent of profit.

In other words, there is no use of operating a business if you cannot show at the end of each year a substantial profit or gain. The cost of any job, then, should be divided into at least four items:

1. Net Cost of Material
2. Net Cost of Labor
3. Overhead Expense
4. Profit

Experience has shown that on a small business of under $20,000.00 gross per year, the overhead will frequently run as high as 30 to 35 per cent. The larger the volume of business, the less the percentage of overhead should be; and with a gross business of $60,000.00 per year we would usually figure about 20 to 25 per cent. Your profit should certainly be at least 10 per cent above all expenses, and this should be in addition to a fair salary for your time.

If you do a total of $40,000.00 worth of business in a year, at the end of the year, your income tax report should show that, after paying all bills and your salary and considering all debits and credits, there remains a clear profit of 10 per cent, or $4,000.00.

By adding all your overhead items together you should get about 25 per cent, or $10,000.00. If your overhead is more than that amount it shows that there is something wrong in your methods, and you should try to reduce it during the next year, by looking over each item to see where economy can be effected.

130. METHOD OF FIGURING OVERHEAD AND PROFIT IN AN ESTIMATE

When figuring on any certain job we don't know, of course, what the gross price is going to be, and, therefore, have to make allowances for these extra items. For example, suppose we consider a job where we find the material will cost $32.00. The next item to consider will be the labor. While this varies a great deal in different sections of the country, we might estimate it to be about equal to the cost of the material, or slightly more, and we will say it is $33.00. This makes a net cost, so far, of $65.00 for material and labor. If we are going to allow 25% for overhead and 10% for profit to make the total cost, or 100%, this leaves 65% for the net cost. If $65.00 is 65% of the cost, then 100%, or the total cost, would be $100.00, which should be the price quoted for this job. **If you multiply the net cost for labor and materials by .54 it will give the approximate total cost, including the extra 35% for profit and overhead.**

In some cases, of course, a job can be quoted at a figure which doesn't cover these extras. For example, where you have a chance to sell equipment which you buy direct from a dealer for a certain job and do not have to carry in stock yourself, this reduces your overhead. In fact the more of this class of business you can do and the less idle stock you carry, the greater your profit will always be. However, in an active business of any size some standard items must always be kept on hand.

131. ALWAYS DO FIRST-CLASS WORK

Never make a practice of trying to get a job by cutting your price so low that you have to install poor materials, or do a poor job of the installation.

Always do first-class work at a fair price, and explain to your customers that you are certain they will remain better satisfied with this kind of work than if you cut the price and give them a poor job.

132. GETTING NEW CONTRACTS

Very often a number of new jobs can be secured by keeping in close touch and on friendly terms with building contractors and architects, and those in your community who are in a position to know first of new buildings being erected and who may perhaps recommend you for the electrical work.

133. PRACTICAL ESTIMATING PROBLEMS

As an example of laying out a job and materials for the estimate, let's consider the installation shown in Fig. 143.

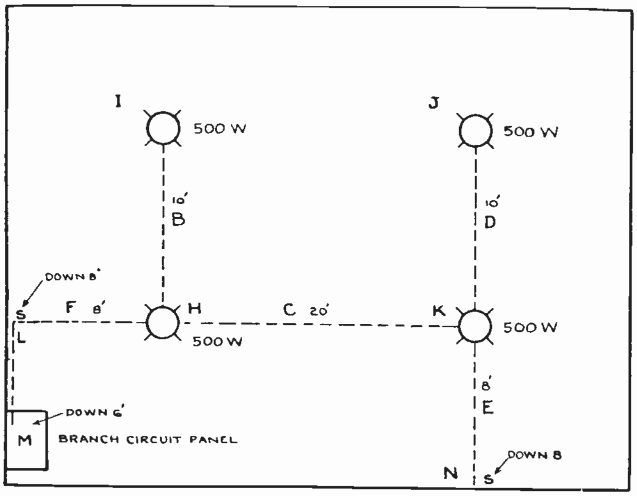


Fig. 143. Layout of a wiring system for four large lights, showing the measurements to be taken in preparing a list of the materials for such a job. Note the explanation and list given in the accompanying paragraphs.

This diagram shows a room in a finished building, such as a store or shop, where the customer desires an installation of exposed conduit. As this is not a new building and there are no blue prints, you should make a rough sketch of the proposed wiring system; and, after locating the outlets and switches, measure the room carefully for the necessary lengths of material. We have four outlets, each for a 500-watt lamp, which means we will need two branch circuits. We will assume that the layout is such that outlets "H" and "I" can be on one circuit, and "J" and "K" on the other. With the distance shown No. 14 wire and ½-inch conduit can be used. The wires for both circuits from the cut-out box to the outlet "H" can be run in one conduit. At the point marked "L" one circuit will have a wire looped down for a switch connection to control lights "H" and "I". Where the conduit changes direction to run down the walls to the cut-out boxes and switches, condulets can be used.

