PRACTICAL ELECTRIC WIRING

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PREFACE

The object of this volume is to present to the student the practical side of electrical wiring. The endeavor throughout the book has been to furnish not only general information but sufficient special information to enable the student actually to install electric wiring. The subject is treated comprehensively from the method of distributing current by different systems to the minute details in wiring for and in installing the different fittings.

For the wireman or electrical contractor the wiring tables and data will form a ready reference and some of the practical methods for saving time and material may suggest a source of increased income.

Several important rules from the National Electrical Code have been given but the complete regulations have not been included as they may be had for the asking by applying to the National Board of Fire Underwriters in New York, Boston or Chicago. A special effort, however, has been made throughout the book to comply with the rules contained in the 1913 edition of the code.

The author is indebted to Professor Louis D. Bliss of the Bliss Electrical School for many criticisms and valuable suggestions of an electrical nature and to Professor Robert J. Peters of Carnegie Institute of Technology for criticism and arrangement of the final copy.

PUBLISHER'S NOTE

In the revision of this text certain necessary changes have been made, and the necessary new matter has been included to make the volume thoroughly up to date and in accordance with the most recent electric wiring practice.

CONTENTS

PRACTICAL ELECTRIC WIRING

CHAPTER I

INTRODUCTION

Importance of Electric Wiring.—Electricity has become such an important factor in our industries and homes that a general education is not complete without some knowledge of this subject. Those who specialize in electricity find the field so wide and the work so varied that a further specialization in one of its branches must be made before one can hope to reach any high degree of success. Electric wiring is a very important branch of the business not only because it is essential wherever electrical appliances are used but because the safety of the buildings through which it passes depends on the character of such work. If the wiring is done according to the rules of the National Electrical Code and in a workmanlike manner, there is little likelihood that electricity will cause trouble or property loss. However, where the Code rules are not complied with and an honest job is not executed, many vexatious troubles and dangers may arise. An attempt is not made to cover the entire field of electricity in this volume, but principles of electricity with illustrations and instructions are given to assist the student in becoming a practical electric wireman.

Electricians' Tools and Their Uses.—A wireman, first of all, must understand the purpose of various tools and know how to use them. Much time will be saved if the right tools are used and used properly. The following list comprises a number of tools that the wireman may need, with some brief instructions as to their uses.

The screw drivers used may be classed as cabinet, machinist, ratchet and yankee. Cabinet and machinist are the ordinary screw drivers, the former being used for small and the latter for large wood and machine screws. The ratchet screw driver may be either large or small, the advantage being that it is not necessary to remove the driver from the screw on the backward stroke. The yankee screw driver, used mostly for the larger screws, has a spiral gear whereby the screw is turned by simply pushing on the handle. With any screw driver there is usually a tendency for the driver to twist out of the groove of the screw. This tendency may be overcome by grinding or filing off the edge squarely, making it conform very nearly to the shape of the groove in the screw.

Pliers are made in many different styles but those most used by a wireman are side cutter, long-nosed, and combination gas pliers. The side cutter is used for cutting and splicing wires and general use. The 7-inch is the most popular length for this class of work. The long-nosed is used chiefly for reaching nuts, screws, etc., in places out of reach of the ordinary plier. The combination gas plier is used for turning lock nuts, bushings, and small pipes.

The hammers used are nail and machinists' ball and peen. Nail hammers with straight claws are sometimes preferred as they may be used in notching joists. The machinists' ball and peen is used by the wireman for drilling holes in brick, concrete, etc.

Braces should be either a ratchet or a corner brace. The ratchet permits boring in close places where the handle can be rotated only part of a turn. The corner brace allows faster boring in a corner.

The bits more commonly used are bell hangers', ships' auger and expansion. The bell hangers' bit is used in drilling small holes usually for bell wires. The size more commonly used is $\frac{1}{4}$ inch by 18 inches. Ships' auger car bits are used chiefly in boring joists for porcelain tubes. The size should be $\frac{5}{8}$ inch by about 20 inches. Expansion bits have a cutter that is adjustable for different-sized holes and are used in boring holes for conduit, etc. A good size to employ is one capable of adjustment from $\frac{7}{8}$ to $1\frac{1}{2}$ inches.

Bit extensions are often used in boring deep holes with a short bit. The electrician usually prefers one about 18 inches long that will follow a $\frac{5}{8}$-inch bit.

Boring machines are used for boring floor joists for porcelain tubes. Some types allow the wireman to stand on one floor and drill the beams of the floor overhead. They are rather expensive and are not in common use.

Saws for the electrician may be classed as compass, molding and hack saws. The compass saw is used for many purposes, though its main use is for sawing off floor boards in a finished house preparatory to removing them. Fourteen and 16-inch are good lengths for general use. Molding saws, as the name implies, are used for cutting wood molding. Hack saws are used chiefly for cutting conduit, armored cable and metal molding. Fine-tooth blades are preferred for this class of work.

Chisels may be classed as wood, floor and cold. Wood chisels are used with saws in notching floor joists, etc. Half-inch is the width commonly used. Floor chisels have thin wide blades and are made specially for removing floor boards. Cold chisels are used for cutting iron and for drilling holes in brick, concrete or stone.

Star drills and drill heads are more commonly used for drilling brick and concrete.

The wrenches used are known as monkey or pipe. The monkey wrench, though not usually necessary for a wireman, may be used on lock nuts and sometimes on machine bolts and nuts. Stilson or other pipe wrenches are always necessary on a conduit job for screwing pipes into couplings and for other pipe work.

Pipe vises are required on a conduit installation to hold the conduits for cutting and threading.

Stock and dies are used for cutting threads on the conduit. Dies and guides for different-sized conduits may be used in the same stock. A stock of the proper size with the following size dies and guides, $\frac{1}{2}$, $\frac{3}{4}$, 1 and $1\frac{1}{4}$ inch, makes a good threading outfit for a wireman.

Pipe cutters are faster than hack saws for cutting conduits and are generally employed for the larger jobs.

Reamers are for wood and iron. The wood reamer is used chiefly in reaming out the screw holes in wood molding so that the screw head will be counter sunk. Iron reamers of about the same size are also used in reaming out screw holes in metal molding. Iron or conduit reamers are used in reaming the burrs from the inside of the conduit after it has been cut. The size in most general use tapers from $1\frac{1}{4}$ inches to $\frac{7}{16}$ inch.

The files used chiefly are round or rat-tail, flat, and three-cornered. The round is used for reaming burrs from the inside of conduits. The flat is used for scraping pipes and conduits, for ground clamps, and for sharpening bits, screw drivers, and other tools. The three-cornered is used chiefly for cutting metal molding.

Steel fish tape is used in fishing wires through conduits. Fifty feet is a good length for ordinary use.

Combination squares are used in mitering wood molding.

Miter boxes or miter frames are used in mitering wood molding.

Lever molding cutters are used in cutting metal molding.

Drills are chiefly hand and breast drills. The hand drills are used for drilling screw holes in wood molding. The breast drills are used for drilling holes in metal, such as cabinet or switch boxes, for the screws that hold the switches or cut-outs in place. An assortment of twist drills should be kept on hand for drilling holes in switch or cabinet boxes for wood or machine screws. Sizes $\frac{9}{64}$ and $\frac{11}{64}$ make the right-sized hole for tapping for 8-32 and 12-24 machine screws and are usually the most important.

Taps are often required for tapping holes for machine screws in metal boxes. For supporting switches, branch blocks, etc., the 8-32 and 12-24 are most commonly used.

A tap wrench, of course, is required for turning these taps.

Splicing clamps are used for holding the larger or stiffer copper or iron wires while the joint is being made. They are most used by the lineman; an interior wireman seldom needs them.

Torches are generally gasoline or alcohol. The gasoline torch is used chiefly in heating the larger joints for soldering and in heating soldering coppers. The pint size is preferred because it holds enough gasoline for the usual job and is lighter to carry. The alcohol torch is employed in soldering the smaller wires such as Nos. 18, 14, and 12. It can be started much more quickly than the gasoline torch and for that reason is preferred for lighter work.

Soldering coppers are used in soldering wire joints. Where it is practical they should be employed for all soldering instead of using a flame. The copper is safer and a joint so soldered is less liable to become overheated and cause the wire to break.

Measuring rules for the wireman are usually the zigzag type, either 4 or 6 feet in length.

Molding cutters of the lever type are employed in cutting the backing and capping of metal molding. Lever punches are also used for cutting slots in metal molding from the screw hole to the end of the molding. Trowels of the smaller size are often required for "patching up" the holes around switch or cut-out boxes.

Wire gauges are sometimes required for gauging different sizes of wire, though wiremen seldom find it necessary to use one.

Tools Required by Wiremen.—The wireman may have occasion to use all the tools before mentioned but it would be a useless expense to buy them all outright, as some would seldom be required and others, especially the heavier ones, are frequently furnished by the contractor. A much better plan is to buy a few of the most used tools and add to the stock as conditions on the job require. The following list of tools makes a good outfit for a wireman:

1 6-inch machinist's screw driver
1 3-inch cabinet screw driver
1 pair of 7-inch side-cutter pliers
1 pair of combination gas pliers
1 1-lb. claw hammer
1 ratchet brace—10-inch sweep
1 ship's auger car bit, size $\frac{5}{8}$ by 20 inches
1 bell hanger's bit $\frac{3}{8}$ by 18 inches
1 expansive bit with range of $\frac{7}{8}$ to $1\frac{1}{2}$ inches
1 hollow handle hand drill
1 10-inch Stilson wrench
1 14-inch Stilson wrench
1 14-inch compass saw
1 10-inch hack saw
1 gasoline torch, pint size
1 alcohol torch
1 soldering copper, $1\frac{1}{2}$-lb.
1 set of drills and taps
1 tap wrench
1 8-inch mill file
1 4-foot zigzag rule
1 jackknife
1 tool bag

Standard Symbols for Wiring Plans.—The builder's symbols for wiring plans, shown on the following pages, are used to signify the different outlets to be wired for in a new building. The building contractor usually submits to the electrical contractor a blue print of the plans of the building, using the following symbols to indicate the location of the outlets. The electrical contractor locates the distribution centers, if they are not already located, and groups the outlets on the branch circuits. The branch circuit wiring is planned by drawing a red or white dotted line, for each branch, from the center of distribution to all the outlets to be included on that circuit. An effort, of course, is made to use the smallest possible amount of wire and material and still allow no branch circuit to carry more than 660 watts of energy.

STANDARD SYMBOLS FOR WIRING PLANS

AS ADOPTED AND RECOMMENDED BY

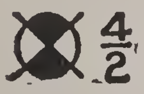
THE NATIONAL ELECTRICAL CONTRACTORS' ASSOCIATION OF THE UNITED STATES

AND

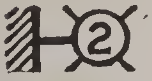
THE AMERICAN INSTITUTE OF ARCHITECTS

Copies may be had on application to the Secretary of the National Electrical Contractors' Association, Utica, N. Y., and the Secretary of the American Institute of Architects, Washington, D. C.

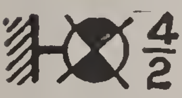
Ceiling Outlet; Electric only. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.



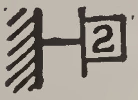
Ceiling Outlet; Combination. $\frac{4}{2}$ indicates 4-16 C. P. Standard Incandescent Lamps and 2 Gas Burners. If gas only



Bracket Outlet; Electric only. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

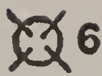


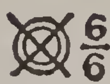
Bracket Outlet; Combination. $\frac{4}{2}$ indicates 4-16 C. P. Standard Incandescent Lamps and 2 Gas Burners. If gas only



Wall or Baseboard Receptacle Outlet. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Floor Outlet. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

 Outlet for Outdoor Standard or Pedestal; Electric only. Numerals indicate number of Standard 16 C. P. Lamps.

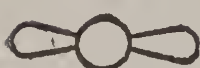
 Outlet for Outdoor Standard or Pedestal; Combination. $\frac{6}{6}$ indicates 6-16 C. P. Standard Incan. Lamps; 6 Gas Burners.

 Drop Cord Outlet.

 One Light Outlet, for Lamp Receptacle.

 Arc Lamp Outlet.

 Special Outlet for Lighting, Heating and Power Current, as described in Specifications.

 Ceiling Fan Outlet.

S^1 S. P. Switch Outlet.

S^2 D. P. Switch Outlet.

S^3 3-Way Switch Outlet.

S^4 4-Way Switch Outlet.

S^D Automatic Door Switch Outlet

S^E Electrolier Switch Outlet.

Show as many Symbols as there are Switches. Or in case of a very large group of Switches, indicate number of Switches by a Roman numeral, thus S^1 XII, meaning 12 Single Pole Switches.

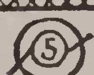
Describe Type of Switch in Specifications, that is,

Flush or Surface, Push Button or Snap.

 Meter Outlet.

 Distribution Panel.

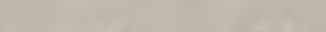
 Junction or Pull Box.

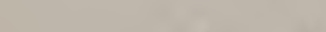
 Motor Outlet; Numeral in center indicates Horse Power.

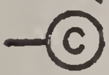
 Motor Control Outlet.

 Transformer.

 Main or Feeder run concealed under Floor.

 Main or Feeder run concealed under Floor above.

 Main or Feeder run exposed.

	Branch Circuit run concealed under Floor.
	Branch Circuit run concealed under Floor above.
	Branch Circuit run exposed.
	Pole Line.
	Riser.
	Telephone Outlet; Private Service.
	Telephone Outlet; Public Service.
	Bell Outlet.
	Buzzer Outlet.
	Push Button Outlet; Numeral indicates number of Pushes.
	Annunciator; Numeral indicates number of Points.
	Speaking Tube.
	Watchman Clock Outlet.
	Watchman Station Outlet.
	Master Time Clock Outlet.
	Secondary Time Clock Outlet.
	Door Opener.
	Special Outlet; for Signal Systems, as described in Specifications.
	Battery Outlet.
	Circuit for Clock, Telephone, Bell or other Service, run under Floor, concealed. Kind of Service wanted ascertained by Symbol to which line connects.
	Circuit for Clock, Telephone, Bell or other Service, run under Floor above, concealed. Kind of Service wanted ascertained by Symbol to which line connects.

NOTE.—If other than Standard 16 C. P. Incandescent lamps are desired, Specifications should describe capacity of Lamp to be used.

Suggestions in Connection with Standard Symbols for Wiring Plans.—It is important that ample space be allowed for the installation of mains, feeders, branches and distribution panels.

It is desirable that a key to the symbols used accompany all plans.

If mains, feeders, branches and distribution panels are shown on the plans, it is desirable that they be designated by letters or numbers.

Heights of Centre of Wall Outlets (unless otherwise specified)

Living Rooms	5′	6″
Chambers	5′	0″
Offices	6′	0″
Corridors	6′	3″
Height of Switches (unless otherwise specified)	4′	0″

CHAPTER II

WIRE JOINTS AND SPLICES

Importance of Good Joints.—Wire joints and splices are a vital feature of an installation. If the joint or splice is not made and soldered properly it may cause the wire to heat abnormally because of the high resistance contact, or if the joint makes loose contact it may produce an arc which, if near inflammable material, will set fire to the building. For these reasons much care should be used in splicing wires or making joints for branches carried from them.

Requirements for a Good Joint.—The following are the requirements for a good joint or splice:

1. It must be as strong mechanically as the wire itself.
2. It must have as great a conductivity as the wire, otherwise it would be liable to become excessively heated by the passage of the current through it.
3. It should be so secure that the wires cannot be worked back and forth, thereby making a loose-fitting contact.
4. It should be neatly made and as small as possible, consistent with the observance of the preceding requirements.
5. It must be as well insulated as the wires which it joins.

In the 1913 edition of the National Electrical Code the requirements for wire joints and splices are as follows: (16 — C) The wires "must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered unless made with some form of approved splicing device and covered with an insulation equal to that on the conductors."

Preparing Wires for a Joint or Splice.—In preparing the wires for a joint the insulation should be removed for from 3 to 10 inches of the length, depending on the size of wire used. The insulation should be removed with a knife, care being taken not to nick the wire. In removing the insulation the knife blade should be passed into the covering almost parallel to the wire as shown in Fig. 1A. The insulation should not be cut with the knife blade at right angles to the wire as shown in Fig. 1B, for in doing so one is likely to cut the wire so deeply that it will break later.

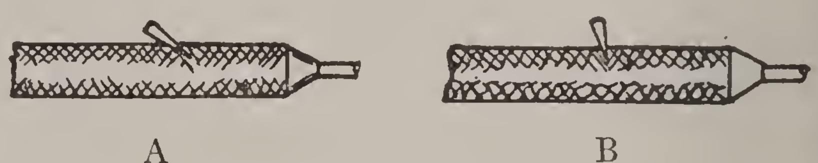


FIGURE 1.

After the insulation is cut off, the wire must be scraped till it is clean and bright. This not only insures good electrical contact between the wires but is very necessary where the joint is to be soldered. In scraping the wire clean of impurities the cutting edge of the knife, of course, may be used, but a much better plan is to use one of the square or right-angle edges at the back of the blade for this purpose. The foregoing general instructions for preparing the wire for joints or splices may be used for all wires.

Instructions for Making Joints and Splices.—With the following instructions for making wire joints or splices some uses of the joint or splice in practice will be given.

Western Union Splice.—The Western Union splice is by far the most widely used splice. Though its greatest use is with small wires it may be employed with large solid wires with the aid of splicing clamps and pliers. It is used almost exclusively for making splices in interior wiring for bells, lights and motors. Also in outside work most of the joints that are made in solid wires are West-

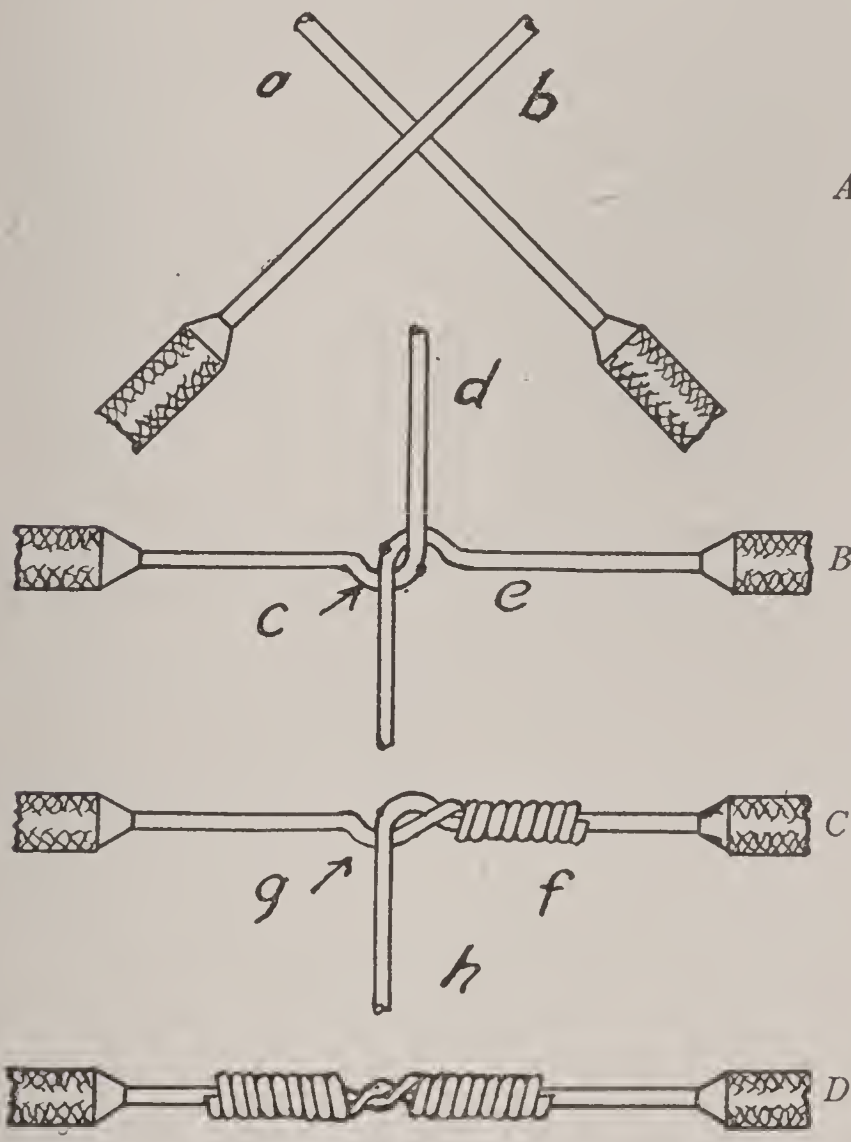
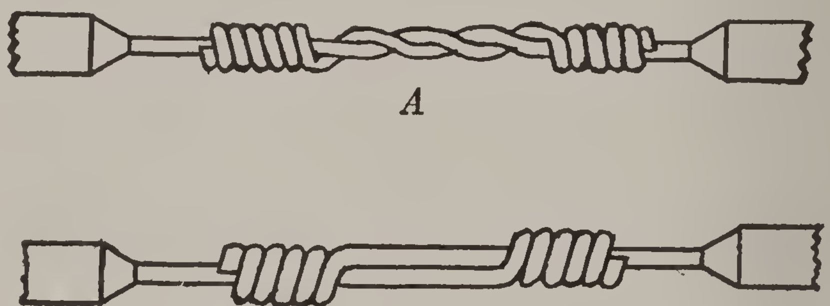


FIGURE 2.

ern Union. There are two types of the Western Union splice, namely, the long tie and the short tie, the main difference in these being in the length of the twist between the wrappings. As the names indicate, the short tie has a short twist between the wrappings, while the long tie has a long twist which is sometimes made with a pair of connectors or splicing clamps.

To make the short tie Western Union splice use two pieces of No. 14 wire and scrape off about 3 inches of the insulation as previously described. Cross the wires as shown in Fig. 2A and twist by holding the lower part of the cross with the hands and pushing the point b from you and pulling a toward you.

Then hold the twist with the pliers at the point c in Fig. B and wrap the wire d round e for at least five turns, making the wrappings fit snugly up against the wire e. Next grip the splice at the point f, Fig. 2C, and



A

B

FIGURE 3.

wrap h round g for five or six turns, making a finished joint as shown at D. The ends of the wrapping wire should be cut off close to the main wire and the end pressed in against the main wire to prevent piercing the tape with which the splice is to be wrapped. From ½ inch to 1 inch of bare wire should be left between the joint and insulation to avoid burning the insulation when the joint is soldered.

The long tie Western Union splice made with small wires, shown in Fig. 3A, is made in the same manner as the short tie, the only difference being that a longer twist is made in the wires before the wrapping is begun. The advantage claimed for the long tie over the short tie is that the twist between wrappings allows a better chance for solder to pass in between the wires.

To make a long tie Western Union splice with large wire, the wires are held together by splicing clamps and one wire is wrapped round the other on both sides of the clamp. Pliers are used for this purpose when the wires are too stiff to be wrapped with the hand. Fig. 3B shows a splice made in this manner.

Tee Joint.—The tee joint is used in making a branch or tap-off from an existing line of wiring. It is used in interior wiring for bells, lights, and motors, and also in outside work where solid conductors are used. There are two tee joints, the plain tee and the loop tee. The plain tee shown in Fig. 4A is made by wrapping the end of the branch or tap wire round the installed conductor.

Loop Tee Joint.—The loop tee shown in Fig. 4B is the same as the ordinary tee except that a loop is made before the wrapping is begun. To make the loop tee joint, pass the wire a in Fig. 4B round the wire b, then pass it across the wire a and wrap it round the wire b in the opposite direction from the way it was started. For small wires this joint is considered much better than the ordinary tee because the loop prevents the wire from unwrapping under strain.

When it becomes necessary to run a double branch circuit, that is, a branch circuit each way, from a line of wiring, the joints shown in Figs. 4C and D make neat and also good electrical and mechanical connections. In Fig. C the crossing wire is cut and two tee joints are made with the first layers of the wrappings of each joint lying adjacent. In Fig. D the crossing wires are bared of their insulation and a short piece of wire of the same size is wrapped round both of them for five or six turns.

Three-ply Splice.—The three-ply joint, though not often used in practice, is an excellent joint where extra mechanical strength is desired. To make this joint an extra wire is placed parallel to one of the wires as shown in Fig. 5A and a twist is made in the same manner as the twist for the short tie Western Union joint. Then the wires at c are wrapped together round b for five or six

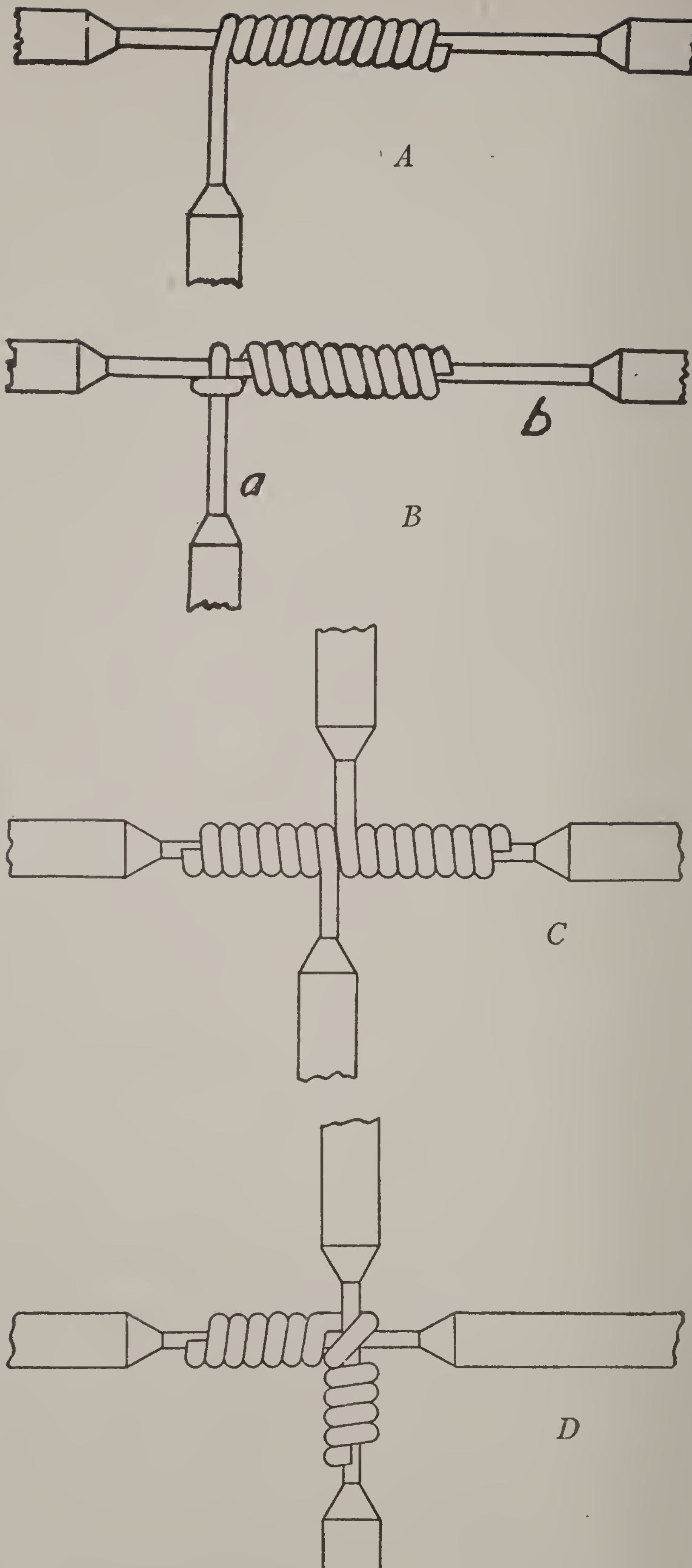


FIGURE 4.

turns. The extra wire at a is then pulled parallel to d and the two wires are wrapped round a, making the joint shown in 5B.

Rat-tail Joint.—The rat-tail joint is used almost entirely in joining wires at junction or outlet boxes in a

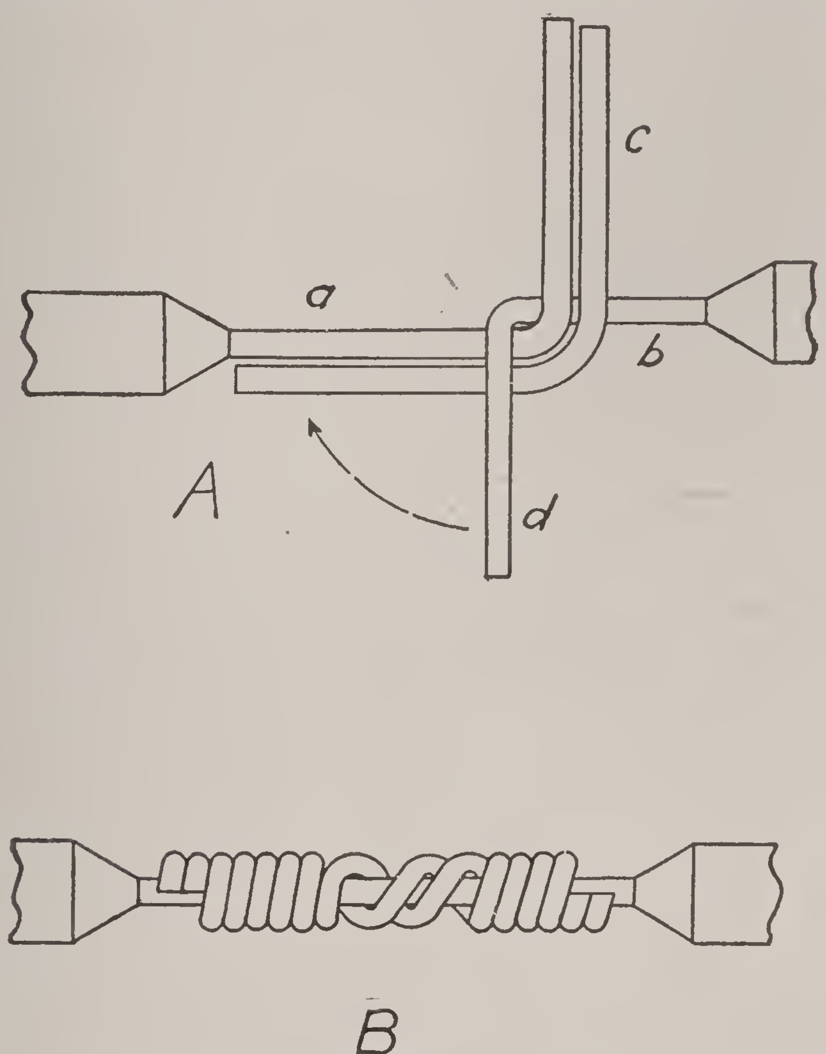


FIGURE 5.

conduit system. This joint is not very strong mechanically and should not be used where there is any strain on the wire, but for a junction or outlet box where there is no strain on the joint it is equal to any other electrically and is much more easily made. To make this joint the wires are crossed, lying almost parallel to each other and twisted together as shown in Fig. 6A.

As shown in the figure only two wires are included in the twist, though almost any number may be joined in the same manner.

Fixture Splice.—When a fixture wire which is usually size 18 is to be joined to a branch circuit wire which is size 14 or larger, the joint is made similarly to Fig. 6B. The smaller wire is wrapped round the larger wire for

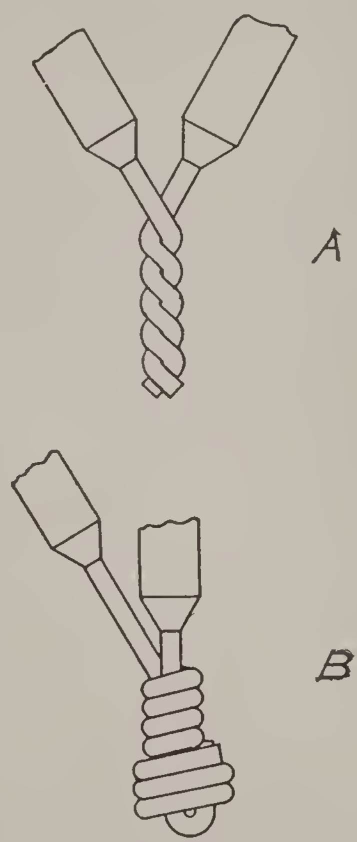


FIGURE 6.

several turns, then the end of the larger wire is bent back over the joint and the smaller wire is wrapped round the joint and the bent back portion of the wire for a few turns. This hook in the large wire prevents the wrappings made by the small wire from slipping off the end of the larger wire.

Britannia Splice.—The Britannia splice is used in outside line work or anywhere that large solid wires are to be joined. Though it is not so popular as the long tie Western Union joint, it makes an excellent splice when properly made and soldered. In the Britannia splice the wires, which have been previously cleaned of their insulation for about five inches, have about a half-inch of the ends turned at right angles to the wire. As shown in Fig. 7 the right-angled turns should be made as sharply as possible and the surface of the two wires should fit snugly when held together.

For a No. 6 or 8 wire allow about 4 inches for the joint and prepare 5 or 6 feet of No. 18 for the wrapping

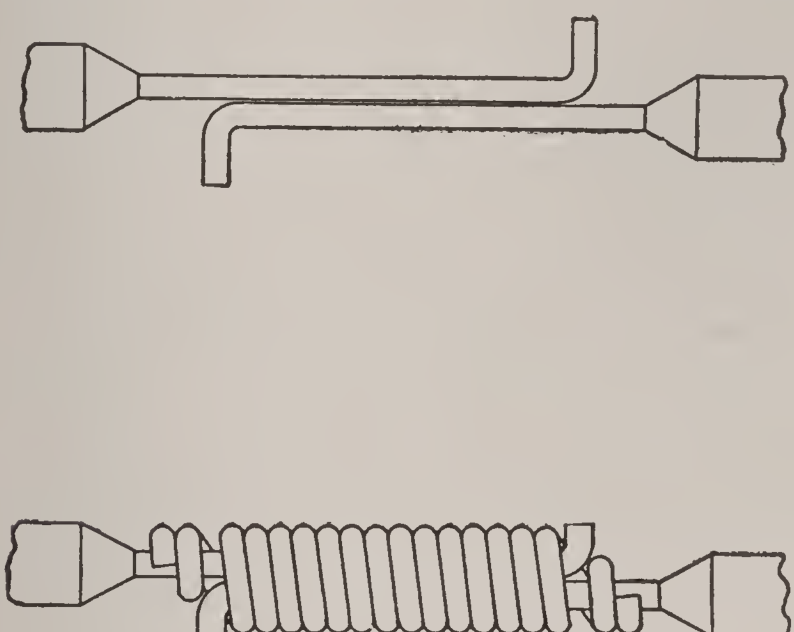


FIGURE 7.

wire. Hold the wires together with a pair of pliers or connectors and beginning at the middle of the joint and also the middle of the small wire, wrap the small wire round the two wires to the end of the joint and for a few turns on the single wire. The joint is then turned about and the other half of the small wire is wrapped round the other portion of the joint in a similar manner. Lastly, the ends that are turned up are cut off close to the joint.

Taper Cable Splice.—There are several methods of joining stranded wires, but the taper cable splice is so much superior, both electrically and mechanically, to all the other splices known to the writer that the instructions for making it will be given. To prepare the wire for the joint the insulation should be removed from the cable from 6 to 10 inches, depending on the size of the wire. Then each wire of the strand should be drawn back and scraped until it is clean and bright. The core, which is the wire or wires in the center of the cable, should have about two-thirds of its length cut off and the remaining wires twisted together as in the original core, and then all strands should be put back as they were before cutting the core, doing this as far as the end of the core. At this point the outer wires should be bent back almost at right angles to the cable as shown in Fig. 8A.

After the other cable of the splice has been prepared in a similar manner the wires of the two cables are meshed together as shown in Fig. B. The wires from cable a are pressed down on cable b and the wires from cable b are pressed down on cable a as shown in Fig. C. Then one of the wires is wrapped round all the conductors as shown in Fig. C. Another wire is drawn up near the end of this wire and passed round all of the remaining wires. This operation is kept up until all the wires on that side of the joint have been passed round the cable. The other end wires are treated in the same manner, presenting a finished splice shown in Fig. D. To make the splice look neat the overlapping wires should form a round surface for the wrappings and the last wire used in wrapping should be made to end, usually by cutting it off, at the point where the next wire starts. This splice is called the taper cable splice because it tapers from the middle toward each end.

Tee Joint for Stranded Wire.—A tee joint made with stranded wire is usually made as shown in Fig. 9. After the wires have been cleaned of their insulation and prepared for the joint, the strands of cable a are divided equally and are spread out V-shaped to fit over cable b as shown in Fig. 9A. Then all the wires of the right-hand section are passed together round the cable in

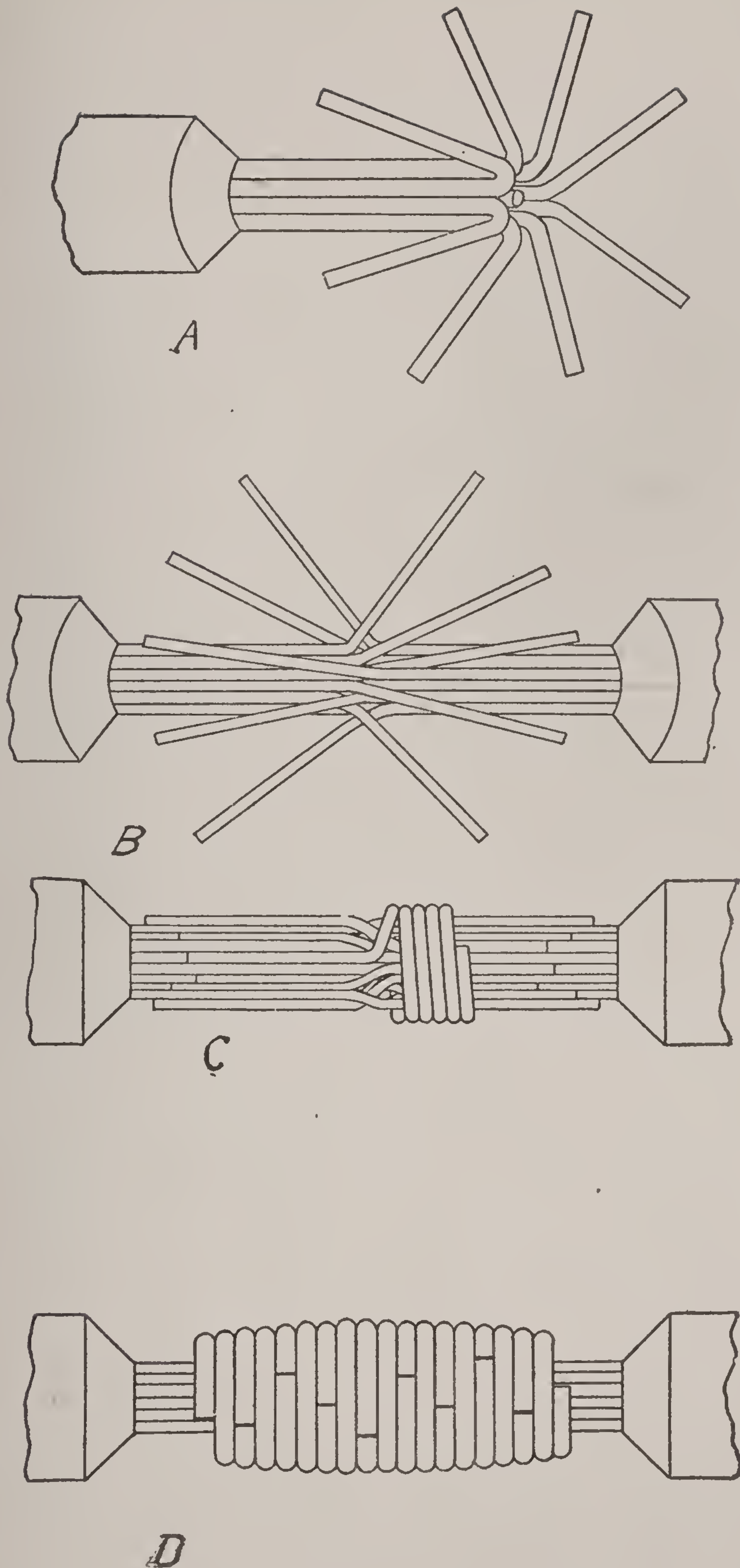


Figure 8

one direction and all in the left-hand section are passed round the cable in the other direction. The finished joint is shown in Fig. 9B.

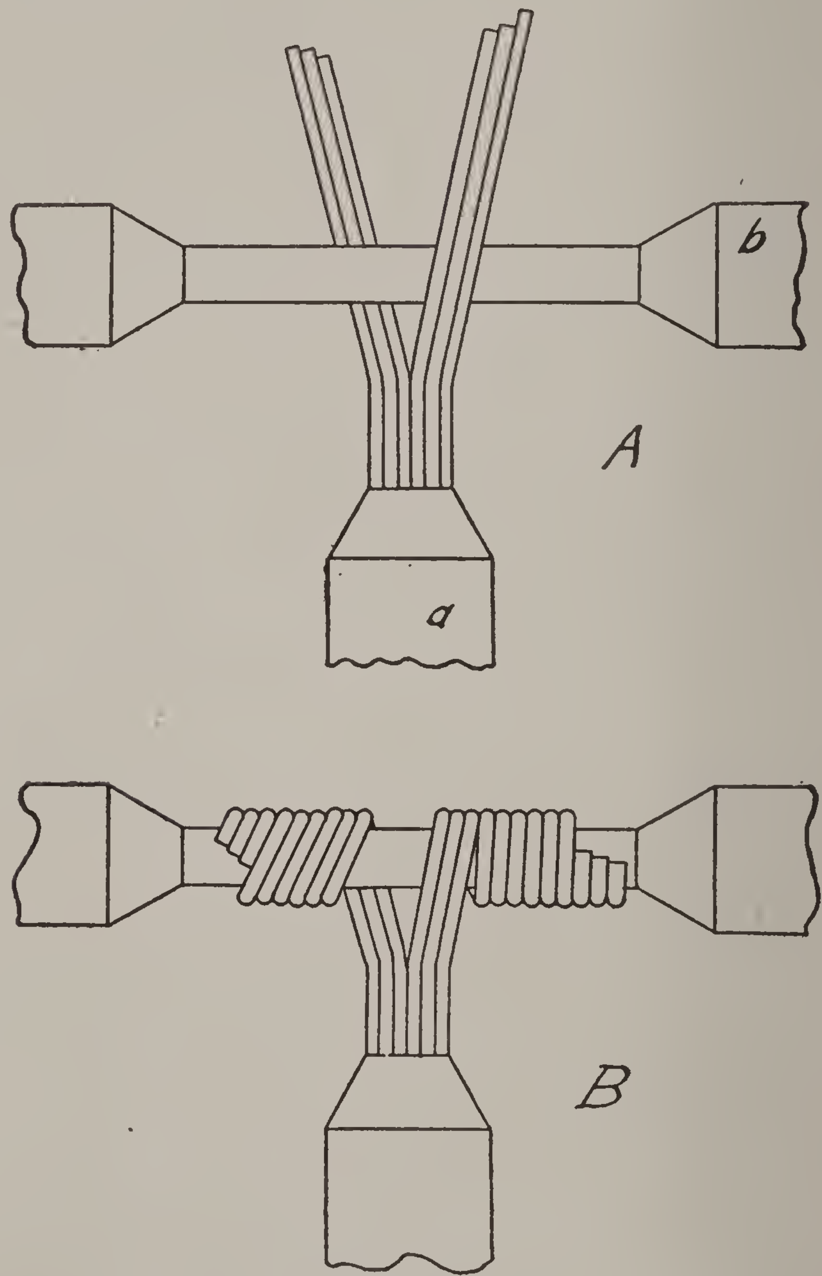


FIGURE 9.

When it becomes necessary to splice two wires that are braided or twisted together, such as duplex or twisted lamp cord, the joints should be staggered as shown in Fig. 10. This not only makes a neater looking job but avoids the possibility of the wires becoming short-circuited through the tape at the joints.

Soldering Joints.—All the joints and splices previously described, if used in interior wiring, must be soldered and taped. In wiring for bells and annunciators,

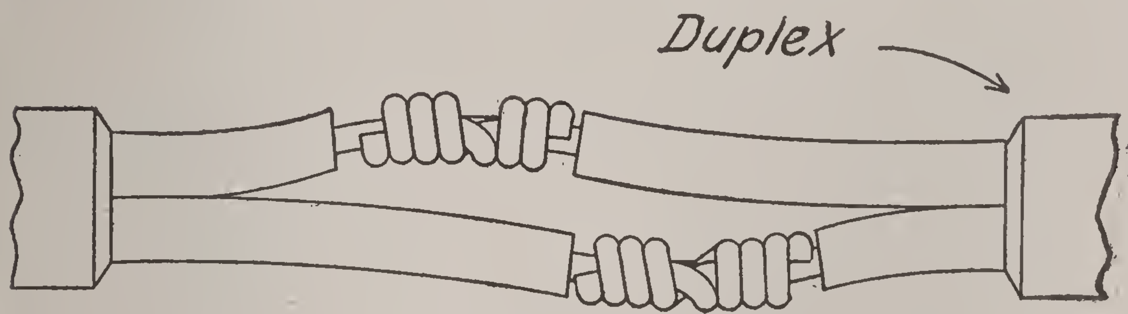
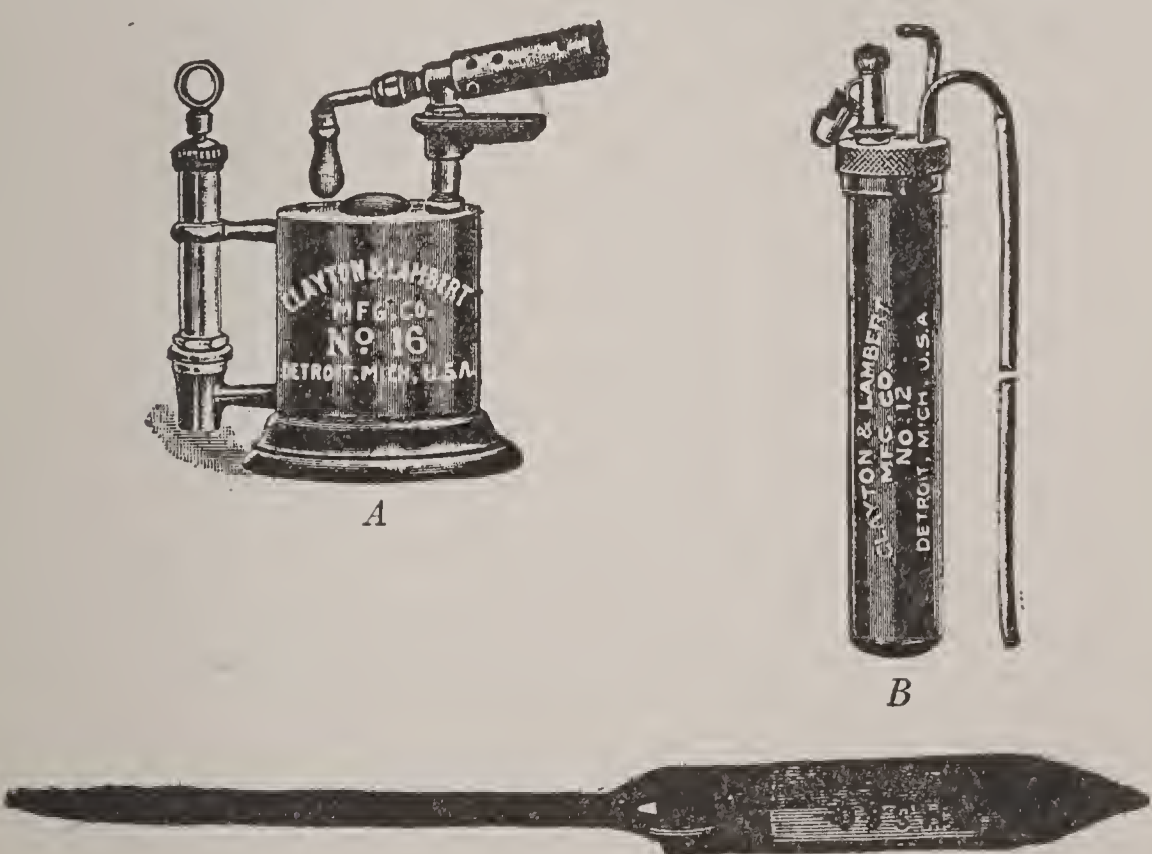


FIGURE 10.

or other instruments where the voltage is low, there are no Code requirements and, except in rare cases, the joints are not soldered.