From this lay-out we find the approximate list of materials will consist of the following (not including the cut-out box or fuses):

85 feet ½-inch conduit
4 4-inch Octagon outlet boxes
4 Fixture studs
2 Type L ½-inch condulets
1 Type LBR ½-inch condulets
3 ½-inch blank condulet covers
2 Flush switch condulets
2 Flush switch condulet covers
2 Single-pole flush switches
9 ½-inch conduit bushings
9 ½-inch lock-nuts
20 ½-inch pipe straps
225 feet of No. 14 R.C. wire
Also the necessary solder, tape, and screws.

After making up an estimate from the above, it is generally a good plan to add 5% to cover small items that cannot be foreseen in advance.

In another case, suppose we consider a house-wiring job where our records show that we can figure by the outlet. Assume this to be a knob and tube installation in a new building under construction, and that there are to be 50 outlets, half of which are lighting outlets and half are flush switches or flush receptacles. If our records show that on this sized job we should get $2.75 per lighting outlet and $3.25 per switch or convenience outlet, then the estimate should be $150.00, plus the service price, which the records may show will average $15.00; thus we make the total estimated price $165.00. In such cases as this your records of previous jobs of similar type will be of great assistance in making an accurate and intelligent bid.

133-A. WIRING PLANS AND LAYOUTS

Figures 144 and 145 show the basement and first floor plans of a one-story bungalow, with a layout of the wiring system. This is a very simple system with just the ordinary number of lights and convenience outlets, and could quite easily be installed in an old house, using BX or non-metallic sheathed cable.

The heavy dotted lines show the circuits feeding to the lights and outlets, while the light dotted lines show the wires from the lamps to the switches which control them. The wiring does not need to run exactly as the lines are shown here, but could, of course, be altered somewhat to suit the building.

In the basement, which in this case is wired with conduit, the equipment is as follows:

"A" is the service switch and branch circuit fuse box.

"B" and "C" are lights controlled by a switch at the head of the stairs.

"D" is the laundry light, controlled by a switch at the door to the laundry room.

"E" is a convenience outlet for washing machine, flat iron, etc.

"F" and "G" are lights on drop cords, controlled by switches on the light sockets.

"H" is a bell transformer which is connected to the junction box "J".

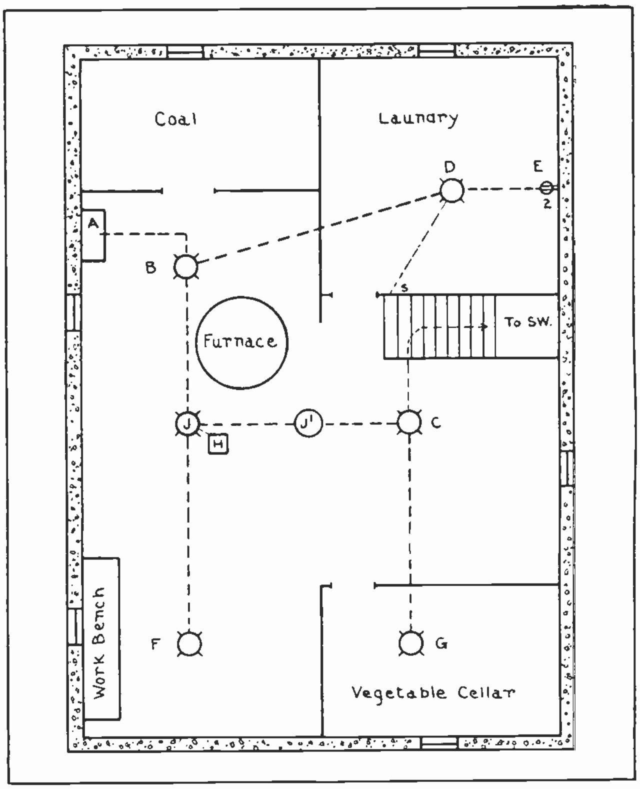


Fig. 144. This diagram shows the basement wiring plan for a one-story building. Check carefully each of the circuits and outlets shown with the explanations given.

"J-1" is a junction box from which BX will be run up through the partition to feed the branch circuits on the floors above.

The number of wires which we will have in each of these runs will be as follows:

"A" to "B"—six wires, three black and three white.

(One two-wire circuit for the basement, and two circuits for upstairs)

"B" to "J-1"—seven wires, four black and three white.

"J" to "F"—two wires, one black and one white.

"C" to "G"—two wires, one black and one white.

"B" to "D"—two wires, one black and one white.

"D" to "E"—two wires, one black and one white.

"J-1" to "C"—three wires, two black and one white.

"D" to switch outlet—two black wires.

"C" to switch outlet—two black wires.

Here again, we can see one of the advantages of polarized wiring, as all of the white wires can be connected together, leaving much less chance for mistakes and wrong connections than if we use all black wires.

In the floor above we have one ceiling light in the center of each room except the living room, which has two; and one in the hall near the bathroom. There is also a light at the head of the stairway. The living room and kitchen lights are each controlled from two different places, by three-way switches. This provides the convenience of being able to turn them on or off at either door at which one might enter these rooms.

The six double convenience-outlets shown represent just a minimum for an installation of this type; so it might be desirable to install several more of these while wiring the house. The convenience-outlets are located near each other on opposite sides of the walls in the different rooms. This greatly simplifies the wiring as one run can be made to take care of each pair of these outlets.

The dotted lines in this view show only the runs from the lights to the switches which control them. The branch circuits to the lights are not shown; as their position would be a matter of choice and convenience, according to the construction of the house and the points at which they could be best carried through partitions, floors, and ceilings.

Fig. 146 shows a sample form for listing the outlets used on a job, such as shown in Figures 144 and 145. The lighting, switch, and convenience-outlets for this particular job are shown listed on this form. Forms of this type are a great help in getting an accurate list of all the parts and fittings needed for the various rooms of any house-wiring job.

In wiring a new home we would undoubtedly put in a greater number of lights and convenience outlets, as well as three-way switches for selective

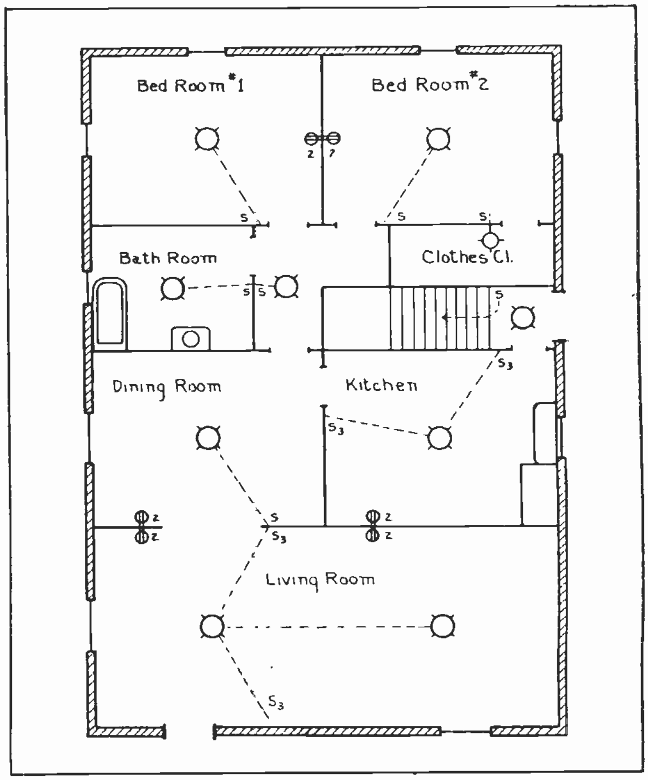


Fig. 145. Wiring diagram for a bungalow residence. Note the location of lights, switches, convenience outlets, etc.

ROOMS	CEILING OUTLETS	WALL BRACKETS	CONVENIENCE OUTLETS	SWITCH OUTLETS	REMARKS
BASEMENT	2			1	AT HEAD OF STAIRS
LAUNDRY	1		1	1	
VEG. CELLAR	1				
WORK BENCH	1				
BELL TRANSF.	1				
LIVING RM.	2		2	2	3 WAYS
DINING RM.	1		1	1	
KITCHEN	1		1	2	3 WAYS
BATH	1			1	
BED RM. #1	1		1	1	
BED RM. #2	1		1	1	
HALL	1			1	
CLOSET		1		1	
ALL CONVENIENCE OUTLETS ARE DOUBLE					

Fig. 146. Simple forms of this type are a great help in totaling the number of outlets for any job. Other forms are used for listing the materials for each room and the total wiring job.

control. Fig. 147 shows a cut-away view of the first floor in a modern home, which gives some idea of the arrangement of wall bracket lights, convenience outlets, and switches. In addition to those shown, there would probably also be a ceiling light in the living room, dining room, and kitchen.

134. WIRING SYMBOLS

Fig. 148 shows a number of the more common symbols used in marking various electrical outlets on the building plans. Examine each of these carefully and become familiar with them, as they will be a great help to you in reading any blue prints supplied either by contractors or architects where the electrical wiring of any building is laid out in advance. A knowledge of their use will also be very handy to you in drawing up a sketch or plan for a building in which you may be laying out the wiring system yourself.