The three most popular methods of soldering joints are with a gasoline torch, an alcohol torch, or a solder-



A

B

C

FIGURE 11.

ing iron, which are shown in Figs. 11A, B and C respectively. Each one is adapted to a particular kind of work, though where the heat furnished is sufficient, they may be used interchangeably. The gasoline torch furnishes the largest flame and is adapted to soldering large wires, to sweating wires into lugs, or to heating a soldering copper. The alcohol torch is adapted to soldering only the smaller wires such as joints made in sizes Nos. 18, 14 and 12. Though it does not furnish enough heat to solder the larger wire, it has a great advantage over the gasoline torch in that to prepare it for soldering it is only necessary to light it. The soldering copper is adapted to use where a flame is objectionable, as on the wall of a room or between floors.

Gasoline Blowtorch.—To start a gasoline blowtorch proceed as follows: First, select a place where there is no material that burns readily and where the black smoke from the gasoline is not objectionable. This operation should be done out of doors but the torch must be shielded from the wind or it will not heat properly. Second, put pressure on the gasoline by working the pump until it becomes rather hard to pump. Third, holding the hand over the end of the burner, open the needle valve and allow gasoline to flow down and fill the container under the burner. Fourth, with the needle valve *closed,* touch a lighted match to the gasoline in the container which, if allowed to burn up, will heat the burner to working temperature. Fifth, open the needle valve and hold a lighted match to the end of the burner; if a blue flame is produced, the torch is ready for use.

Sometimes even after this process the flame produced is not blue, which fact indicates that the burner has not been heated sufficiently to vaporize the gasoline. The burner may be brought to working temperature by applying the flame to the ground or some metallic surface and allowing the heat from the flame to rise and heat the burner.

To solder a joint with a gasoline torch, first apply a soldering paste over the entire joint. Next hold the joint in the flame and when it is hot enough to melt solder apply solder over it for the entire length of the joint. The solder must be sweated in between the wires, which is generally indicated by the smooth surface of the solder covering the joint.

When using a gasoline torch one should use much care to prevent overheating the wires, which may result in either of two things. If the joint gets too hot before the solder is applied the solder will not adhere to it. The solder may adhere before the joint is overheated, but overheating the wires makes it so brittle that it is liable to break after it is put into service.

Alcohol Torch.—In soldering with an alcohol torch the flame from the wick is blown upon the joint and the joint is soldered as with a gasoline torch.

Soldering Copper.—To solder a joint with a soldering copper the copper should be heated until it will melt solder quickly. It is then held against and preferably under the joint which has been covered with soldering paste and as the joint becomes heated the solder is applied.

Tinning Soldering Copper.—Before a soldering copper is used it must be thoroughly tinned; that is, the sides at the point must be covered with a film of solder. To tin a soldering copper the copper is heated until it will melt solder, and the surface at the joint is filed or sand-papered clean. Then solder which has a small amount of paste clinging to it is applied to the point. This should form a film of solder over the point of the copper. If the solder fails to adhere, it is probably due to a dirty surface or to the copper's being overheated. If, when filing the copper, the surface turns blue, this fact indicates that the copper is too hot and solder will not adhere until the copper has been cooled and the surface refiled. After the copper has been tinned each time it is taken from the heat preparatory to soldering, the surface should be wiped with a piece of waste or a rag. In the use of a soldering copper many electricians tin only one side which, when the copper is held under the wire, prevents the solder from spreading to the other sides and dropping to the floor. Another excellent plan for soldering wires with a copper is to cut a groove across one side of the point, as shown in Fig. 12, into which the wires are placed for soldering.

If only the inside of the groove is tinned the joint

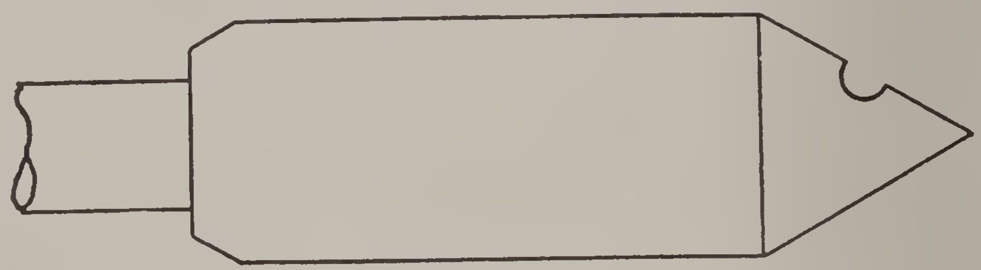


FIGURE 12.

may be placed in the groove and solder applied until the joint is partially or wholly covered with molten solder.

Summary.—As a summary, the following brief instructions should be followed in soldering joints:

1. Thoroughly clean the wires;
2. Apply soldering paste freely;
3. Heat, but do not overheat the joint;
4. See that solder covers the joint, is thoroughly sweated in, and presents a smooth surface.

Soldering Wires into Lugs.—The Code states that all wires whether stranded or solid, when they have a conductivity greater than that of No. 8B & S gauge, must be soldered into lugs for all terminal connections, except where an approved solderless terminal connector is used. Unless these wires are properly soldered into the lug the wire may pull out when in service, or the high resistance of the poor contact may cause the joint to heat.

The most common way of sweating wires into lugs is with a gasoline blow-torch. The wire should be scraped clean of insulation far enough back from the end to allow the wire to reach the bottom of the lug when inserted. The lug is held in the flame of the torch and as it heats soldering paste is inserted into the lug followed by solder which is fed in until the lug is about three-fourths full.

The wire to be inserted should first be covered with soldering paste and then tinned. To tin the wire immerse it in the molten solder in the lug and after a few seconds take it out and see if a thin film of solder covers the wire. If the surface is not covered with solder the operation must be repeated until the wire is thoroughly tinned.

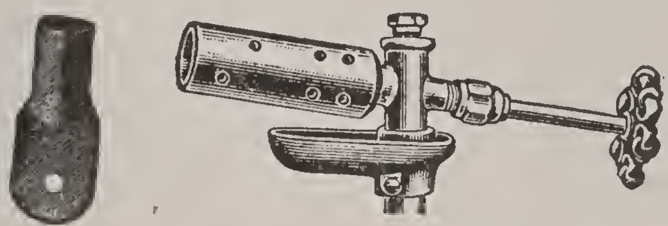


FIGURE 13.

After the wire is tinned it may then be inserted into the lug and then both are allowed to cool. The lug may be cooled much quicker by applying it to some wet waste. The wire should never be plunged into the lug before it has been tinned or before it has been heated to a temperature near that of molten solder. If in this process the lug has been blackened by the flame it may be cleaned with sandpaper.

Taping a Wire Joint.—In wiring for lights and motors all joints must be taped with either friction tape or rubber and friction tape both. In open wiring where weatherproof wire is permitted friction tape is approved for taping the joint. In all other systems of interior wiring both rubber and friction tape are required. In all systems the insulation formed by the tape must be equal to the insulation on the wire; therefore, as the joint has a larger diameter than the wire, the taped joint will be a little more bulky than the insulation.

To tape a joint with friction tape begin at the insulation and wrap the tape spirally round the joint and bare wire, making each succeeding convolution overlap the preceding one from one-half to two-thirds the width of the tape, continuing the operation back and forth until the insulated joint has a diameter a little larger than the insulated wire, as shown in Fig. 14.

Where rubber and friction tape are used together the rubber tape is placed next to the wire as the insulation and the friction tape is wrapped over it as a binder. The rubber tape should be tightly wrapped round the wire

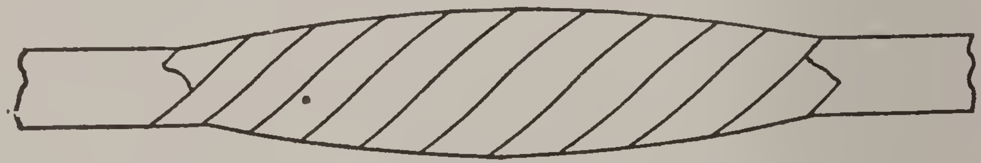


FIGURE 14.

making an insulation of thickness equal to that of the rubber covering of the wire. This rubber may be vulcanized upon the wire by applying heat from a lighted match or by grasping it with the hand for a short period of time. Friction tape is then wrapped round the rubber tape, forming a finished joint as shown in Fig. 14.

Tearing Friction Tape.—If, in wiring, a man uses methods of separating friction tape other than tearing it with his fingers, he is considered a novice by experienced men. If the tape is held firmly in the hands and given a quick pull, causing the strain to come on one edge, it will tear very easily. As a convenience leave one inch or two of tape between the roll and the place where it is torn off.

QUESTIONS.

1. What dangers may arise from a poorly made joint?
2. What are the requirements for a good joint?
3. Describe the method of preparing wires to be joined.
4. Where is the Western Union splice used?

5. What is the difference between a short and a long tie Western Union joint?
6. Describe in detail the method of making a short tie Western Union splice.
7. Describe the method of making the long tie Western Union splice in large wire.
8. Where is the tee-joint used?
9. Describe the method of making: (a) The ordinary tee; (b) The loop tee.
10. Explain two methods of making the double tee joint.
11. Where is the rat-tail joint used, and how is it made?
12. How is the fixture joint made?
13. (a) Where is the Britannia splice used?
    (b) How is it made?
14. Describe in detail the method of making the taper cable splice.
15. Explain the method of making a tee joint with stranded wire.
16. Explain the method of making joints in duplex wires.
17. On what systems must joints be soldered?
18. In soldering wires, where is each of the following best adapted for use? (a) Gasoline torch? (b) Alcohol torch? (c) Soldering copper?
19. State in detail the method of starting a gasoline blow-torch.
20. Explain in detail the method of soldering a joint with a gasoline torch.
21. In soldering with a gasoline torch, what must be guarded against?
22. Describe a method of tinning a soldering copper?
23. Make two practical suggestions in the use of the soldering copper.
24. Describe a method of soldering wires into lugs.
25. Where may friction tape alone be used, and where must rubber and friction tape both be used in taping a joint?
26. Describe the method of taping a joint with both rubber and friction tape.

CHAPTER III

WIRING FOR BELLS, ANNUNCIATORS, GAS LIGHTING

General Rules.—The National Electrical Code does not prescribe how wires for bells, telephones, annunciators and similar appliances shall be run except with relation to keeping them separate from lighting and power circuits. Such signal circuits as they are called must never be run in the same conduits or tubes with light and power wires and should at all places be kept well separated from them.

In general current for bells, etc., should never be taken from the lighting circuit of a building except where an approved transformer is used (bell-ringing transformer).

Electric gas lighting, except the so-called frictional system, should not be used on the same fixture with electric light.

All signal wiring should be just as well done electrically and mechanically as work for electric light and power.

Vibrating Bell.—One of the most common devices used in low voltage wiring is the vibrating bell shown in Fig. 15.

In the operation of this bell the wires from the battery and buttons, or other fittings, are connected to the binding post "a" and "a′." The current passes in at contact "a," flows through the coils through the adjusting screw "c," and through the armature spring "d," and comes out at binding post "a′" to line. The current passing through the coils causes their cores to be magnetized, which fact draws the armature d against these cores. This movement of the armature opens the circuit at the contact between "c" and "d," causing the coils to be demagnetized, and the armature is forced back by the spring at "f." This operation is repeated as long as the current continues to flow through the bell. The circuit being continually opened and closed at the contacts between c and d produces a small arc. To prevent this arc from oxidizing the contact points, they are tipped with some non-oxidizable metal, such as German silver, silver, platinum or platenoid. The contact screw c may be adjusted to give different lengths of stroke of the armature. The spring at f may be adjusted for batteries of different strength.

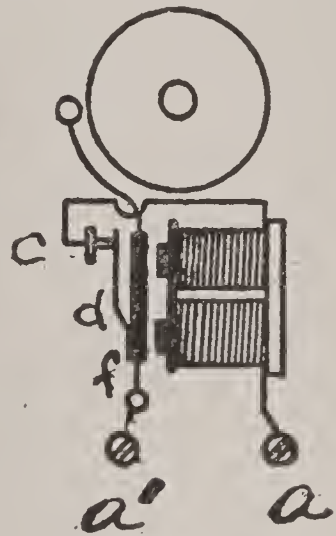


FIGURE 15.

Concealed Wiring.—Low voltage wiring is both concealed and open. In a new house all the wiring should be concealed; this also makes a neater job in a finished house but it is not always possible. The best method of running the wires concealed is to pass them through a rigid conduit. The conduit is laid in the process of construction of the building and the wires are pulled through after the building is completed. Conduit raceways for the wires are used in fireproof buildings, but they are very desirable in frame buildings where there are a large number of wires. Bell wire may be used in the conduits, but it is usually advisable to use a better insulated wire such as a rubber-covered fixture wire or the regular lighting wire No. 14, single-braid rubber-covered.

Usually in buildings of frame construction such as residences, the wires are run on the framework while the house is being built. In carrying the wires across joists holes are drilled in the joists and the wires are bunched together and passed through these holes. In running parallel to joists or studding the wires are either secured separately under staples or are taped into a cable and the

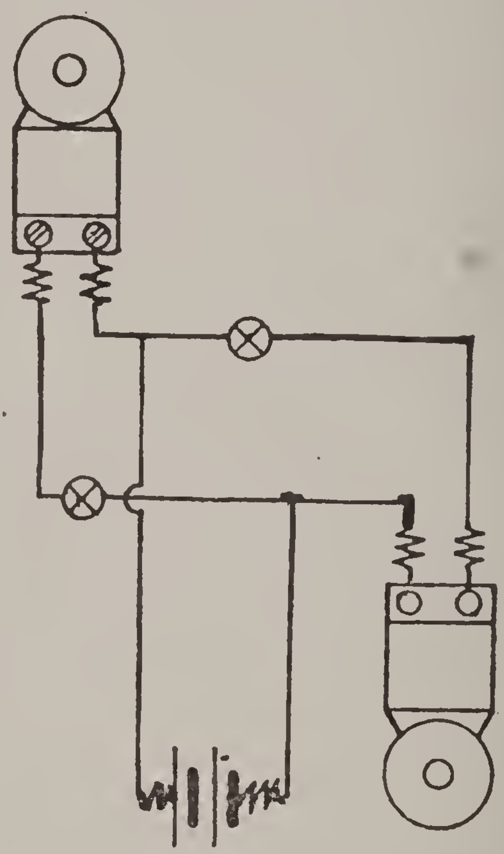


FIGURE 16.

cable held with a cleat. Wires with different-colored insulations are usually used in cables to simplify connections.

Open Work Wiring.—In doing open work wiring the work should not only be done well electrically and mechanically but it should look neat. After connecting the wires under binding screws each wire should be passed around its screw to the right so that tightening the screw will tend to pull the wire in nearer the screw instead of pushing it away. Only one wire should be fastened under a binding screw—if necessary make a joint instead of placing two wires under a binding post.

A coil should be made in the wires where they connect to the bell or other instruments and at the battery as shown in Fig. 16.

The coil is made by wrapping the wire around a pencil five or six times. The coil adds to the appearance of the job and is a ready help should extra wire be needed.

Staples should be placed over the wires at intervals of every four or five feet. Joints are not usually soldered but should be taped with friction tape. The taped joint should be only slightly larger than the insulated wire.

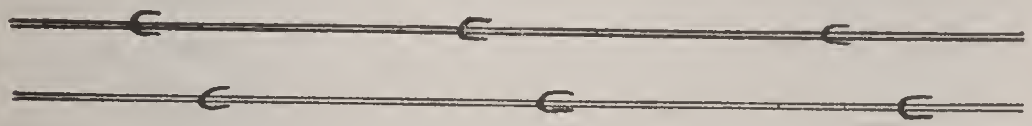


FIGURE 17.

Using only half the width of the tape will assist the workman in making the joint small and neat. Each wire leading out from a joint should be held by a staple to take the strain off the joint. The wires should run parallel and turns should be made at right angles to give a neat appearance. The wires may be run any desired distance apart, but where they are run side by side the same staple, unless it has an insulated saddle, should not cover two wires as the metal of the staple may short-circuit the wires. Where wires are run near each other the staples should be "staggered," as shown in Fig. 17, and not placed side by side, as the staple points may touch each other in the wood and make a short circuit.

Wires often have kinks which prevent their lying flat against the surface wired over. To straighten the wire secure one end and holding the wire in the hand pass over the wire with some pressure something smooth such as the side of a hammer handle.

To cross one wire over another the top wire should be taped with three or four layers of friction tape and a staple placed over each end of the taping to prevent its sliding along the wire.

Often in open work wiring in a room it is desirable to run the wires so that they will be inconspicuous. This may be accomplished in many instances by running the wires side by side on the top of the baseboard and along the side of window and door facings. Also, the wires used may have an insulation of the same color or near the

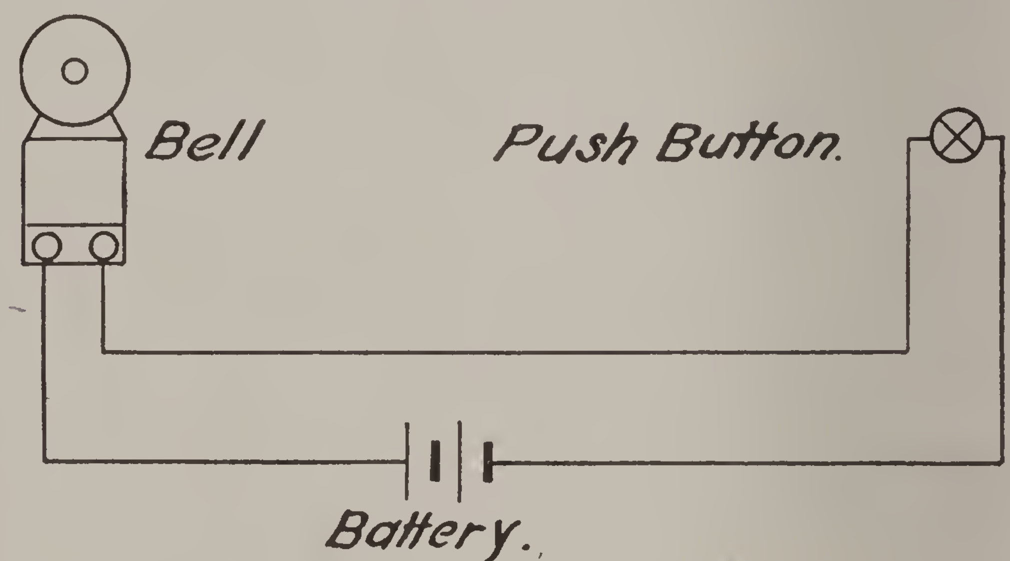


FIGURE 18.

color of the surface wired over, which makes them less noticeable.

Bell Wiring.—In the operation of bells the most common arrangement is to place some circuit-closing device, such as a push button, in the circuit, so that when the button is pressed the current will flow from the battery through the button to the bell or bells.

Where a number of bells are to be operated simultaneously they may be connected in series or in multiple. Generally bells operate better in multiple than in series. With bells in series very poor results will be obtained unless one bell is used as a master and all the other bells are made single stroke. This is accomplished by placing a short circuit round the make and break contacts on all the bells except one. Then the master bell makes and breaks the circuit for all the bells and they vibrate together. Placing bells in series adds more resistance to the circuit and more cells of battery are required to operate them than would be required for a multiple arrangement.

Simple Door Bell.—In bell wiring the simplest arrangement of connections for a door bell is as shown in Fig. 18 where the bell, battery and button are all in series.

Door Bells with an Annunciator.—Fig. 19 shows an

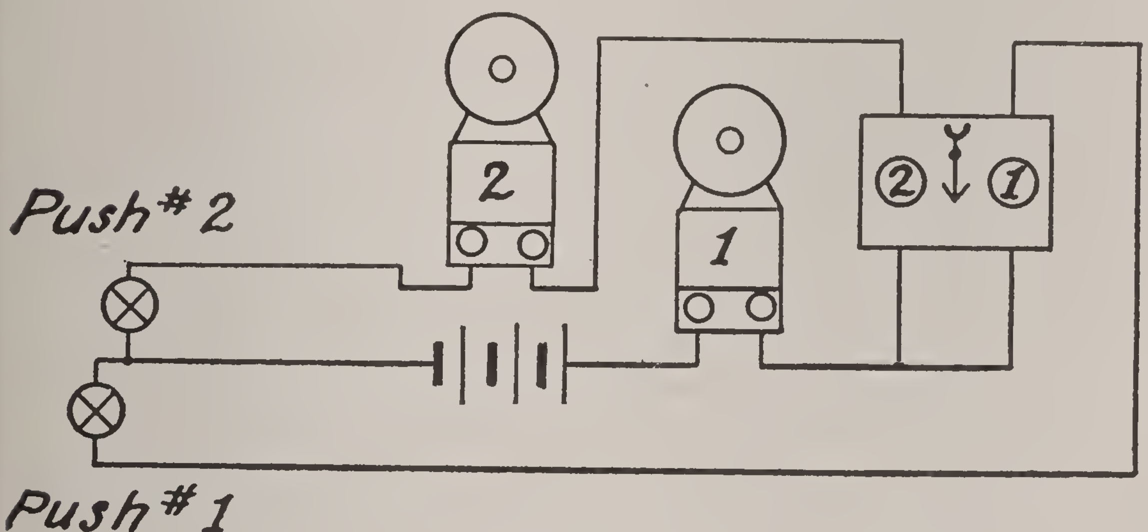


FIGURE 19.

arrangement of two buttons, two bells, and a two-drop annunciator, adapted for a basement floor house. The pushing of button No. 1 causes current to flow from the battery through the button and back through the annunciator and bell No. 1, ringing bell and pulling the hand over to No. 1 point on the dial. Pushing button No. 2 causes current to flow from the battery through bell No. 2, annunciator, and bell No. 1. This rings both bells, of course, and pulls the drop over to point No. 2 on the annunciator. The hand of the annunciator, which is soft iron, hangs near the iron core of the two coils at 1 and 2. When the current is passed through these coils it causes the iron core to be magnetized, which in turn attracts and holds the pointer.

Two Bells and Buzzer.—Fig. 20 shows an excellent plan of wiring a residence for two door bells and a buzzer for the dining-room. The buzzer and both bells are usually located in the kitchen and the bells are differently toned so that the sound indicates from which door the call comes.

Bells in Multiple.—Fig. 21 shows the wiring for the operation of bells in multiple. Other bells may be added

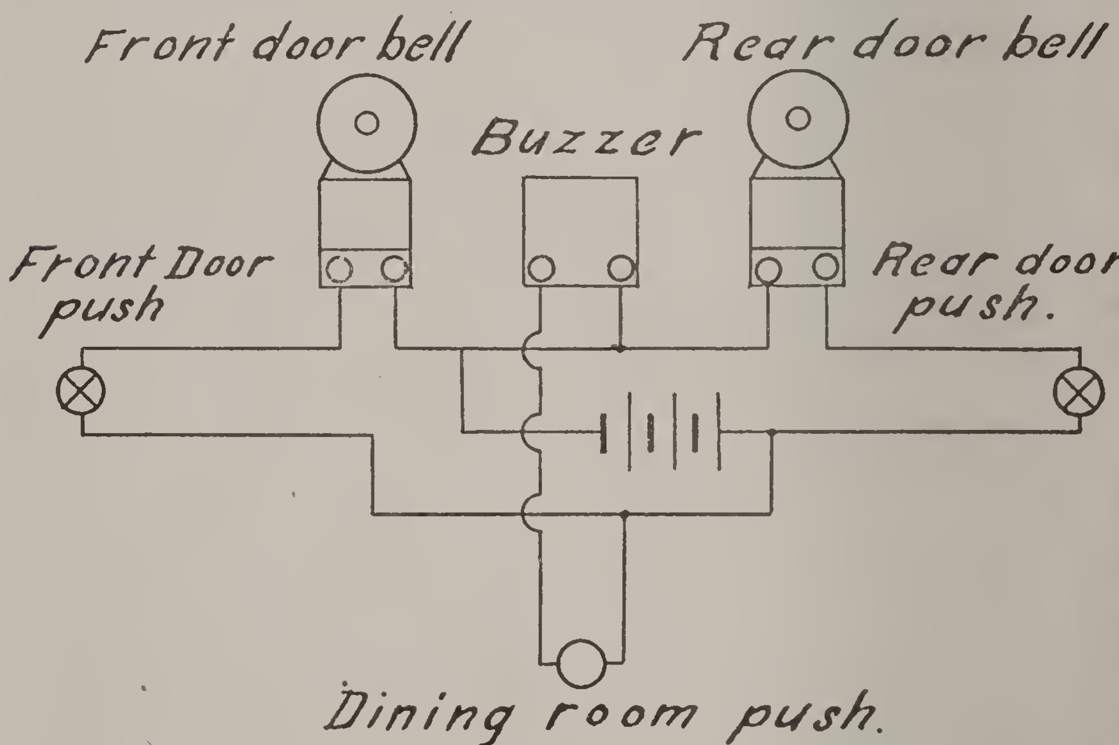


FIGURE 20.

by connecting them across the upper and the middle wires. More buttons may be added by connecting them across the upper and the lower wires on the left side of the battery.

Bells in Series.—Fig. 22 shows the wiring for bells in series. More bells may be added by opening the circuit wires and connecting them in series with the others. Other buttons may be added by connecting them across the wires to the left of the bells.

In this arrangement the "make" and "break" contacts on two of the bells should be short-circuited as was previously explained. Because of the extra resistance encountered by placing bells in series a few more cells of

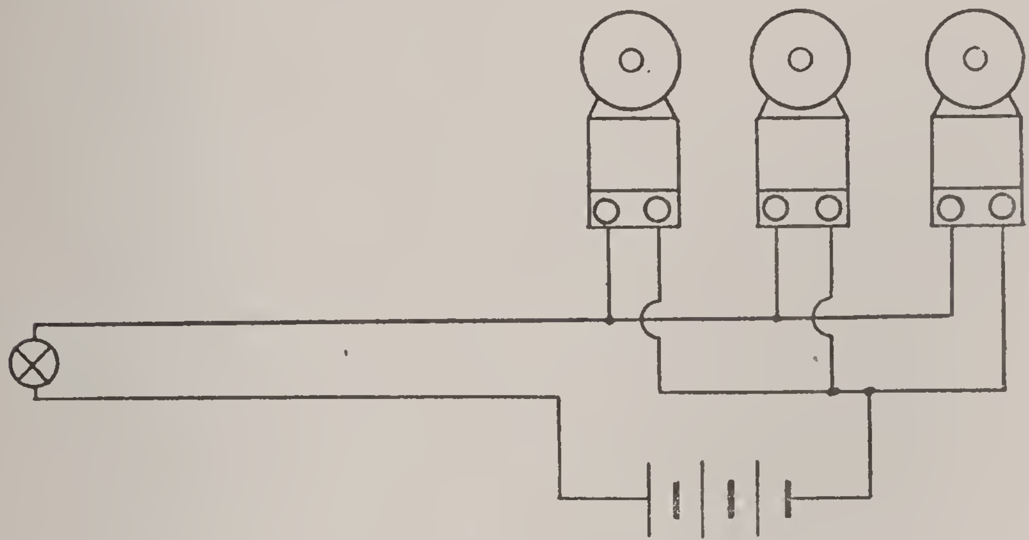


FIGURE 21.

battery are required than would be necessary for the same number in multiple.

Return Call Systems.—Figs. 23 and 24 show two return call systems; that is, the home button will ring the distant bell and the distant button will ring the home bell.

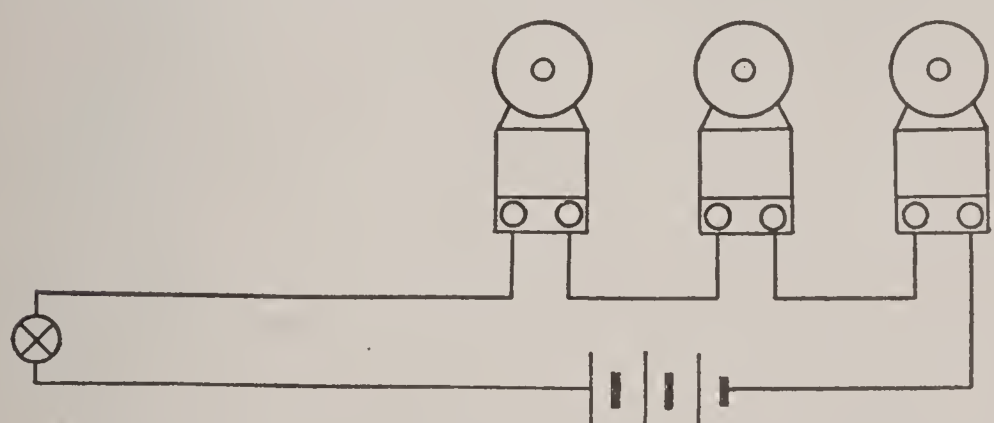


FIGURE 22.

In Fig. 23 only one set of battery is employed but three wires are required between the two locations.

In Fig. 24 only two wires are employed between the two stations, but two sets of battery and double contact push buttons are required. In connecting the double contact push buttons the line wire is connected to the strap or spring in the button, the bell wire is connected to the upper contact, and the battery wire connected to the lower contact. In using either of the foregoing dia-

FIGURE 23.

grams often one of the wires between the two stations may be eliminated by using a water pipe, gas pipe, or other metallic connection between the two points.

Open Circuit Burglar Alarm System.—Fig. 25 shows an open circuit burglar alarm system; that is, one in which the circuit is normally open. The figure at the left is a window spring which is mortised into the window-facing so that when the window sash is raised the spring will be depressed and the closed circuit will ring

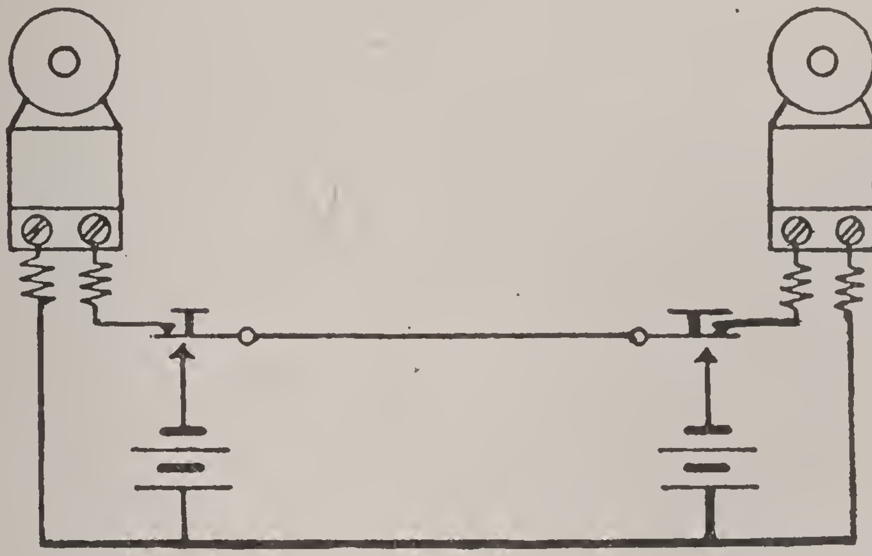


FIGURE 24.

the bell. The device shown at the top of the figure is a constant ringing device called an automatic drop. When

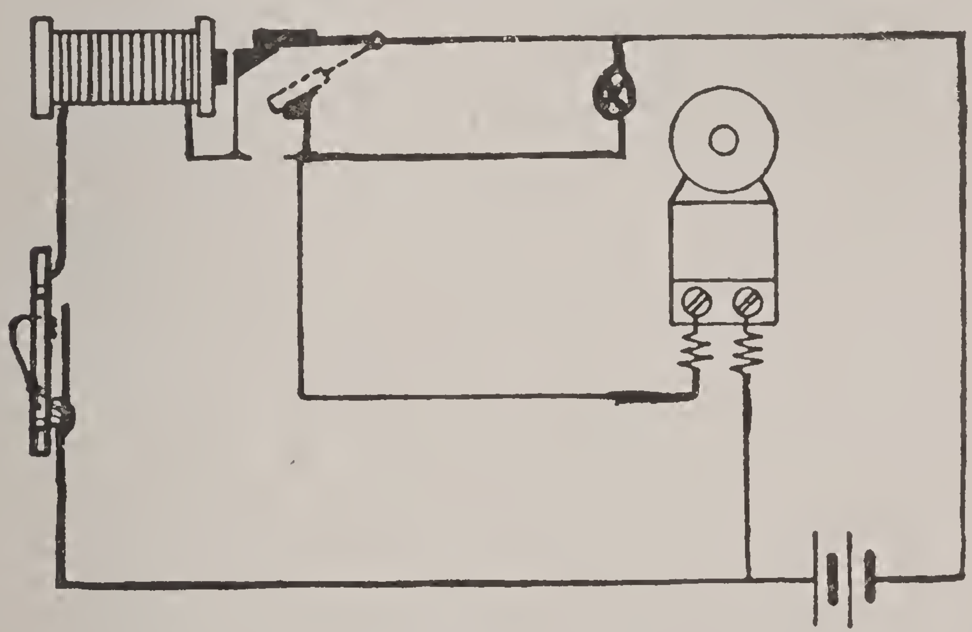


FIGURE 25.

the circuit is closed at the window spring, the current flows from the battery through the spring and through the coils in the drop and back to the battery, causing the armature of the device to be drawn forward, releasing the drop and allowing it to fall and close a local circuit through the bell and battery. The bell will of course ring until the drop is reset even though the window be lowered immediately.

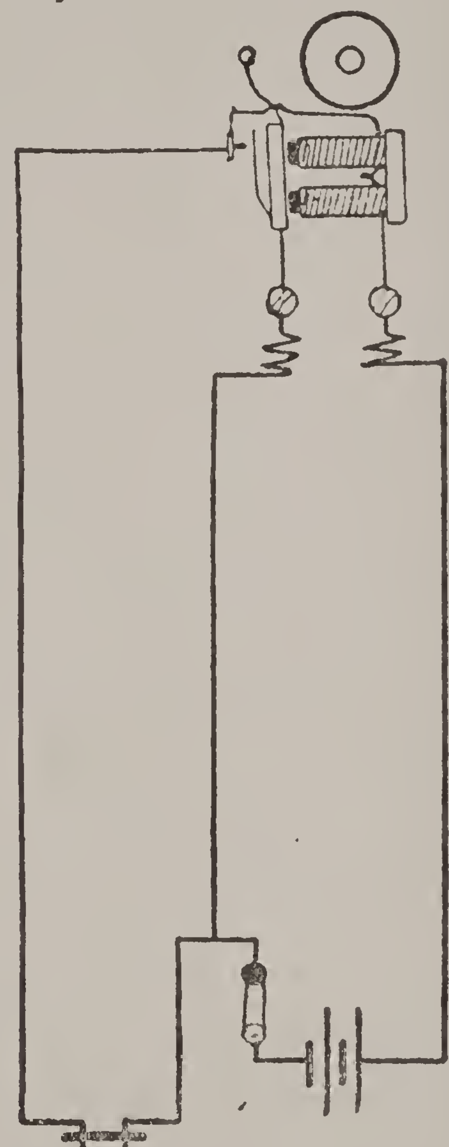


FIGURE 26.

Closed Circuit Burglar Alarm System.—Fig. 26 shows a closed circuit burglar alarm system; that is, one in which the circuit is normally closed. The fitting shown at the bottom of the figure is a door spring which is mortised in the door frame on the hinge side. When the door is closed the circuit is closed at the spring and current is flowing through the spring and bell, but the current is carried out from the screw of the make and break of the bell and the armature is held against the magnets so that the bell does not ring. When the door is opened the circuit is broken at the spring which causes the armature of the bell to fall back after which the bell operates as a vibrating bell. The battery switch shown in the

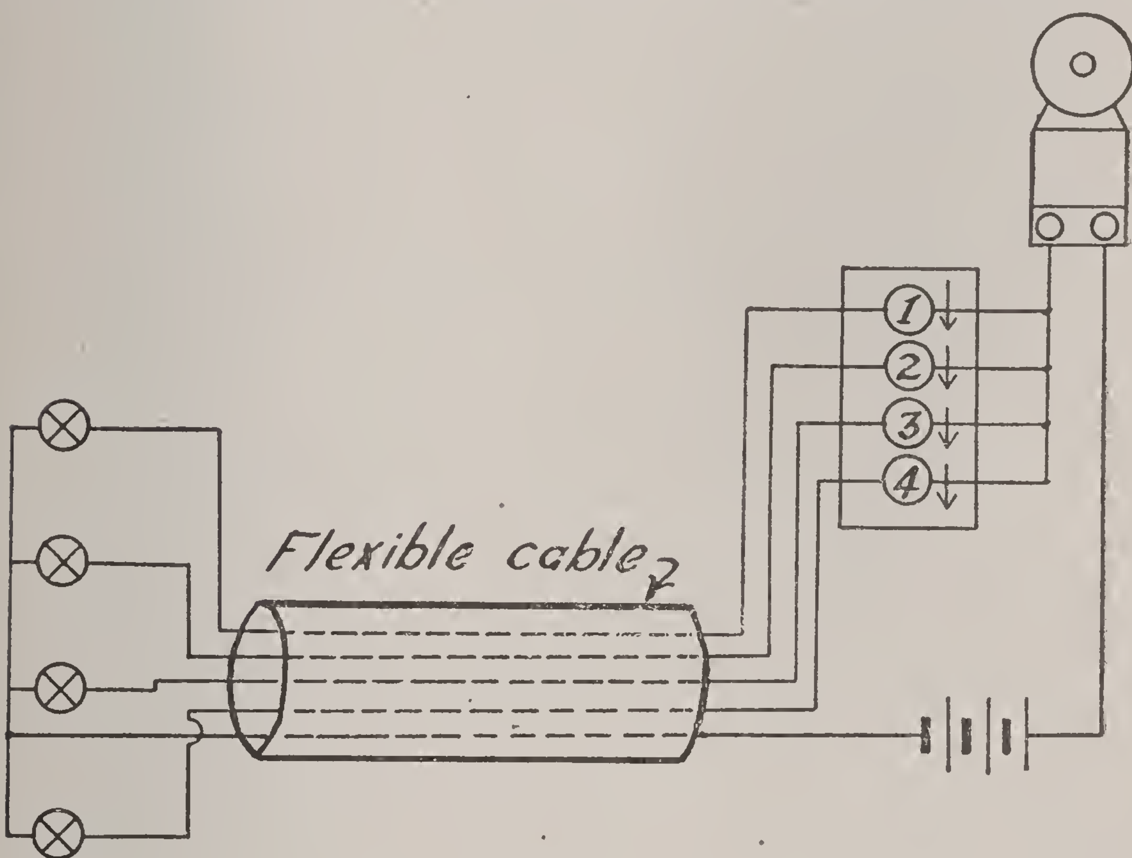


FIGURE 27.

figure is used to shut off the battery current in the daytime or when the system is not in use. The chief advantage of this system is that should the wires leading to the spring be opened in any way the bell will ring. The battery used with this system should be some closed-circuit type, such as the Gravity or Gordon cells.

Simple Annunciator.—The wiring for a simple annunciator is shown in Fig. 27. There is a wire for every drop and a common battery wire. The two wires that connect into the button always come, one from a drop and the other from the battery. The wires that pass into the annunciator should be grouped into a cable as shown in Fig. 27.

There are two types of annunciators in use, the gravity drop and the needle annunciator. In the gravity drop type there is a coil of wire wound round an iron core at each drop opening. When the button for this coil is pushed the current flows through the coil and attracts its armature which trips the drop and causes it to fall. The needle type has a coil near the needle which attracts the soft iron needle when current is passed through the coil. These needles are made of soft iron and it is generally taken for granted that they do not retain enough magnetism to show polarity, but often in practice such is not the case. For instance, if the current is sent in one way through the coil the needle will be attracted, but if the current is sent in the other direction through the coil the needle will be repelled. This plainly shows that the needle has developed a strong polarity. The needles of old annunciators usually possess more magnetism than those of new ones, though in either case the magnetism may be strong enough to keep the needle from being attracted when the current is passing through the coil in the wrong direction. Usually in testing an annunciator of this kind, if the bell rings and the pointer is not attracted, reversing of the battery will cause the pointer to be attracted. If then the drops fail to operate, it is usually necessary to renew the cells or add more cells to the battery. New annunciators of this type have the common connection marked positive or negative or "connect zinc here," so as to insure the right connection.

Return Call Annunciator.—The wiring for a return call annunciator is shown in Fig. 28. This system requires one more common wire than the simple annunciator, also two double contact push buttons and a bell in each call circuit.

When the double contact push button No. 1 is pressed, the upper contact is opened and the lower contact is closed, causing the current to flow from the battery up through the button, down through the drop, through the push button in the annunciator and down through the bell to the battery. When the double contact push button No.

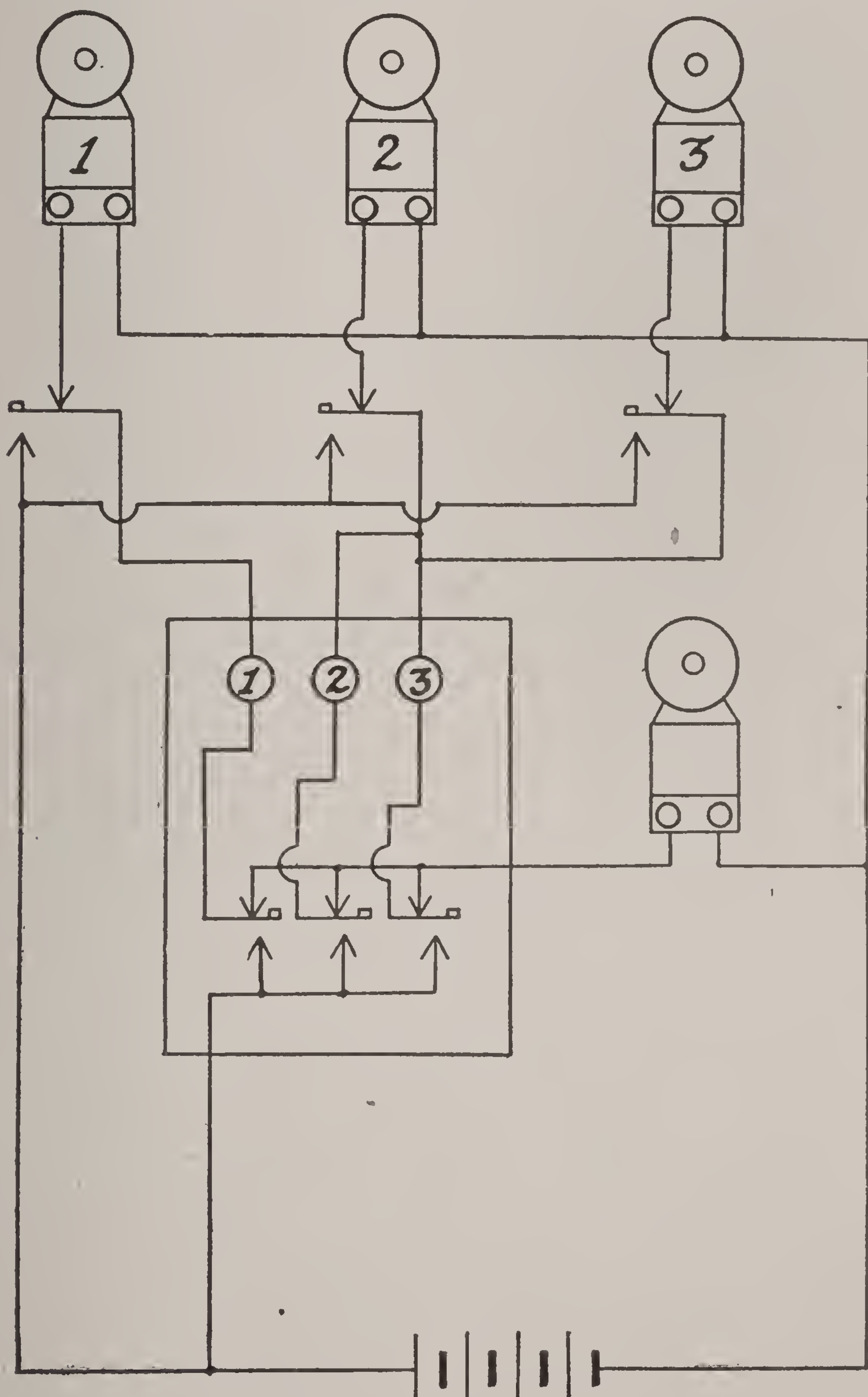


FIGURE 28.

1 in the annunciator is pressed, the upper contact is opened and the lower contact is closed, causing the current to flow from the battery up through the button, drop, and bell No. 1, passing back to the battery by the common bell and battery wire.

Wiring for Gas Lighting.—In buildings gas is often lighted, or controlled and lighted, by electricity. In residences the pendant and automatic burners are more com-

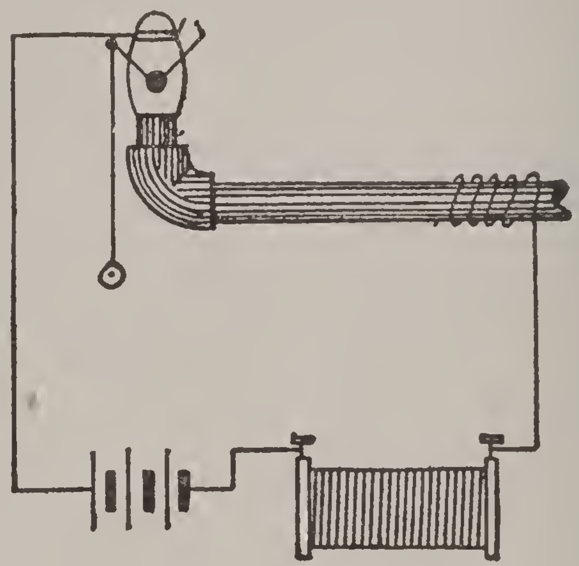


FIGURE 29.

monly used in connection with a battery and spark coil, while in large rooms such as auditoriums or theaters jump spark burners are used in connection with an induction coil and battery, or a static machine.

Pendant Burner.—The pendant burner shown in Fig. 29 has a lever which, when pulled down, opens the gas cock and closes and opens a contact through a battery and spark coil, producing a spark in the path of the gas sufficient to light it. The lever is pushed back to the original position to extinguish the gas. The spark produced by opening the battery circuit alone would not be of sufficient intensity to ignite the gas but by adding a spark coil an arc of much greater length is produced due to the self-induction of the coil. The spark coil generally used consists of a bundle of iron wire 8 inches long by $\frac{3}{4}$ inch in diameter, round which from four to six layers of No. 18 magnet wire are wound.

Automatic Burner.—The automatic gas burner, as shown in Fig. 30, has two separate circuits through it. When current is passed through one set of coils an armature is raised which opens the gas cock and at the

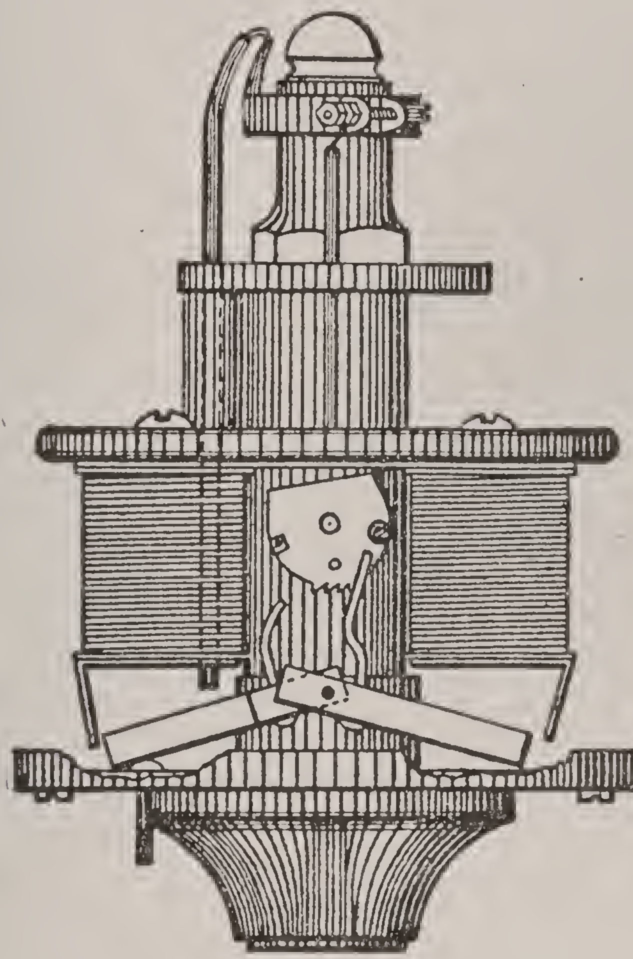


FIGURE 30.

same time opens and closes the circuit at the gas tip which ignites the gas. Current flowing through the other set of coils causes their armature to be raised, which closes the gas cock. As shown by the wiring diagram, Fig. 31, the gas pipe is used as one side of the circuit for both pendant and automatic gas burners.

Fig. 32 shows the wiring for a stairway control of two automatic burners; that is, with two burners and two button plates, one on each floor; either burner may be lighted or extinguished from either floor. From four to six cells of battery are required for such a system, the Leclanché wet cells being generally used.

Although the voltage of such a system is considered low, it soars to considerable height when the circuit is broken and for this reason the wires should be well insulated from each other. Annunciator wire is commonly

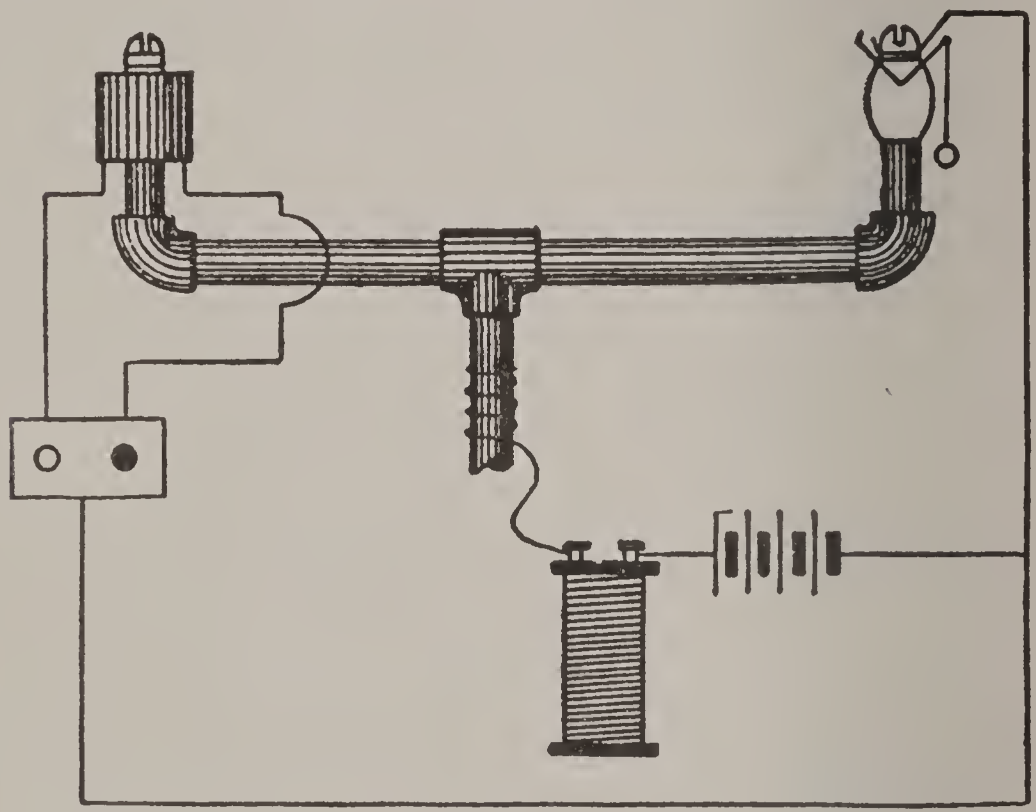


FIGURE 31.

used but much more satisfactory results are obtained by using a better insulated wire such as office or rubber covered wire. If the wiring is concealed as in the partition of a new house, it is excellent practice to allow three or four inches of extra wire where the wires connect into the buttons. This allows access to the connections from the front in case trouble develops in the system after the house is finished.

It is very important that the ground connection be properly made; otherwise there is a constant source of trouble.

Instructions for Making a Good Ground.—1. Scrape the pipe clean of scale and rust with a file or sand-paper.

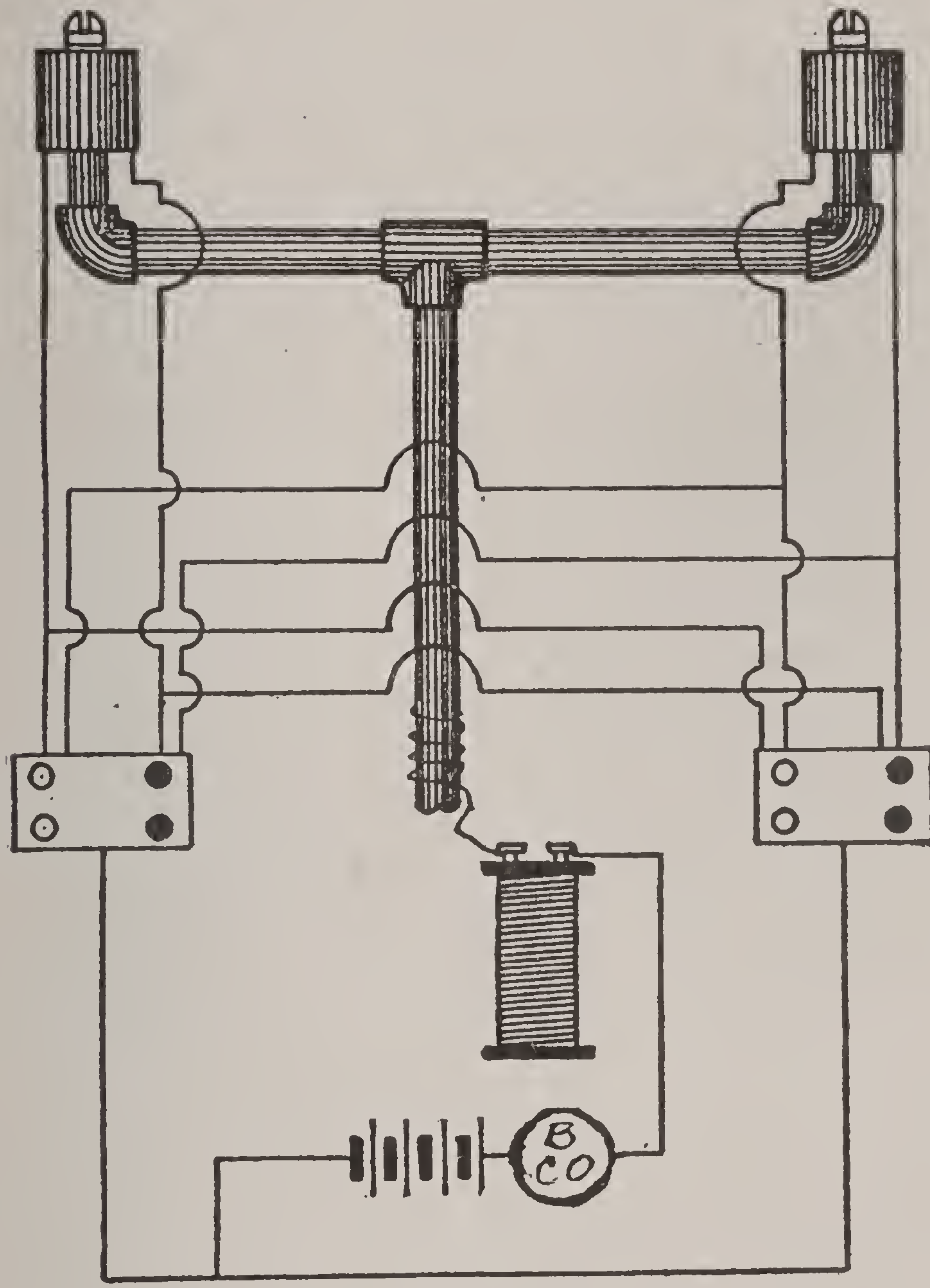


FIGURE 32.

2. Wrap from six to ten turns of the bare wire around the pipe and tie it tightly.

3. Solder the wrapping to the pipe or wrap the wires and pipe with tin foil—the latter is preferable.

4. Wrap the joint with friction tape.

The copper ground clamps used in grounding conduit systems make excellent grounds for gas lighting systems, but are seldom employed because of the extra expense involved.

Two plans are used for installing the wiring for a gas lighting system. One plan is to place the battery and spark coil in the basement or in some other inconspicuous place and connect the ground wire to the nearest gas pipe. Then it is only necessary to run one wire up through the house for the button plates or pendant burners.

The other plan is to carry the ground wire through the house and ground it to each fixture that is wired.

The latter plan, though more expensive, makes a more reliable installation. Gas pipe is considered a poor conductor because the lead used in the joints is sometimes of sufficient thickness to interrupt the circuit.

The wires that run to the pendant and automatic gas burner often become grounded to the pipe and run down the battery. To prevent this a device called a battery cut-out is placed in series with the battery and spark coil, as shown in Fig. 32. One type is wired to close the circuit on an electric bell and battery after the current has passed for a period of time longer than that necessary to light the gas. Another type opens the circuit after current has passed for a few seconds. Battery cut-outs, though not absolutely necessary, often more than pay for themselves by minimizing battery expense.

Wiring Fixtures.—In wiring a fixture for electric gas lighting, the wire or wires are usually concealed between the casing and gas pipe to the ball where the arms branch. The wires are then carried out through small drill holes in the casing and wrapped spirally around the arms out to the burners. Where the wires are exposed they may be painted to make them less conspicuous but a metallic paint should not be used unless the wires are rubber insulated.

Multiple Gas Lighting.—In large rooms where a number of different gas burners are to be lighted simultaneously, usually an induction coil and battery or a frictional machine is employed. A special burner, which has a short gap over the burner tip and contacts well insulated from the pipe, is used for this purpose. The burners are connected in series as shown in Fig. 33. Both contacts of all burners are insulated from the pipe except one

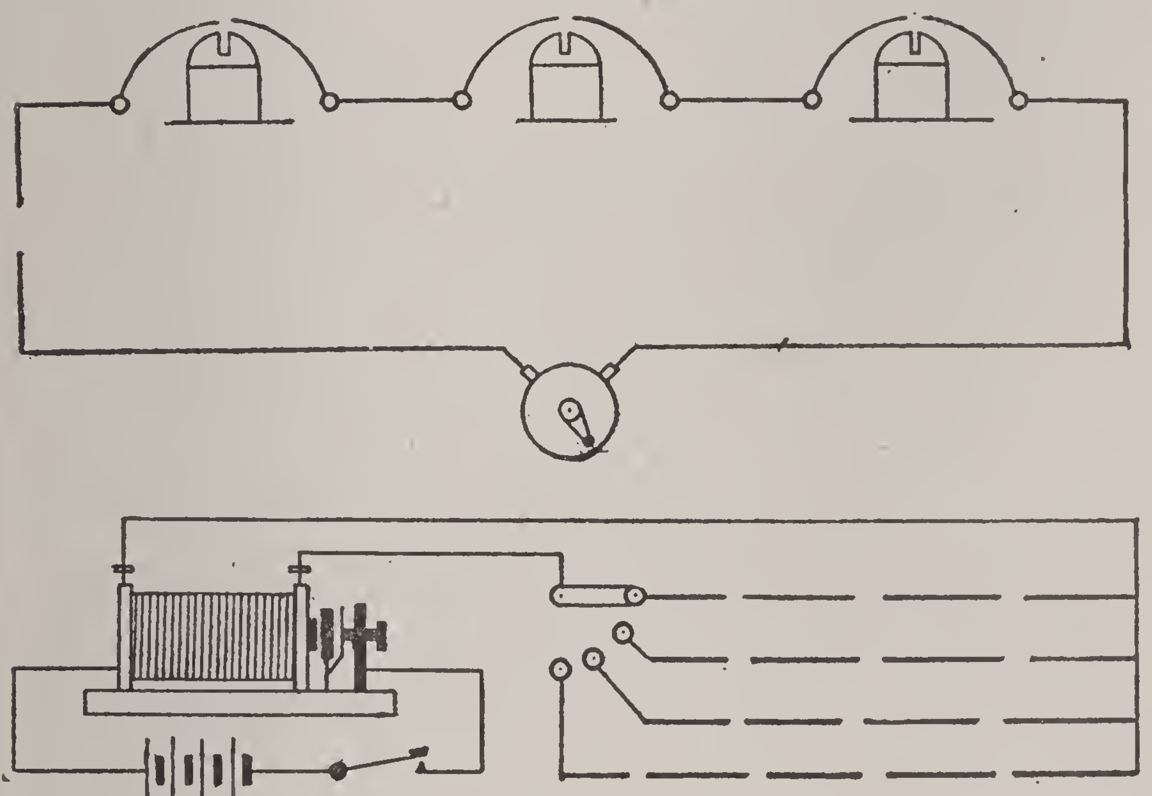


FIGURE 33.

contact on the last burner which is grounded to the pipe for the return circuit.

A very small copper wire, about No. 24 or 26, is strung from burner to burner. The wire should be kept at least an inch and a half from the gas pipe and, where insulators are required, a glass tube should be used. For lighting a number of burners a multiple circuit switch may be required, so that the lighting may be done by sections.

Locating Trouble on Battery Systems.—If the bells do not ring, the most likely cause is a dead battery. To test out the battery connect an ordinary bell across the terminals of each cell. If any of the cells do not ring the bell, they should be discarded for new ones. If the battery is in good order, look for an open circuit in the buttons. Next, look for a short circuit in the bell or bells and test each one separately. Next, the trouble may be due to a short circuit between the wires. As a last resort look for an open circuit in the wiring. Where an open circuit is suspected at a point in the wiring, a length of good wire may be connected on each side of the supposed opening.

If the bells ring continually, the trouble is probably due to the buttons making contact, or a short circuit of the wires leading to the button.

Sources of Power for Low Voltage Systems.—A battery of primary cells is usually employed for low voltage work. For open-circuit work, that is, where the current is used only at short intervals, as for bells, annunciators, etc., the Leclanché is commonly used.

Leclanché Cells.—The Leclanché cell is made in two types; namely, the wet and the dry cell. The wet cell consists of a glass jar container, a cylindrical carbon and a pencil zinc as elements, and a solution of sal ammoniac. The dry cell employs the same elements and solution, the difference being that the solution is in a paste instead of a liquid form.

The wet cell is usually preferred in stationary work, as the upkeep is less than it is with dry cells. Under ordinary service these cells should last for a year, after which they may be renewed very easily. If the loss in voltage is due to evaporation of the solution, water may be added to bring the solution up to the usual level. The zinc should be examined at the same time, and if covered with a deposit, the latter should be scraped off. If the zinc has been almost wholly consumed, of course a new zinc should be used.

The carbon element lasts much longer than the zinc, though after four or five zincs have been consumed the carbon should be renewed. The life of an old carbon may sometimes be renewed for a time by placing it in boiling water for twenty or thirty minutes.

Renewing Cells.—To renew the solution place four ounces of sal ammoniac in the jar and add water until the jar is about three-fourths full.

Dry cells are sometimes used for ringing bells, annun-

FIGURE 34. LECLANCHÉ WET CELL.

çiators, etc. Two types of cells are manufactured, those built for automobile ignition and those for lighter work. The cells may be bought in either of the two types, the igniter for automobile use and the regular for light open-circuit use. The cells used should be fresh and it is not wise to purchase more than needed, as they deteriorate even though not in use. To test a cell connect an ammeter directly across the terminals. This connection should be closed only momentarily, as the short circuit thus formed will ruin the cell in a few minutes. A new cell should show at least 20 amperes of current on a short circuit and when it is discharged below five it should be discarded.

Gravity Cells.—For closed circuit work the gravity cell or one of the several other cells adapted to this class of work should be used. The gravity cell derives its name from the way in which its two fluids are separated, that is, by gravity. As illustrated by Fig. 35 there is a crowfoot of zinc near the top of the cell and a similar form of copper in the bottom. The solution before use is copper sulphate, but the chemical action of the copper sulphate upon the zinc causes zinc sulphate to be formed as the lighter liquid.

Charging Cells.—To charge a gravity cell place one pound of copper sulphate crystals in the jar and add water to bring the solution to the proper level. Dissolve the copper sulphate until the solution is saturated and leave the cell on short circuit overnight. Should the cell

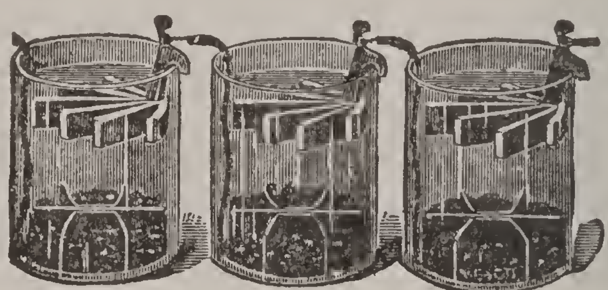


FIGURE 35. GRAVITY CELLS.

be needed for immediate use a little sulphuric acid added to the solution will facilitate the action. This solution when working will have what is known as the blue line, that is, the line where the blue and white liquids meet. This line should be kept midway between the top and the bottom of the cell. If the blue line is too low the cell has been worked too hard and should be left on open circuit, but if the blue line is too high the cell has not been worked enough and should be put to work.

Bell-ringing Transformers.—Bells and other low voltage devices are sometimes operated by bell-ringing transformers. Such a transformer has four wires passing out from it, two of which are to be connected across the electric light wires and two others which are to be connected to the bell wires in place of the battery. The electric light wires to which the transformer is connected must of course supply an alternating current. The connections should be made as shown in Fig. 36A. If one transformer is not strong enough to operate the bells, two may be used by connecting them as shown in Fig. 36B. If the transformers thus connected do not fur-

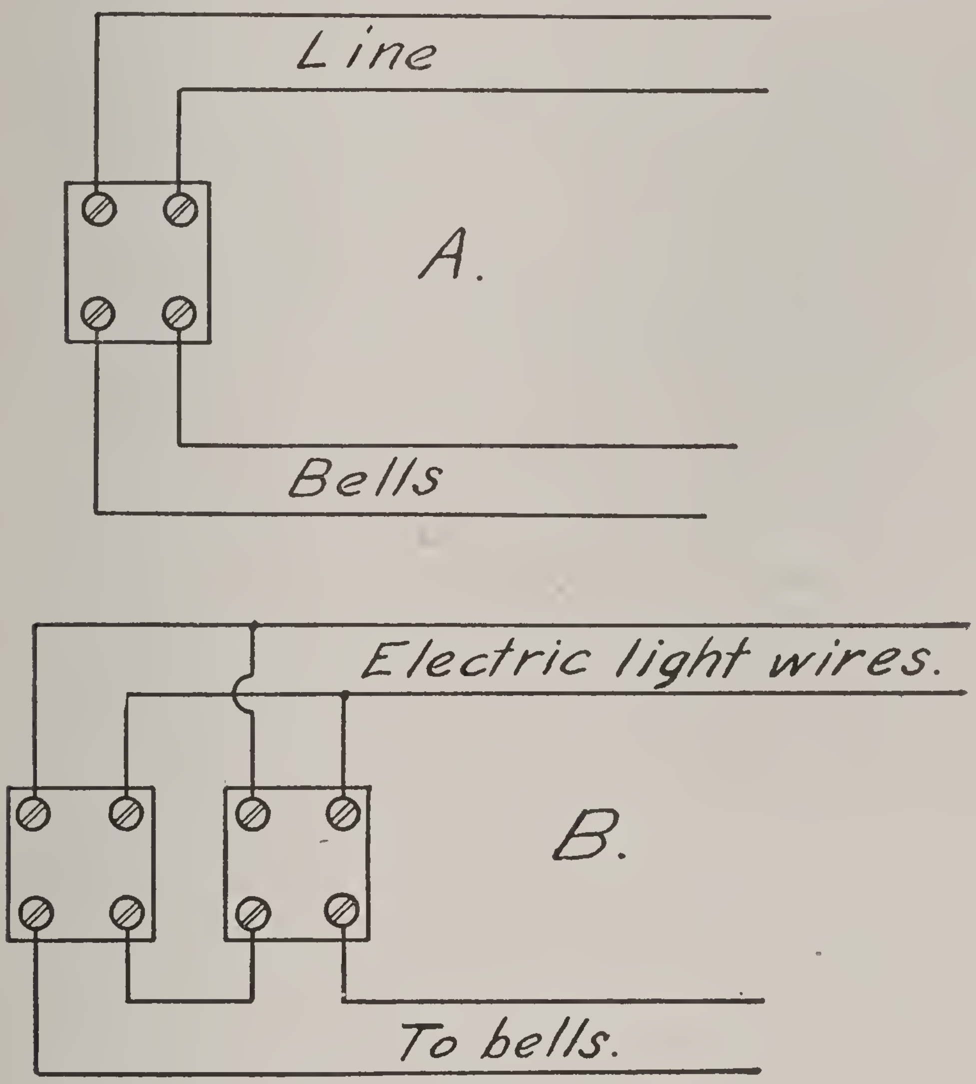


FIGURE 36.

nish any current the connections of one transformer on the bell side must be reversed.

Motor Generator Sets.—Motor generator sets as shown in Fig. 37 may be used for ringing bells on a large scale or for other low voltage work. The motor for the set is wound for 110 or 220 volts of alternating current and the generator furnishes 15 volts of direct current, which may be reduced by means of a field rheostat to suit the resistance of the circuit. As the current drawn from the generator is likely to be rather large, wires leading

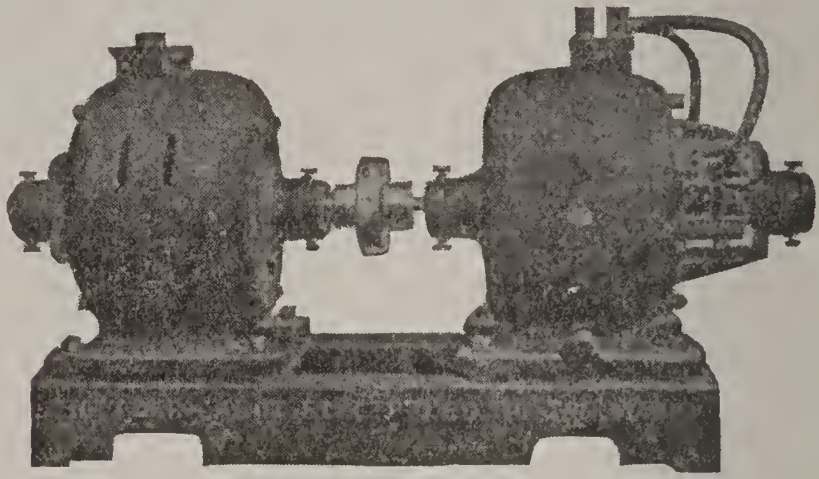


FIGURE 37. MOTOR GENERATOR SET.

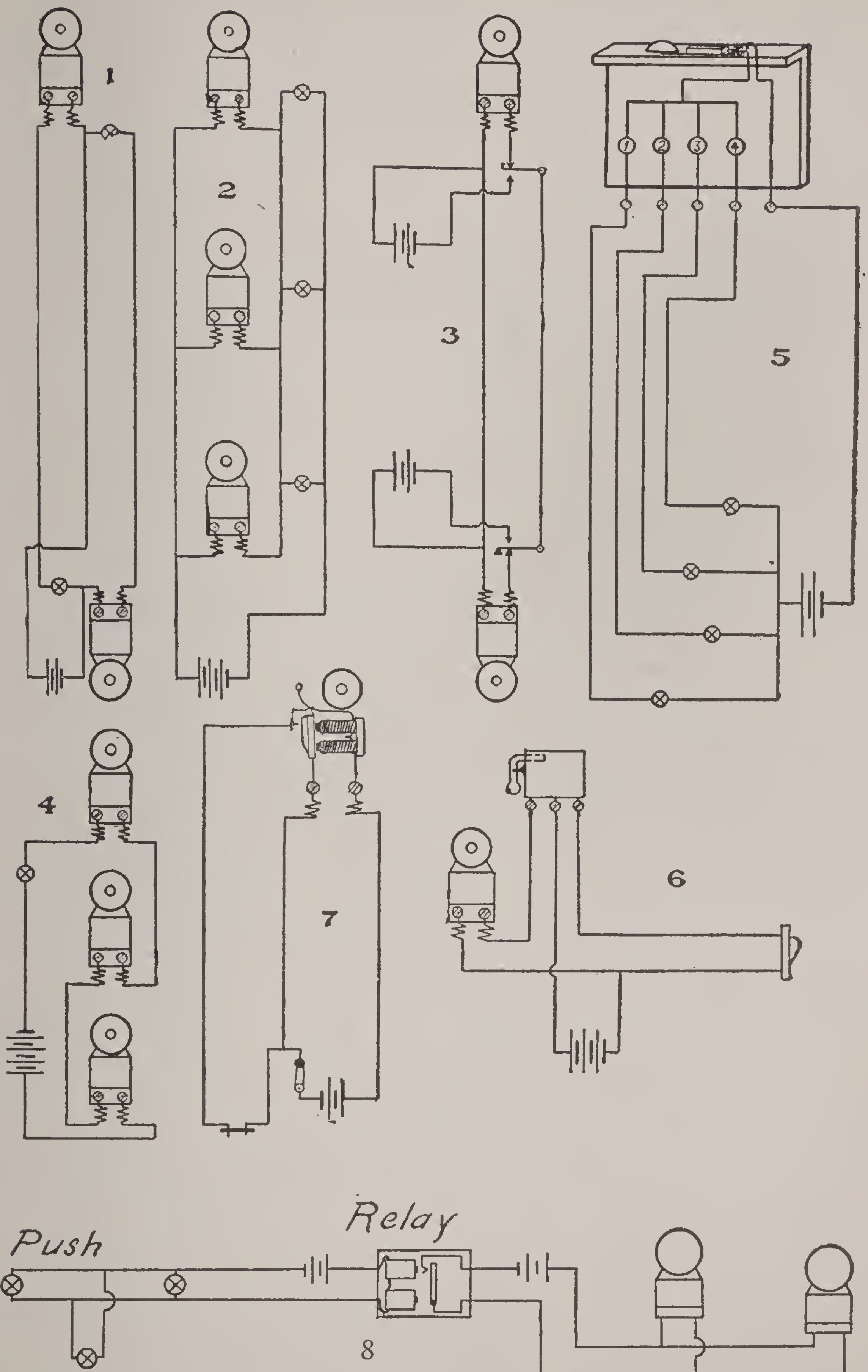
from it to the bells should be heavier than bell wires. It is good practice to use No. 14 or No. 12 for the main wires leading out from the generator and tap off with No. 18 bell wire for branch wires to different sets of bells.

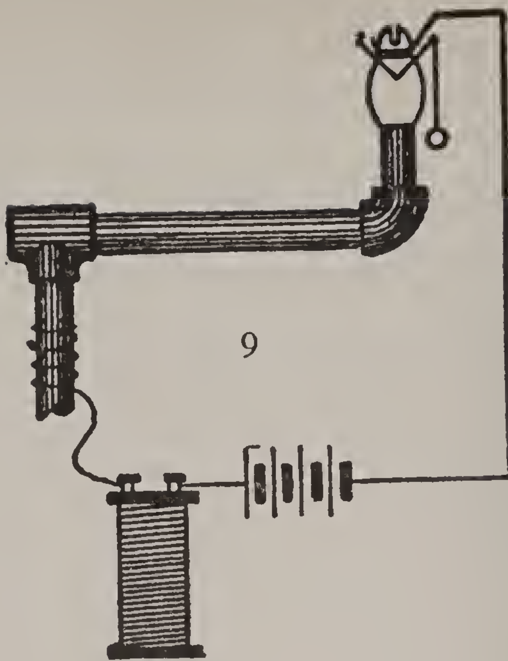
QUESTIONS.

1. What are the code requirements for wiring for bells or other low voltage wiring?
2. Explain the principle of operation of a vibrating bell.
3. Describe two methods of carrying bell wires concealed.
4. How should wires be secured under binding screws?
5. How are coils made in bell wires? Where are they used? Why are they used?
6. What space should be allowed between staples on bell wires?
7. Are joints in bell wiring usually soldered and taped?
8. In open work, may the wires be run near each other? Why are staples "staggered"?
9. How may the kinks be taken out of bell wire?
10. Describe a method of crossing one wire over another in open bell wiring.

11. How may open bell wiring be made less noticeable?
12. Do bells operate better when connected in series or in multiple?
13. Explain a method of operating bells in series.
14. How may a wire in a low voltage system sometimes be eliminated?
15. Why is an automatic drop used with a burglar alarm system?
16. Explain the operation of a closed circuit burglar alarm system.
17. How many wires are required in wiring for a simple annunciator?
18. Explain the operation of the gravity drop annunciator.
19. Explain the operation of the needle type annunciator.
20. In wiring for needle drop annunciators, is it sometimes necessary to reverse the polarity of the battery? Explain.
21. How many wires are required in wiring for a return call annunciator?
22. Explain the lighting of gas with a pendant gas burner.
23. Explain the lighting and controlling of gas with an automatic gas burner.
24. What is a spark coil, and what is its use?
25. Explain the operation of a battery cut-out.
26. Explain in detail a method of grounding a wire to a gas pipe.
27. Is a gas pipe considered a good conductor for the return circuit to a burner? Explain another method of wiring for the return circuit.
28. Give a plan of wiring a fixture for gas lighting.
29. How are a number of gas burners lighted simultaneously by electricity?
30. Explain in detail the different things to be done in locating trouble on a battery system.
31. What is the construction of a Leclanché wet cell?
32. How long should a Leclanché cell last, and how may it be renewed?
33. How much current should a fresh dry cell furnish on short circuit?

34. For what class of work is the gravity cell used? What is the construction?
35. How may a gravity cell be charged?
36. Explain the connecting of two bell-ringing transformers to work in series on a bell circuit.


1
2
3
5
4
7
6
Push
Relay
8



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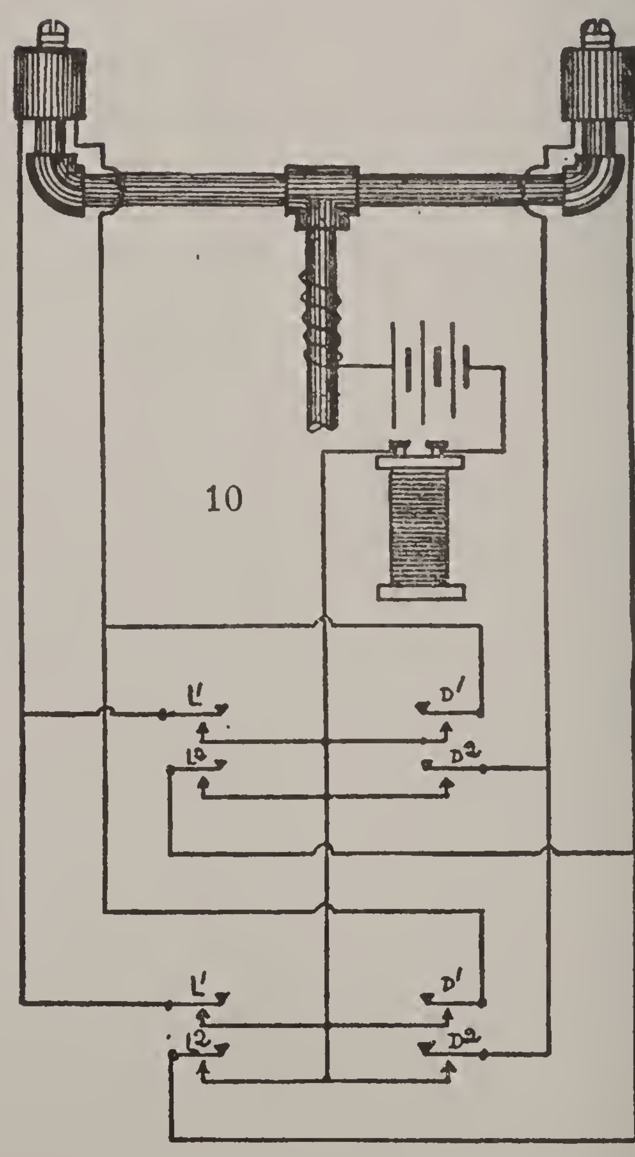

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CHAPTER IV

OPEN WIRING

Open wiring in a finished house may be done with either knobs or cleats, but two wire cleats are usually used because less time is required to install them. As is the arrangement for practically all other systems of wiring, the fittings for lamps and power are connected in multiple; that is, connected between the two wires of the circuit.

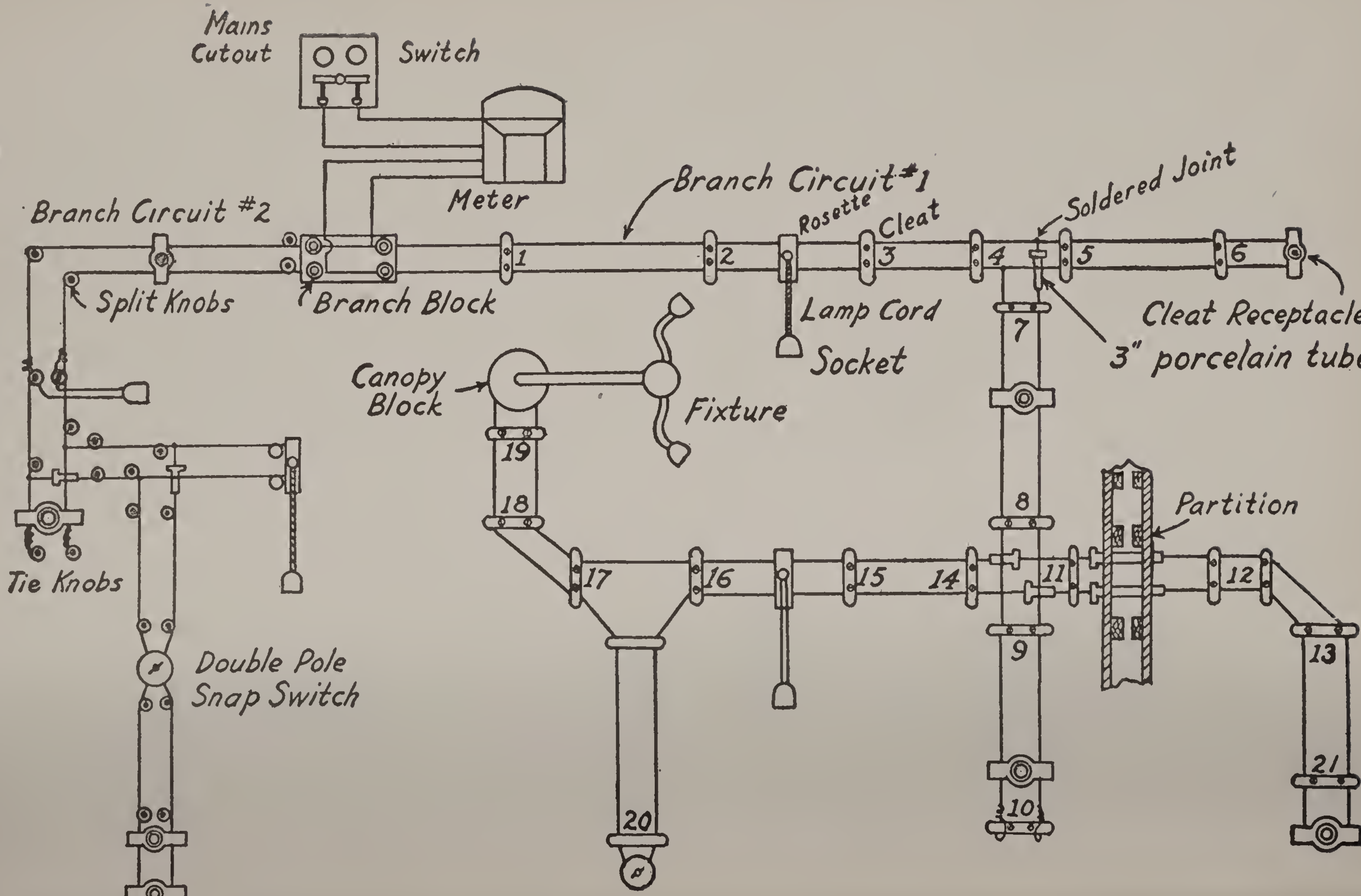
Switches are cut in the line between the device to be controlled and the source of power. Single-pole switches break one side of the line and double-pole switches break both sides.

Diagram.—The following wiring diagram for a small house will enable us to explain in detail the execution of the work.

To proceed as a wireman or contractor, after the number of outlets and their location are decided upon, the next step is to make a list of material needed.

Material Required.—The following is an approximate list of material for wiring a house according to the following diagram:

1 main-line entrance switch and cut-out, two wire, 30 amperes capacity
1 double-branch block two wire to two wire
8 cleat receptacles
3 cleat rosettes
3 key sockets
21 two-wire cleats
28 size 4½ split knobs
2 tie knobs


Mains
Cutout
Switch
Meter
Branch Circuit #1
Branch Circuit #2
Rosette
Cleat
Soldered Joint
Split Knobs
Branch Block
Lamp Cord
Socket
Cleat Receptacle
3" porcelain tube
Canopy
Block
Fixture
Partition
Tie Knobs
Double Pole
Snap Switch
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

1 single-pole snap switch
1 double-pole snap switch
2 sub-bases for switches
1 doz. $1\frac{3}{4}$-inch No. 6 round-head blued wood screws
20 3-inch porcelain tubes
10 6-inch porcelain tubes
300 feet of No. 14 single-braid rubber-covered wire
1 stamped metal or cast-iron box 6 x 9 x 4 inches
1 large box bushing
6 box bushings for $\frac{7}{8}$-inch hole
10 feet of $\frac{1}{4}$-inch circular loom
1 4-inch wood canopy block
1 two-light fixture, brushed brass finish
$\frac{1}{2}$ gross $2\frac{1}{2}$-inch No. 8 wood screws, flat head, bright
$\frac{1}{2}$ gross 2-inch No. 8 wood screws, round head, blued
2 doz. $1\frac{1}{4}$-inch No. 7 wood screws, flat head, bright
1 pound of solder wire
$\frac{1}{4}$-lb. box of soldering paste
1 $\frac{1}{2}$-lb. roll of friction tape
2 15-ampere plug fuses
4 6-ampere plug fuses
10 feet No. 18 fixture wire

Tools Required.—The following tools are needed to install the wiring:

1 small screw driver, cabinet style
1 large screw driver, machinist's style
1 ratchet bit brace
1 $\frac{5}{8}$-inch bit
1 pair 7-inch pliers
1 15-ounce nail hammer
1 gasoline or alcohol soldering torch
1 jackknife

Execution of the Work.—*Entering with Mains.*—In the execution of this job as planned, the wires for the mains should come into the building through porcelain tubes long enough to bush the entire length of the hole. The service entrance should be made well above the second-story window and the wires carried on knobs or cleats to the cabinet box if it is located on the second floor. A better mechanical, and perhaps a more satisfactory method, is to locate the cabinet box either on the first floor or in the basement and run the mains from the point of entrance in rigid conduit to the box. It is always better to consult the insurance and city authorities about running the entrance wires, as there are many local rules.

Switch and Cabinet Boxes.—In the present installation we will suppose the wires are carried to the cabinet box on knobs, passed into the box through separate bushed holes and fastened to the binding screws in the cut-out. Two wires from the service switch and two from the central contacts on the double-branch block are carried through one large box bushing to be connected to the electric meter. Wires for the branch circuit pass out of the box bushings and are carried on cleats or knobs to the fittings to be installed.

Branch Circuits.—On branch circuit No. 1 the first cleat should be within three inches of the box to take the strain off the wires and small binding screws where they are dead-ended in the branch block. The second cleat may be four and a half feet away from the first, and the cleat rosette, which is considered as a cleat so far as supporting the wires is concerned, may be placed any distance up to four and a half feet from other cleats.

Tap Circuits.—Where there is a circuit tapped off from a line, the strain should be taken off the joint by placing cleats near the joints on all wires passing out, as shown by cleats 4, 5 and 7. Instructions for soldering and taping a joint are given in Chapter II. In case a blow-torch is used care must be taken to prevent smoking or burning the ceiling or wall. Place a piece of tin or asbestos about four inches square between the joint and the wall and proceed as with other soldering.

The porcelain tube shown at the joint is threaded over one wire to insulate it from the other live wire. There must be some method of holding the tube in place. In this case it is done by placing the cleat near enough on one side so that with the joint on the other it will prevent the tube's slipping either way. Where the wires cross over other wires or pipes the tubes are generally held in place by two other methods, one of which is to tape the wires at both ends of the tube with sufficient layers of tape to keep it from slipping either way. The other method is to drive a wooden peg between the wire and the tube.

Rosettes and Receptacles.—To install cleat rosettes and cleat receptacles in a line, the wires are scraped clean of the insulation for about one-half inch and the wires passed under the binding screws. Where wires are dead-ended at a rosette, receptacle or other fitting, they should be scraped clean of the insulation and passed around the binding screw to the right, so that tightening the screw will tend to draw the wire toward the center of the screw.

In making a double tee joint as shown between cleats Nos. 8 and 9, there are several styles of joints used but the one shown in Fig. 39 makes the neatest and best joint mechanically.

Scrape the wire already installed for about one and a half inches, remove the insulation from the ends of the other wires, and wind them tightly each way round the wire installed.

A "dead end" is seldom made on cleats, but where one is used the wire should be passed back over the cleat and wrapped round the wire for three or four turns, as shown at cleat No. 10. To get the wrappings closer together and to tighten the wires, grip the turns with a pair of pliers and pull them round in the original direction as far as possible.

Wiring between Rooms.—In going from one room to another through a partition, holes should be bored and porcelain tubes inserted long enough to bush the holes through the entire partition, as shown in the foregoing wiring plan.

In making a right-angle turn, the cleats should be placed near each other and at right angles, as shown by Nos. 12 and 13. The inside wire makes almost a right angle while the outside wire makes a gradual curve from one cleat to another.

Mounting Switches.—In mounting single-pole and dou-

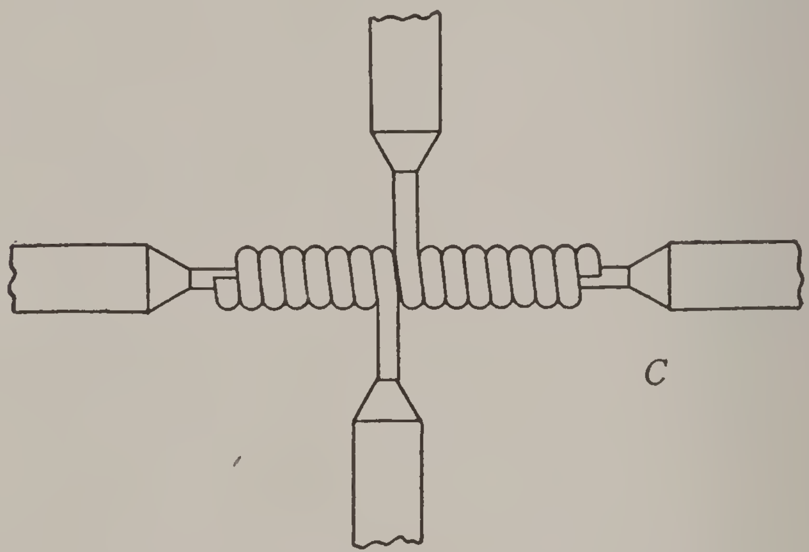


FIGURE 39.

ble-pole snap switches the usual practice is to place them four feet two inches from the floor; however, they may be mounted higher or lower to suit the convenience of the customer. Snap switches must have sub-bases of porcelain or similar material placed between the switch and the wall. Two screws only are required to hold both the switch and the sub-base, screws being used that are long enough to pass through both and secure them firmly.

Wires may be run open on side walls where they are not subjected to mechanical injury. Where the wires are apt to be disturbed they should be incased in rigid conduit, wood or metal molding on the side walls.