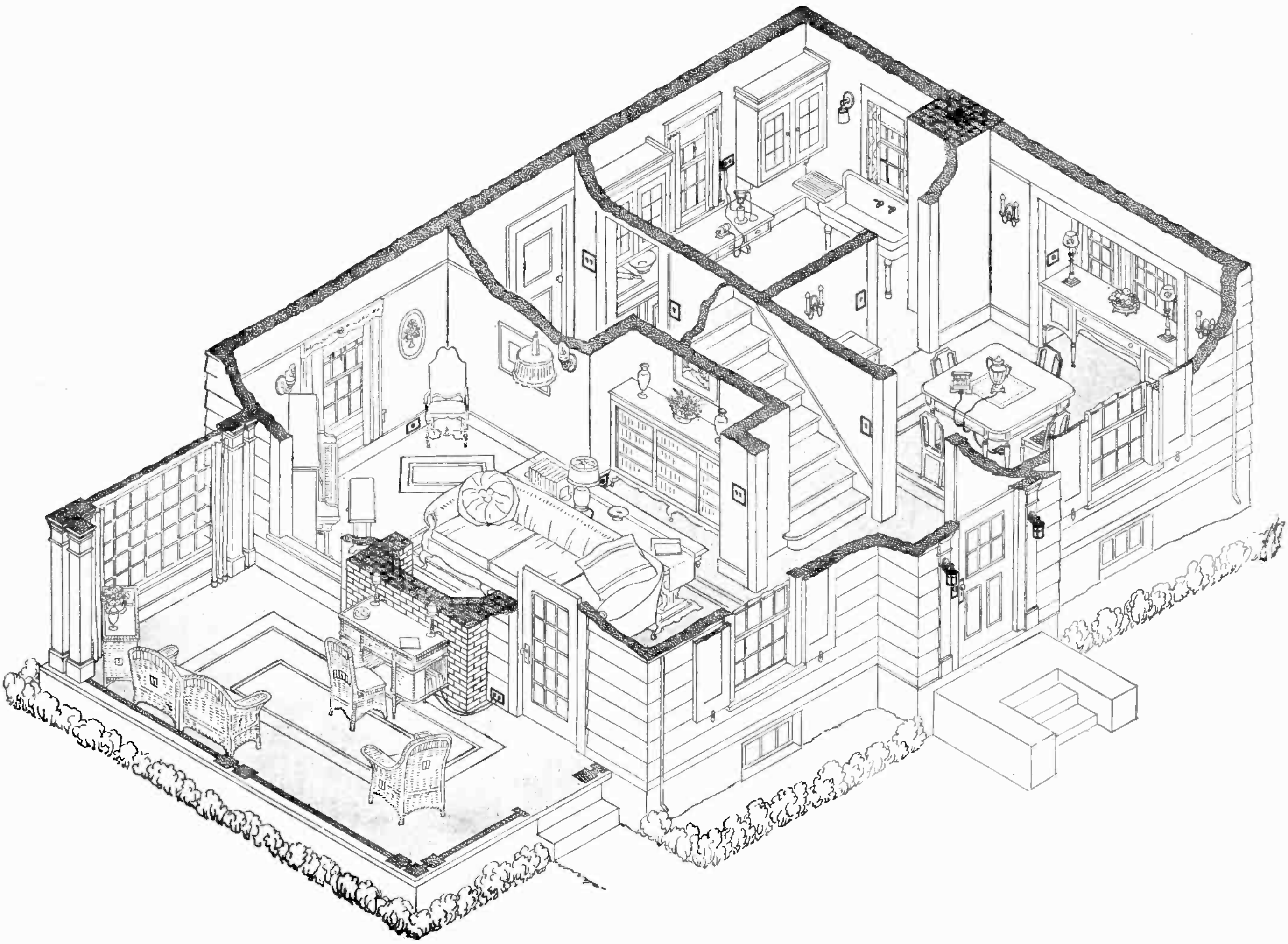


Fig. 147. Sectional view of ground floor of a house, showing the location and arrangement of lights, switches, and convenience outlets.

STANDARD SYMBOLS FOR ELECTRICAL EQUIPMENT OF BUILDINGS

Ceiling Outlet		Automatic Door Switch	S^D	Feeder Run Exposed	- - - -
Ceiling Fan Outlet		Key Push Button Switch	S^K	Feeder, Run concealed under Floor	— —
Floor Outlet		Electrolier Switch	S^E	Pole Line	
Drop Cord	D	Push Button Switch and Pilot	S^P	Push Button	
Wall Bracket		Remote Control Push Button	S^R	Annunciator	
Wall Fan Outlet		Motor		Interior Telephone	
Single Convenience Outlet		Motor Controller	M.C.	Public Telephone	
Double Convenience Outlet	2	Lighting Panel		Local Fire Alarm Gong	F
Junction Box	J	Power Panel		Local Fire Alarm Station	F
Special Purpose Outlet-Lighting, Heating and Power as Described in Specification		Heating Panel		Fire Alarm Central Station	F.A.
Special Purpose Outlet-Lighting, Heating and Power as Described in Specification		Pull Box		Speaking Tube	
Special Purpose Outlet-Lighting, Heating and Power as Described in Specification		Cable Supporting Box		Nurses Signal Plug	N
Exit light		Meter		Maid's Plug	M
Pull Switch	P.S.	Transformer		Horn Outlet	
Local Switch- Single Pole	S^1	Branch Circuit, Run concealed under Floor Above	———	Clock (Secondary	
Local Switch- Double Pole	S^2	Branch Circuit, Run Exposed	- - - - - -	Electric Door Opener	
Local Switch-3 Way	S^3	Branch Circuit, Run concealed under Floor	— —	Watchman Station	W
Local Switch-4 Way	S^4	Feeder, Run concealed under Floor Above	———	4 No.14 Conductors in 3/4 in. Conduit Unless Marked 1/2 in.	||||
This Character Marked on Tap Circuits Indicates 2 No 14 Conductors in 1/2-in. Conduit.	||	3 No.14 Conductors in 1/2 in. Conduit.	|||		

Fig. 148. The above wiring symbols with their explanations should be very carefully studied so you will be able to recognize the more common of these symbols readily and easily when working with wiring diagrams or plans. Make a practice of referring to these symbols every time you find one you cannot recognize in a diagram.