Fixtures.—Fixtures are usually ordered not wired and are wired in the shop or on the job. To wire the fixture shown in the following diagram it is necessary to fish two wires from the canopy of the fixture down into the ball at the bottom. There should be at least six inches of free wire left in the canopy to tap to the branch wires. Wires are connected to the binding screws in the

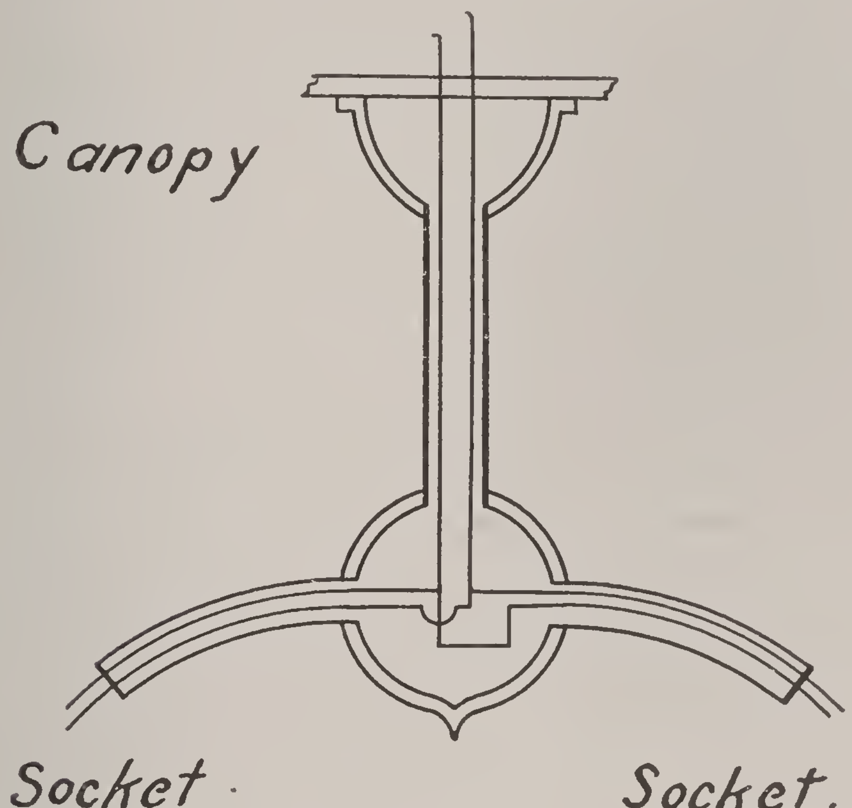


FIGURE 40.

sockets and fished through the fixture-arms to the ball. The wires in this ball are connected in multiple, as shown in the diagram, and are usually joined with a rat-tail joint, which is described in Chapter II.

These joints must be soldered, of course, and taped with rubber and friction tape.

To hang a fixture on a plastered ceiling a wooden canopy block should be installed for the purpose of supporting the fixture. Before this block is installed two $\frac{3}{8}$-inch holes should be drilled from the outside of the block to the center to carry the wires into the center of the canopy. The holes should be about $2\frac{1}{2}$ inches apart and drilled at an angle so that they will come out under the canopy. (See Figs. 40 and 41.)

The fixture is secured to the block by screws which are passed through the holes in the crowfoot, from which the fixture is hung. The joint to be used in the canopy is the fixture joint described in Chapter II.

Time-saving Methods.—In installing cleat work much time will be saved and a neater job will be made if the wires are drawn taut between distant cleats. That is, referring again to the preceding house wiring diagram,

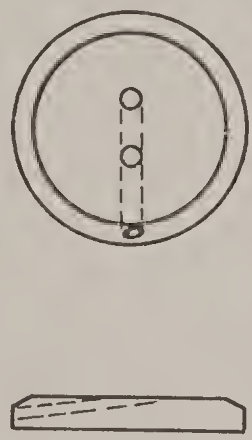


FIGURE 41.

beginning from the cabinet box put up cleat No. 1 with the wires in place and tighten up the screws, then instead of installing cleat No. 2 install cleat No. 4, which is about sixteen feet away, then place the wires in the grooves in the cleat, draw the wires taut and tighten up on the screws. After the wires have been drawn taut in this way it is an easy matter to put in the other intermediate cleats and rosettes and get a straight line of wiring.

One of the best methods of drawing the wires taut is the following: Having the wires secured in one cleat, carry them forward to the other, put up the cleat with the wires in place and turn the screws until the wire will barely slide through the grooves. After having tightened the wires with the hands as much as possible, grip one wire to be tightened with a pair of pliers close to the cleat and turn them in toward the bottom of the cleat and at the same time with a screw driver tighten the screw nearest this wire. If the pliers injure the insulation of the wire a piece of sheet fiber may be placed over the wire.

Drop Cords.—In open work drop cords are generally used and therefore should be made strong mechanically. The "drop," as it is usually called, consists of three parts: rosette, cord, and socket. The rosette should have no exposed metal contacts; the cord should be No. 18 twisted lamp cord, or reinforced cord; the socket should be of some approved make and should be suspended at least six feet from the floor. In damp places "packing house cord" should be used. Metal sockets may be used in dry places, but porcelain or other weatherproof sockets should certainly be used in damp places. Usual practice in wiring a residence is to install metal sockets in all rooms except the bathroom which, with the basement and damp porches, has weatherproof sockets.

The National Electric Code requires that some method be employed to take the strain off the small wires and binding screws at the rosette and socket. To accomplish this the cord should have a knot tied in it that is as bulky as possible, and this knot should then be taped with friction tape until it will not readily pass through the hole. The underwriter knot which is shown on page 68 is considered the best knot for this purpose.

To fasten the stranded wires of the lamp cord under the binding screws in the rosette or socket all the separate wires of the strand should be twisted together and then passed round the screw. This not only increases the conductivity of the connection but also prevents stray wires of the strand from touching the other side of the circuit and thereby causing a short circuit.

Running cleat work or knob work on the lower side of the joists, where the wires are exposed to mechanical

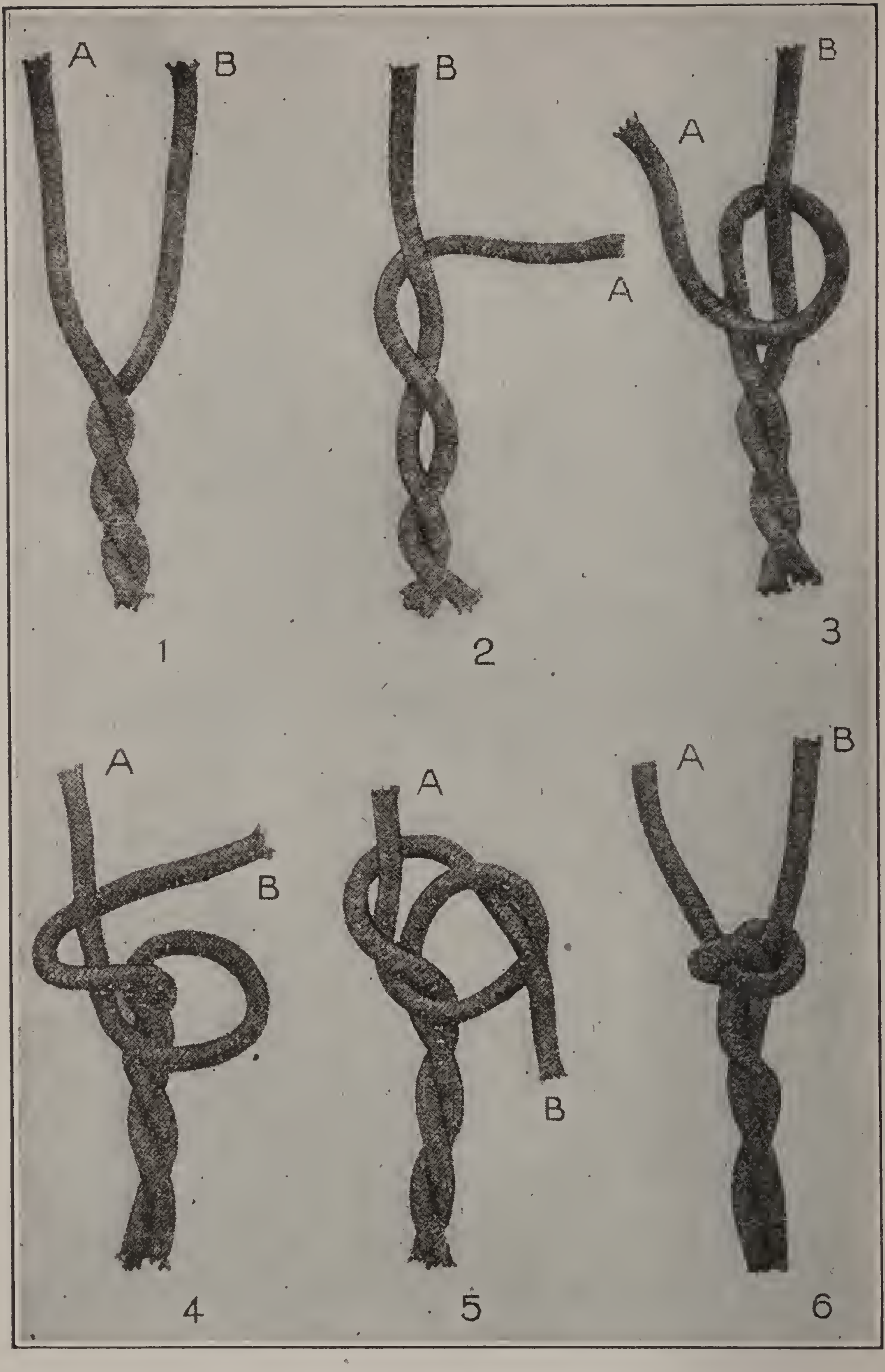


Figure 42. The Underwriter Knot.

injury, may be done in either of two ways. One is to carry the wires and insulators on a wooden board $\frac{1}{2}$ inch thick and 3 inches wide. The other is to fasten the insulators directly upon the underneath side of the joists and run guard strips $\frac{7}{8}$ inch in thickness and as high as the insulators on each side, and close to the wires.

Branch circuit No. 2 of the foregoing wiring diagram shows a circuit run on porcelain split knobs. Where the voltage is 110 volts and there is an even number of wires there is no particular advantage in using knobs for open work, although they are sometimes used, especially for motors, and should be mentioned. There are two types of knobs; namely, the split knob and the solid knob. Split knobs are now approved by the Code and are used almost entirely in preference to the solid or tie knob. The tie knob is sometimes used in connection with the split knobs but only as a "dead end" knob. In making a turn with a split knob as a support, the wire should be placed in the groove on the outside of the screw, so that the screw will prevent the wire's slipping out of the groove should it become loose.

Either tie knobs or split knobs may be used on a dead end, the same method of dead-ending the wires being used for both. Pass the wire round the knob and back over itself four or five times as in dead-ending at a cleat.

Tests.—Tests of open work are seldom made before the power is turned on; however, when the contractor wants to be sure of the wiring before he leaves it, he should make a test for short and open circuits. The most common method of making these tests is with a magneto, though a bell and battery may also be used. When using a magneto connect the wires from the magneto to the wires of one circuit of the system. This is usually done by passing the wires from the magneto under the binding screws at the cut-out with the wires of the circuit. With the connections thus made, turn the crank of the magneto and if the bells ring with no lamps in the sockets, there is a short circuit on the system. If there is no ring the wiring is free from short circuits. If a short circuit is indicated, it will probably be found in a rosette, socket, or fixture.

The other test to be made is for open circuits. Leaving the magneto connected in the same way as for the first test, screw a lamp into a socket, turn on the key or switch and turn the crank of the magneto. If the bells ring the circuit is complete, but if the bells do not ring look for an open circuit between this socket and the magneto. This test should be performed in a similar way upon every lamp socket in the system. A vibrating bell and a battery may be used to perform the above tests; but when testing for open circuits a fuse plug should be screwed into the socket or a screw driver should be held across the contacts in the socket, because a lamp has too high a resistance to transmit the battery current.

Wood Molding.—Installing wires in wood molding is often done in connection with other systems, but a wiring job alone is seldom made in wooden molding. Wooden molding cannot be used in damp places; therefore damp rooms, cellars and outside spaces must be wired in some other manner.

Where the installation is to be entirely in wooden molding the cabinet box should be located on the first or second floor. The mains should be passed through the outside walls in porcelain tubes long enough to bush the entire length of the holes. The wires can then be carried in wooden molding down to the cabinet box and from the cabinet box, the branch-circuit wires can be passed out in molding to the different floors.

The molding used must be covered or painted with at least two coats of waterproof material or be impregnated with a moisture repellant.

Parts.—The molding consists of two parts; namely, a backing and a capping. The backing is secured to the surface wired over; the wires are then inserted in the grooves and the capping is tacked on with small nails called capping brads. This holds the wires in place and presents a finished appearance.

Where wood molding is laid on plaster it should be secured with wood screws. It makes a better job mechanically to use them for securing the backing throughout the installation. However, sometimes nails are used instead on wooden surfaces. To install molding with screws, holes should be drilled in the backing for the screws to pass through, and these holes should be countersunk, so that the screw heads will go in flush with the surface.

In a building where the molding is to be run on an outside brick wall that may be damp, a backing of at least $\frac{7}{8}$-inch thickness should be placed behind the molding. Usual practice is to place a piece of the molding backing under the molding, with the groove side toward the wall.

Support.—To fasten wood backing to a brick wall the usual method is to drill a hole three or four inches deep with a star drill or cold chisel and to drive into this hole a wooden plug which is then sawed off close to the wall. To this plug the wooden backing is secured by a screw.

In a building of hollow tile construction toggle bolts make the best support for the molding. A hole is drilled into the tile large enough for the bolt with the toggle arrangement to be inserted. Then the toggle turns, making a tee that will not pull through the hole, and the bolt is tightened.

Wooden molding is not approved for any concealed places. Therefore in passing through floors and partitions some more secure form of insulation is required. In passing through a partition the molding is carried to the partition on both sides and the wires are passed through the wall in porcelain tubes long enough to bush the entire length of the hole. In passing through floors the same method is used with the addition of a "kicking box" to protect the wires and tubes where they pass down through the floor. There are two types of kicking boxes, one of cast-iron and one constructed of wood, as shown in Figs. 44 and 43.

The cast-iron kicking box shown in Fig. 44 may be bought for any size of molding and makes a very neat appearance. The wooden box, as shown in Fig. 43, may be built by the wireman and answers very well as a substitute for the metal box.

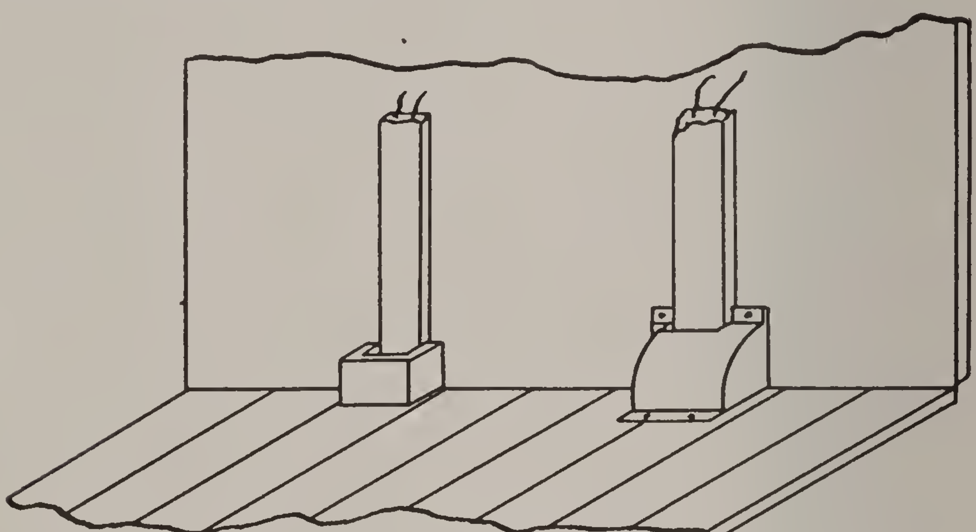


FIGURE 43. FIGURE 44.

Where a right-angle turn is made with wooden molding both the backing and the capping should be mitered to make a neat joint, as shown in Fig. 45. Some time will be saved and perhaps neater work will result if the capping and backing are held together and the miters cut in both at the same time.

Mitering.—For mitering wooden molding, wooden miter boxes, iron miter frames, or combination squares may be used. The combination square is more popular for jobs outside the shop because it is lighter and less awkward to carry than either of the other two.

Where a single-pole switch is to be inserted in one of the wires that pass in a line of molding, the wires are usually carried to the switch in an additional piece of molding which is butted against the line already installed.

The usual method is to cut grooves in the side of the main line of the molding through which the wires are passed down into the molding leading to the switch, as shown in Fig. 46. Fig. 47 shows a much neater method of cutting in for a switch. In this plan an A-shaped block is cut out of the main line of molding, and the end

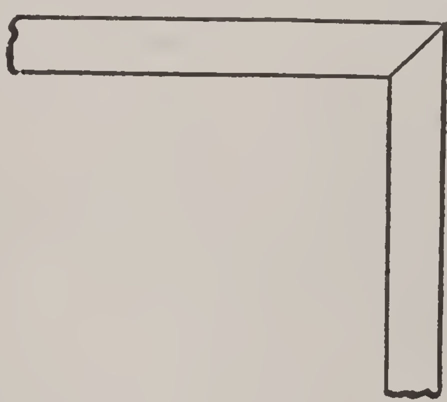


FIGURE 45.

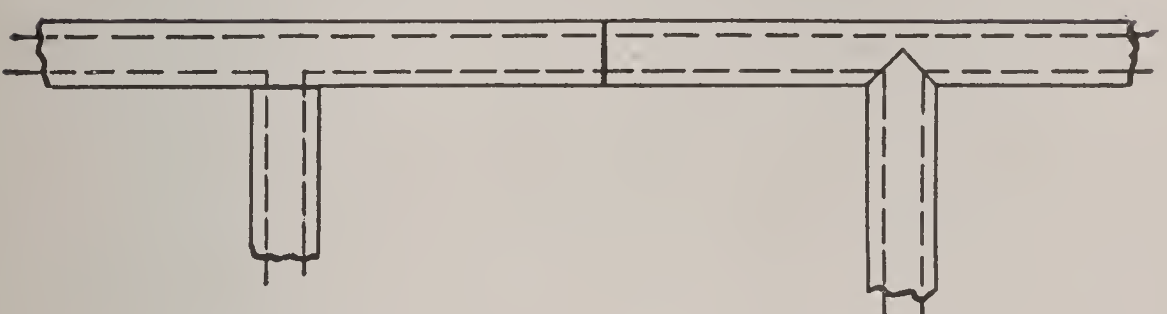


FIGURE 46. FIGURE 47.

of the switch molding is cut A-shaped to fit the slot. With this method the grooves of the two moldings fit together, which fact avoids the necessity of cutting grooves for the wires to pass out of the main run of molding.

No joints or splices are permitted in the wires in the molding; that is, the wires must run in continuous lengths from outlet to outlet or from fitting to fitting. Where tap circuits are taken from a line of molding for one or more lights, a porcelain fitting called a taplet is used to take the place of joints. The taplet, as shown in Fig. 48, consists of two parts, a base and a cover.

The base is first secured to the backing and the wires that pass through are bared of the insulation for a short distance and are passed under the binding screws, as shown in Fig. 48. For the tap circuit the end wires are secured under the other set of binding screws and are passed out to the lights or other current-consuming devices. The porcelain cover is then placed over the base to conceal the live metal contacts. The reader must not

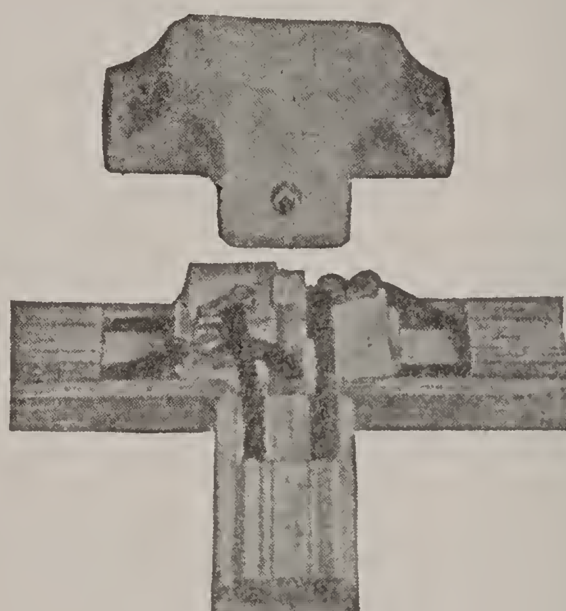


FIGURE 48.

mistake the use of this taplet and use it to tap off for a single-pole switch because such an arrangement, when the switch is closed, will make a short circuit on the line. The taplet is only used when it is desired to put two sets of current-consuming devices in multiple.

Where rigid conduit is used in connection with wood molding there are three approved methods of passing the wires from molding to conduit. The first is to use a condulet, as shown in Fig. 49; the second is to use a condulet made for this purpose, as shown in Fig. 51; and the third is to carry the wires into a junction box through porcelain tubes or box bushings, as shown in Fig. 50.

Switches.—Snap switches are used almost entirely on a wooden molding installation, because they are less expensive than others and make a neater appearance. The switch should have the regulation porcelain sub-base installed under it to insulate it from the surface wired over. The appearance of the job may be improved if the wireman will let the capping extend over the sub-base and cut the end circular in form to fit up round the switch, as shown in Fig. 52. This covers the wires where

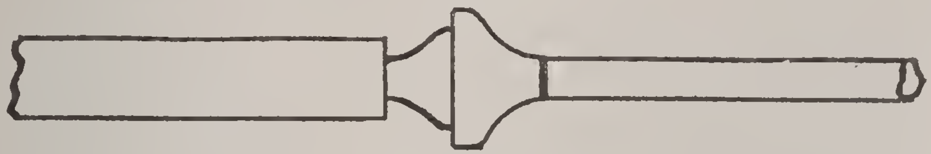


FIGURE 49.

they pass into the switch and helps to add neatness to molding work.

To install a fixture in connection with wooden molding, a wooden canopy block should be used similar to the one previously described in this chapter. One-fourth inch holes should be drilled from the outside to the center of the block, as shown in Fig. 53, through which the wires are carried.

This method avoids the necessity of cutting the canopy

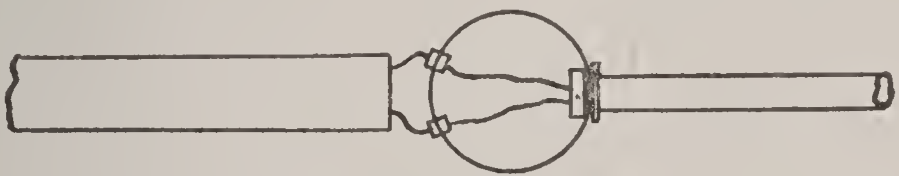


FIGURE 50.

where the wires pass into it and gives a much neater finish to the job. The fixture is hung with a crowfoot as described for straight electric fixtures in Chapter V.

Molding receptacles and molding rosettes are of two kinds; those that sit on the top of the backing and those that lie on the surface and have the molding butted against them. The former type is usually employed because it does not necessitate cutting of the backing where the fitting is to be installed.

Wooden molding may often be made less conspicuous by painting it the same color as the surface over which

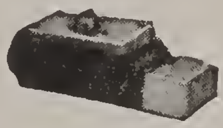


FIGURE 51.

the molding is placed. This is especially desirable if there is a contrast in colors between the molding and the surface.

Wooden molding is often used with open work wiring, where the wires pass down on the side walls for switches or pass through the floors. Besides making a neater

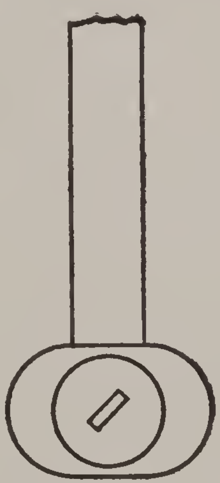


FIGURE 52.

job it provides an excellent device for protecting the wires from mechanical injury.

Wooden molding of a decorative character is sometimes used in rooms that are adapted for it. The most common decorative method is to make it represent a picture molding. In this case it is installed all round the room, and the wires are run in it along the walls to the different outlets. The fittings for lights and fixtures are seldom installed on the molding itself, the usual position

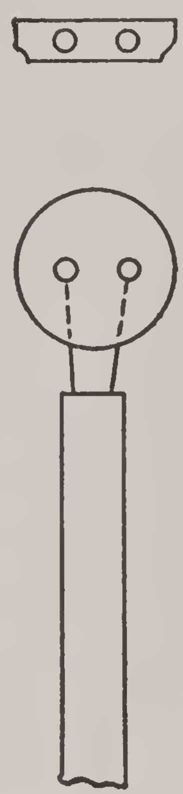


FIGURE 53.

for outlets being either below on the wall or above on the ceiling. The wires for the outlets are carried through

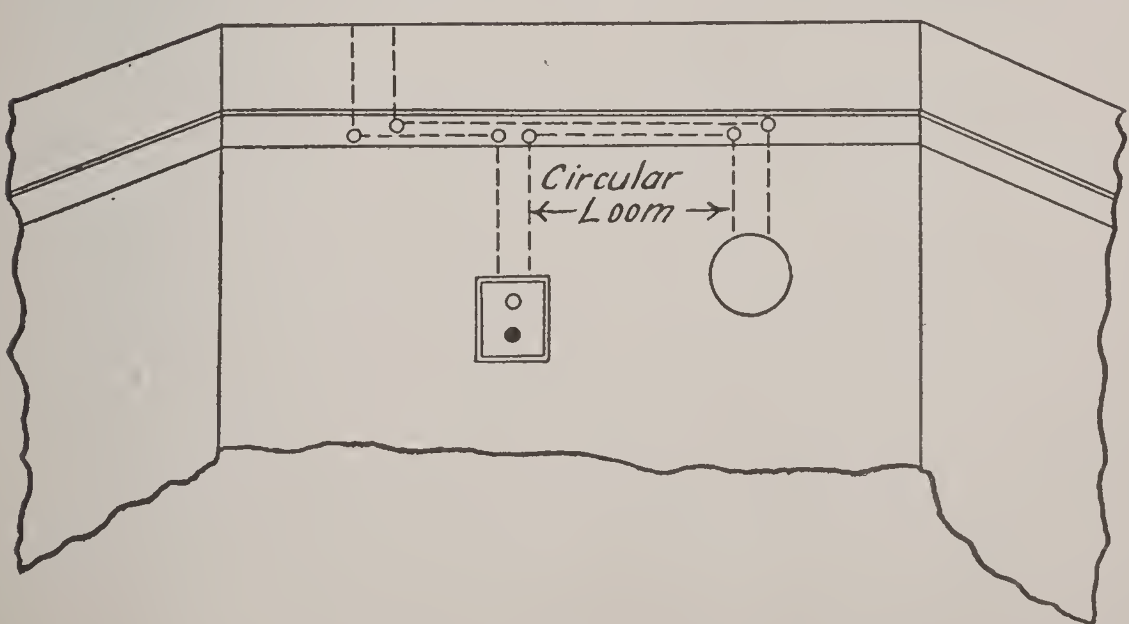


FIGURE 54.

the backing and are fished through the wall in circular loom to the outlets, as shown in Fig. 54.

The final tests on the installation should be for short circuits and open circuits, as previously described in this chapter.

QUESTIONS.

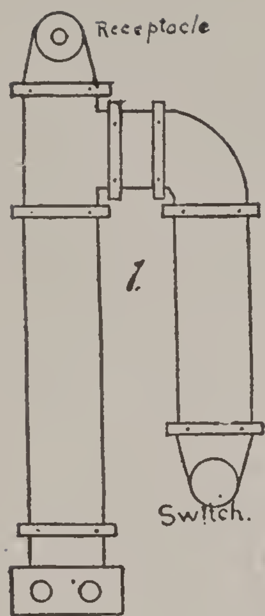
A. OPEN WORK.

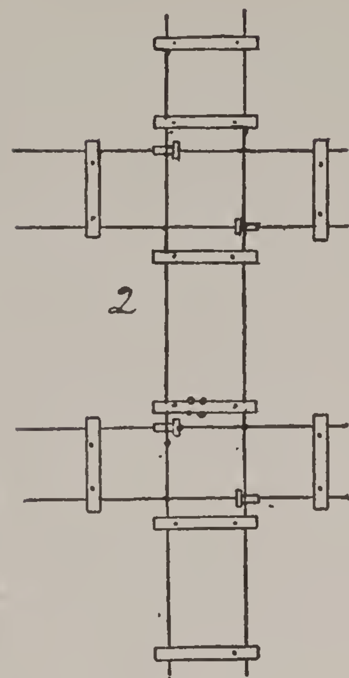
1. How are current-consuming devices usually connected on a wiring circuit?
2. How are switches connected to control current-consuming devices?
3. What is the difference between single-pole and double-pole switches?
4. What tools are necessary for an installation of open work wiring?
5. Describe two plans for carrying the main wires into the building for open work.
6. What is the greatest distance allowed between cleats or knobs in open work wiring?
7. How is a tap circuit made from a line of cleat-wiring?
8. When soldering wires in open work with a torch, how may the surface behind the joint be protected from the flame of the torch?
9. Describe two approved methods of holding tubes in place when placed over wires.
10. How is a "dead end" made in cleat work?
11. How should wires be insulated where they pass through partitions?
12. How is a right-angle turn made in wiring with cleats?
13. In mounting single-pole snap switches, what is the usual height above the floor? How should they be insulated from the wall?
14. When and how should wires be protected on side walls?
15. Explain the method of wiring a two-light electric fixture.
16. Explain in detail the method of installing a fixture for open work on a plastered ceiling.

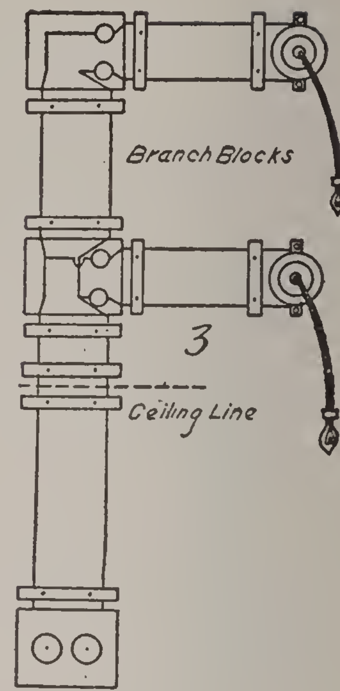
17. Explain in detail a time-saving method for installing cleat work.
18. How may the wires be drawn taut in the cleats?
19. How must lamp cord be supported where it passes into the rosette and socket?
20. Show the method of tying the underwriter's knot.
21. What type of knob is commonly used for knob wiring?
22. Explain the method of making turns with split knobs.
23. How is a "dead end" made on knobs?
24. Explain two methods of installing knob or cleat wiring on the underneath side of joists.
25. Explain the method of testing with a magneto for short circuits on a wiring system.
26. Explain the method of testing with a magneto for open circuits.

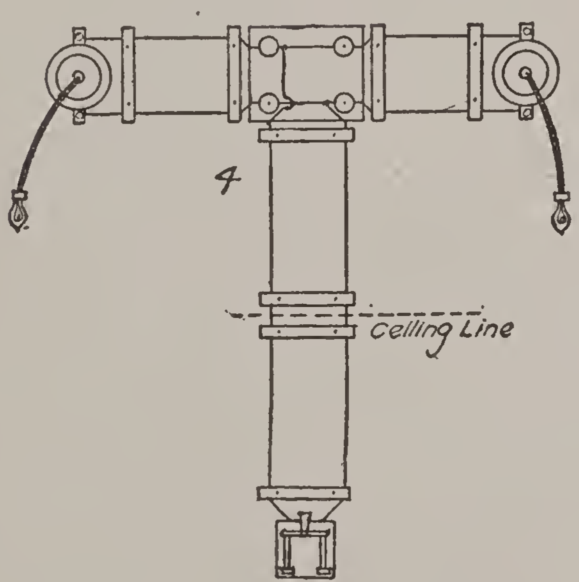
B. WOODEN MOLDING.

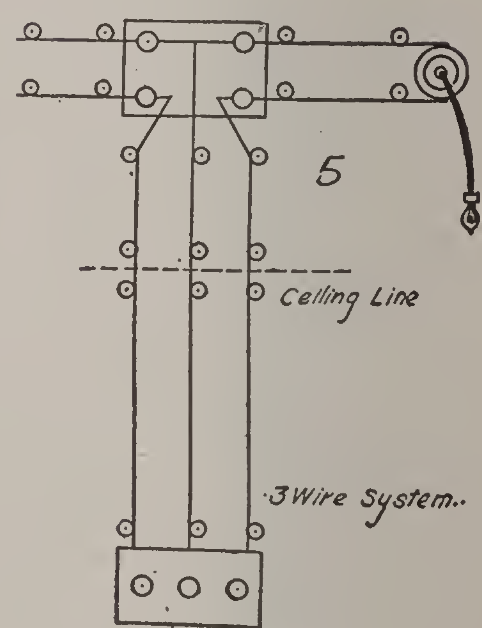
1. Explain a method of making a service entrance for a building with wooden molding.
2. Explain the method of installing wooden molding.
3. How should molding be protected from the moisture of a brick wall?
4. How may wooden molding be supported on (a) Brick walls? (b) Hollow tile construction?
5. How is wooden molding wiring carried through (a) Partitions? (b) Floors?
6. How should turns be made with wooden molding?
7. Explain the plan for carrying wires from a line of molding to a single-pole snap switch.
8. How is a tap circuit made from a line of wooden molding?
9. Explain three methods of passing wires from wooden molding to conduit.
10. Explain a method of installing an electric fixture on a molding circuit.
11. How may wooden molding often be made less conspicuous?
12. Explain the use of decorative wooden molding.

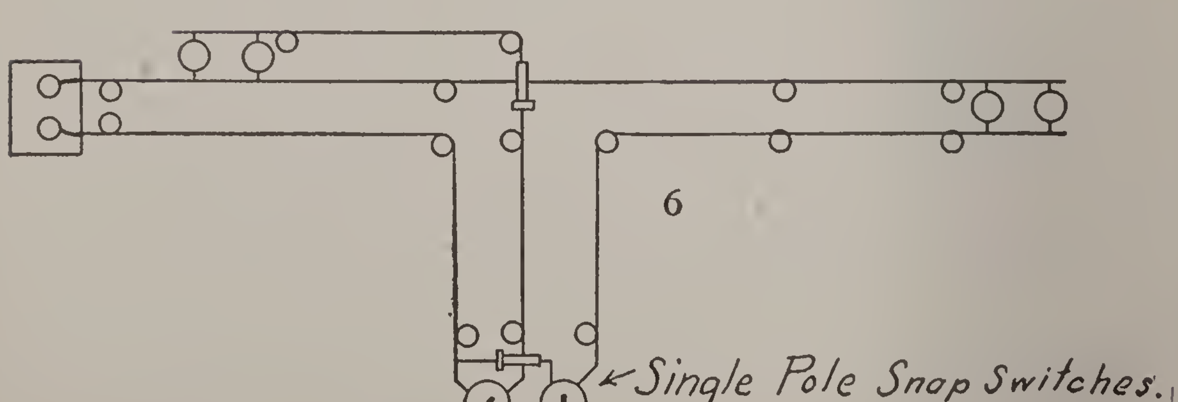

Receptacle
1.
Switch.

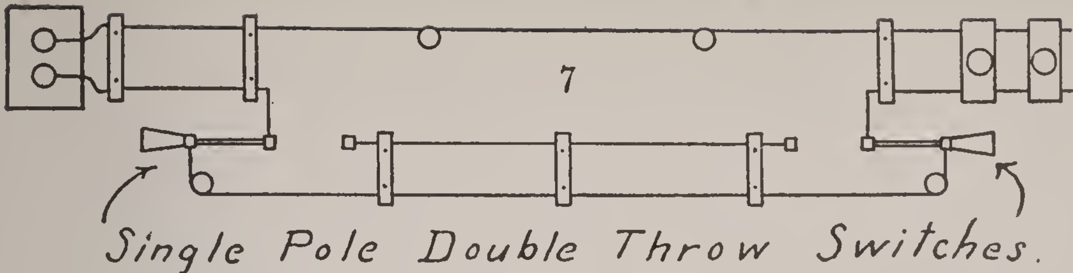

2

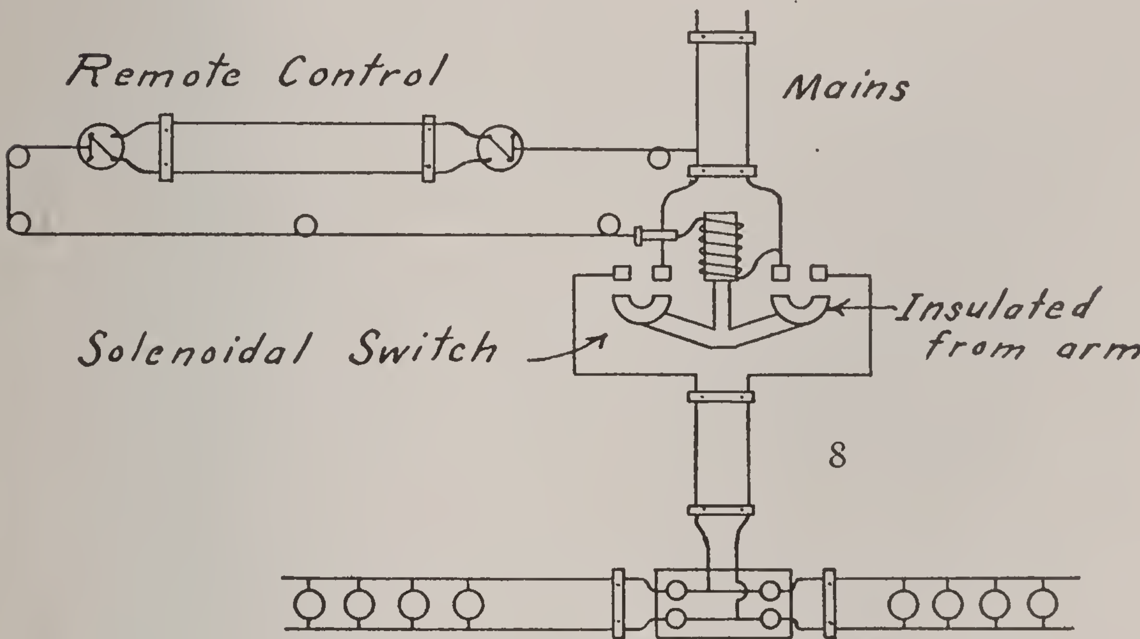

Branch Blocks
3
Ceiling Line

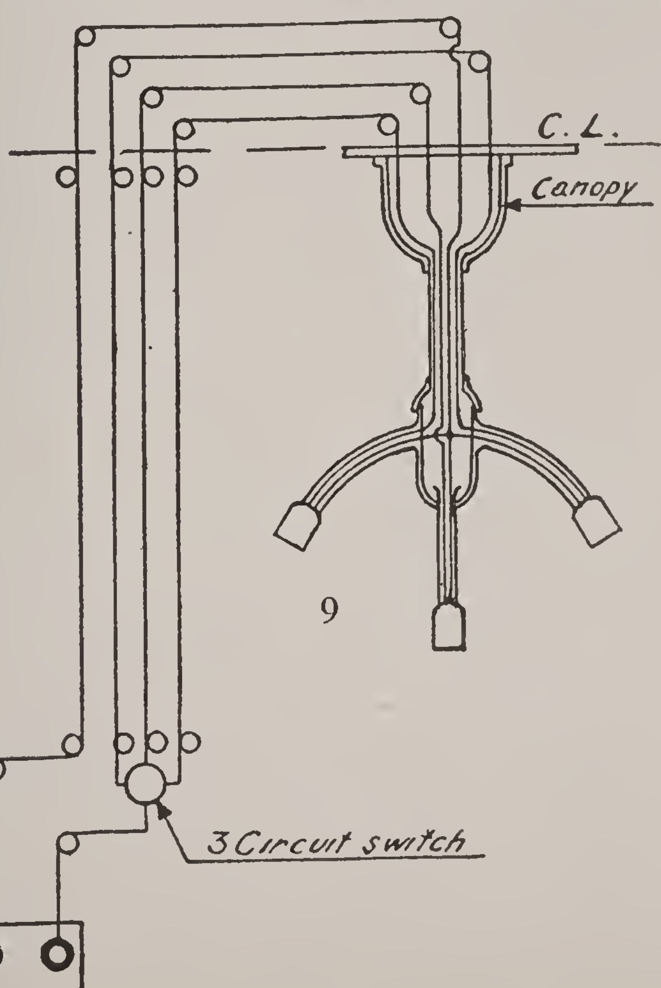

4
Ceiling Line

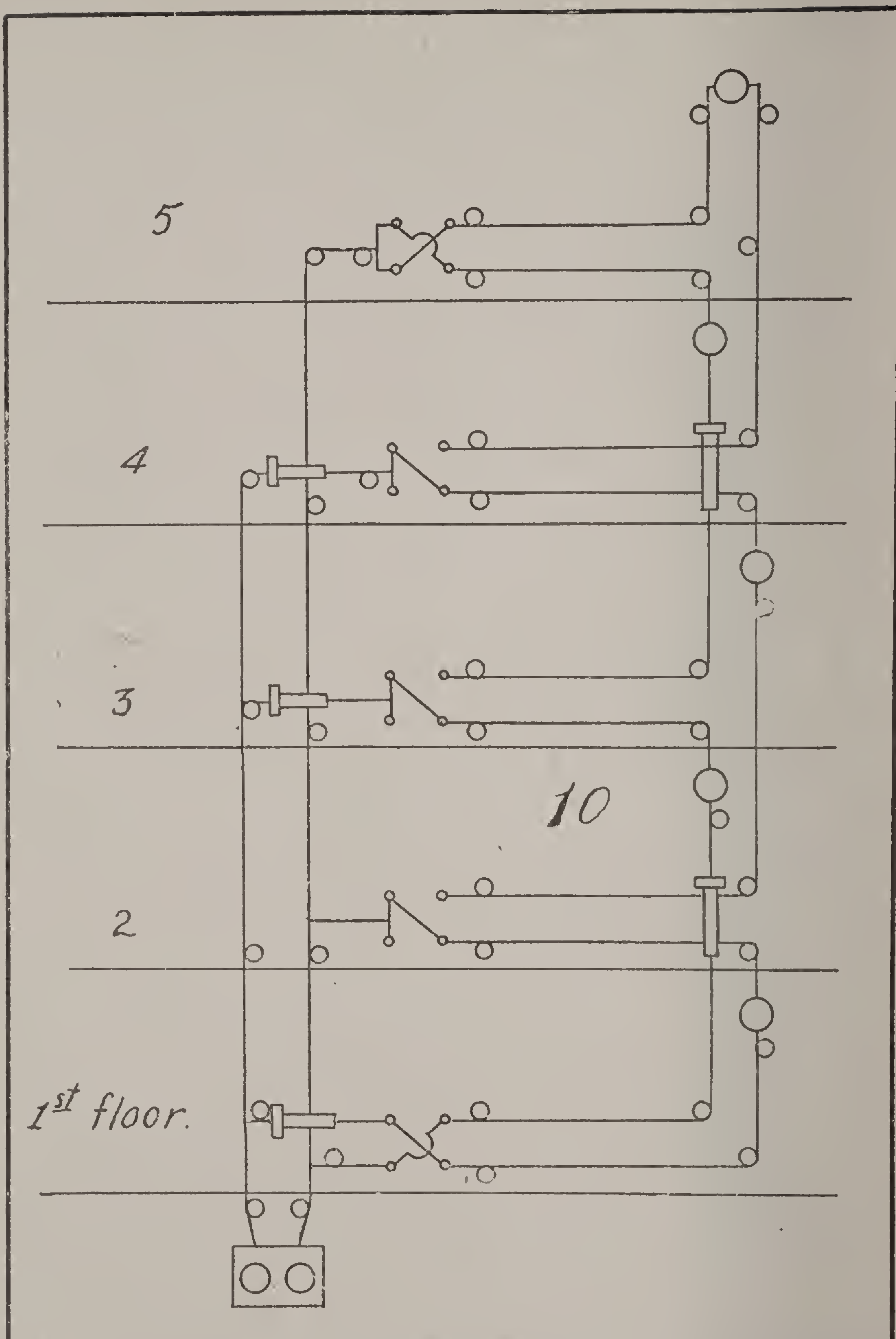

5
Ceiling Line
3 Wire System..

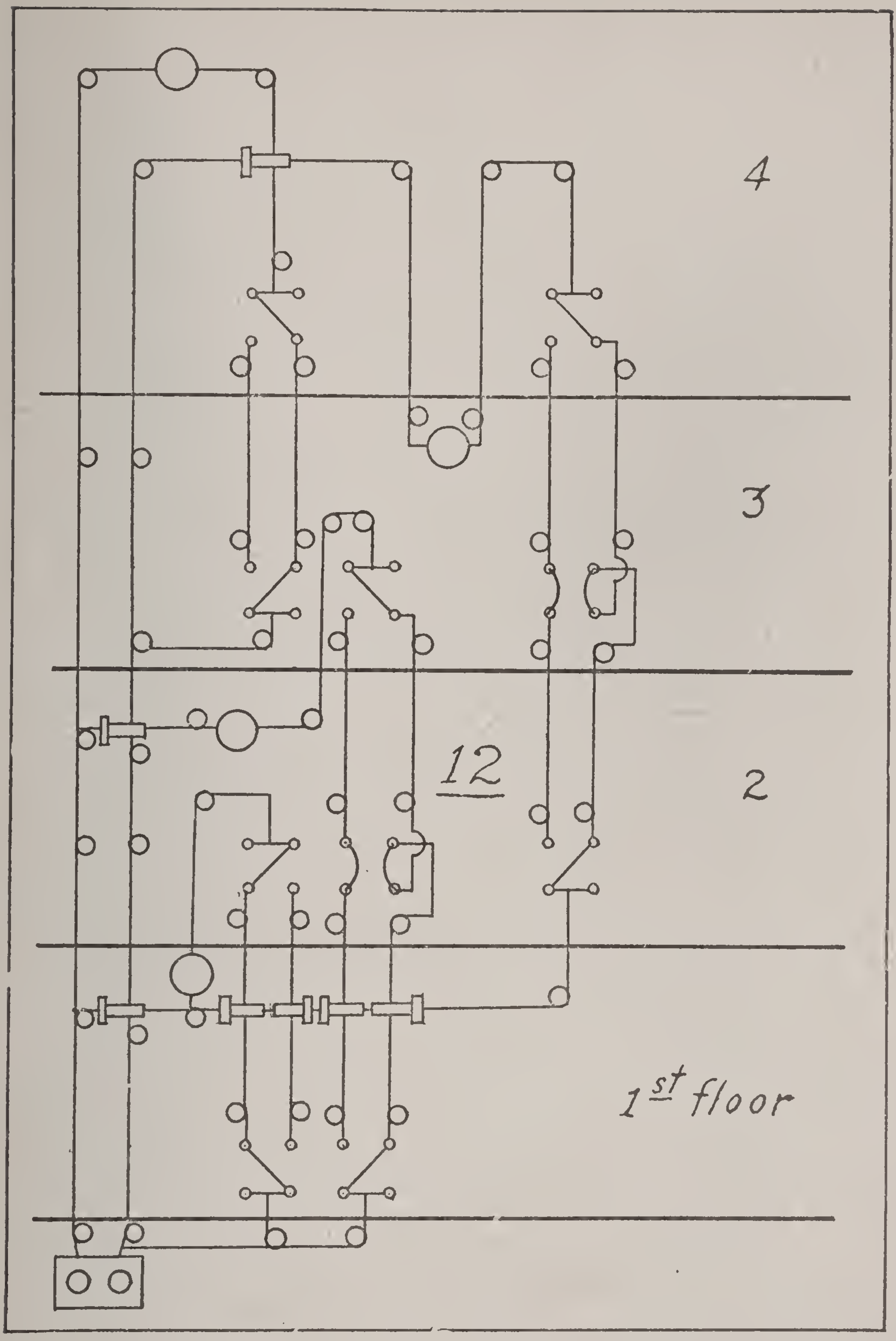

6
Single Pole Snap Switches.

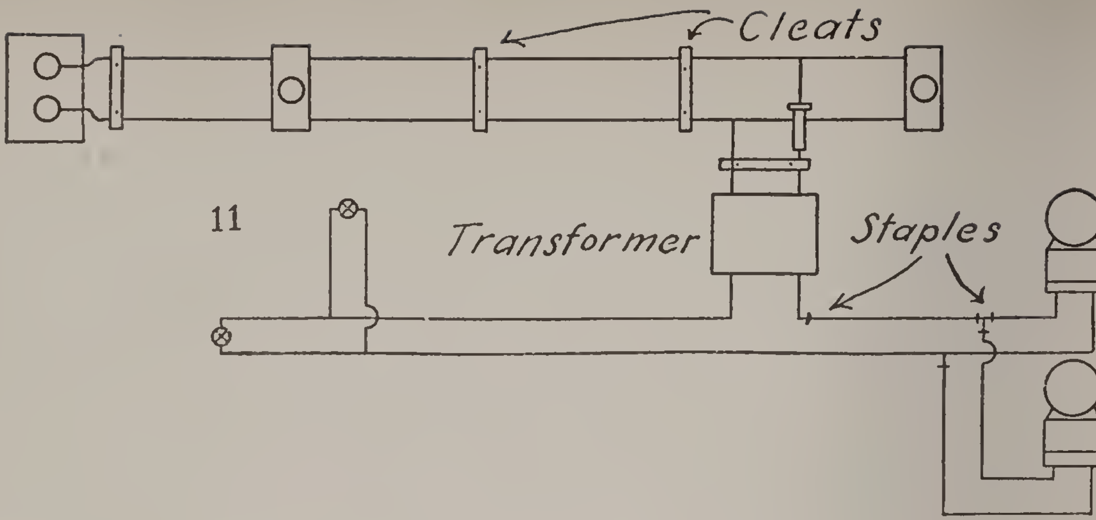

7
Single Pole Double Throw Switches.


Remote Control
Mains
Insulated from arm
Solenoidal Switch
8


C. L.
Canopy
9
3 Circuit switch


5
4
3
10
2
1st floor.


4
3
12
2
1st floor



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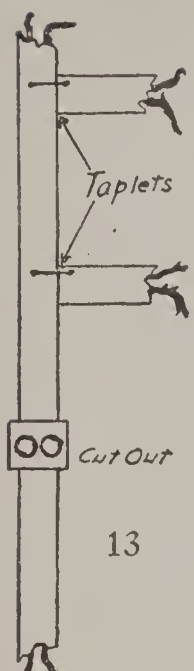

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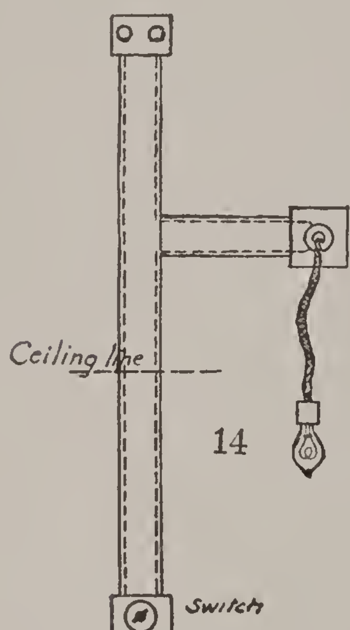

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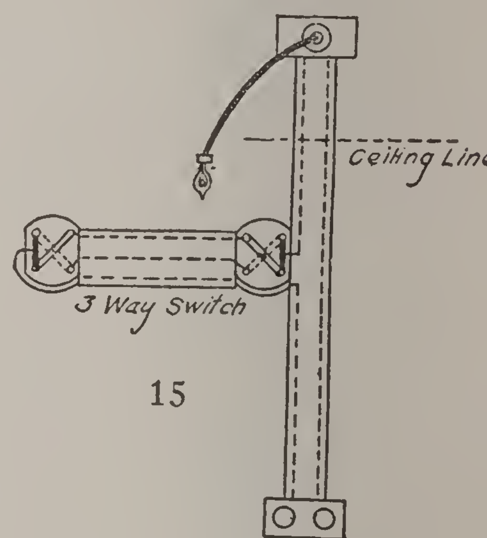

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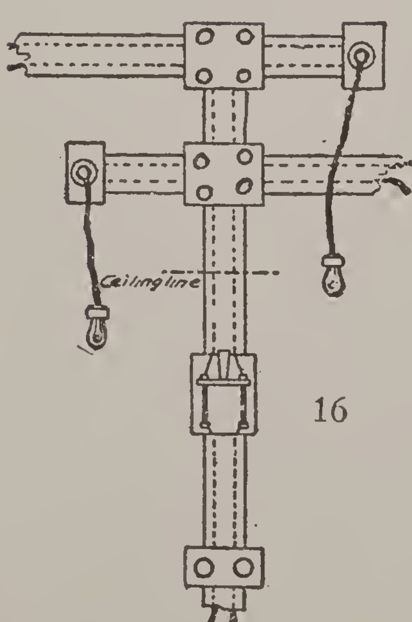

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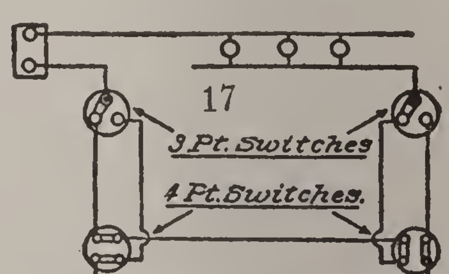


17

Independent Control any Number of Points.

CHAPTER V

CONCEALED KNOB AND TUBE WIRING

I. New House.—In concealed knob and tube work in a new house part of the work must be done at two stages in the process of building. The running of the circuits, or the "roughing-in job," as it is usually called, must be done when the floor joists are accessible. The ideal time to do this is when the floor joists are laid and the studding for all the rooms is installed. The remaining work on the job, namely, the installation of switches, "cut-outs" and other fittings that may come in the contract, should be done after the house is finished, that is, after the floors are laid and the plastering is completed.

Planning Installation.—To enable the electrical contractor properly to lay out the installation, he should be furnished with a blue print of the plans of the building, on which are shown by symbols the location of outlets for lights and switches, the number of fifty-watt lamps for each lamp outlet, and the number and kind of switches for the switch outlets. From the plans the next step is to locate the entrance switch, the entrance cut-out and cabinet box, and trace out the branch circuits. This must be done according to the rules applied to other systems. The wiring on branch circuits should now be arranged so that not more than twelve lights will be on any one circuit.

In doing concealed knob and tube work, the code requirements should be kept constantly in mind. One of the most important of these is the rule that wires must be kept at least five inches apart when run on the insulators.

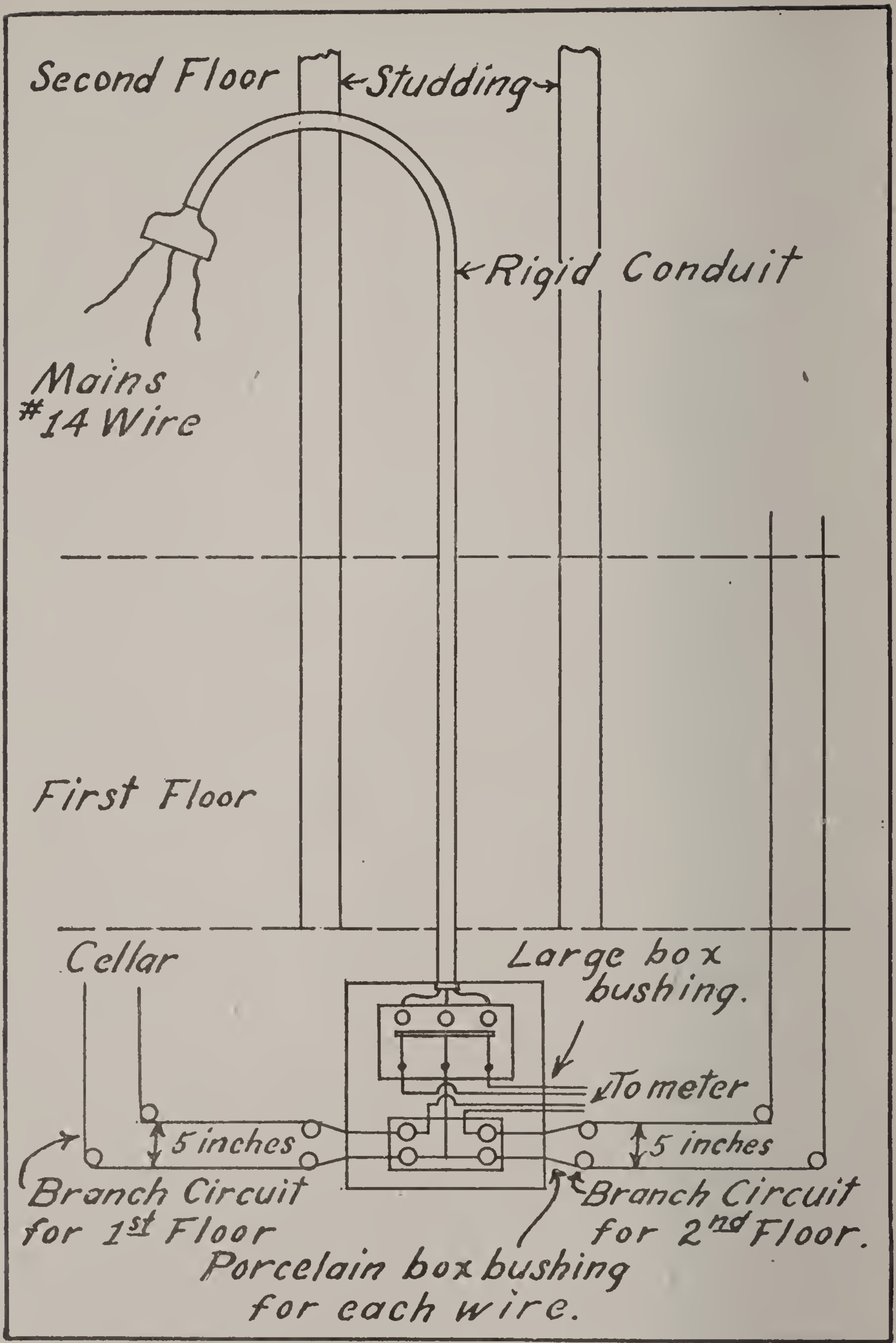

Second Floor
Studding
Rigid Conduit
Mains
#14 Wire
First Floor
Cellar
Large box bushing.
To meter
5 inches
5 inches
Branch Circuit for 1st Floor
Branch Circuit for 2nd Floor.
Porcelain box bushing for each wire.

FIGURE 55.

Entering the Building.—For bringing mains into the house, the arrangement shown in Fig. 55 is considered superior to all others, from a mechanical as well as an electrical standpoint.

The mains are carried in rigid conduit from the point of entrance on the second floor down through the side walls to the iron box in the cellar. In this box are placed the main-line switch and cut-out, and branch blocks. Wires for meter and branch circuits are carried out through porcelain box bushings.

Branch Circuits.—All concealed wires for the branch circuits are usually carried on split knobs or are passed through porcelain tubes to lights or other current-consuming appliances. If conditions make it desirable, wires may be run in rigid conduit or in circular loom.

Where curves are made with knob wiring, the knob should be placed so that the screw comes on the inside of the curve to prevent the wire's slipping out of its groove, as shown in Fig. 55. Where wires are passed through floor beams or joists in porcelain tubes, the tubes should be long enough to bush the entire length of the hole and the holes should be bored at a slight angle from the horizontal, so that when the tube is inserted with the head up, gravity will prevent its slipping out of the hole.

Boring Floor Joists.—In boring the holes in the floor joists for the tubes and wires, some wire and much time will be saved if the electrician will use a bit with a long shank instead of the ordinary carpenter's bit. As is shown in Fig. 56, the long bit permits the swing of the brace to come between the first and the second joists from the one being bored, which fact allows the hole to be bored more nearly at right angles to the joist, making the hole shorter.

A $\frac{5}{8}$-inch bit is required for boring holes for tubes of $\frac{1}{4}$-inch internal diameter. The writer recommends a bit called the "ship's auger." However, if this cannot readily be secured, it is a fairly easy matter for a blacksmith to weld an extension to a carpenter's bit, which will answer the purpose.

Much energy is often wasted in boring joists, because the wireman takes a position that is a strain on him and does not increase the rapidity of boring. If a good bit is used, it is not necessary for the wireman to get behind the brace and push with all his might to make it feed. A better position is to stand or sit beside the brace, give the butt of the brace a tap with the palm of the hand to

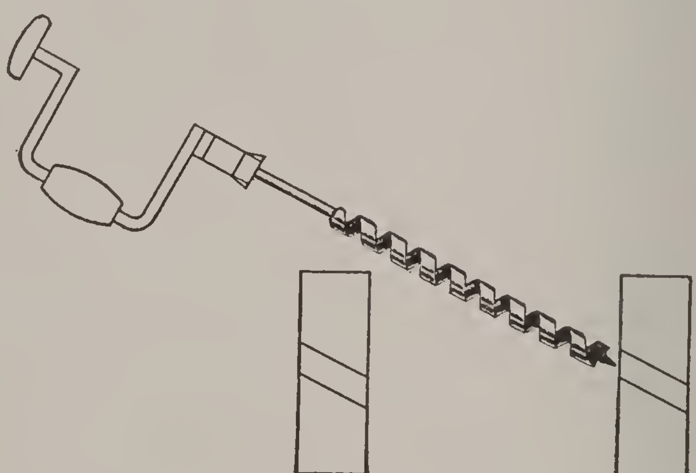


FIGURE 56.

start the bit and turn the brace at the same time, bearing on the brace with one hand to make it feed.

Inserting Wires.—In threading the wires into the holes that have been bored in the joists for the tubes, the wireman will find it much easier to thread the wires through the tubes and leave the tubes between the joists while the wires are being pulled in, as shown in Fig. 57.

This allows the wire to be pulled more nearly straight through the holes and permits longer pulls than otherwise could be made. After the wires have been pulled through in this way for the entire length of the run across the joists, the tubes may then be inserted in the holes, as shown in Fig. 58.

Tubes should always be placed in the hole with the head up, except where there is to be a right-angle turn at the lower point of the hole. In this case the head of the tube should be placed down, so that the pull on the curve of the wire, which is stronger than the gravity of the tube, will hold it in place.

Where wires pass up from one floor to another in a partition that is to be plastered, besides passing through a tube that bushes the entire length of the hole in the floor beam, there should be an additional 4-inch tube placed on the wire above the hole to protect it from any plaster which may fall and accumulate round it.

Split knobs are held in place by two methods, that is, with wood screws or nails, and leather heads. Nails and

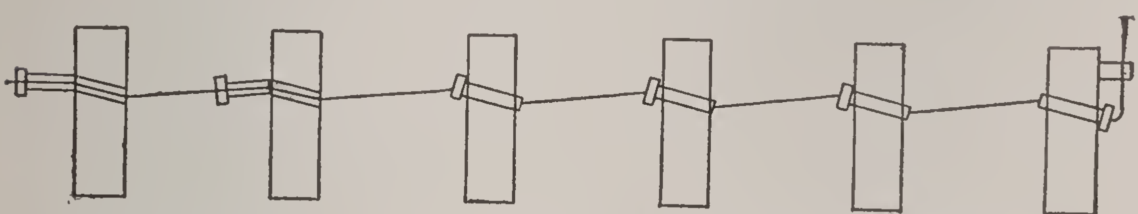


FIGURE 57. FIGURE 58. FIGURE 59.

leather heads are being used almost entirely now for securing the knobs in concealed knob and tube work, because with them much less time is required to do the wiring. The nail used is the ordinary wire head nail, which must be long enough to pass through the knob and into the wood for a distance equal to half the height of the knob. For a No. $5\frac{1}{2}$ split knob, which carries a No. 14 wire, a 10-penny wire head nail should be used. The leather washer is designed to act as a cushion between the head of the nail and the knob.

Wires Parallel to Joists.—Where wires are run on and parallel to studding, joists or rafters, the wires should be run on separate timbers or on opposite sides of the same timber. Sometimes the timbers are wide enough to allow the 5-inch spacing between the wires on the same side of the timber, but this is not considered good practice and wires run over each other on the same timber will not be approved by the electrical inspector.

Fixture Outlets.—To make a fixture or drop cord outlet in concealed knob and tube work, a board 7/8 or 1 inch thick and 6 inches wide is nailed between the joists with its under side just back of the under side of the joists, as shown in Fig. 60. Two 5/8-inch holes are drilled into the board about half an inch apart, through which the wires and the circular loom are to be passed. The wires should be supported by knobs near the outlet and encased in circular loom through the outlet. The loom should extend from the knobs, through the outlet holes, and 2½ inches below the board. The wires should extend about 6 inches below the outlet to allow for tapping with the fixture wire.

The board in the outlet described serves as a support to the canopy block, which in turn supports the fixture. Screws of sufficient length to pass through the canopy block, plaster and into the board should be used. The method just described is for "straight electric" fixtures, that is, where there is to be no gas piping connected with the fixtures. Where the fixture is to be both gas and electric, known as a "combination," the board is unnecessary, the fixture being supported by the gas pipe, as shown in Fig. 61.

In work where there is to be both gas and electricity, the gas fitter should have the house piped for gas before the electrician comes upon the job. In this case the outlets have been located by the gas fitter and it is only necessary for the wireman to bore the holes beside the gas pipe outlet and pass the wires and circular loom through the holes. Where there is no board near the ceiling on which to support the wires and loom, they may be held to the gas pipe by friction tape passed round them, as shown in Fig. 61.

The wires for straight electric combination fixtures and drop cord outlets are twisted together and left till the building is completed, when the fixtures are hung and the rosettes and switches installed.

Flush Switches.—In concealed work flush switches of the push button type are used almost entirely, because they make a much neater appearance. These switches

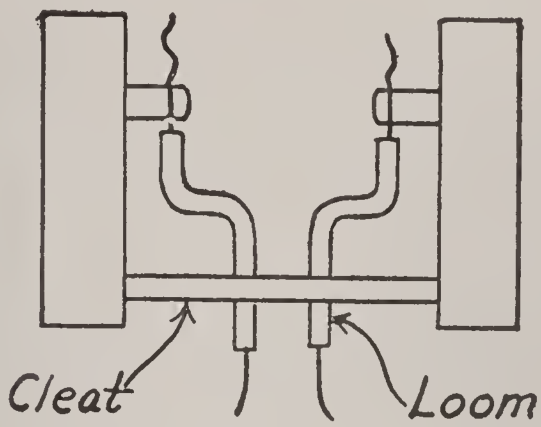


FIGURE 60.

must be mounted in iron switch boxes, of which there are two types; namely, the one for circular loom and the one for conduit. The box used in concealed knob and tube work has punchings cut for circular loom. Where the

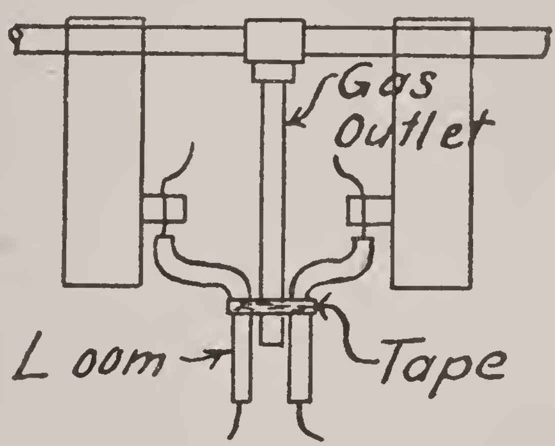


FIGURE 61.

height of the box is not specified by the customer, usual practice is to place the center of the box four feet two inches above the floor.

To install a flush switch, the box should be held in proper position between two cleats long enough to reach between adjacent studding. Then nail the cleats to the studding, flush with the front side of the same, one against the top and one against the under side of the box. Next hold the box in the hand and with the edge of the hammer face knock out as many plugs as there are wires to enter the box. Then fasten the box to the cleats previously installed, with wood screws. Where the wall is to be plastered, a flush switch box should be installed, so that the front of the box lies one-half inch from the front surface of the studding, which with the usual depth of plaster makes the box accessible after the house is completed and also assures the wireman that the box will not extend out from the plaster. By means of movable ears on the front of the box, its distance from the front of the studding may be adjusted. This is done by loosening the screws by which the ears are fastened and turning the ears around. The wires passing into the box should be encased in circular loom from the knobs through the holes into the box, as shown in Fig. 62. There is generally some device provided in the box for clamping the circular loom to prevent its slipping out of the holes.

Where more than one switch is to be installed at a switch outlet, a switch box called a gang switch box should be installed large enough for the total number of switches, which allows the use of one gang switch plate for all the switches instead of separate single switch plates for each switch.

Outlets for drop cords are made in the same manner as straight electric fixture outlets, care being taken to have the pieces of circular loom near enough together so that the concealed work rosette will cover the loom and holes.

Outlets for floor and baseboard receptacles should have the wires and circular loom carried through in a manner similar to that for a ceiling outlet; and after the carpenter's work is done the switch box may be fitted into the board, the wires and loom put into the holes and the receptacle installed. The above described type of floor and baseboard receptacle is approved only in residences and places that are not considered damp. For floors subject to dampness, the wires should be run in rigid conduit and receptacles of a waterproof type installed in a water-tight box.

When rigid conduit is used in mixed concealed knob and tube work, the rules for rigid conduit must be com-

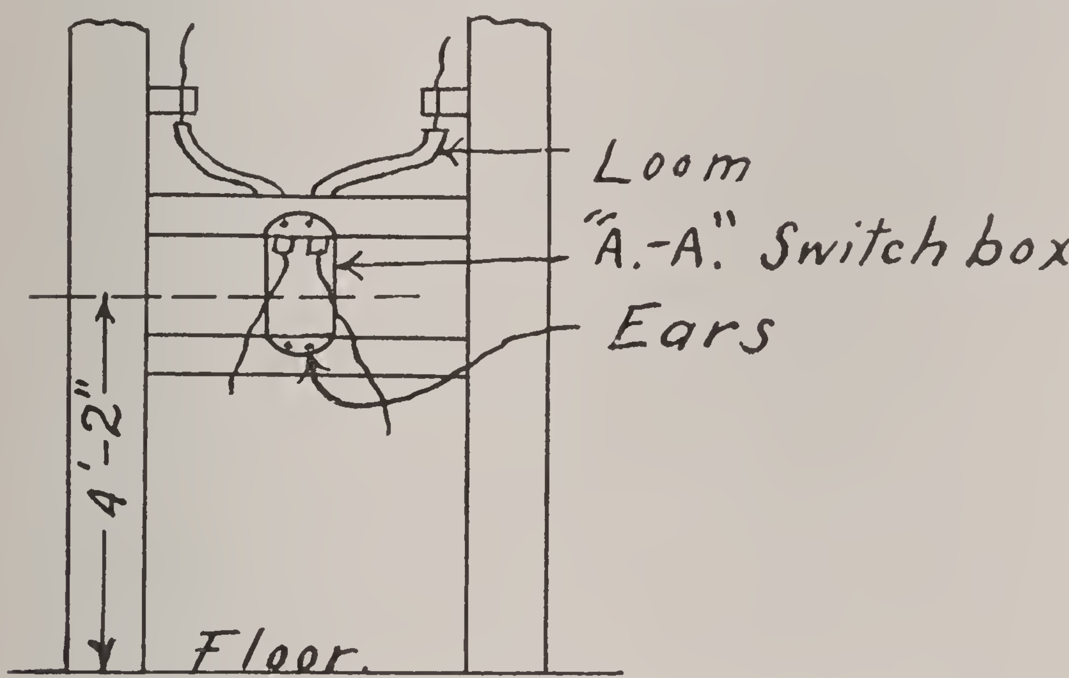


FIGURE 62.

plied with. All conduits must be grounded as described in Chapter V. Where live wires pass through rigid conduit except from a box, a fitting having a separate bushhole for each conductor must be used for terminating the conduit and there must be no splice joists or taps in the fitting. The usual method is to use a fitting which screws to the conduit, called a condulet. They are made for all sizes of conduit and with any number of holes up to 80. Figure 63 and 64 show how they may be used.

Cellar or Basement Wiring.—Outlets in a cellar or basement are usually for drop cords, which drop cords should be made with weatherproof sockets as a protection to life. If a metal socket is installed in a cellar and the ungrounded wire of the system happens to make contact with the metal of the socket and a person who is standing on the ground touches this socket, the current will pass through the person's body to the ground. The seriousness of the shock depends on the condition of the ground and the contact at the socket. With a low

FIGURE 63.

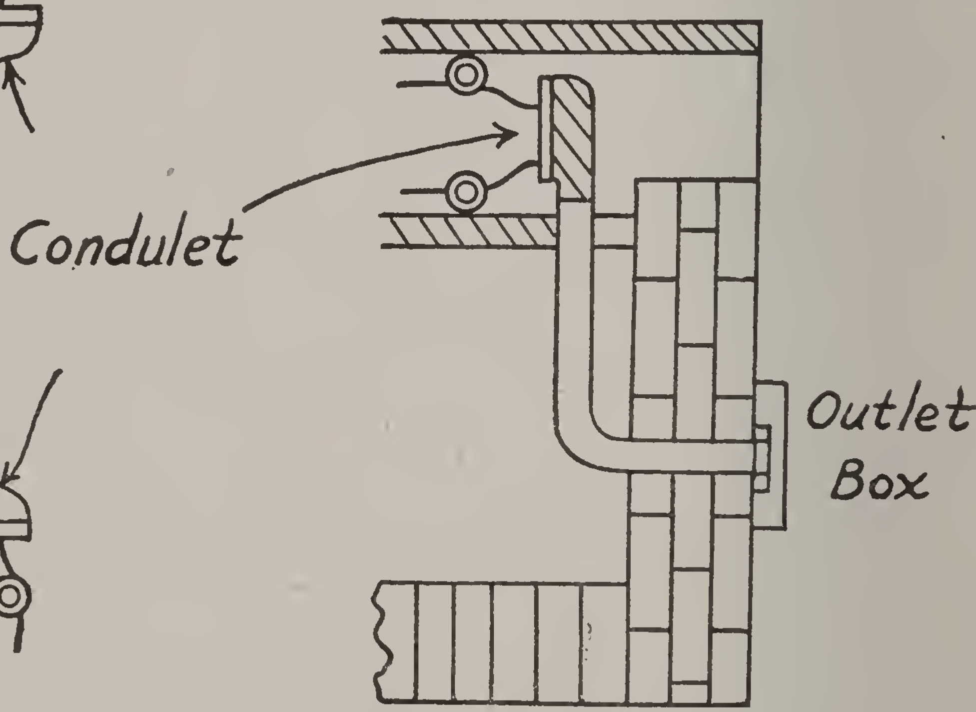


FIGURE 64.

resistance contact between the hand and the wire and a good wet ground connection, a very severe shock may be obtained on only a 110-volt circuit.

The wiring in the cellar is usually made to conform to the rest of the house; the wires are carried on the sides of the joists and through the joists, as previously explained.

In crossing the joists in a cellar, the wires are sometimes run on knobs on the underneath side of the joists, in which case, however, guard strips are required beside the wires to protect them from mechanical injury.

Outlets in an attic are wired similarly to those in a cellar, except for the socket, which may be of the metal type instead of porcelain.

Tests.—Tests are seldom made on the roughing-in wiring of concealed knob and tube work, as there is little likelihood of finding trouble. However, in a large or very important installation it is sometimes wise to make a thorough test. The test on an installation of this kind should be for short circuits and open circuits. With a magneto or bell and battery, ring across every pair of wires leading out from the cabinet box, as explained in Chapter IV. If the bells do not ring, the circuits are free from short circuits. To test for open circuits, connect the wires from the magneto or bell and battery to the wires of a branch circuit, short-circuit the wires at the outlets one at a time and, if the bells ring when each outlet is short-circuited, the wiring is free from open circuits.

Completing the Job.—After the building is completed, the floors laid, the plastering done, etc., a second trip to the job must be made to install switches, cut-outs, drop cords and to make final tests. Fixtures are usually not included in the contract with the electrical contractor and, therefore, are not hung by the wireman, but are usually bought from a local fixture house, which has them hung without charge to the customer. However, for those who may be called on to install fixtures, the methods for concealed knob and tube work will be given.

Fixtures.—For a straight electric fixture, a canopy block, which has holes bored in it for the wires and loom to pass through, is secured to the outlet by wood screws long enough to pass into the cleat which has been installed behind the laths. Upon the end of the fixture there is screwed a three-legged fitting called a crowfoot. Wood screws are passed through the feet of the crowfoot, which secures the fixture in place. The usual fixture joint is made, the joint is soldered and taped with

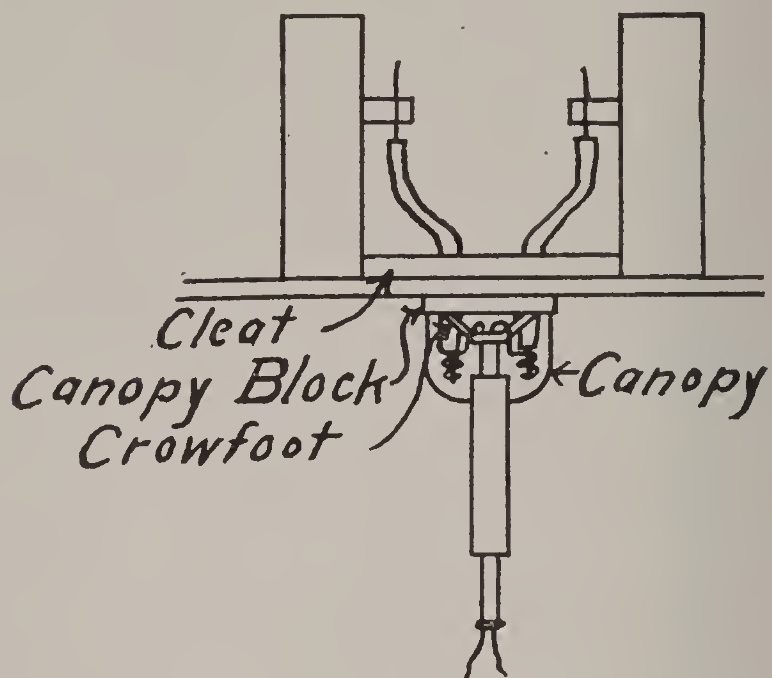


FIGURE 65.

rubber and friction tape and the canopy is set against the block, as shown in Fig. 65.

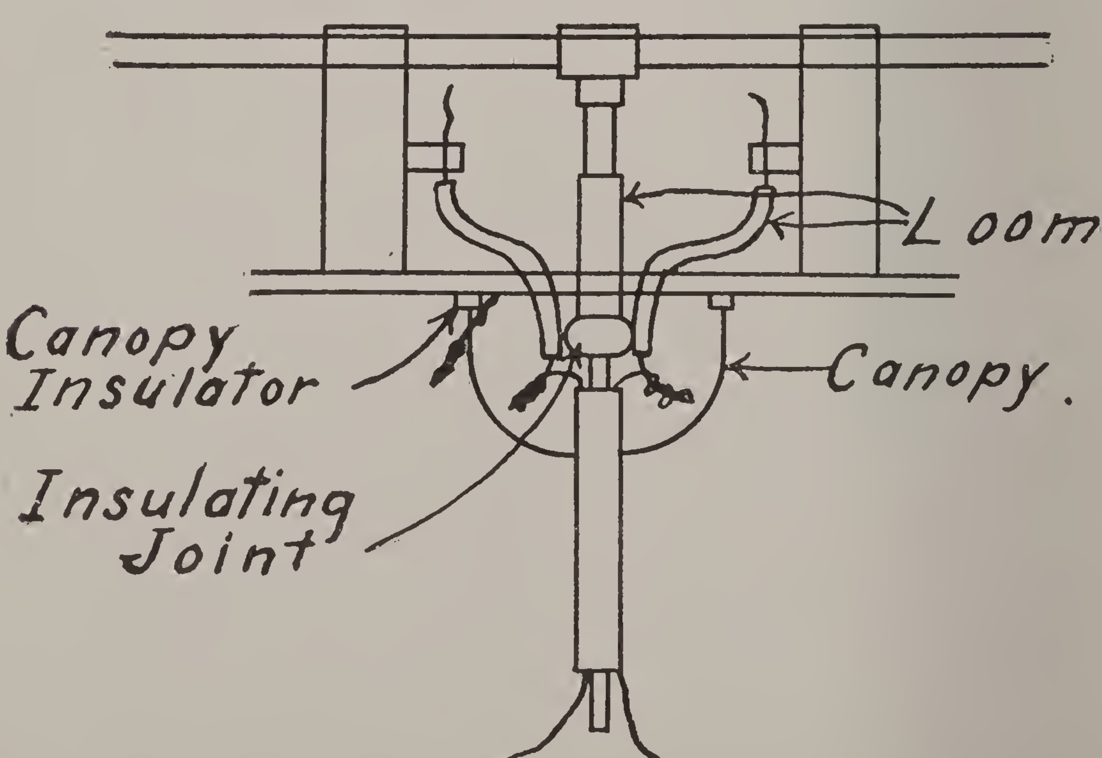


FIGURE 66.

To install a combination fixture upon concealed knob and tube work, the gas pipe leading to the fixture should be covered with tape or circular loom to insulate it from the wires, as shown in Fig. 66. An insulating joint should be used to insulate the fixture from the gas pipe, and a canopy insulator to insulate the canopy from the ceiling. The insulating joint must be of the combination fixture type, one which has an opening through it for the gas to pass. Canopy insulators are usually fiber and the one that is easiest to install is a fiber ring with a slot into which the canopy fits.

Switches.—To install a flush switch the plaster is

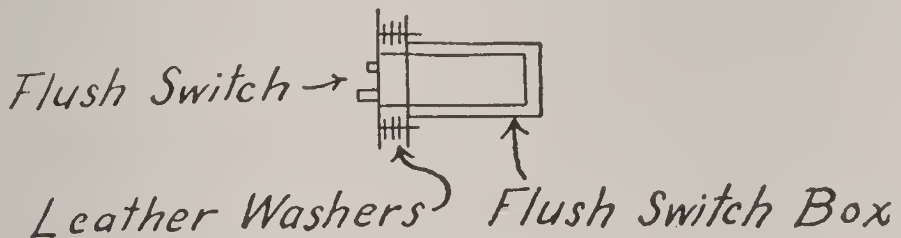


FIGURE 67.

scraped out of the box and the screw holes in the switch box at top and bottom are made accessible. The switch box is often set too deep into the plaster to permit the switch's coming flush with the surface of the plaster when it is installed against the box. Where this is the case, the usual practice is to use the long screws that come with the switch to secure it to the box, and place leather washers on the screws between the switch and the box, as shown in Fig. 67, to make it extend the desired distance. When the switch used is the white and dark button indicating type, common practice is to mount the white button above the dark one.

Other Fittings.—To install drop cords for concealed knob and tube work, apply methods used in open work.

To install knife switches and cut-outs, see Chapter IX.

Finally, to install the branch blocks, connect the wires into the same and pass the wires out of the box for the meter connection. Each of these wires should be encased in circular loom long enough to reach from the box to the meter, though with this method of insulating the wires, the distance between the two should not be more than two feet.

Final Tests.—The final tests on the system should be for short circuits and open circuits, which have been described. If any conduit is used in the installation, a test for grounds should be made as described in Chapter VI.

II. Finished House.—The code requirements for concealed knob and tube work apply to both new and old houses, though in an old house different methods are sometimes necessary to make the installation comply with the code rules.

Entering the Building.—To carry the mains into the house, the best method is to use conduit as described at the beginning of this chapter. In following this plan, however, it would probably be impractical to run the conduit down in the outside wall and the next best method is to run the conduit down on the outside of the wall and through the wall into the cellar to the cabinet box, as shown in Fig. 71, Conduit Work.

Other methods for carrying the mains into the house may be employed, but where any less secure plan is used, the main-line "cut-out" should be nearer the point of entrance than it is in the described conduit system.

Branch Circuits.—The branch circuit wires are encased in separate pieces of circular loom and are carried through the walls or partitions to the floors above. The circular loom should extend in continuous lengths from the last support below to the first support above.

Wiring under a Floor.—To wire for lights on the first floor, the floor boards on the second floor are taken up to allow the wire to be passed to the different outlets. It is not necessary to take up many boards and, if the wireman uses the methods which will be described, and is careful, the boards may be removed and replaced without marring the appearance of the floor.

The following plan of a small house (Fig. 68) shows the layout for wiring for lights on the first floor by re-

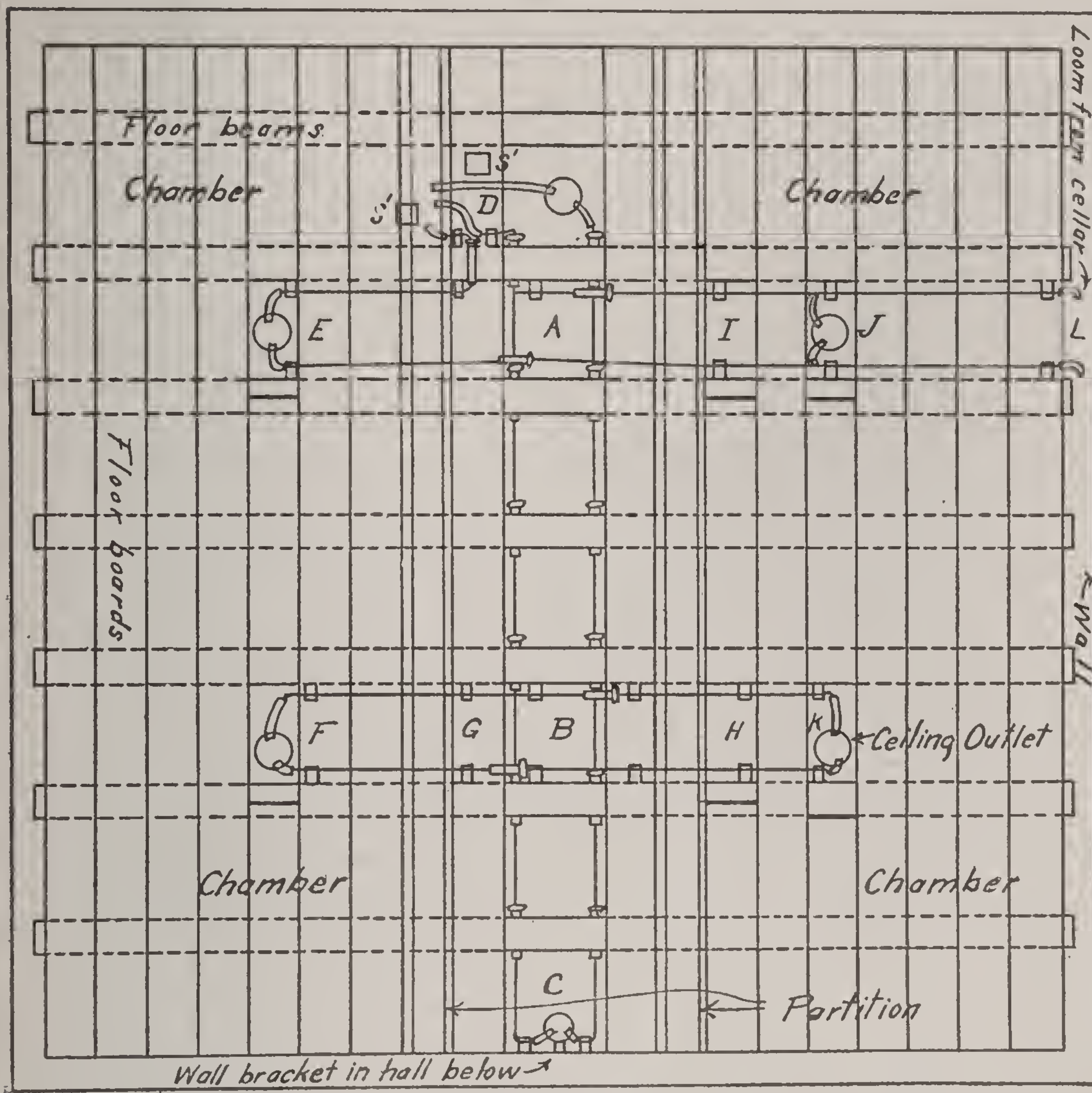


FIGURE 68.

moving the floor boards and doing the wiring on the second floor.

Pockets.—In order to bring the wires from the cellar to the second floor, it is necessary to take up a short piece of board near the wall or partition, called a pocket, at the point L. To open a pocket, find a board, if possible, that has an end near the desired place, then with a putty knife and hammer cut the tongue out on both sides of the board to the next joist. Now, by using a sharp-pointed keyhole saw and driving it with the palm of the hand into the slot made with the putty knife, at right angles to the grain, and working it carefully back and forth, it may gradually be forced entirely through the board without first boring a hole which would afterwards be unsightly. Saw the board off close to the joist. Remove the board by prying it up with a putty knife or floor chisel. After the pocket is open, the wires are inserted in the knobs and the knobs are secured to the joists with nails and leather heads.

In passing the wires under the floor boards parallel to the joists, the former practice was to encase the wires individually in circular loom and fish them through. Because of the expense of the loom, this method has been abandoned. The latest method of crossing the floor is to take up pockets every four or four and a half feet and support the wires entirely on insulators, as shown at G, H and I.

In passing the wires through the joists, it is necessary to take up two floor boards for the entire length of the cross-joist run; see A, B and C. Where there are rooms on both sides of the hall these boards are usually taken up in the hall, as shown in A.

Removing Floor Boards.—To take up these boards, cut out the tongue of the boards with a putty knife for the entire length of the run. In using a putty knife, care must be taken to select one that is not too hard and will not break too easily. Usually the cheaper ones serve the purpose better. Cut the tongue out between joists, but do not attempt to cut out the tongue at joists, as the nails will ruin the knife.

Flush Switches.—To install a flush switch with concealed work in a finished house, first take up a pocket in the floor above the place where the switch is to be installed, then drop a weight tied to a string down the partition or wall to make sure there is no obstruction between the opening above and the switch outlet. Next, locate the studding by tapping on the plaster. This is done to avoid the possibility of cutting out for a switch and finding a studding directly underneath. Having decided upon the location of the switch, bore a hole in the plaster round which the box hole is to be cut. The hole for this switch box must be cut so that the ears at top and bottom will rest on a lath or part of a lath. If this does not make the box rigid, wooden strips may be placed behind the laths and fastened to them with wood screws and the

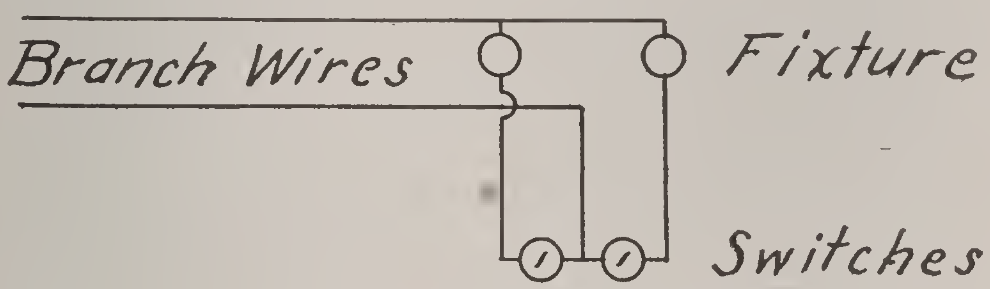


FIGURE 69.

box supported by them. The wireman should be very painstaking in cutting for a switch, to avoid making the hole so large that the switch plate will not cover it. The holes round the box, and all other holes that the wireman has made, should be filled. Plaster of Paris is usually used for this purpose, as it is very easily and quickly worked.

Fixtures.—With a ceiling outlet for a fixture, a board should be nailed to the joists above the laths to bear the weight of the fixture, as previously described in this chapter.

At the flush switch outlet, shown in Fig. 68, there are three instead of four wires carried to the two switches, thus saving one length of wire and loom to the switch. This is done by carrying one side of the line down to feed both switches, as is shown in Fig. 69.

The wiring of the other floors of the building would be done in the same manner as the one shown in Fig. 68.

After the wiring is finished, the floor boards must be left up until the electrical inspector has inspected the "roughing-in" job.

Replacing Floors.—After the installation has been approved by the inspector, the floor boards are laid, and any remaining work on the job is finished. Eight- or ten-penny finishing nails are usually used to secure the floor boards in place. To lay the board that has been taken up for a pocket, it is first necessary to nail a cleat on the

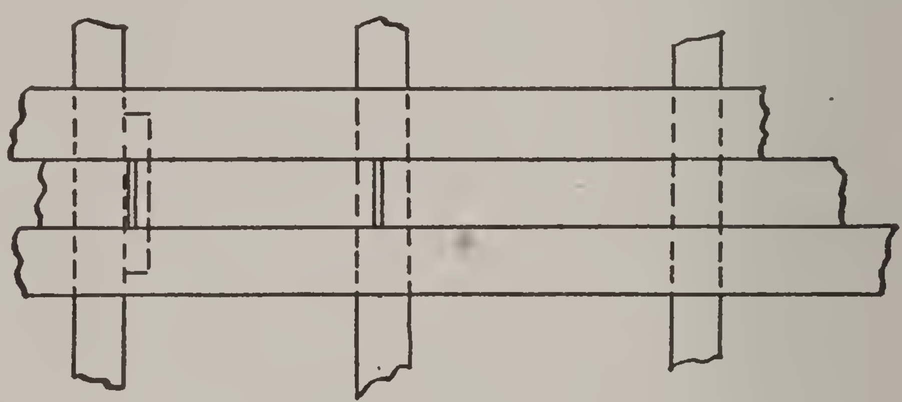


FIGURE 70.

floor joist at one end of the board to support the board, as shown in Fig. 70. The board is then nailed to the floor joist at one end and to the cleat at the other.

Final Tests.—As a precautionary measure, tests for short circuits and open circuits may be made at this time. The tests for short circuits and open circuits are described in Chapter IV. If three-point switches are used in connection with the installation, they should be tested as they are installed.

Inspection.—After the wireman has completed the installation, it is then necessary to have a final inspection made.

QUESTIONS.