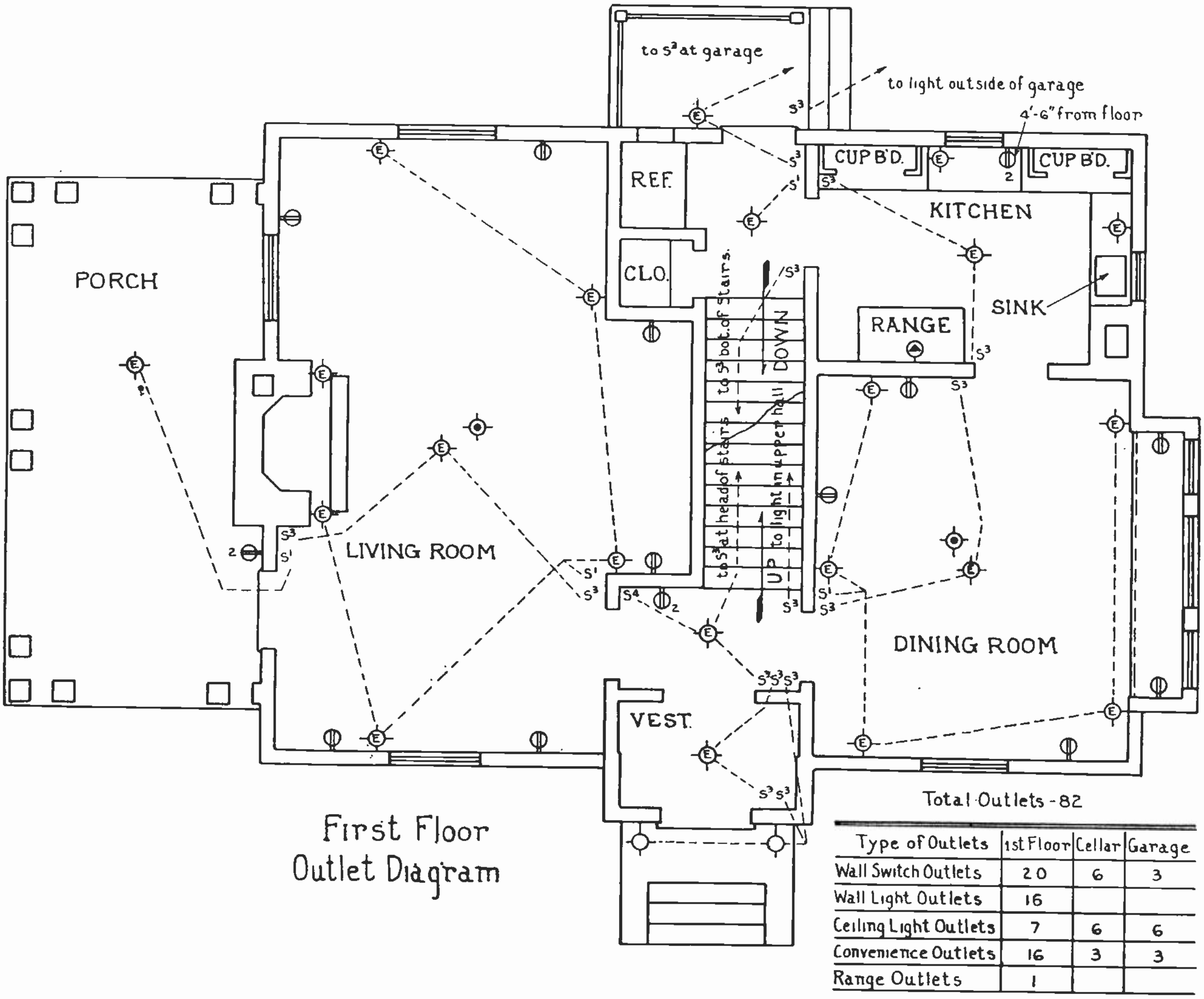
135. NEW HOUSE WIRING PLAN

Figures 149 and 150 show the wiring plans for the first and second floors of a modern home. These plans show a very complete system of lights, convenience outlets, three-way switches, etc., such as we would be most likely to install in a new building. Some home-owners might not care to go to the expense of quite as complete an installation as these plans show, but whenever possible the customer should be sold on the idea of wiring the house complete for every possible need when it is erected, as it is so much cheaper to install these things when the house is being built than to put them in afterward. With the ever-increasing use of electrical appliances and light in the home, the owner is likely to regret it later if the home is not quite completely wired. However, it is very easy to leave out a few of the items in a suggested plan of this type, if desired.

By referring to the chart of wiring symbols in Fig. 148, you will be able to recognize each of the outlets in this wiring plan. Check each of them carefully until you have a thorough understanding of the location of each outlet and what they are for.

The dotted lines in these diagrams only show which outlets are connected together, and the runs from the switches to the lamps which they control. The plans do not show where the conduit or BX runs come up from the basement or from one floor to the other.

Several different organizations, such as the General Electric Company and the National Contractors' Association, have some very valuable printed forms, which can be obtained to aid you in listing materials for an estimate; and also sample forms for contracts with the customer. The Society for Electrical Development furnishes valuable material and information, such as the Franklin Specifications and Red Seal Plan for good lighting, which should be of great value to anyone in business for himself.



Type of Outlets	1st Floor	Cellar	Garage
Wall Switch Outlets	20	6	3
Wall Light Outlets	16		
Ceiling Light Outlets	7	6	6
Convenience Outlets	16	3	3
Range Outlets	1		

Fig. 149. This wiring diagram gives a more complete layout of the proper lights, switches and convenience outlets for a modern wiring job in a new building. Compare each of the different outlet symbols with those in Fig. 148.

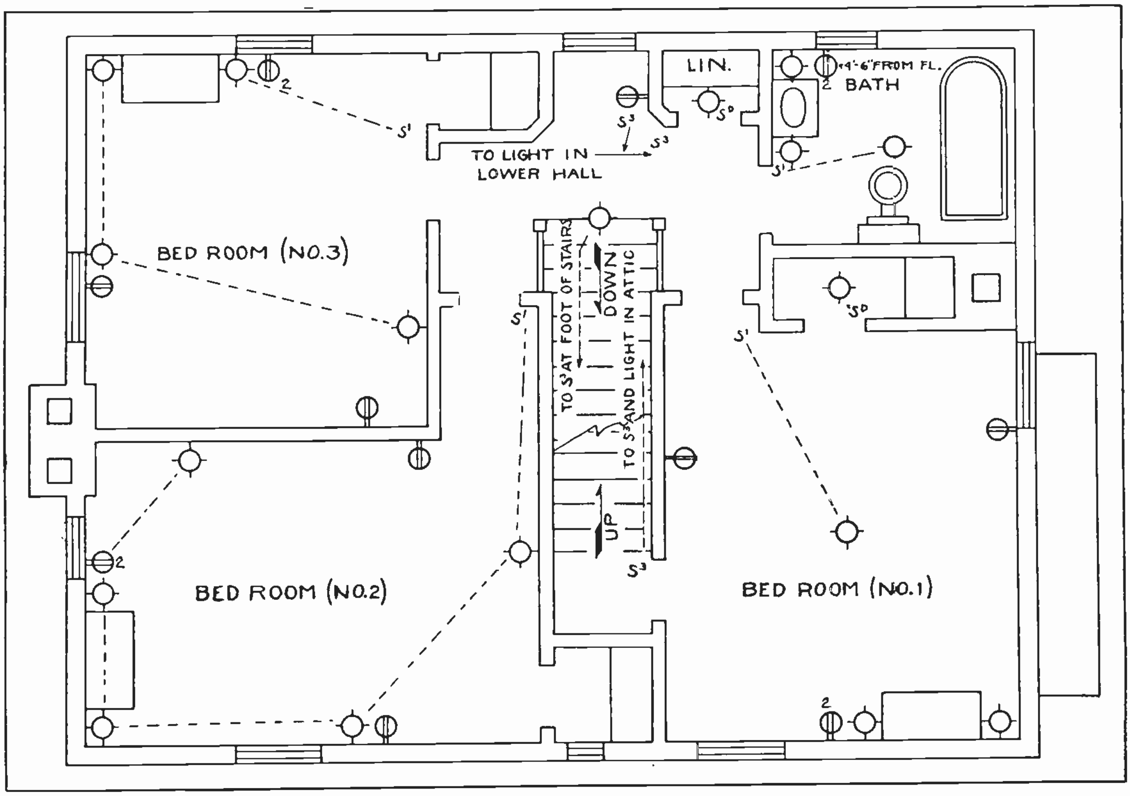


Fig. 150. Second-floor plan and wiring diagram. Note the location of the switches to control the various lights, and particularly the three-way switches for controlling lights from more than one place. Compare this diagram to the one in Fig. 149, to get a complete understanding of the arrangement of switches at the stairway.