I. NEW HOUSE.

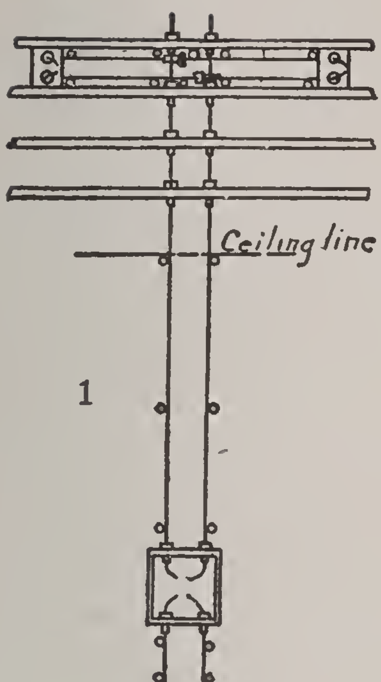
1. When should the wires be installed for concealed knob and tube work in a new house? When should the fittings be installed?
2. What distance must be kept between the wires when run on knobs?
3. Explain a plan for making a service entrance with rigid conduit.
4. How must porcelain tubes that carry wires be placed in floor joists?
5. Explain a labor-saving plan for drilling holes in floor joists.
6. Explain a quick method of threading the wires through joists and inserting the tubes in the holes.
7. What additional insulation is required where wires pass concealed from one floor to another?
8. Explain two plans for securing split knobs.
9. How should wires be run parallel to studding joists or rafters?
10. Explain the method of making an outlet for a drop cord.
11. Explain the method of making an outlet for (a) straight electric fixture; (b) combination fixture.
12. Explain the method of installing a switch box for a flush switch.
13. When should gang switch boxes be used?
14. What type of outlet box is commonly used for a baseboard or floor outlet?
15. Why should insulating sockets be used in cellars or damp places?
16. Explain the method of installing a straight electric fixture on a concealed knob and tube work job.

II. FINISHED HOUSE.

1. Describe a plan for carrying service wires into a house with exposed conduit.

2. How are the wires usually insulated in the walls or partitions where they pass from one floor to another?
3. How are the ceiling outlets on a floor wired for?
4. Describe a method of taking up a board for a pocket in a floor.
5. How are the wires insulated when they pass parallel to joists?
6. Explain the method of taking up floor boards for cross-joist wiring.
7. Explain the method of installing a flush switch in a finished house.
8. How is a ceiling fixture outlet made?
9. How may the number of wires to be carried to a gang switch outlet be reduced?
10. What must be done to make the wiring accessible to the inspector?
11. How should the end of a floor board be supported when it does not rest on a joist?

EXERCISES FOR PRACTICE.



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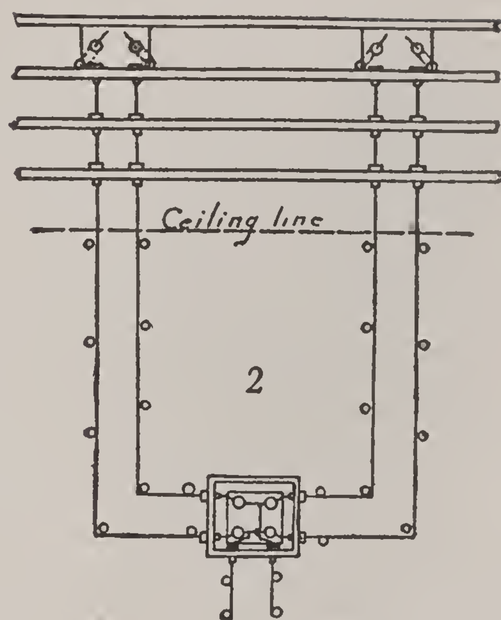

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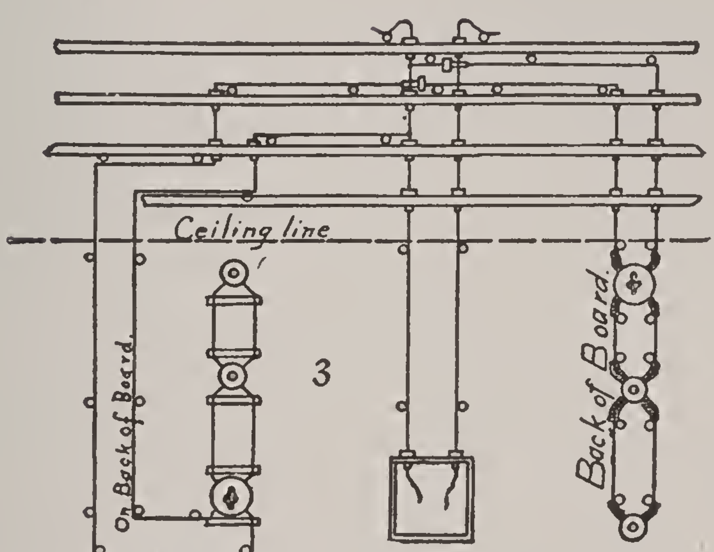

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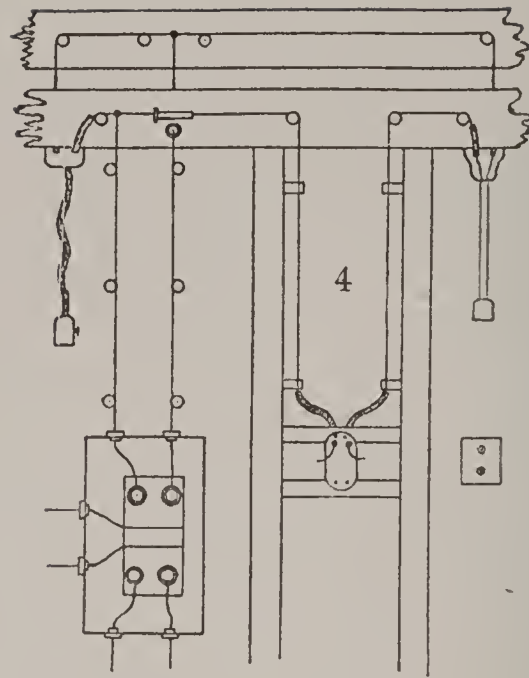
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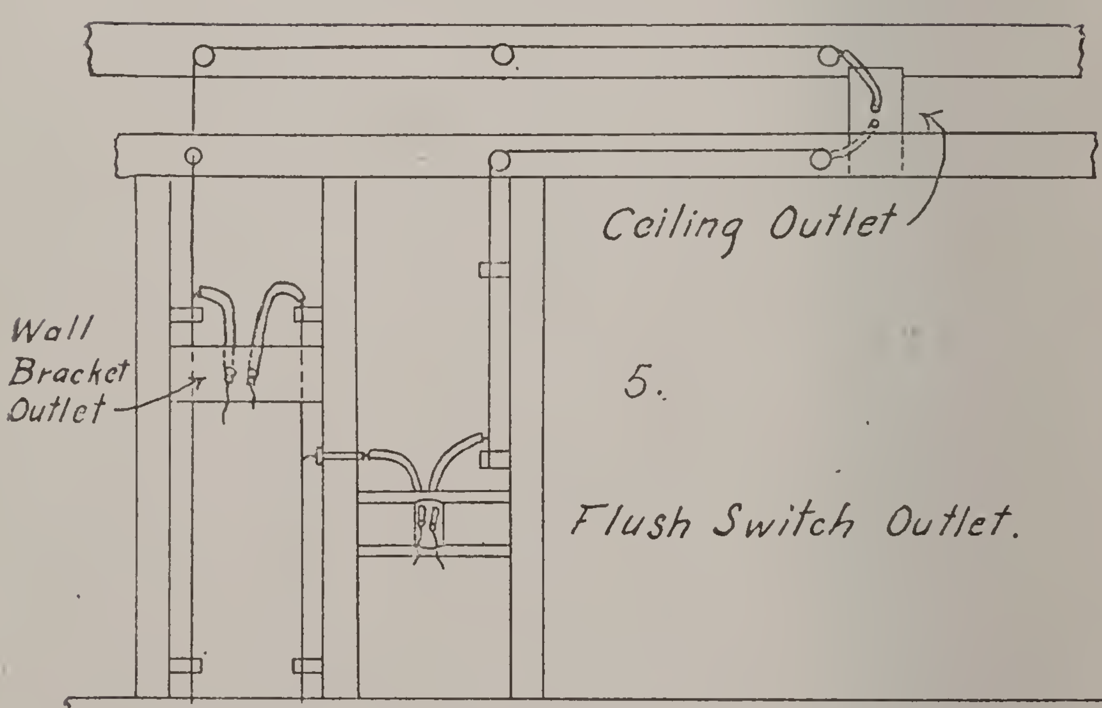

Ceiling Outlet
Wall Bracket Outlet
5.
Flush Switch Outlet.

CHAPTER VI

RIGID CONDUIT

Rigid conduit is a specially constructed iron pipe, which usually has a protective coating of enamel on both outside and inside. The external diameter is the same as for gas or water pipe of the same so-called size, but, owing to the thinness of the wall of the conduit, its internal diameter is a little greater. Conduits are similar to gas and water pipes, but in no case are wires approved when run in these instead of conduit.

Rigid conduit wiring has the following advantages for most purposes: first, because the wires are protected from mechanical injury by the rigid metal of the conduit; second, should a short circuit or an arc occur in the conduit, there is little likelihood of its spreading to the building; third, if the wires show defects between the outlet boxes, it is an easy matter to draw them out and insert others.

Concealed and Open Conduit.—The conduit may be either concealed or exposed. Where appearances are important, the conduit should be concealed. The method of carrying the mains into the house in this case is shown in Fig. 55 in Chapter V.

Entering the Building.—The following arrangement (Fig. 71) is a standard method of carrying the mains into a house with exposed conduit wiring.

As shown in Fig. 71, the conduit should have a bend of almost 180 degrees to form what is called a "drip loop" to prevent water from passing down the pipe. The fitting used where the wires pass into the conduit has the trade name of A13 condulet. Each letter and figure of the code of marking has a meaning in regard to the size, style and number of holes in the condulet. In this case, A signifies a straight type, 1 means a ½-inch con-

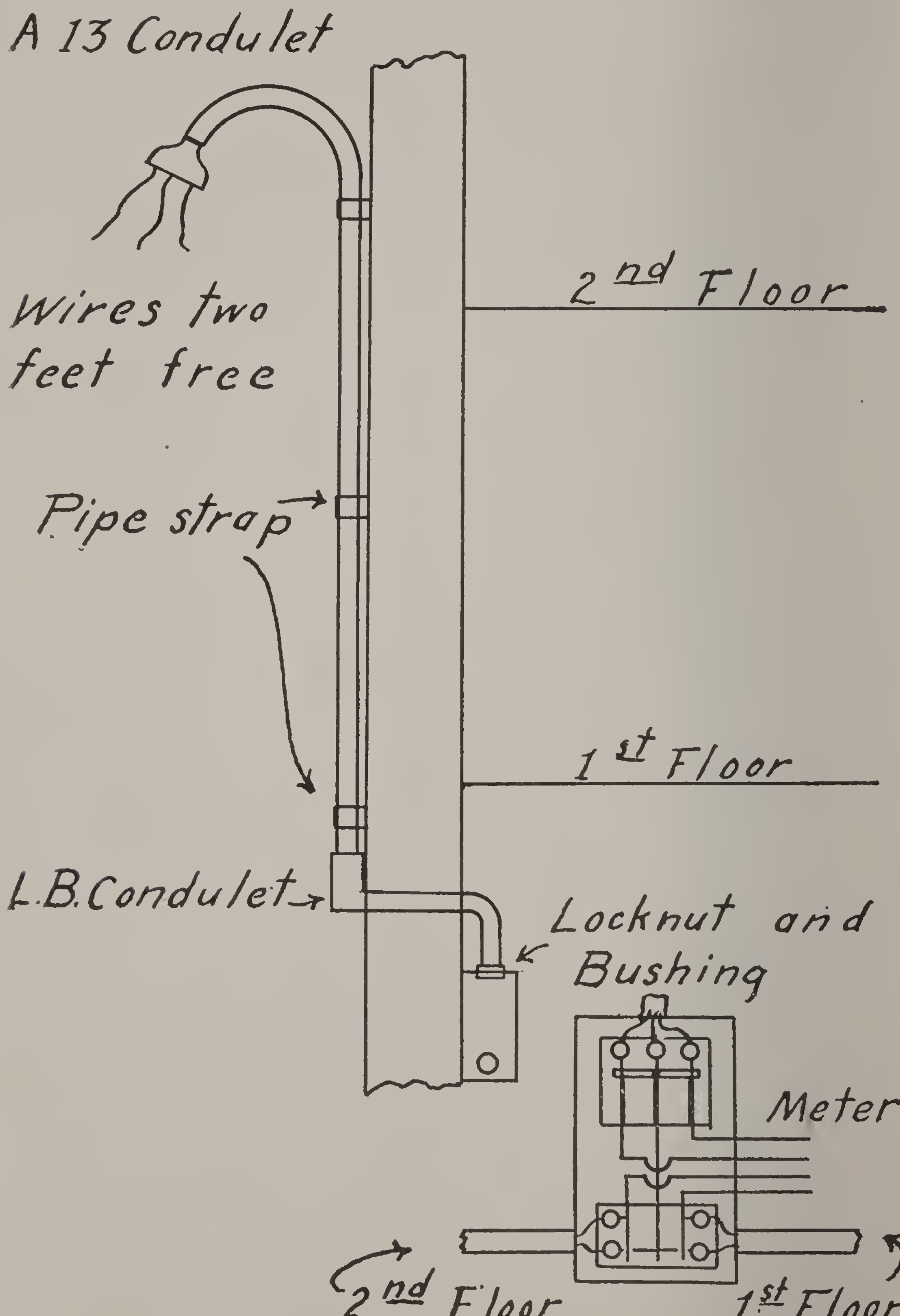


FIGURE 71.

duit, and 3 means that the porcelain bushing has three holes. Any supply house catalogue will enable the wireman to select the condulet for the particular place desired and also furnish further information in regard to the system of marking. It is recommended that the service condulet extend out at least one foot from the building and, where practical, the condulet should be at least twenty-five feet above the ground.

Pipe straps are placed on the pipe as a support, as shown in Fig. 71. They should be secured to wooden surfaces with wood screws and placed near enough together to make the conduit secure. Good practice is to place them not more than six feet apart on straight runs.

It would be less expensive to make a bend in the conduit where it passes into the house instead of using the L condulet shown in the figure; however, the condulet makes a neater job. The cover for the condulet is a closed or blank cover; that is, it is of metal and has no openings for wires. Outside work is considered the same as a damp place, and extra precautions should be taken to keep water out of the pipe. The cover of the L condulet used should have a rubber gasket placed under it to exclude moisture. The pipe threads, where they pass into couplings, condulets, etc., should be painted with white lead or similar substance that will make the joint water-tight.

Where the service pipe passes into the cabinet box, the plan used at all pipe-to-box connections should be employed. The pipe should have threads cut on it with a standard stock and die, and the burrs on the inside of the pipe should be removed with a reamer or round file. After being fitted with a lock nut, the pipe is installed in the hole of the box. Then a bushing is screwed upon the end of the pipe inside the box, and the lock nut and bushing are screwed together until they grip the box firmly. This not only makes a good job mechanically, but insures good electrical contact between the conduit and the box, which is necessary for grounding the metal conduit of the system.

Wiring for Meter.—The wires for the meter may be carried out of the box through one large porcelain box bushing or through separate bushings and may be passed in circular loom to the meter; or, if the run is long, it is advisable to use a conduit and pass the wires through a condulet at the end of the conduit.

The conduits, shown at the bottom of the box, after being threaded and secured into the box with lock nuts and bushings, as previously described, are carried to the outlets throughout the building.

Tools Used.—The following is a list of tools necessary for installing conduit:

1 pipe vise
1 stock with a set of dies
2 pipe wrenches
1 pipe reamer or round file
1 pipe cutter or hack saw
1 pipe bender
1 ratchet brace
1 $\frac{7}{8}$-inch bit
1 steel fish tape, 50 to 75 feet long
2 screw drivers, large and small size
1 compass saw, 14-16 inches long
1 claw hammer
1 gasoline or alcohol blowtorch
1 pair 7-inch pliers
1 $\frac{1}{2}$-inch wood chisel
1 $\frac{11}{64}$-inch twist drill
1 can of oil for dies

Preparing Conduit for Use.—One of the first things to be done in starting a conduit job is to find a suitable and convenient place to install the pipe vise. The preparing of the conduit for use on the job is done at the vise; therefore it should be handy. As the work progresses, lengths of conduit must be cut and threaded to pass into the boxes, couplings, condulets, etc.

In being cut, a piece of conduit is placed in the pipe vise and is cut off with a wheel pipe cutter or hack saw. For a job of ordinary size, the hack saw is usually preferred, because it is lighter to carry. When a hack saw is used, care should be taken to avoid passing the saw too rapidly through the pipe, as the heat thus generated is apt to ruin the blade.

After the pipe is cut, the next step is to ream the sharp burrs left from the cutting, out of the inside of the end of the conduit. This is done so that the sharp edges of the burr will not injure the insulation of the wires when they are pulled into the conduit. With the pipe still in the vise, threads are cut on it with the stock and dies. As the threads are being cut, oil, preferably lard oil, must be applied to lubricate and preserve the temper of the dies. The threads should extend on the pipe from $\frac{7}{8}$ inch to 1 inch; however, the wireman is soon able to judge from experience the number of threads it is necessary to cut.

Bending Conduit.—There are several methods of making bends in rigid conduit, three of which will be described. One is with a regulation wheel bender, which has attached to a lever a wheel which rolls the conduit round a surface of the desired curve. This device is too heavy to warrant its use on small jobs.

Another method, a temporary makeshift, however, is to bend the pipe with the aid of a stationary bender. Among the various plans to be employed, the following are the most practical. One is to bore a hole in a piece of timber a little larger than the pipe end and, using the length of pipe as a lever, bend it into the required curve. Another application of the same method is to fasten two cleats to a surface and make the bend, as shown in Fig. 72.

In making a bend in this manner it is wise to bend the pipe only a small amount at a time, and to pass the pipe backward or forward through the cleats until the required curve is obtained.

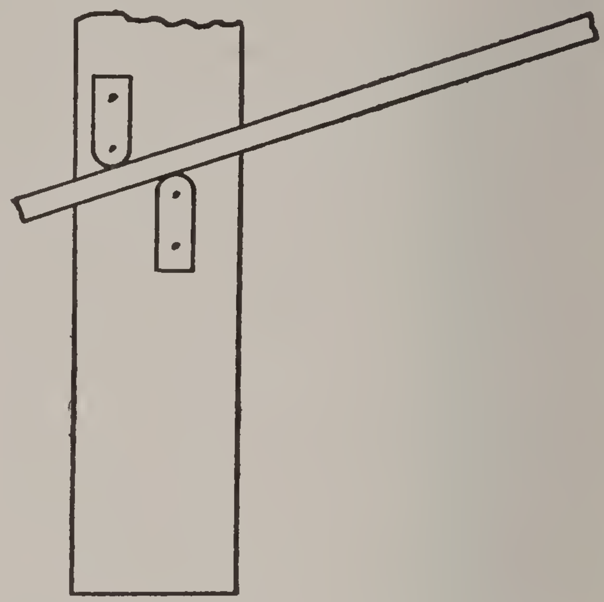


FIGURE 72.

The third method, the one most used, is to use a tee-pipe bender, commonly called a "Hickey." They are made in different sizes for different-sized pipe, but the

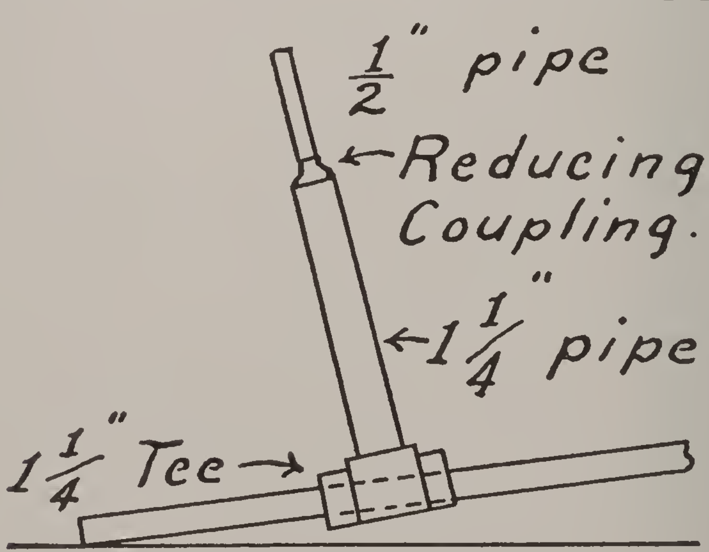


FIGURE 73.

one used generally for bending $\frac{1}{2}$-inch pipe is made by screwing a piece of $1\frac{1}{4}$-inch pipe into a $1\frac{1}{4}$-inch tee, as shown in Fig. 73. To make the handle of the bender fit the hand better a short piece of $\frac{1}{2}$-inch pipe may be screwed to the end of the $1\frac{1}{4}$-inch pipe with a $1\frac{1}{4}$-inch to $\frac{1}{2}$-inch reducing coupling as shown in Fig. 73.

To make a bend by this method the conduit to be bent is passed through the tee, as shown in Fig. 73, and is

FIGURE 74.

placed on the floor. Standing with both feet on the conduit, the operator pulls or pushes on the handle of the bender to make the desired bend. The entire bend should not be made at one pull, as the sharp edges of the tee will kink the conduit, but short pulls should be

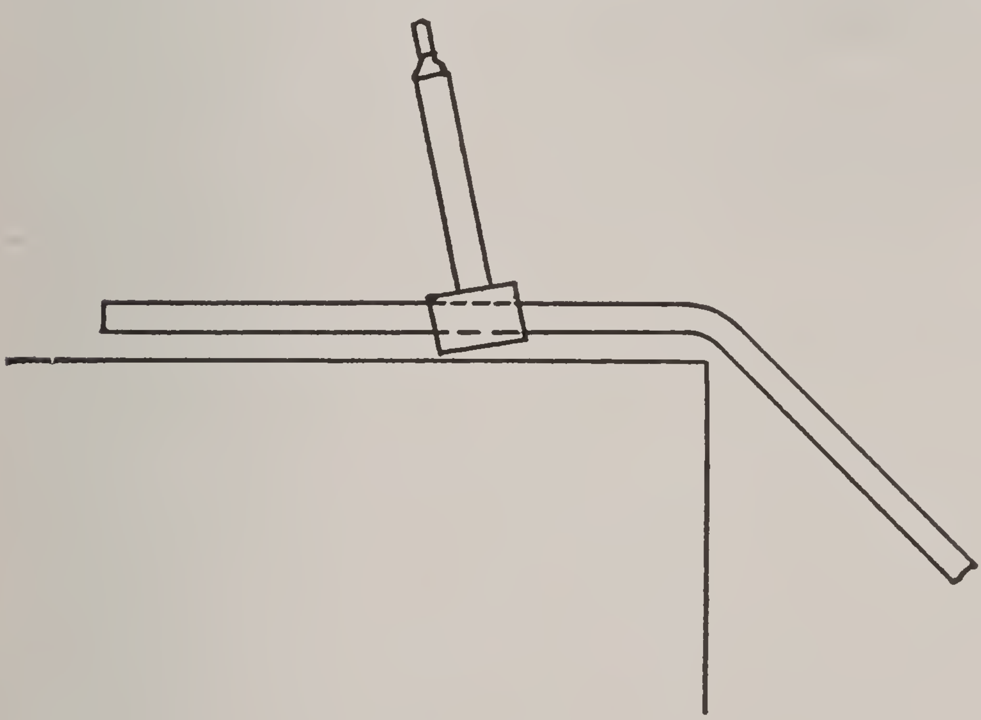


FIGURE 75.

made on the bender, slipping it along between pulls to avoid kinking. The Code states that the radius of the inner curve of the bend must not be less than $3\frac{1}{2}$ inches, though, as a general rule, it is only necessary to see that no kinks are made in the conduit. As to the number of bends, the Code specifies that the conduit shall not have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlet not being counted.

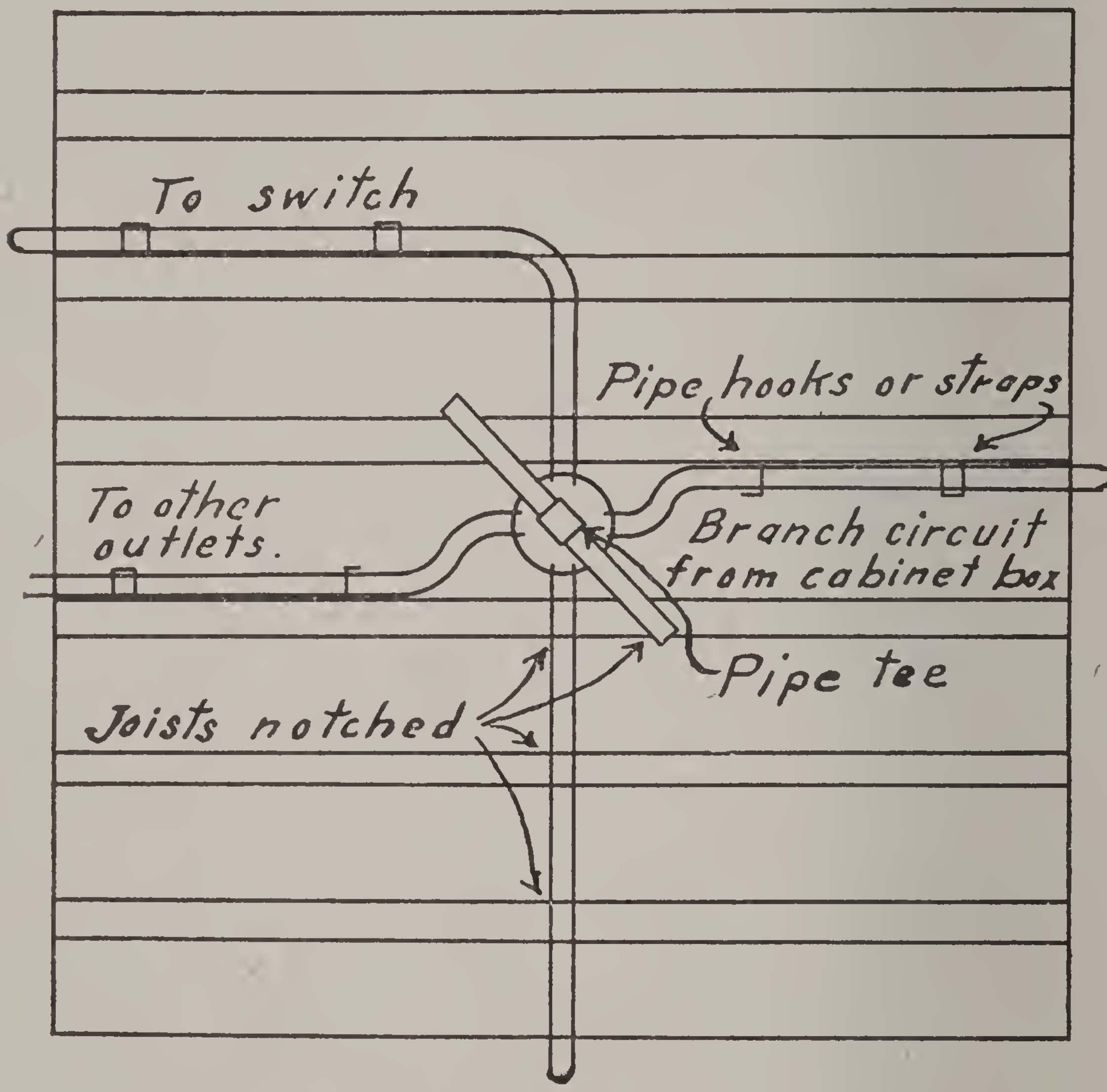


FIGURE 76.

Offsets.—Where the conduit passes from one plane to another, or around an obstruction, a bend is required, called an offset, as shown in Fig. 74.

This requires bending the conduit in opposite directions and making the bends at different places. The first bend may be made with the tee bender in the usual way, and the second bend is made most easily with the bender, by allowing the curve of the conduit to extend down from an abrupt step, such as from a bench or porch, and then bending the conduit up in the usual way, on the higher plane, as shown in Fig. 75.

The methods of doing concealed and open-conduit wiring are very similar, but each has some rules and methods that differ. In open conduit wiring the conduit is installed, the wires drawn in, and the fittings installed immediately. In concealed conduit work the conduit is installed during the process of construction of the build-

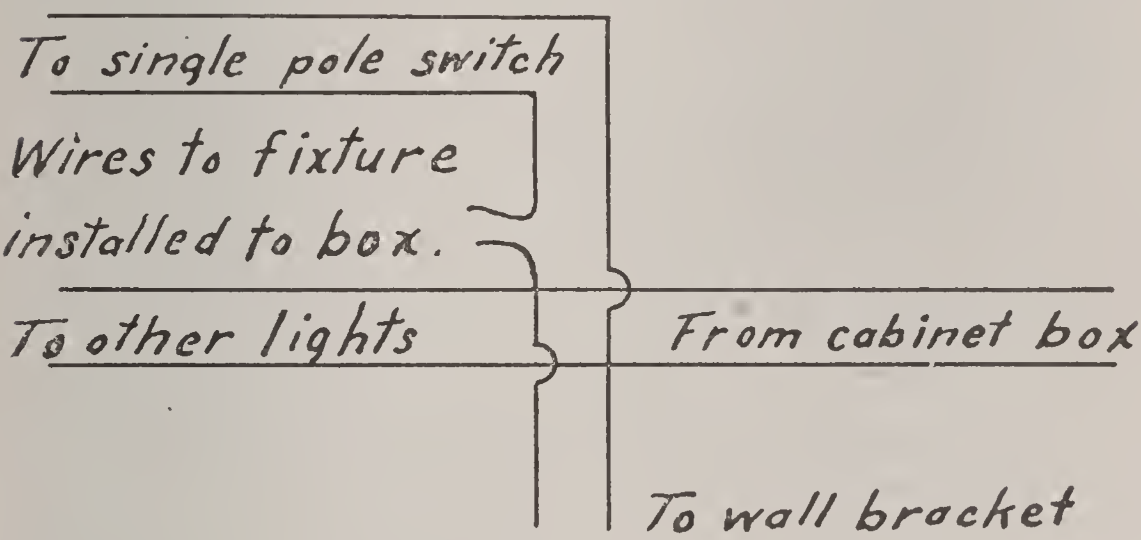


FIGURE 77.

ing, but the wires must not be fished in nor the fittings installed until the building is completed.

The preceding diagram (Fig. 76) shows the method of wiring one room with concealed conduit in a house of frame construction.

When the conduit passes parallel to the floor joists, it is secured to the side of the same with pipe straps or pipe hooks.

When the conduit passes across the joists, the joists are notched with a saw and wood chisel, and the conduit is placed so that it lies just below the upper surface of the joists. Where supports are required for the conduit in these notches pipe hooks are usually used.

Outlet.—The outlet or junction box usually used in conduit work has five punchings in the bottom that may be knocked out for pipes to be inserted in the holes. These punchings for knock-outs are placed one in the center and four round the edge. The center hole is meant for the gas pipe to pass through, or for some other support to be placed in. The wireman will probably save himself considerable inconvenience if he makes it a rule never to pass a conduit through the center hole in the bottom of the box. The conduits that pass into the box must be threaded, and held firmly in place with a lock nut on the outside and a bushing on the inside of the box.

Supporting Outlet Boxes and Fixtures.—There are several methods of supporting the outlet boxes and the fixtures attached to them. When the conduits that enter the bottom of the box do not interfere, the box is sometimes secured to a wooden board nailed between the studding or joists. If a fixture is to be hung to this box a small fitting called a fixture stud should be secured to the bottom of the box before it is installed. This fitting is similar to a crowfoot with the exception that the nipple is male instead of female. The fitting is secured to the bottom of the box with short bolts called stove bolts. When properly installed this makes an excellent support for a fixture.

When an outlet box is installed in connection with a gas outlet, the box is held in place by securing it to the gas pipe with a fitting called a "dead ground box support." The fitting is placed over the center hole, and secured to the bottom of the box with stove bolts. After passing the box and the box support up round the pipe to the desired height, a screw in the side of the box support is tightened, causing a nut to be pulled in against the pipe that locks box and pipe together. The fixture is of course hung from the gas pipe, which extends through the box.

If an outlet has no gas pipe passing into it, gas pipe or conduit is sometimes installed similarly to a gas pipe outlet, as shown in Fig. 78.

Three short pieces of pipe are screwed into the tee. The pipe passing down to the outlet has threads cut on it for three or four inches, which allow the box to be held in place with a lock nut on each side of it, and also furnish threads on the pipe to support the fixture. Two other applications of this method may be made. One is to use instead of a tee, a fitting called a box hanger loop, which has the vertical pipe threaded into it, while the horizontal pipe simply slides through. The other

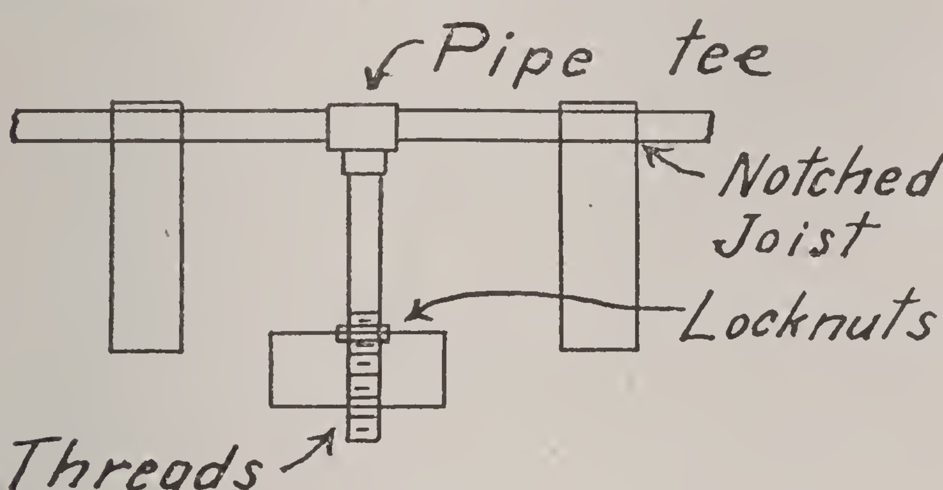


FIGURE 78.

is to use the "dead ground box support" to support the box instead of using the two lock nut method previously described. As to the space to be allowed for lath and plaster to make the front of the box come flush with the same, the usual practice is to install the box so that its front edge will extend three-fourths of an inch from the front side of the joists.

In installing boxes in concealed conduit work, it must be remembered that all outlet, junction, and switch boxes must be accessible after the building is completed. That is, they must not be installed where the inside of the box cannot be reached for fishing the wires, making joints, etc.

The "BB" flush switch boxes used with conduit are installed in the same manner as the "AA" flush switch box described in Chapter V.

Outlet boxes, installed for wall brackets, are usually secured to a board nailed behind them, and have a fixture stem fastened to the center of the box to support the fixture.

Damp Places.—Where conduit wiring is done in damp places such as cellars, damp rooms, bathrooms and outside places, the joints at the couplings, condulets, and similar fittings should be made water-tight with white or

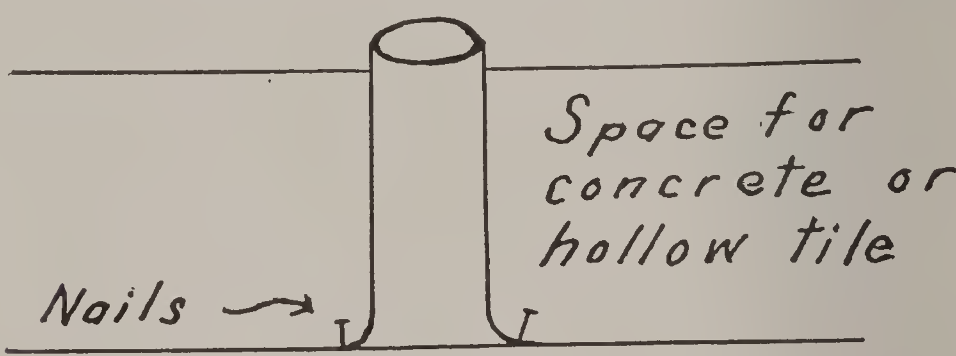


FIGURE 79.

red lead. The sockets and receptacles installed in these places should be porcelain or other insulating material for a protection to life, as described in detail on page 93.

Fireproof Buildings.—In buildings of fireproof construction where the sub-floor is to be concrete or hollow tile much time will be saved if the wireman will install outlet forms where the outlets are to be located. These forms, which are usually made of galvanized iron, are tubular in shape, and have an internal diameter of about 4½ inches.

These forms are nailed to the framework, as shown in Fig. 79, before the concrete is poured or the tile is laid into place. After the sub-floor is laid, the iron tube is then taken out, leaving through the floor a neat hole in which the outlet box and conduits may readily be installed. The conduits between outlets in a building of fireproof construction are commonly laid on the sub-floor over which the main floor is placed.

Grounding Conduit Systems.—The metal of a conduit system must be grounded to a gas pipe, water pipe, or other suitable ground before the job is inspected. A ground must be made to a gas pipe only on the street side of the meter, while the ground to the water pipe may be made anywhere in the building. Where there is neither gas nor water pipe in the building, a pipe or rod may be driven into the ground and the ground wire attached to it. The surface of the ground pipe must have the scale or paint removed to insure good contact. As

GROUND CLAMP.

the conductor to ground, usually No. 10 B & S gauge wire is used, which is large enough for grounding conduits when the largest wire in the system is not larger than No. 0 B & S gauge. The connection of the conduit and pipe is made with ground clamps, which may be purchased for any size of pipe.

In the selection of the location for grounding it must be remembered that the ground clamps and the ground wire must be visible after the building is completed. Usual practice for grounding a conduit is to select a place in the building where the conduit and water pipe run near each other. The pipes are scraped clean of any insulating material where the ground clamps are to be placed. The wire is then cut long enough to reach between clamps, and its ends are soldered into the lugs of the clamps, after which the wire and clamps are secured in place. The wire is soldered into the lugs before they are installed. Heat should never be applied to the lug while it is connected to the conduit.

If the distance between lugs is short, the wire may be passed from one to the other without supports; however, with greater lengths, the wire must be treated as a conductor of the system and passed on insulators or in rigid conduit.

Usually one ground connection is all that is necessary for an installation. Whenever there are two separate parts to a conduit system that are not connected, or cannot readily be connected, each part must be grounded.

FIGURE 80.

When a wooden cabinet box is used or the metal contact broken by some other means, the conduits are sometimes bonded together with ground clamps and No. 10 copper wire.

After the conduit and the boxes are installed and the system is grounded, the work should be discontinued until the building is completed.

Fishing Wires through Conduits.—One of the first things to be done when time comes to resume work on the installation is to fish the wires through the conduits. For this purpose a steel fish tape is usually employed, although, for short runs, duplex wire may be passed through without the aid of the "snake," as it is sometimes called.

To fish the wires through the conduit with fish tape the end of the tape is bent back to form a hook, so that it will readily pass the bends in the conduit. The tape is then pushed through from one outlet to another, and wires are secured to the tape and pulled through. In securing the wires to the tape the joint should be made as small as possible, so that it will pass easily through the conduit. The usual practice is to make a hook in the end of the tape, scrape the insulation from the ends of the wires, and tie them into the hook, as shown in Fig. 80.

Friction tape is then wrapped over the joint and powdered talcum or soapstone is applied to the tape to make it pull more easily. For long pulls in hot weather, because the insulating compound comes through the braid of the wire, it is frequently found necessary to use soapstone, or some other powdered lubricant, on the wires before they are pulled into the conduit. At least six inches of free wire should be left at every outlet and junction box for tapping on with other wires, and for making joints.

Sometimes the wireman may find that the steel fish tape will not pass through the conduit, due to a combination of a long run, some short turns, and possibly a loose-fitting coupling. To get the tape through, use an additional tape, with a hook turned on the end; pass it into the distant end of the conduit, hook it into the end of the first tape inserted, and pull it through. If care is taken to screw the ends of the conduit till they meet in the coupling there is little likelihood of trouble in fishing the tape through.

The National Electrical Code specifies the maximum number and sizes of wires that may be run in different sized conduits. The tables taken from the Code will be found in the Appendix.

Except in the case of stage pocket and border circuits (in theatre work) the same conduit must not contain more than four two-wire or three three-wire circuits of the same system except by special permission from the inspection department. (See Appendix Tables for Conduit.)

Wires of different systems, that is an alternating current and a direct current system or from any two different supply systems, must never be run in the same conduits. This is to make inspection and maintenance easier and to prevent trouble on one system being communicated to the other.

The joints made at outlet and junction boxes are usually made with the rat-tail splice, which is described in Chapter II. The joints are then soldered and taped with rubber and friction tape, are pushed back into the box, and the cover is secured in place.

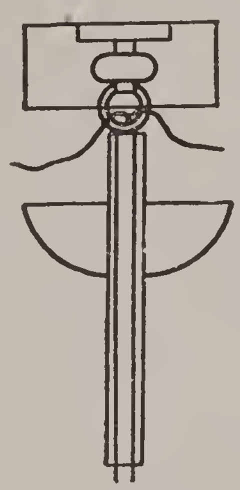


FIGURE 81.

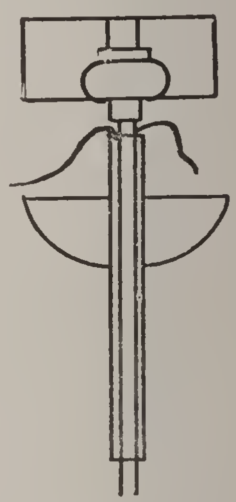


FIGURE 82.

Installing Fixtures.—To install drop cords on a conduit system the round outlet box called an 8B box is usually employed. It has a cover, called a bushed cover, which has a hole drilled in it and threaded for a $\frac{3}{8}$-inch hard-rubber bushing. The drop cord is passed through the bushing, and the wires are knotted and taped to form a support for the cord, as described fully in Chapter IV. The drop cord wires are joined to the branch wires in the box by the fixture splice explained in Chapter II.

To attach a straight electric fixture to a box in conduit work an insulating joint must first be screwed to the stem or pipe. On this is screwed a fitting called a "hickey," through which the wires pass to the inside of the fixture, as shown in Fig. 81.

For combination fixtures an insulating joint is used that has an opening for the gas to pass through. It is merely an insulating coupling between the gas pipe and the fixture. The fixture wires are passed down between the casing and the gas pipe of the fixture. The canopy, with either type of fixture, should be insulated from the ceiling, as described on page 96.

The final tests on the installation should be for short circuits, open circuits and grounds. The methods for testing for short circuits and open circuits were described on pages 69, 70, and 95.

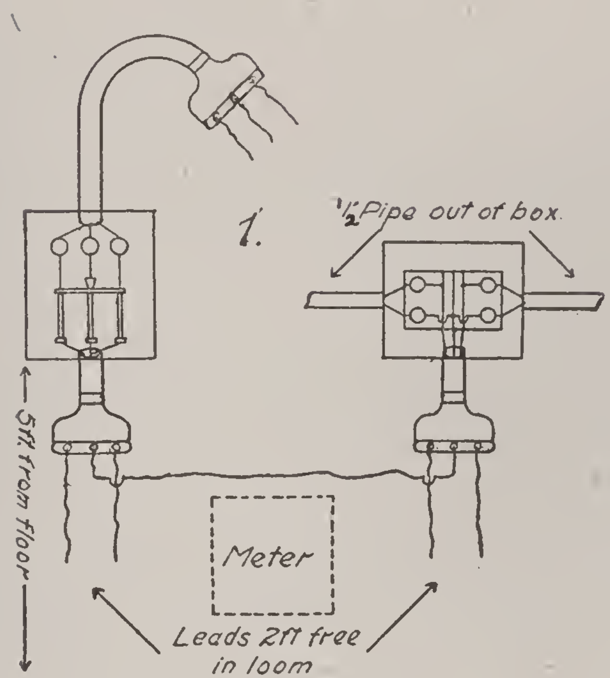
Test.—To test for a ground, secure one wire from the magneto or bell and battery to a clean bright place on the pipe or box, and touch the other wire to one wire leading out of the cabinet box. If, when the crank of the magneto is turned, the bells ring, there is a ground on that wire; but if the bells do not ring, the wire is free from grounds. Each wire leading from the cabinet box should be tested in this manner. If there are any switches that open any of the wires on the branch circuits, they should be closed to make a reliable test.

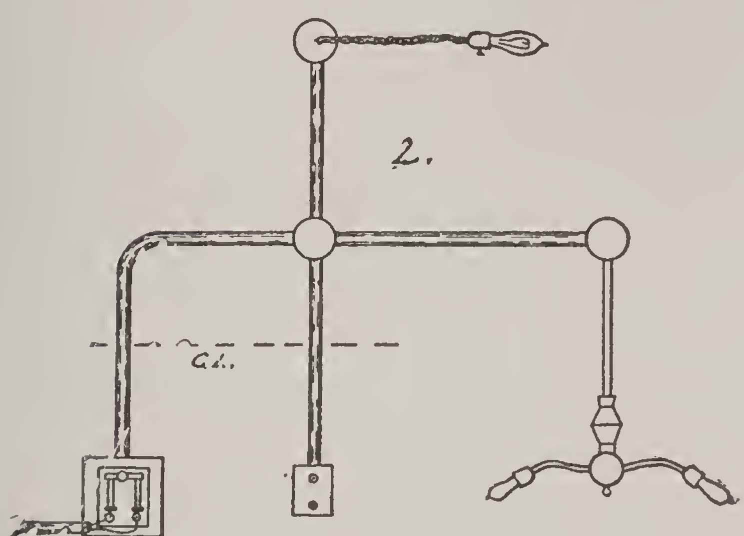
QUESTIONS.

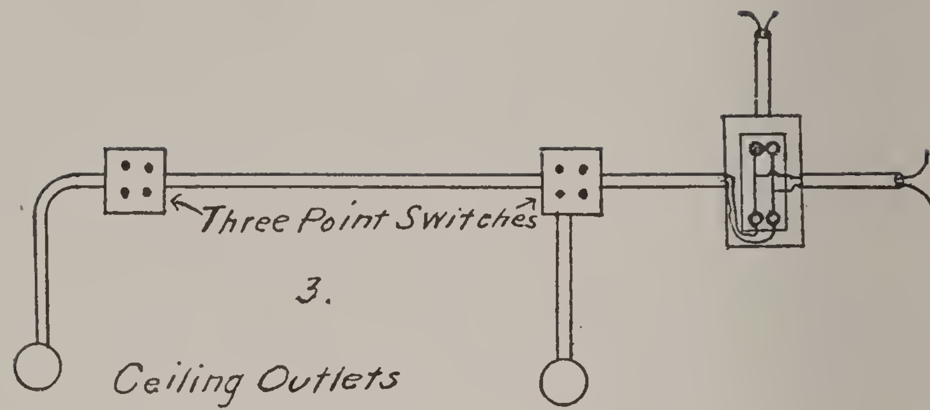
1. What advantages are to be gained by using rigid conduit?
2. Explain in detail the best method of bringing the service into a building by rigid conduit.
3. What distance should be allowed between supports for rigid conduit?
4. Explain in detail the method of making rigid conduit water-tight in damp places.
5. Explain the method commonly employed for securing rigid conduit in an outlet box.
6. How are the wires passed out of a switch or cabinet box to the meter?
7. Make a list of the tools necessary for installing conduit.
8. In using a hack saw for cutting lengths of conduit, what should be avoided?