136. TOOLS

Perhaps you will wonder how many and what type of tools will be required to start in electrical wiring. It is not necessary to have such a complete or elaborate layout on tools to start your first jobs with. A list of the more common and necessary ones for this type of work are as follows:

Several screw drivers of various sizes
Side-cutting pliers.
7 or 8-inch diagonal cutting pliers.
Long-nosed pliers.
6-inch combination pliers.
8-inch gas pliers.
Claw hammer.
Ballpein hammer.
Wood chisels, one narrow and one wide.
Cold chisel.
Hack-saw frame and blades.
Hand saw.
Key-hole saw.
Corner brace and wood bits.
Hand drill or push drill.
Stillson pipe wrench.
Five-foot rule.
Blow torch and soldering iron.
Two or three putty knives, for prying off wood strips.
100 ft. steel fish tape.

In addition to this list, an electrician who owns his own shop should acquire as soon as possible a boring machine, step ladders, conduit bender, vise, pipe cutter, pipe reamer, stock and dies for threading pipe, and set of star drills. A number of other items will be found convenient as the shop or business grows, and these can be purchased as the profits of the business will pay for them.

TROUBLE SHOOTING

137. TROUBLE SHOOTING

Whether you are employed as an electrical wireman or maintenance man, or in the business for yourself, a great deal of your work may often be what is commonly known as **"Trouble Shooting."**

This covers a wide range, from such small jobs as finding a short circuit in a domestic flat iron to tracing out troubles in a power circuit of some large shop of factory. In any case, it usually requires merely a thoughtful application of your knowledge of circuit tracing and testing. We have previously recommended and will emphasize here again the necessity of **keeping cool** when emergencies of this sort arises, and going about the location of the trouble in a systematic and methodical manner, testing one part of the circuit or system at a time, until the trouble is cornered.

Keep in mind that every trouble shooting problem can be solved, and someone is certainly going to solve it. If you succeed in locating and remedying the trouble, it will always be to your credit, and it may be the source of new business for you or a promotion on the job.

In general, the same methods can be followed for trouble shooting and testing in light and power circuits as have previously been explained in the section on signal wiring. A dry cell and buzzer, taped together and equipped with a pair of flexible leads five or six feet long, is always a handy and use device for this work.

Where part of the system is still "alive", or supplied with current, a pair of test lamps are very handy. These can be connected together in series for 220-volt tests or one can be used separately for testing 110-volt circuits. They are particularly handy when testing for blown fuses, and this test will often locate the whole source of trouble.

138. FUSE TROUBLES

In testing wiring circuits we should first start at the service switch or fuse box. Test to see if the line is alive from the outside service wires, and if it is, then test the fuses. If cartridge fuses are used, testing across diagonally from the service end to the house end, will quickly show which fuse is blown. If the contact springs or clips which hold cartridge fuses are blackened or burned, this is likely to be the cause of the trouble. Sometimes these springs become bent and do not make a good contact to the ferrule on the fuse. This results in a high-resistance connection and heating, which softens and destroys the spring tension of the clips. When clips or springs are found in this condition they should be renewed.

Fig. 151 shows several conditions that will often be found with cartridge fuse clips. When fuses of the cartridge type are found to be blown, it is well to examine them a little before replacing. If the fuse link is found to be blown in the manner shown at "A" in Fig. 152, it is probably caused by a light overload, which gradually heated the fuse to a point where one end melted out. Occasionally you may find the fuse burned in two at the middle and not at the narrow points where it is supposed to blow. This condition is shown at "B", and is sometimes caused by the slow heating of the fuse, and from the heat being conducted away from the ends by the fuse clips, thus causing the center to melt first. When a fuse has been blown from a severe overload or short circuit, it will often be found melted in two at both of the narrow spots, allowing a whole center section to drop out, as in Fig. 152-C. In such cases there will be a tremendous rush of current that may melt the first point open in a fraction of a second, but the extremely heavy current flow may maintain an arc across this gap, long enough to melt out the other weak point also.

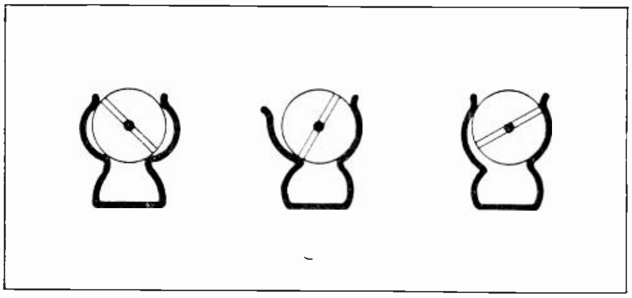


Fig. 151. Fuse clips that are bent out of shape in the manner shown above very often cause heating of the ferrules which results in blown fuses, and other fuse troubles. Burned or weakened fuse clips should be replaced and new ones adjusted to fit the ferrule of the fuse outlet.

With plug fuses, we can also very often tell something of the nature of the trouble by the appearance of the window in the blown fuses. If the window is clear and shows the strip melted in two, it was probably a light overload which blew the fuse. But if the window is badly blackened by a violent blowing out of the fuse, it is usually an indication of a severe overload or short circuit.