9. How are the burrs reamed out of a conduit, and why is this necessary?
10. In the use of a stock and die, what should be done to preserve the temper of the dies?
11. Describe three methods of bending rigid conduit.
12. How many quarter bends does the code allow between outlets?
13. How is an offset made in rigid conduit?
14. When may the wires be drawn and the fittings installed:
    (a) In open conduit wiring?
    (b) In concealed conduit wiring?
15. Explain the method of passing concealed rigid conduit across and parallel to joists in a building of frame construction.
16. For what should the center knock-out hole in a round outlet box be reserved?
17. Explain two methods of installing outlet boxes for straight electric fixtures.
18. Explain the method of installing an outlet box for a combination fixture.
19. Describe in detail the use of forms for outlet boxes in fireproof buildings.
20. How are outlet boxes installed for wall brackets?
21. Explain in detail the method of grounding the metal of a conduit system.
22. How are wires drawn through the conduit?
23. Explain the method of installing a straight electric fixture to an outlet box.
24. Explain the method of installing a combination fixture on a conduit system.
25. Explain the method of testing a conduit system with a magneto for short circuits, open circuits, and grounds.

Exercises for Practice.







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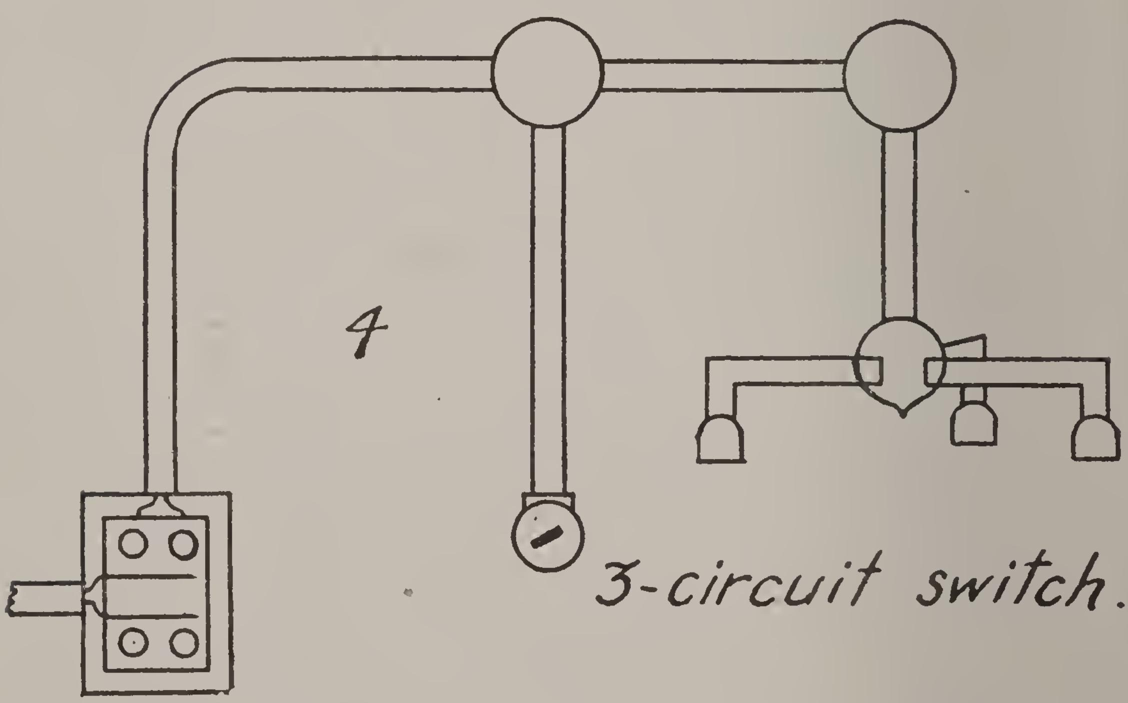

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CHAPTER VII

ARMORED CABLE AND METAL MOLDING

I. **Armored Cable.**—Armored cable consists of two spiral windings of metal tape round a diameter of about half an inch, which forms a flexible protection for the wires. Usually wiring is done with a cable called "BX," in which the wires are inserted. This "BX" may be purchased loaded with different numbers and sizes of wires. The one commonly used contains two No. 14 wires. The ordinary "BX" may be used in places that are not considered damp; for damp rooms, cellars and outside places a cable is required that has a lead sheath between the wires and the armor, known as "BXL." Where conditions will permit the use of rigid conduit, however, "BX" is usually installed instead of "BXL," because the expense is somewhat less.

Armored cable is used simply as a substitute for rigid conduit in concealed wiring, and the general rules and methods for conduit wiring apply also to wiring with armored cable. Switch outlets and junction boxes, fixture supports and ground clamps are of the same type, and are installed in the same manner as in a rigid conduit system.

Use of "BX" in Finished House.—Though wiring with armored cable is done in new houses, around machinery, etc., it is more commonly used for wiring finished or old houses. In wiring a finished house with "BX" the main wires are usually brought into the cabinet box in exposed rigid conduit, as shown in the chapter on conduit work. From this cabinet box the branch circuits are run with "BX," with the exception of those that are run in the cellar. Where it is necessary to wire across the cellar before the cable is fished up to lights above, the common practice is to install a junction box where the "BX" leaves the cellar, and to run conduit over to it from the cabinet box. The box, of course, serves as a coupling between the conduit and the cable, and furnishes a place to join the wires.

For runs of cable of ordinary length in walls, partitions, or between floors, supports are not required, the cables being simply fished through and installed at the outlet boxes. Where the cable is run open, pipe straps to fit the cable should be used generously to make a neat appearance.

Securing Cable to Boxes.—When a cable passes into

FIGURE 83.

a cabinet, outlet, or junction box, the cable must be firmly secured to the box for grounding purposes, and some kind of bushing must be provided to protect the wires from the sharp edges of the cable. Outlet boxes may be purchased that have a combined bushing for the wires and clamp for the cable. At cabinet boxes, and where the ordinary conduit boxes are used, a cable-to-box connection is required. The connection, which is called a "Hood" connector, has some method of clamping the cable, and a lock nut and shoulder to clamp the box, as shown in Fig. 83.

Cutting Armored Cable.—In preparing the "BX" to be inserted into the "Hood" connector and into the box, about seven inches of the cable must be cut off, to allow wire for joints in the box. There are several cable cutters on the market for this purpose. However, a hack saw seems to be a more popular tool for this purpose. To cut the cable with a hack saw, it should be bent over something and, while held firmly, the outer armor is sawed partly through, and is then broken by bending the cable back and forth at the joint. This done, the outer sheathing may be twisted toward the end of the cable, and the inner layer may be cut in the same manner. In using a hack saw to cut a cable care must be taken to prevent the hack saw's passing through the cable and cutting the wires. Also, unless the cable is held securely, the cable may turn and twist the hack-saw blade into two pieces. For this purpose hack-saw blades with flexible backs may be secured, and they are considered less expensive because of their lasting qualities.

The cables must be continuous from outlet to outlet. If the cable between outlet boxes is to be spliced, it is necessary to install a junction box into which to pass the cables, so that the joints in the box will be accessible.

Passing Cable under Floors.—"BX" is considered superior to concealed knob and tube work for wiring an old house, because the cable gives better protection to the wires and less work is required to install it. In passing the cable across floor joists, it is only necessary to take up one floor board instead of the two required for concealed knob and tube work. When the cable is passed parallel to floor joists no supports are required; therefore it is only necessary to take up pockets at the outlets and near the walls or partitions where the cable is to be fished down or up.

Where the cable passes across joists, the cable must not be laid in notches cut in the joists, as is done for conduit, because the nails from the floor boards are likely to pass into the cable and short-circuit the wires. Holes should be bored into the joists and the cable threaded through. For boring holes a $\frac{3}{4}$-inch bit should be used, and preferably one with a long shank.

In fishing the cable parallel to joists under a floor invisible obstructions may be encountered. A flashlight and a small hand mirror will assist the wireman in making an examination of the obstruction.

When a mirror is held in the opening of the floor at the proper angle, it will reflect the light from the flashlight to the obstruction.

Passing Cable through Partitions.—In fishing cables through walls or partitions, braces between the studding may be encountered. It usually requires considerable work to pass through or by such a brace, and a good

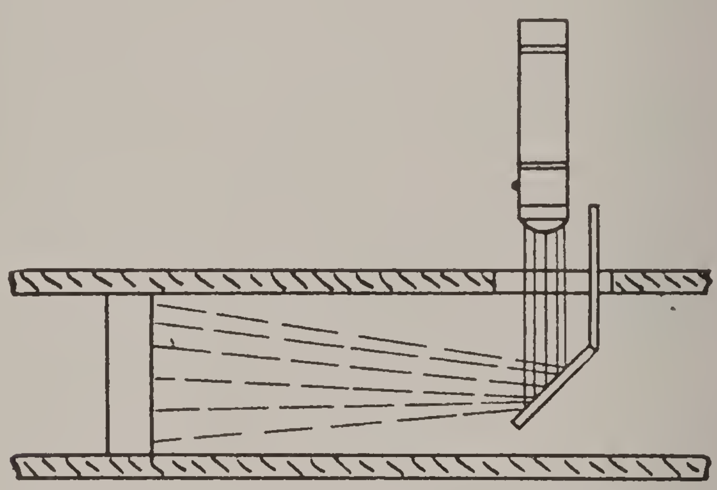


FIGURE 84.

plan is to select another location for the outlet, where the passage for the cables has no obstruction. However, when it is necessary to locate the outlet at this particular place, the cable may be carried to the box by one of the two following methods. In the application of the first method, the writer has in mind a place where there was a cross-brace in a partition, three or four feet above the first floor of the house. In this particular case a $\frac{3}{8}$-inch gas pipe about 4 feet long was used as an extension to a long bit. One end was fastened to the bit and the other end was made square with a hammer and screwed in the brace. The bit was then inserted from the cellar into the passage, and a hole was bored into the cross-piece. Where conditions will permit, this is an excellent method of making a passage through. The other method of passing the cable through the partition or wall is to pass the cable around the brace. If the obstruction is on the outside wall of a weather-boarded house, it is only necessary to remove three or four of the boards, and with a wood chisel cut a notch in the brace through which the cable may be passed. The exact height of the obstruction may be found by fishing a weight tied to a string from above. Where it is not practicable to reach the brace from the outside, it may be necessary to cut the plaster and pass the cable around the obstruction. If the wall is of white plaster it is only necessary to cut out the plaster opposite the brace, pass the cable around, and fill the hole with plaster of Paris. Where the wall is papered one or two plans for removing the paper may be used. If water will not fade the color of the paper a cross is cut in the paper at the place where the opening must be made. Then, with a sponge or rag, warm water is applied to the paper to loosen the paste. This will allow the four pieces of paper to be opened, as shown in Fig. 85, so that the plaster may be removed.

After the cable has been passed around the brace, the hole is filled with plaster of Paris, and the paper is pasted back into place.

Where paper may be secured to match the paper on the walls, the paper over the hole is usually cut out with the plaster, and when the hole is filled new paper is inserted over the hole.

Fixture Outlets.—As previously stated in this chapter, the outlets for concealed "BX" wiring are made in a similar manner to those for concealed conduit. However, a different type of outlet box is usually employed for fixture outlets. Instead of installing the deep "8B" box, used with rigid conduit, a shallow box of the same diameter and about ½ inch deep is used. The plaster is cut out at the outlet to fit the box, so that the bottom of the box rests against the laths. This position of the box allows the canopy of the fixture, when installed, to fit neatly against the plaster.

In a finished house that has been wired with armored cable, one inspection must be made before the floor boards are nailed into place.

Open armored cable wiring is seldom done except in connection with machinery. The cable, being small and flexible, is better for passing around the curves on the machinery to the motors and lights.

FIGURE 85.

II. Metal Molding.—Metal molding is generally used in connection with conduit, and it was probably designed and manufactured as a substitute for rigid conduit. When properly installed, it makes a much neater job than does open rigid conduit, therefore it is generally used instead of exposed conduit, where appearances are a consideration.

Metal molding is like wooden molding, in that it has a backing and a capping. The backing is secured to the surface wired over, and the capping is usually held to the backing by a spring catch arrangement.

Wires in Molding.—The Code specifies that metal molding must not be used for circuits requiring more than 1,320 watts of energy; therefore, wiring with metal molding is confined almost entirely to branch circuits. Even branch circuits are seldom run with metal molding entirely, as conduit is always required in passing through floors, and is sometimes required in passing through partitions. There are several types of molding on the market, but the one generally used has a backing over which a capping is snapped, as shown in Fig. 86.

The molding comes in ten-foot lengths, and the backing has holes in it about 2 feet apart, through which the screws are passed which hold it in place.

If the molding is received with the backing and capping snapped together, the most satisfactory way to separate them is to hook the screw hole in the backing over a nail and pull off the capping.

The backing is first installed and the wires are laid in

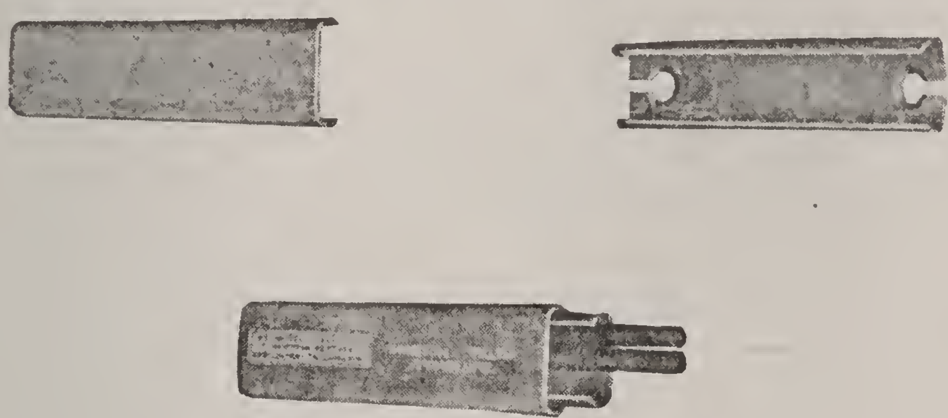


FIGURE 86.

place, and the capping is then snapped over the backing.

Cutting.—Where it is necessary to cut the lengths of molding, it is cut with a hack saw, a three-cornered file, or a "hand shear." In cutting the molding with a hack saw, a fine-tooth blade known as a tube saw should be used. A fine-tooth blade does not catch or stall in the molding, which allows it to work easier, with less liability of its breaking. By using care, the cutting may be done with the ordinary hack-saw blade, but fewer blades will be broken if a blade with a tempered edge and flexible back is used.

To cut the molding with a three-cornered file, each side of the piece of backing is marked deeply with the file, and is then broken into two pieces. A short piece of capping is sometimes used as a straight-edge guide for the file, as shown in Fig. 87A.

The hand shear has a cutter attached to a lever, which cuts off the backing or capping at one stroke, as shown in Fig. 87B. This is the fastest method and is used on large installations.

Supports.—Metal molding is supported by screws or bolts passed through countersunk screw holes in the base

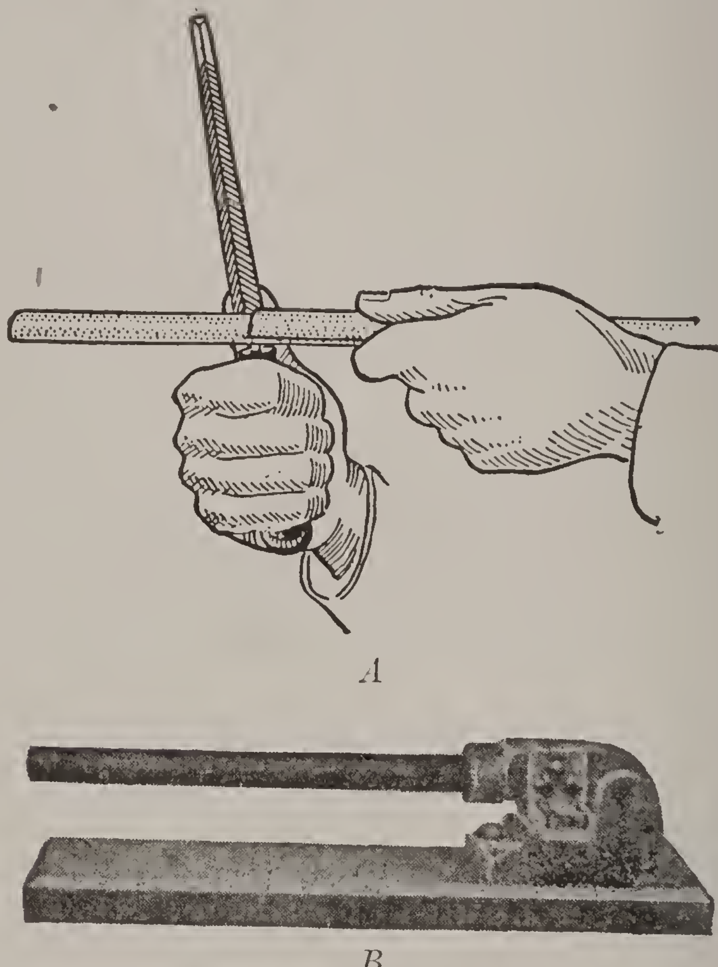


FIGURE 87.

of the backing. Different surfaces require different supports and some of these will be suggested.

For wood surfaces, use a 1-inch No. 8 flat-head wood screw, as shown in Fig. 88A.

In lath and plaster, use a $1\frac{1}{4}$-inch No. 8 flat-head wood screw, as shown in Fig. 88B. This holds securely if the screw goes into the lath, but where it misses the lath some other means of support must be arranged. If the molding runs across laths another hole may be drilled in the backing about a half-inch away, which should cause the screw to enter the center of the lath. In drilling this hole, as well as any other holes in the molding for screws, it must be remembered that all screw holes must be countersunk, so that the screw heads will lie flush with the inner backing surface.

If the metal molding runs parallel to the laths and it is impossible to hit a lath with a screw, the next best thing is to drill a larger hole in the plaster and insert a toggle bolt, as shown in Figs. 88D and E.

On metal ceilings a $\frac{1}{8}$-inch cone-head toggle bolt, 2 inches long, is suggested, as shown in Fig. 88C.

Where the plaster is laid on a metal lath, a T-head toggle bolt, size $\frac{1}{8}$ inch, $2\frac{1}{2}$ inches long, as shown in Fig. 88D, is suggested.

On plastered tile surfaces either of the two toggle bolts mentioned may be used.

On brick or concrete two methods of supporting the molding are suggested, for either of which it is necessary to drill a hole with a star drill or cold chisel. The most common method is to drive a wooden plug into the hole and saw it off flush with the surface; then the screw that holds the backing is driven into this plug. Another method, which is considered superior by some, is to use an expansive screw shield or expansive bolt, as shown in Fig. 88F.

Bonding Lengths.—In the installation of metal molding it must be remembered that the lengths of molding must be connected together at all joints and fittings for the purpose of grounding the metal for the entire system. For this purpose base couplings, as shown in Fig. 89A, may be secured. Still the following method, which is approved, may be of value to the wireman. Cut the sides of the backing off so that its base will lie upon the other length of backing and allow the screw holes to come together, as shown in Fig. 89C. Then a wood screw, passed through the two holes and into the surface wired over, will bond the two lengths of molding together.

Use of Important Fittings.—The adjacent lengths of

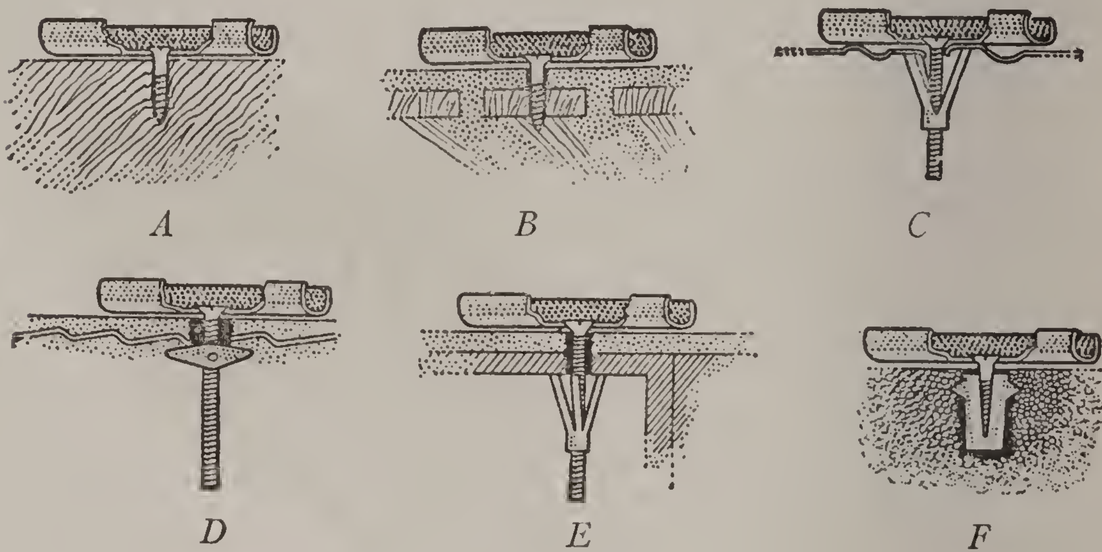


FIGURE 88.

molding must be electrically connected through fittings as well as through couplings, and for this purpose the fittings that are to be inserted in a line of molding must have metal bases with small machine screws, under which the ends of the backing may be secured.

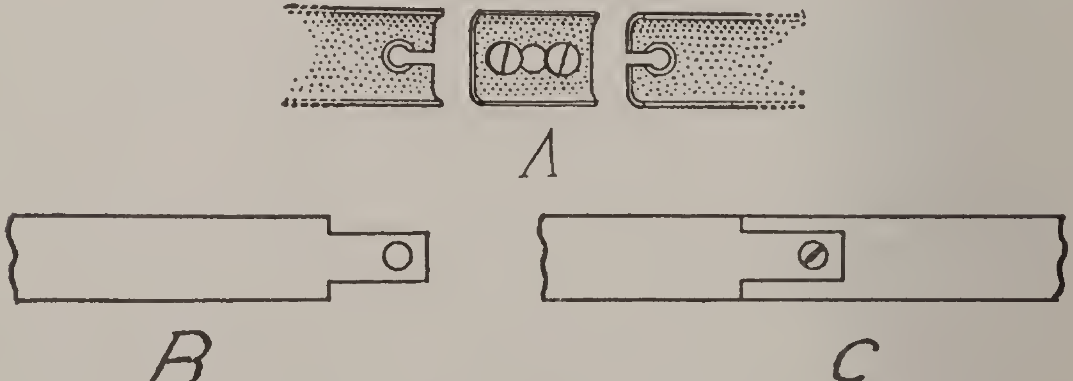


FIGURE 89.

Where it is necessary to run one or two lines of metal molding at right angles from a point in an existing or proposed run, a metal molding tee or cross, as shown in Fig. 90, must be installed at this point. These tees and crosses not only serve as a neat connection between the runs of molding, but also serve as a junction box where joints in the wires may be made. The 90-degree flat elbow, shown in Fig. 90, is for making right-

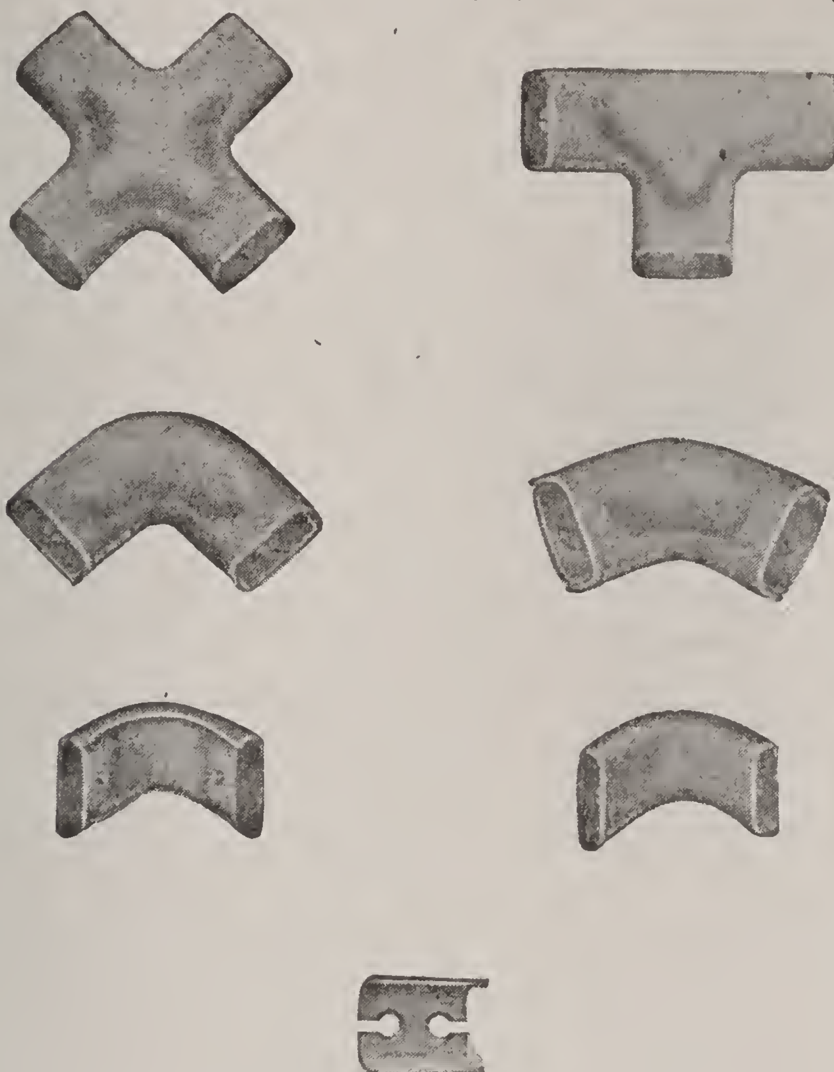


FIGURE 90.

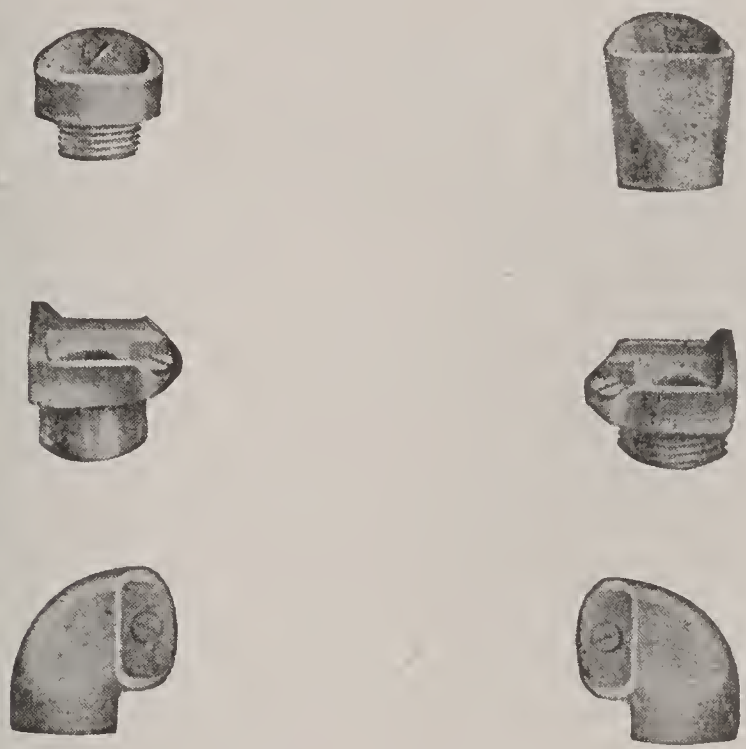
angle turns on flat surfaces with metal molding. The cover of this elbow has also a recess like the tee and cross, which allows room for making joints in the wires. The remaining elbows shown in Fig. 90 will be of much assistance to the wireman in making neat turns. However, joints in the wires should not be made in them, as there is not room for proper taping.

Mitering.—Instead of using the elbows for making turns metal molding is sometimes mitered with a hack saw to form the desired angle. A "V"-shaped piece is cut out of the inner side of the turn of the backing, leaving the outer side as the hinge of the turn. The capping is then cut to fit the backing and laid into place after the wires are installed. The mitered turn must make good electrical connection between the two lengths of molding and, where this conductivity is not maintained with a part of the backing left intact, a short metal strip should lie under the backing and be secured in place by wood screws that pass through both the backing and the strip. Mitered turns, though not used often, have an advantage in that they fit the corners of right-angle turns more snugly than do the purchased elbows. For curved surfaces, or other places where it is desirable, metal molding may be bent. By using care it may be bent for any radius down to 4½ inches. Bends should be made with the backing and capping snapped together, but before the wires are installed.

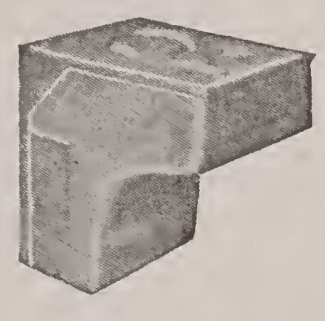
On irregular surfaces there is sometimes a tendency for the backing and capping to spring apart. With the type of molding shown the capping may be made to grip the backing more firmly by hammering on the sides of the capping with a wood mallet. Where this is not sufficient the backing and capping may be held together with the strap clamps shown in Fig. 92, which may be bought for this purpose.

Passing through Floors.—In a metal molding installation, where the circuit is to be passed through the floor, it is necessary to use a piece of ½-inch rigid conduit. Usual practice is to use a length of pipe which extends through the floor and for three inches above the floor, though where the mechanical strength of the molding above is considered inadequate the conduit must extend five feet above the floor. In connecting molding to conduit or iron boxes the couplings shown in Fig. 91A are usually employed, though the corner box shown in Fig. 91B is also often very useful for this purpose.

Passing through Partitions.—In passing through partitions the rigid conduit, required for passing through floors, may be omitted, and the molding may be passed



A



B

FIGURE 91.

directly through, providing the partition is dry and the molding is in continuous length, with no joint or coupling within the partition. In passing through partitions that are considered damp rigid conduit is required; nevertheless, this requirement seldom needs to be enforced, as metal molding is not approved for damp places.

After the backing is installed the wires may then be laid into place and the capping snapped on. Single-braid, rubber-covered wire is approved, and is usually used as the conductor. For alternating current systems the two or more wires of the circuit must be installed in the same molding, and this is also recommended for direct current systems. The Code does not limit the number of wires

FIGURE 92.

to be placed in a line of metal molding. If single-braid wire is used, where it is desirable as many as four wires may be placed in the molding.

Joints or splices made in the wires may be made at tees, crosses, or other fittings, but should not be made in the molding between fittings. All joints must, as with other metallic systems, be soldered and taped with both rubber and friction tape.

Grounding System.—To ground a metal molding system use a ground clamp similar to Fig. 92, and apply the rules and methods for grounding conduit.

Final Tests.—The tests on the installation should be for short circuits, open circuits, and grounds, as described for conduit work, on pages 69, 70, 95, and 123.

As with all open work installations, the request for inspection should be made after the job is finished.

QUESTIONS.

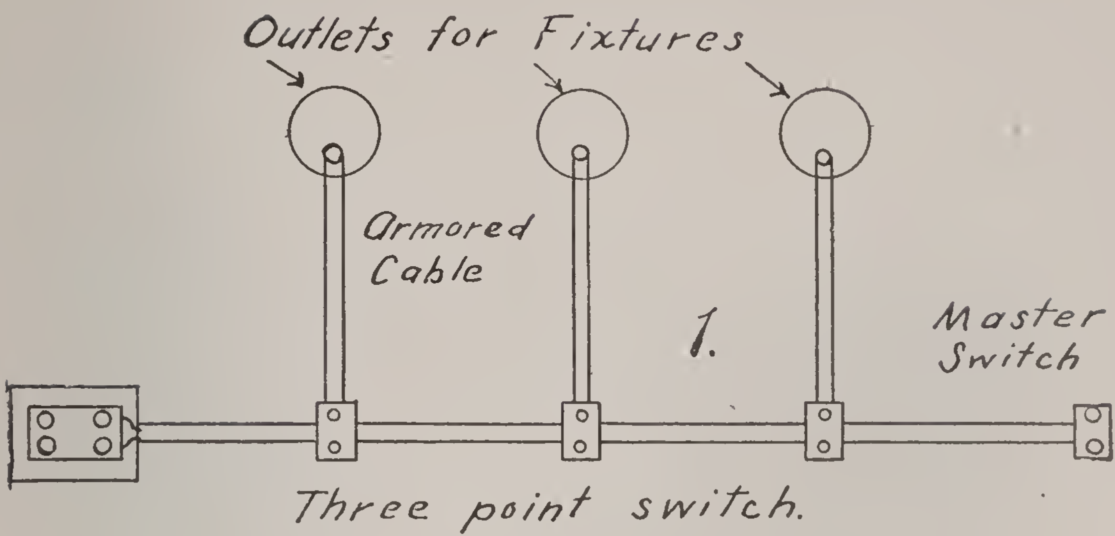
I. ARMORED CABLE.

1. What is armored cable?
2. Where is "BX" approved, and where is "BXL" required?
3. For what class of wiring is armored cable adapted?
4. How is armored cable held in place where it passes into iron boxes?
5. How should you cut off lengths of armored cable?
6. In concealed armored cable wiring, how is the cable carried:
   (a) Parallel with joists?
   (b) Across floor joists?
7. Explain a good plan for examining obstructions between joists under floors.
8. Describe in detail two methods of passing a cable through or around a brace in a partition.
9. In wiring for ceiling outlets with armored cable in a finished house, what type of box should be used and how should it be installed?
10. For this class of wiring, when should requests for inspection be made?

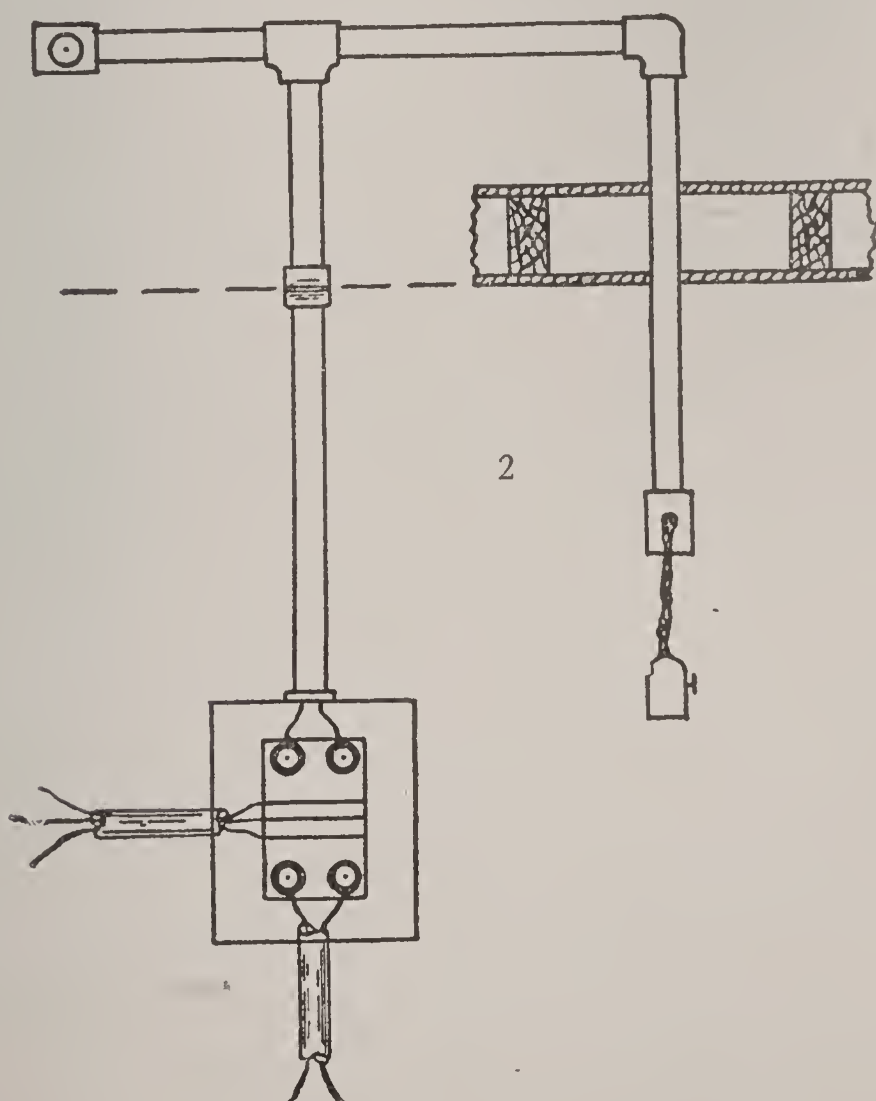
II. METAL MOLDING.

1. How many watts of power are permitted by the code on a circuit run in metal molding?
2. What is the order of installing the backing, capping, and wires?
3. What precautions should be taken in cutting metal molding with a hack saw?
4. How are lengths of metal molding cut with a three-cornered file?
5. How should metal molding be supported on the following surfaces:
   (a) Wood surfaces? (b) Plaster over wood laths?
   (c) Plaster over metal lath? (d) Plaster over tile?
   (e) Metal ceiling? (f) Brick or concrete?

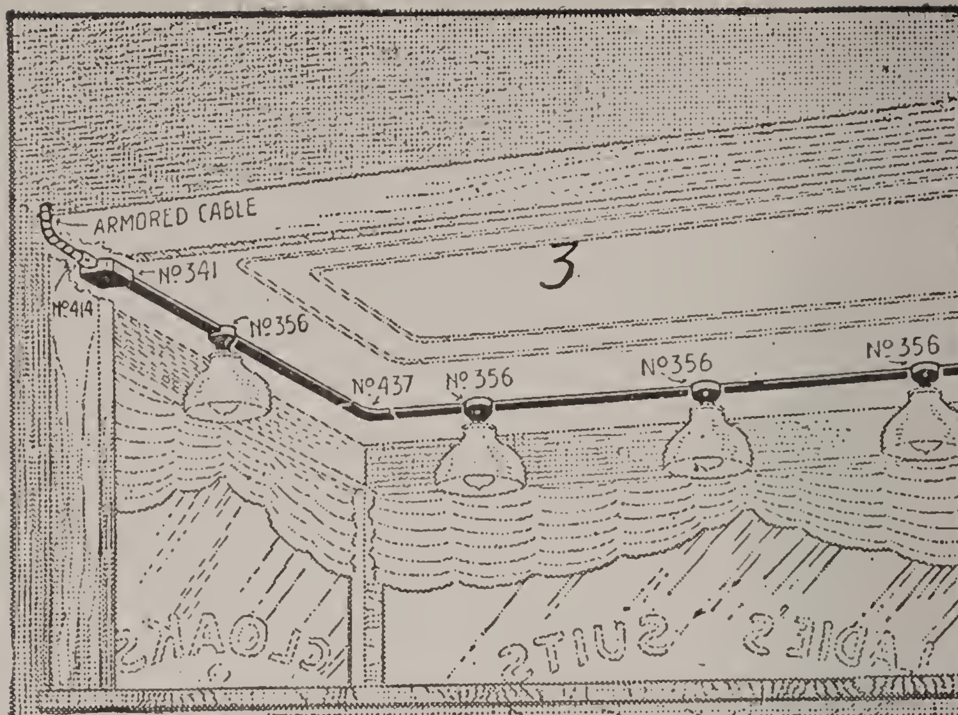
6. Explain two methods of bonding lengths of metal molding together.
7. Explain the method of taking a tap circuit from a run of metal molding.
8. Explain the method of mitering metal molding instead of using the elbow fittings.
9. How should bends in metal molding be made?
10. How are the backing and capping held together where there is a tendency to spring apart?
11. How is metal molding carried through: (a) Floors? (b) Partitions?
12. What kind of insulated wire must be used in metal molding?
13. Should metal molding be grounded?
14. What tests should be made on a metal molding installation?

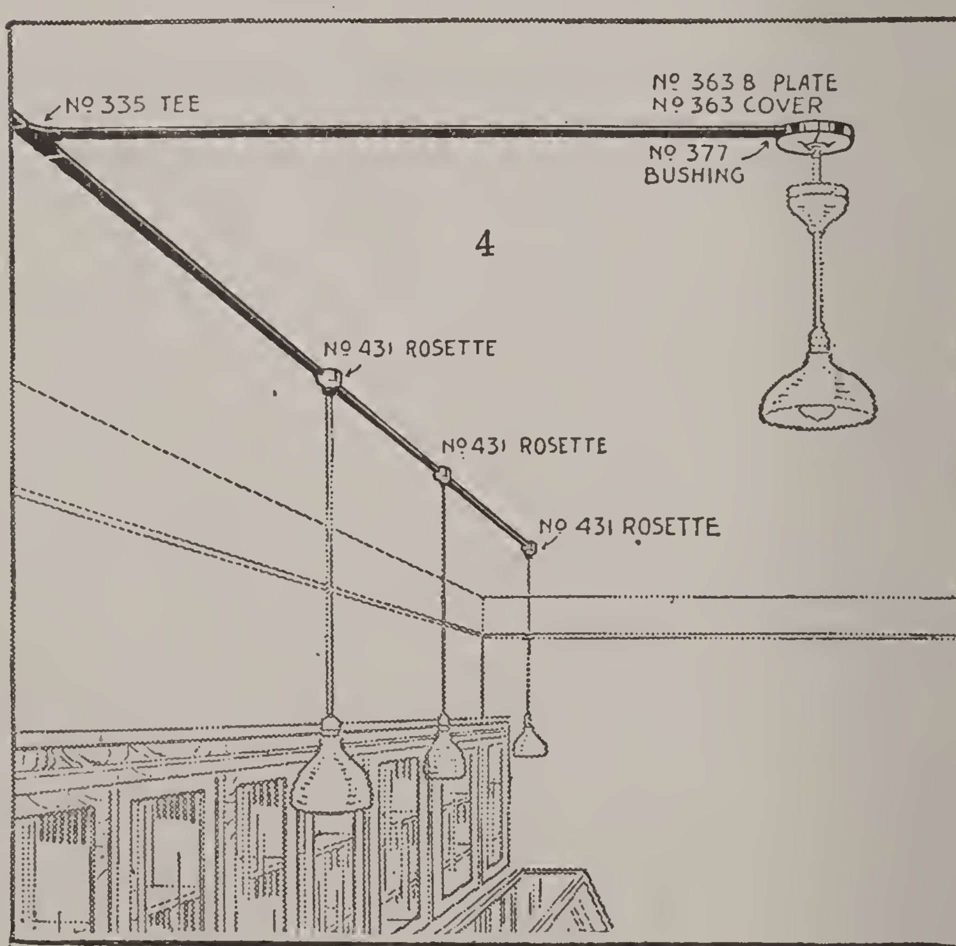

Outlets for Fixtures
Armored Cable
Master Switch
Three point switch.

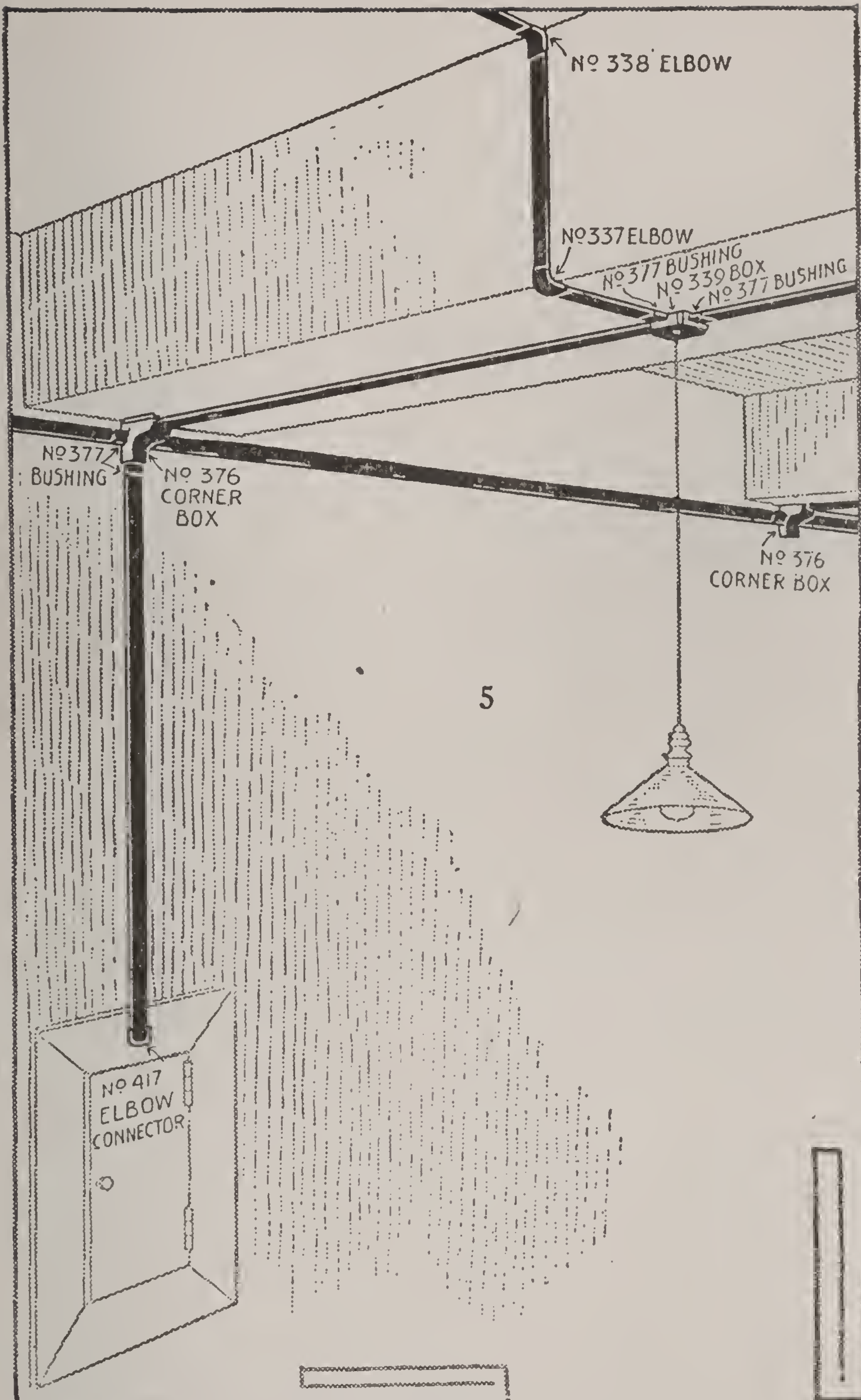
1.