139. COMMON CAUSES OF SHORT CIRCUITS

Wherever blown fuses are encountered it is well to check up on possible causes and conditions in the circuits before replacing the fuses. Sometimes we may find that someone had just connected up and tried out some new electrical appliance which may have been defective or of too great a load for the circuit and fuses. Frequently these devices will be found connected up wrong. Sometimes by inquiring of the people on the premises we can find the probable cause of the trouble.

For example, the lady of the house may have been ironing when suddenly there was a flash at the iron, the lights went out, and the iron cooled off. This would probably indicate a defective cord on the iron or a short circuit on the plug or element. In another case one of the children may have stumbled over a cord to a floor lamp causing all the lights to go out, which would indicate that wires were probably jerked loose and shorted at the lamp or plug; or that the insulation of the cord may have been broken through, causing the wires to short within the cord.

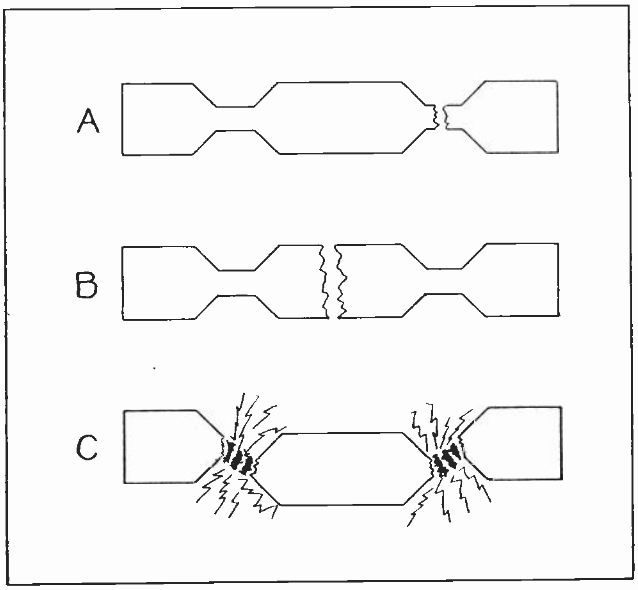


Fig. 152. The above views show several ways in which fuse links may blow. Note particularly the lower view which is the manner in which fuses are often blown by short circuits or severe overloads.

If fuses are blown frequently, it is usually an indication of an overloaded circuit, and in such cases another circuit and set of fuses should be installed. If the circuits are already fused for 15 amperes and are ordinary ones with No. 14 wire, they should certainly not be equipped with larger fuses, as it is in violation of the Code, and the wires might be overheated.

A very handy test for "shorts" is to remove the fuse from the socket and screw a lamp bulb in its place. Then, if the lamp still burns when all the equipment on this circuit is turned off, it indicates a short circuit on the wires.

140. LOCATING SHORT CIRCUITS AND GROUNDS

In locating a short circuit, it is well to see that each light on the circuit is turned off, and each plug removed from any convenience outlets which may be on the circuit. If this does not clear the trouble it indicates that one of these devices is at fault. By having someone watch the test lamp in the fuse socket as these devices are plugged in and switched on again, the one causing the trouble can be found by watching for the instant the lamp lights once more. A great majority of fuse troubles in homes can be traced to defective cords of portable devices.

If removing these devices from the circuit doesn't clear the trouble, then it must be in the wiring. Then we should go along the circuit and open up the outlet boxes, pulling out the splices and even disconnecting them, if necessary, to locate the trouble within one section. In a great majority of cases shorts in the wiring system will be found at poorly taped splices in the outlet boxes. It is very seldom that any defects occur in the wires themselves, especially if they are installed in BX or conduit. Sometimes, however, if repair or construction work has been going on around the building, the trouble may be caused by someone having driven a nail into a piece of non-metallic sheathed cable, metal molding, or even through the light-walled electric metallic tubing, or they may have cut the wires in two with a saw or drill.

Here is another place where inquiry as to what has been happening just before the trouble occurred may help you to locate it.

In shops or factories, blown fuses may be caused by installing additional equipment on certain circuits until they are overloaded, or by the addition of a motor that is too large for the circuit on which it is installed. In other cases a belt may be tightened too much, or the bearings of some machine not properly lubricated, causing a rather severe overload on the driving motor. If the voltage at the service box is too low this will cause motors to draw more than the normal load of current and will blow the fuse.

Whenever some of the lights on any system are found to be burning excessively bright and some of the others very dimly, remember that the cause is likely to be a blown-out neutral fuse on one of the older installations of non-polarized wiring.

The troubles which have been mentioned are some of the most common and are the most frequently encountered. A number of others will come up in your experience, but if you always follow the general methods given in this material and apply your knowledge of circuits and principles of electricity you should have no great trouble in locating them. Every time you find and correct some source of trouble which you have not met before, it should be a source of pleasure and satisfaction to you, because of the added experience it gives and the greater ease with which you will probably be able to locate a similar trouble the next time. So, let us once more recommend that you **always welcome any trouble shooting problem** as a test of your ability and a chance to get good experience.