2


ARMORED CABLE
Nº 341
Nº 414
Nº 356
Nº 437
Nº 356
Nº 356
Nº 356
3


Nº 335 TEE
Nº 363 B PLATE
Nº 363 COVER
Nº 377 BUSHING
4
Nº 431 ROSETTE
Nº 431 ROSETTE
Nº 431 ROSETTE


Nº 338 ELBOW
Nº 337 ELBOW
Nº 377 BUSHING
Nº 339 BOX
Nº 377 BUSHING
Nº 377
BUSHING
Nº 376
CORNER
BOX
Nº 376
CORNER BOX
5
Nº 417
ELBOW
CONNECTOR

CHAPTER VIII

SPECIAL WIRING

Systems of Distribution.—In interior wiring the lamps or current-consuming devices are almost always connected in multiple, that is, across the two wires. The branch wiring is then practically always the same for any installation. The main and feeder wiring, however, may differ because of the nature of the current supplied or of the number of wires used.

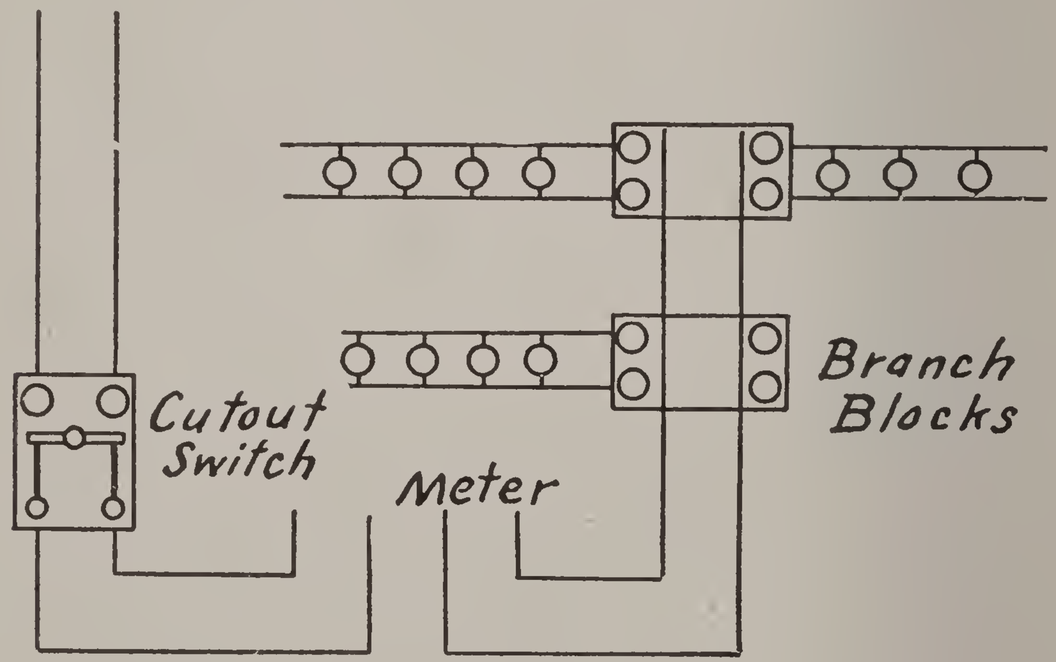


FIGURE 93.

Two-Wire System.—The most common service for interior wiring is to use only two wires from the source to the centers of distribution, as shown in Fig. 93.

This service is used for a line which furnishes either direct or alternating current having a potential of 110 volts. It may be used as well when the potential difference between wires is 220 volts, but it is unusual to use a 220-volt service, because ordinarily the lamps and apparatus are designed for 110 volts.

Three-Wire System.—The three-wire service shown in Fig. 94 is used quite extensively for three-wire direct

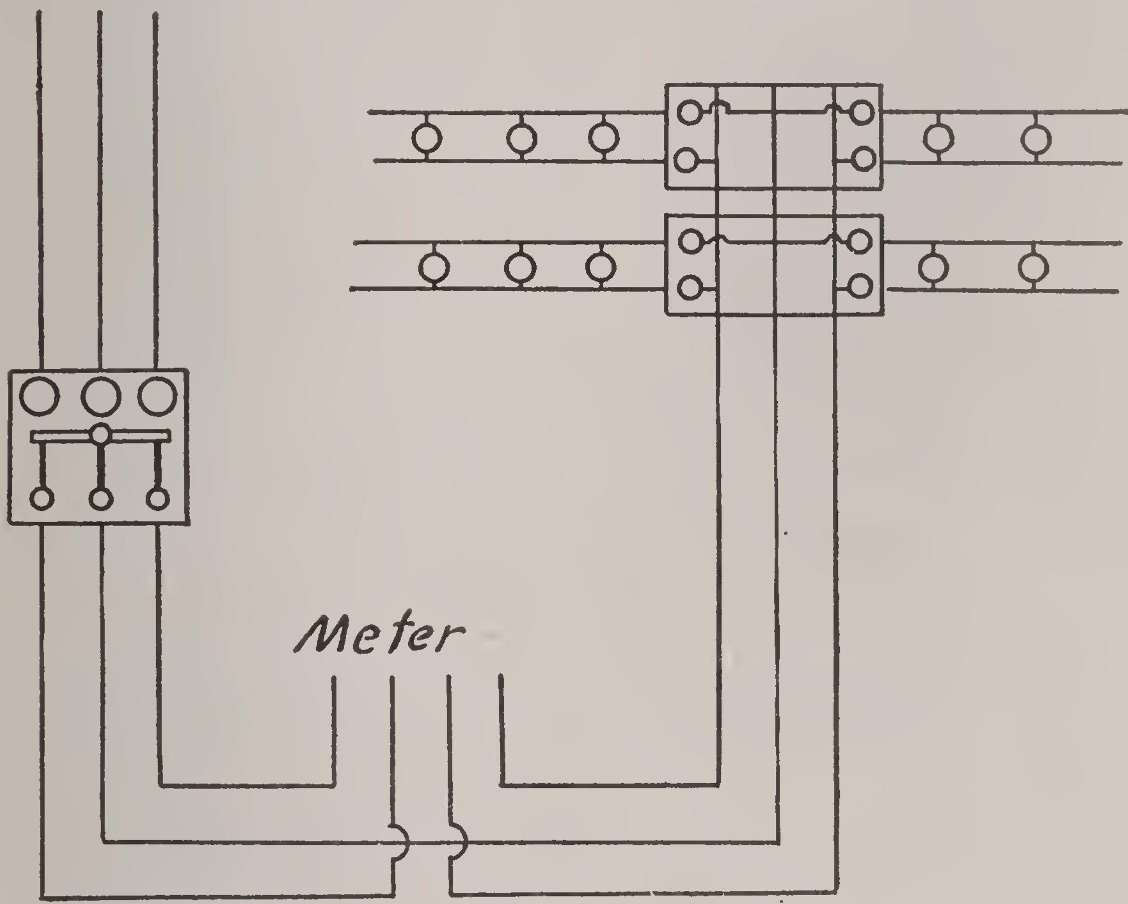


FIGURE 94.

current and three-wire, single-phase, alternating current circuits. Though three wires are required they need to be only half the size of those required on the two-wire system to supply the same load, provided it is balanced.

Three-Wire Convertible System.—In some instances the customer specifies a three-wire convertible system; that is, the system may be so wired that it may be converted into a two-wire system without changing any of the wiring. To do this, it is only necessary to use a neutral wire twice as large as one of the outside wires, instead of using one of the same size. Then when the system is changed from a three-wire to a two-wire the

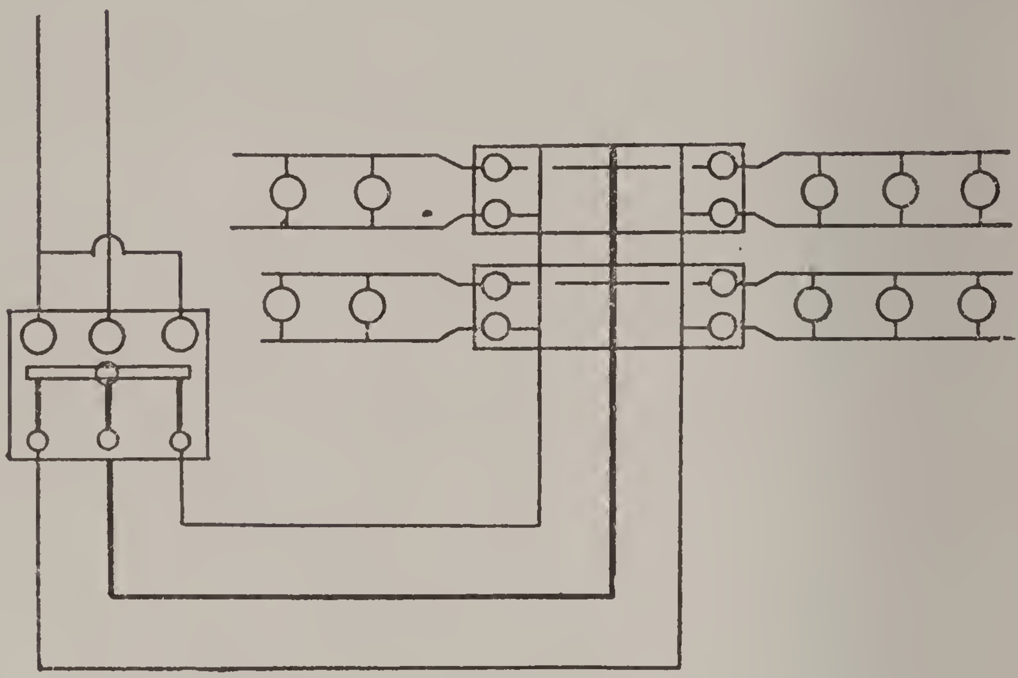


FIGURE 95.

neutral is used as one wire and the two outside wires are connected and used as the other wire, as shown in Fig. 95.

A system wired in this manner may be changed from

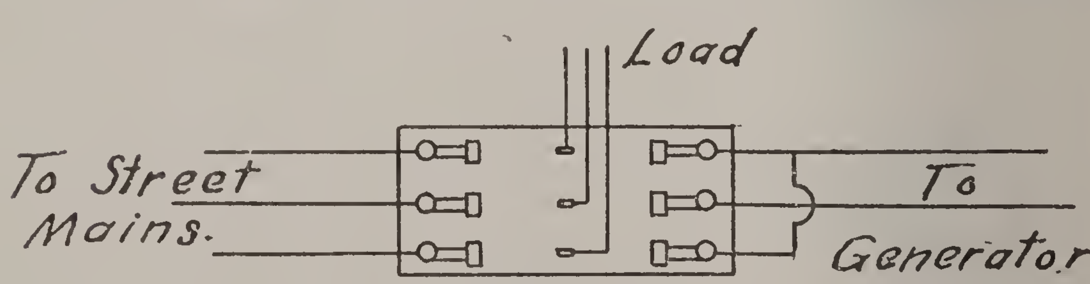


FIGURE 96.

one source of power to another by using a double-throw switch. For instance, in a building that is equipped with a two-wire generating plant, where a three-wire service of the city power company is also desired, a three-pole, double-throw switch would be used, as shown in Fig. 96.

With this connection, however, the fuse in the central pole of the fuse block, on the right-hand side, will be double the capacity of the others.

Four-Wire, Two-Phase System.—A four-wire, two-phase, alternating current service is not often used as such for lighting purposes. The power company's mains in the streets may carry such currents for motors and, therefore, it may be found convenient or necessary to use

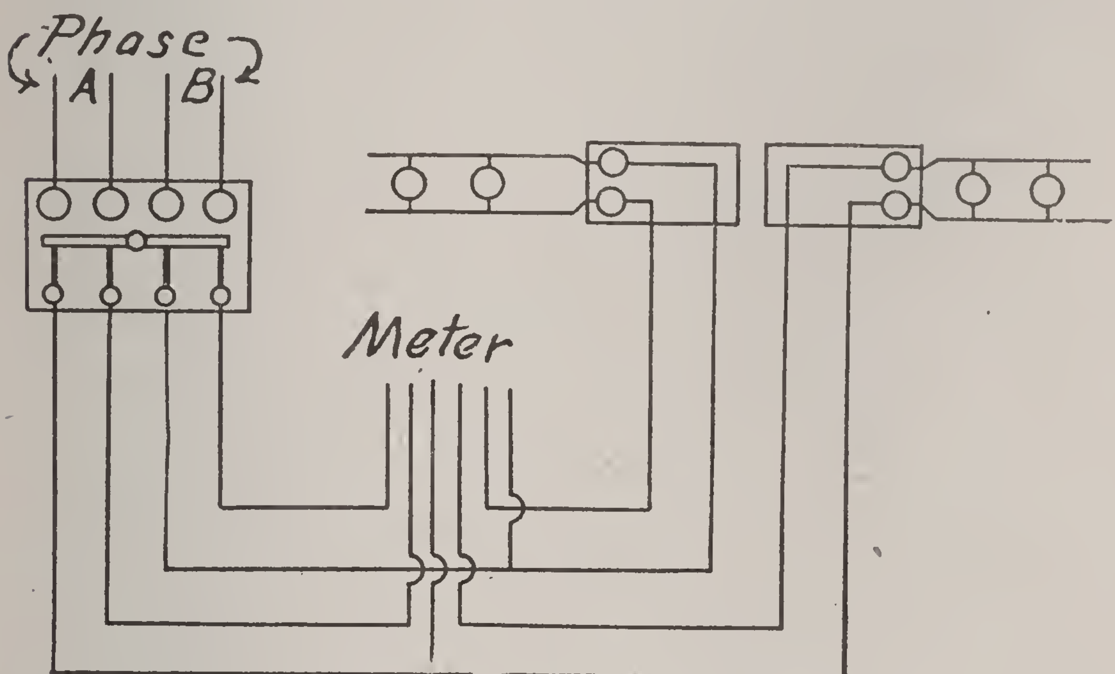


FIGURE 97.

these mains for the lighting load. Where the lamp load is small, perhaps below six or eight kilowatts, the interior wiring is done with a two-wire system and the main wires are tapped to one phase. If the lamp load is very large, a four-wire service is carried into the building, and the load is divided between the two phases, as shown in Fig. 97.

Three-Wire, Three-Phase System.—Small lamp loads to be connected to three-phase, three-wire circuits are usually wired as two-wire systems, having the main wires connected to two wires of the three-phase in the street. Small towns are often wired with this system by balancing the load across each phase.

Meter Loops.—Ordinarily it is not the duty of the wireman to install the electric meter, but wires should be arranged for connection to the meter. This arrangement is commonly called the meter loop. The meter is always connected between the main switch and the branch blocks, and the loop is made differently for different systems.

Two-Wire System.—The usual meter loop for a two-wire system is shown in Fig. 93. A loop that is rather unusual, but will serve for any two-wire meter, is shown in Fig. 98.

Three-Wire System.—For three-wire, direct current,

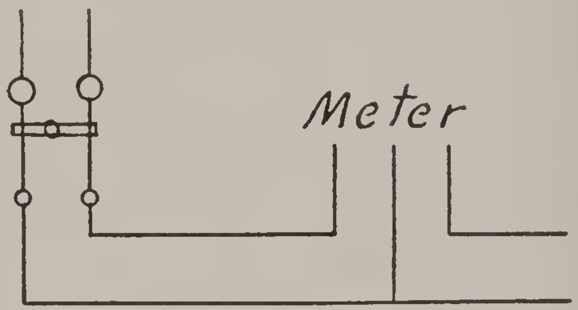


FIGURE 98.

or three-wire, single-phase, alternating current, the wires that pass into the meter may be either four or five in number, depending upon whether the potential circuit is to be connected across 220 or 110 volts. Usually the potential for three-wire alternating current meters is designed for 220 volts, and the meter loop for such a meter is made as shown in Fig. 94. The potential for a three-wire, direct-current meter is commonly connected across 110 volts, and the meter loop is made as shown in Fig. 99.

Four-Wire, Two-Phase System.—For a four-wire, two-phase meter, one wire of each phase is connected through the meter, and a wire is connected to the other wire of each phase, as shown by the meter loop in Fig. 97.

Three-Wire, Three-Phase System.—For a three-wire, three-phase meter, two wires are connected through the meter, and the third wire has a tap taken off for potential, as shown by connections in Fig. 99.

Switch Suggestions.—Single-pole switches are used almost entirely for controlling lamps on branch-circuit wiring, though in some instances it may be desirable, or even necessary, to use double-pole switches. Single-pole switches may be used to control lights on a circuit of 110 volts potential, where the current broken is not more than five amperes, if the wires are not likely to become grounded. Double-pole switches should be used to control lamps where the load is large, or where it is large or small if the wires are located in a damp place.

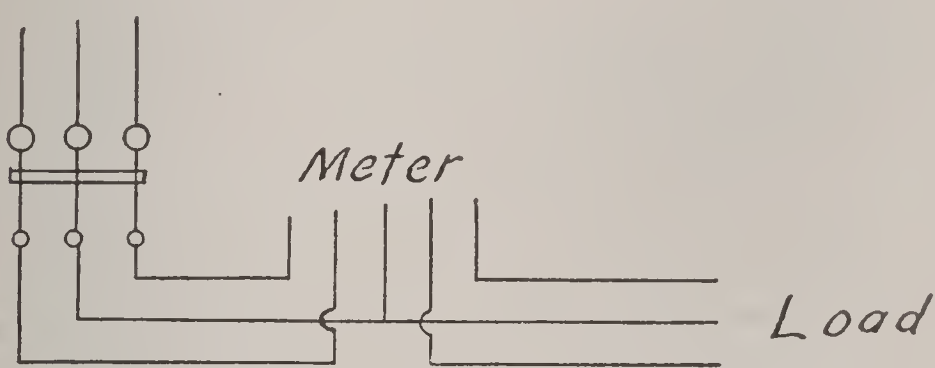


FIGURE 99.

In metallic systems, such as rigid conduit, armored cable or metal molding, it is considered much better practice to place the switch in the ungrounded wire, as shown in Fig. 100.

Should a high resistance ground develop on the wire between the switch and the load, it cannot draw current when the switch is open.

Pendant Switches.—Pendant switches, suspended by a lamp cord, are often used in controlling lights. The usual pendant switch is single pole and is connected to one side of the line leading the load. As a substitute for a pendant switch, a key or pull-chain socket with a fuse plug screwed in it will serve the purpose.

In the wiring of cut-outs or fuse blocks it is recommended that the shells of the block be connected on the load side, to prevent the possibility of a short circuit across the shells when the fuse plugs are removed.

Three-Point and Four-Point Switches.—Three-point and four-point switches are used quite extensively in controlling lights from two or more different points; that is, regardless of the position of the other switches, the

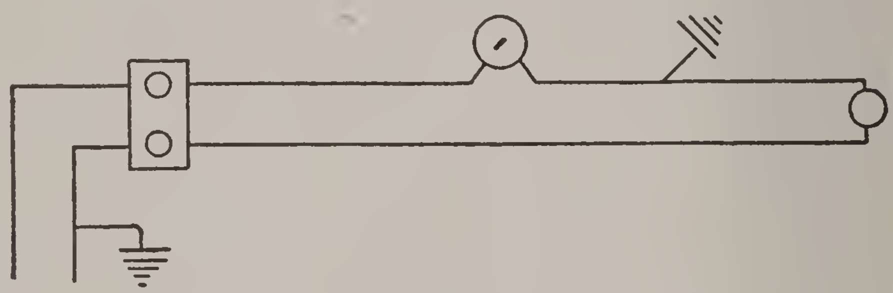


FIGURE 100.

lights can be turned on or off from either switch. For two points of control, such as the stairway control, the three-point switches are commonly used, as shown in Fig. 101. Two of the points of a three-point switch are strapped together and they must be connected to the single wire leading to the source or to the load.

Any number of points of control may be added by con-

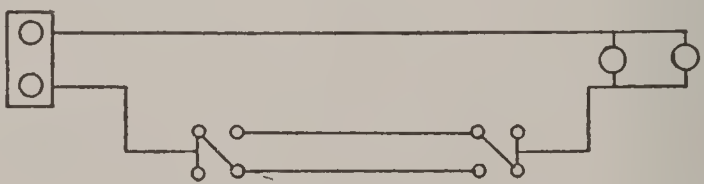


FIGURE 101.

necting four-point switches between the three-point switches, as shown in Fig. 102. In the connection of these, one of the two wires passing through all the switches must be cross-connected at each switch.

Three-point switches cannot be used anywhere except on the end position for independent control, but four-point switches may be used for the intermediate or end positions. Fig. 103 shows the connections for two four-point switches used on the end positions instead of the three-point switches.

Often in residences the hall lights on the first and

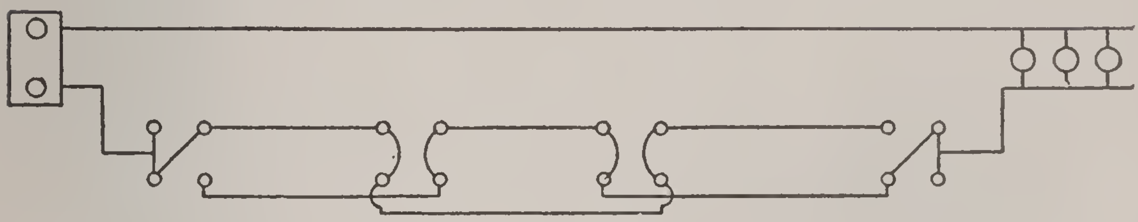


FIGURE 102.

second floors are controlled by three-point switches, requiring four switches and six, five, or four wires between the switches. Where there is no effort made to save wire, six wires are connected as shown in Fig. 104.

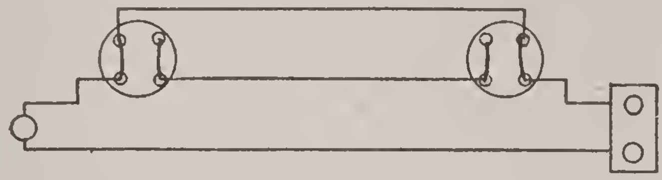


FIGURE 103.

The usual practice is to connect the switches as shown in Fig. 105, and thereby eliminate one wire.

As shown in Fig. 106, only four wires are used be-

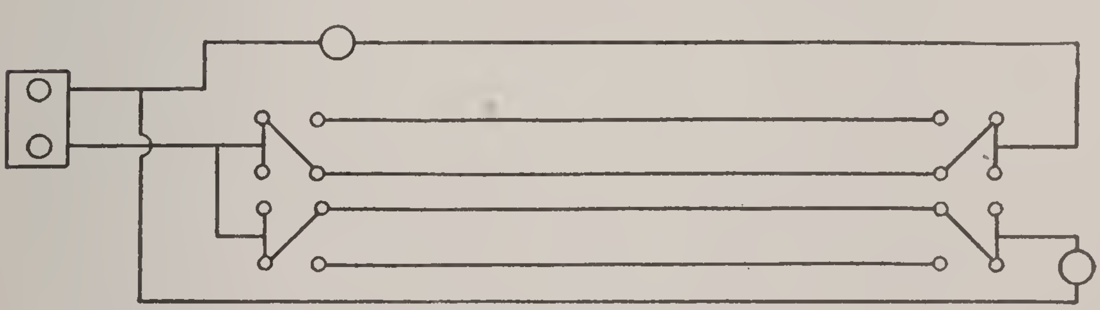


FIGURE 104.

tween the switches, but this plan is only possible where the same circuit has been carried to lights on both floors. This arrangement may be used on non-metallic systems such as open wiring (knobs or cleats), wooden molding or concealed knob and tube work, but it should not be used in rigid conduit, armored cable or metal molding, because of induction troubles that may arise. Further reduction in the number of wires between switches

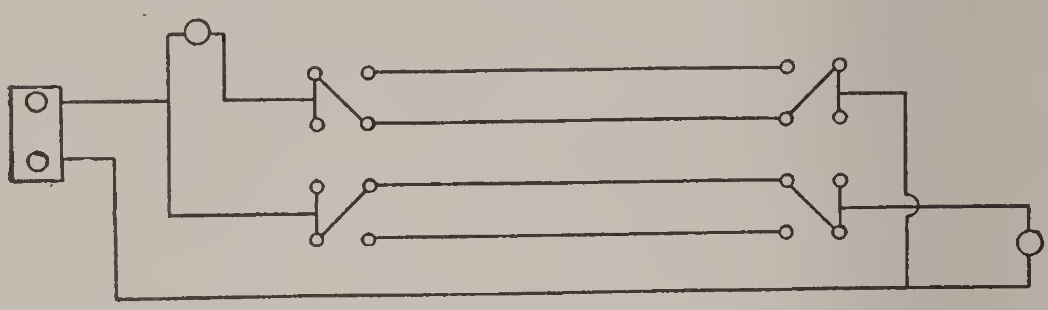


FIGURE 105.

may be made only by connecting both sides of the line into a switch, which method is not approved.

Tests.—Three-point and four-point switch connections should always be tested after they have been installed. As the switches are usually installed before power from the lighting company is available, a bell and battery or

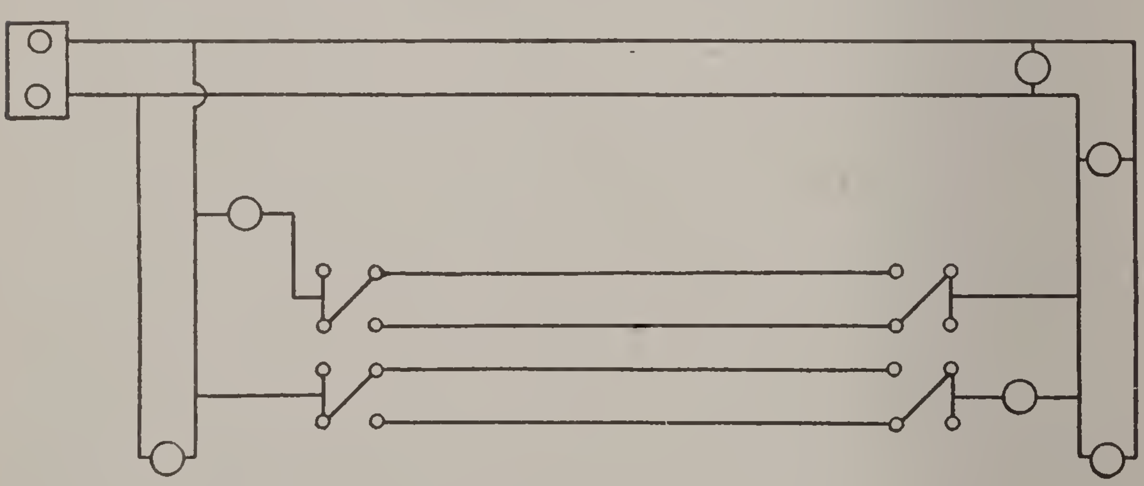


FIGURE 106.

a magneto is commonly used for testing these circuits. To test the circuits with a magneto connect the wires from the magneto to the branch wires and install the lamp at the outlet, or bare the wires and twist them together. Turn the crank of the magneto and the bells

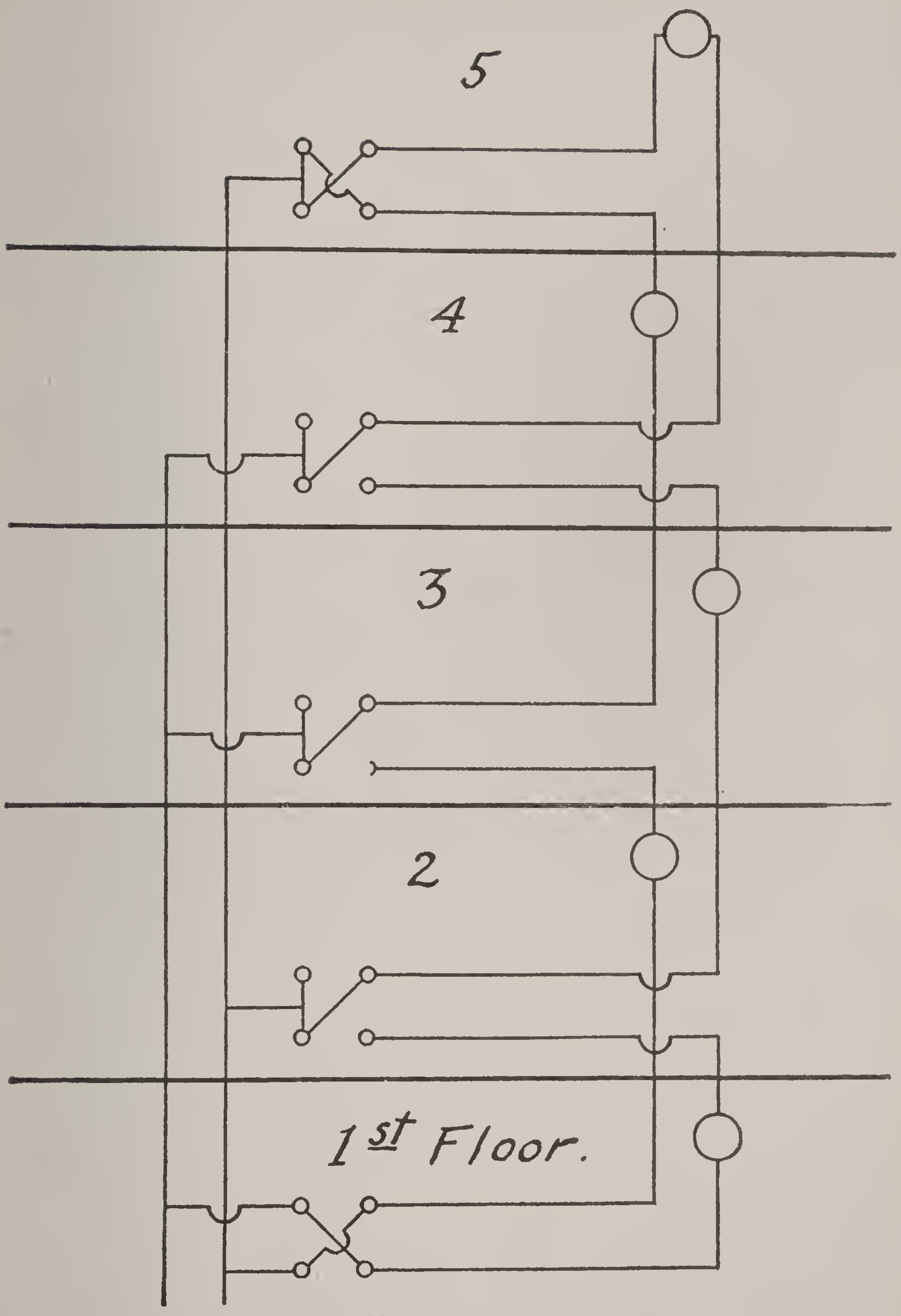


FIGURE 107.

should ring every second change in the position of any of the switches in the circuit.

The three-point and four-point switches may be purchased in either the flush or the snap type. The flush switch makes a neater appearance where it is possible to install it.

Stairway Control Systems.—A stairway control system for a number of floors is shown in Fig. 107.

As to its operation, the turning of the first-floor switch lights the lamps on the first and the second floors; the turning of the second-floor switch lights the lamps on the third and extinguishes the first-floor lamps; the turning of the third-floor switch lights the lamps on the fourth floor and extinguishes the lamps on the second floor; the turning of the fourth-floor switch lights the lamps on the fifth floor and extinguishes the lamps on the third floor; and the turning of the fifth-floor switch extinguishes the lamps on the fourth and the fifth floors. The reverse takes place on the down trip. Two serious objections are made to this system; first, the turning of a switch out of order will cause the lamps to light out of their proper order; secondly, when the switches have been operated on the up-trip they must be operated again on the down-trip before the lamps will light in order for the next up-trip.

Double-pole switches are used on the first and fifth floors, three-point switches are used on the other floors.

A more expensive, though a much more satisfactory, system of stairway control is shown in Fig. 108. Two switches must be turned at each landing to operate the lights on the floors above and below, instead of one used in Fig. 107, but the selective control of the lights, which this gives, more than offsets this disadvantage. The switches on the first floor will control the first- and the second-floor lights, the switches on the fourth floor will control the fourth- and the third-floor lights, and the switches on each of the other floors will control the light

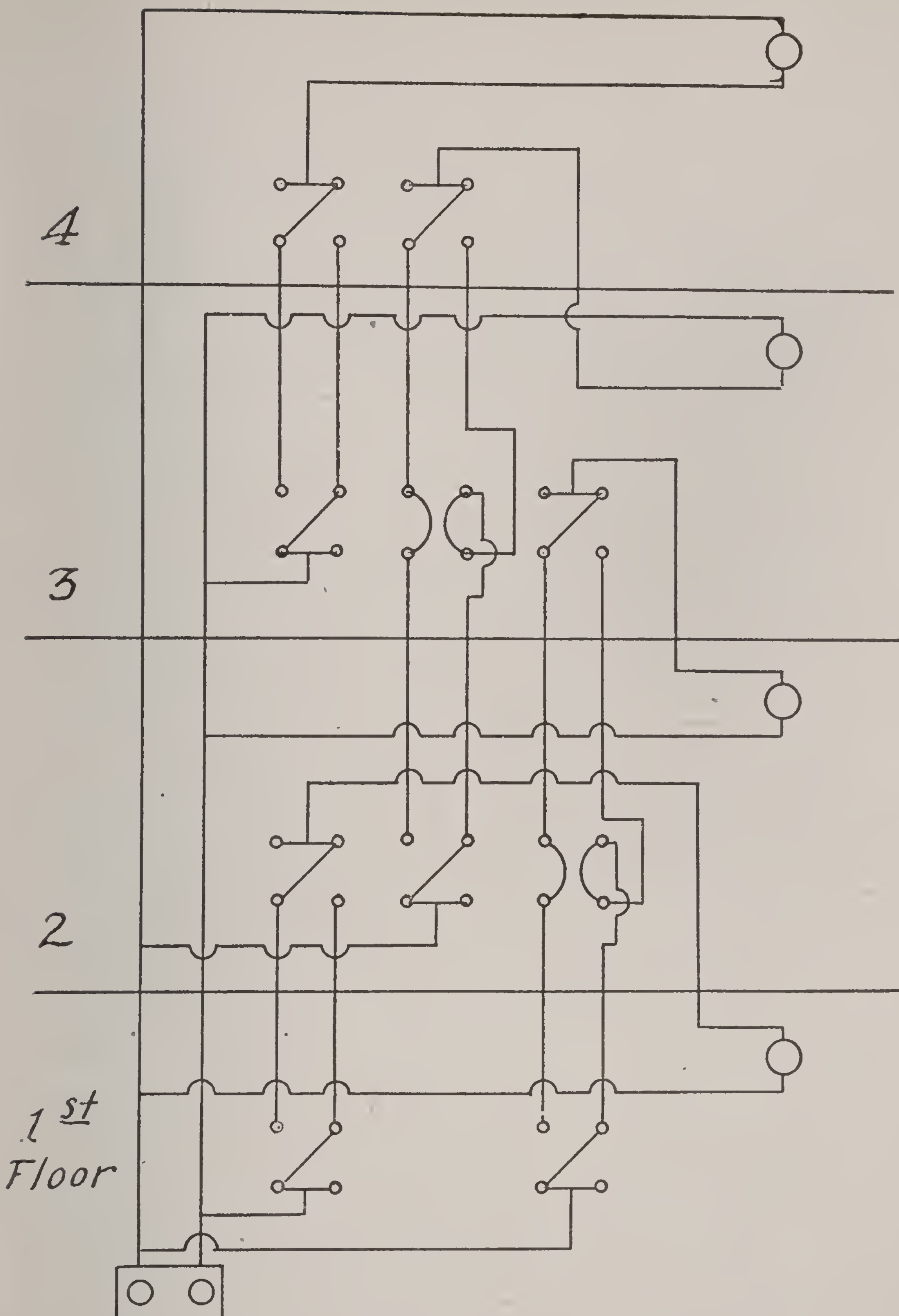


FIGURE 108.

on that floor, on the floor below, and on the floor above. This system is always "set" for operation, and the turning of any switch will operate the lamp on that circuit regardless of the position of the other switches. Two three-point switches are used on each floor with a four-point added on the second and the third floors.

Electrolier Switches.—Two-circuit and three-circuit electrolier switches are used in controlling separate lamps or separate groups of lamps in an electric fixture. They may be purchased in either the snap or the flush type; the only difference in their operation is that one has a key to be turned while the other has a plunger to be

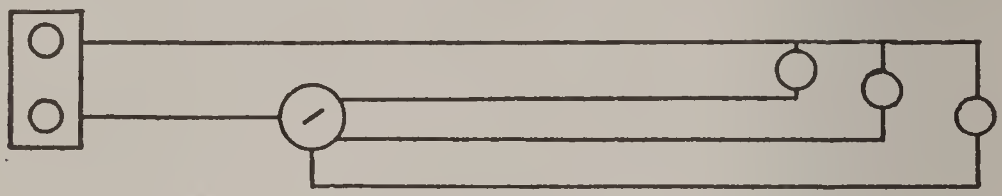


FIGURE 109.

pushed. One quarter-turn of the three-circuit snap switch lights one lamp or group of lamps; the second quarter-turn lights the second lamp or group of lamps; the third quarter-turn lights the third lamp or group of lamps; and the fourth quarter-turn cuts off the current from all lamps. Fig. 109 shows the wiring of a three-circuit switch used with a three-light fixture.

The two-circuit switch, as the name implies, is like the three-circuit switch except that it controls two lamps, or groups of lamps, instead of three.

Burglar Circuit.—In residence wiring a very desirable feature known as the burglar circuit is sometimes added. By its use, in case of an alarm in the night, the entire house may be flooded with light by closing one switch. There are separate switches for controlling such lamp, or group of lamps, and one master switch that turns them all on or off. Three-point switches are used at the individual control points and a single-pole switch is used at the master control point as shown in Fig. 110. The individual switches must be in the off position before the lamps can be controlled by the master switch.

In connecting these three-point switches the wire coming from the lamps must connect to the two points in the switch that are strapped together, while the other two wires may be connected interchangeably to the other two contacts.

Remote Control Switches.—Sometimes the customer

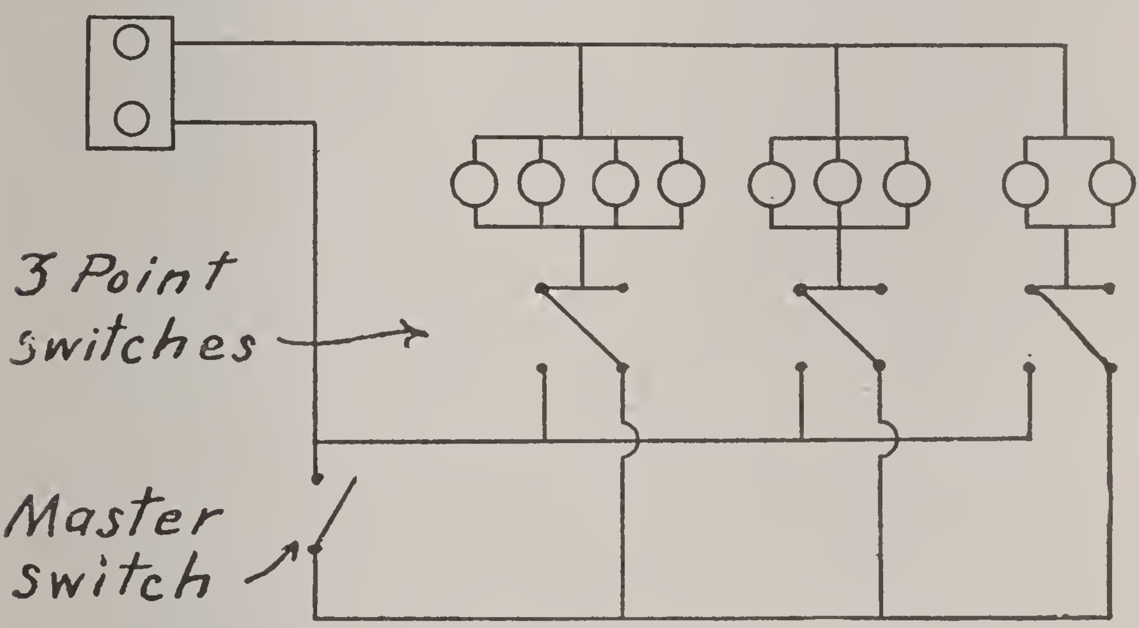


FIGURE 110.

specifies a point of control for a large number of lamps remote from the main switch. This may be accomplished by using the solenoidal switch shown in Fig. 111.

The remote control switch may be an indicating, single-pole snap or flush switch. If other points of control are desired three-point or three- and four-point switches may be employed instead of the single-pole switch.

Safety Switches.—Where machinery is driven by motors it is sometimes desirable to have several points throughout the building from which the main switch may be opened in order to stop all the motors. The remote control switch shown in Fig. 111 may be used for this purpose, but a much less expensive switch may be devised. Fig. 112 shows an arrangement whereby the blow from a falling weight upon a lever will open the switch. The tripping arrangement for the weight may be made with a lever and the coils and armature of an electric bell, arranged as in the plan shown. Two to four cells of battery are sufficient to operate the trigger, and buttons may be placed in convenient places.

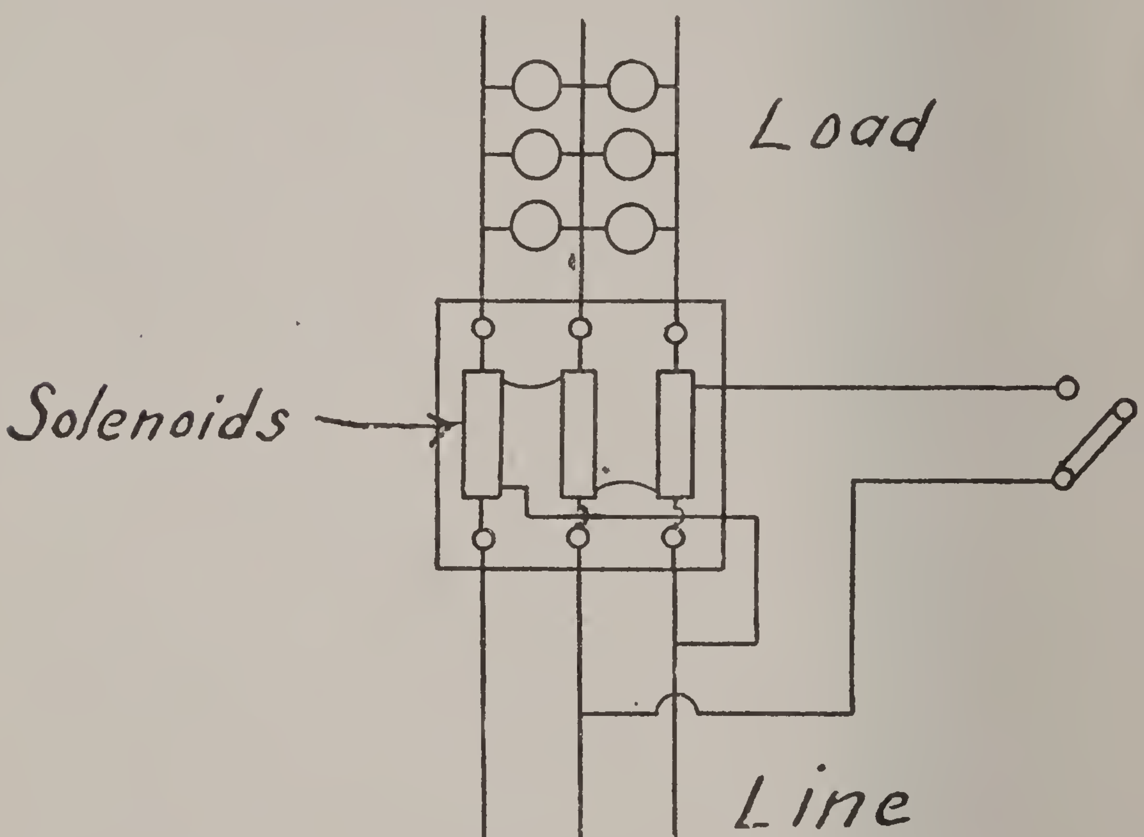


FIGURE 111.

Tank Switches.—Motors connected to a pump for supplying water to a tank are usually controlled automatically by a tank switch. There are several tank switches on the market which open and close the circuit by the action of a float. They are manufactured in both single- and double-pole and give different ranges of water height. In the wiring of a motor and a float switch there should be a switch near the motor to cut off the current to switch and motor and another switch arranged to put the motor on the line, independent of the float switch. This may be accomplished by using a double-pole, double-throw knife switch in connection with a single-pole float switch, as shown in Fig. 113.

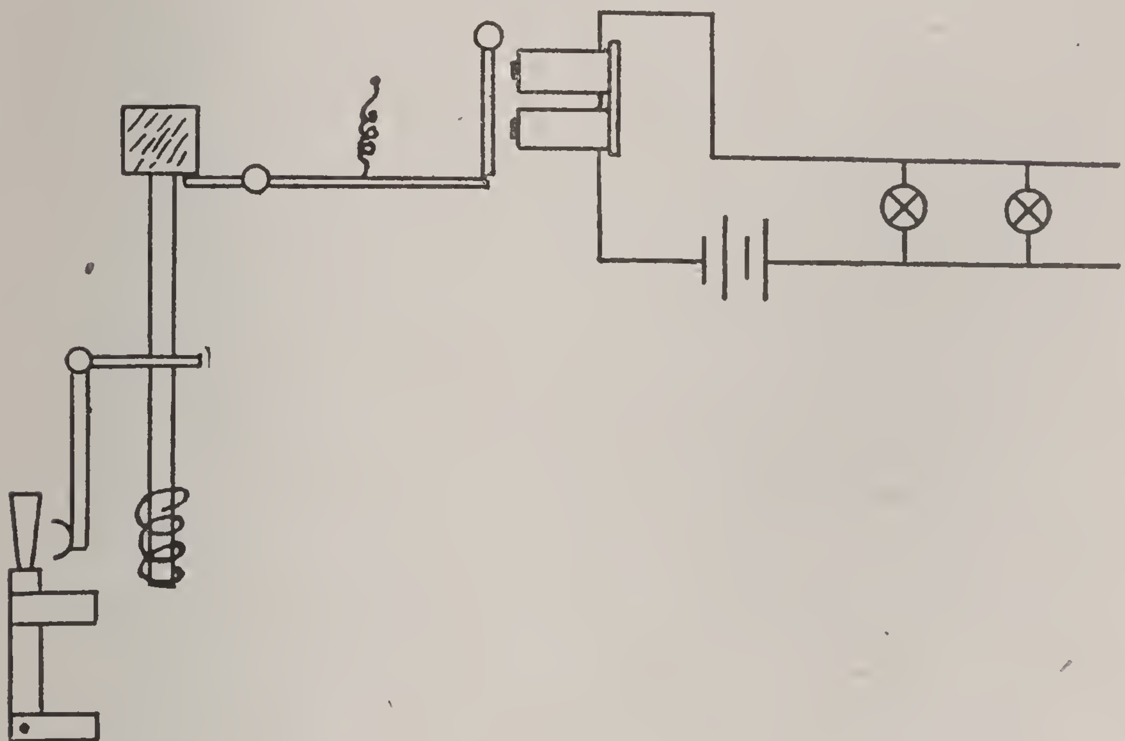


FIGURE 112.

Small alternating current motors, that is, up to two horsepower, are usually connected directly across the line,

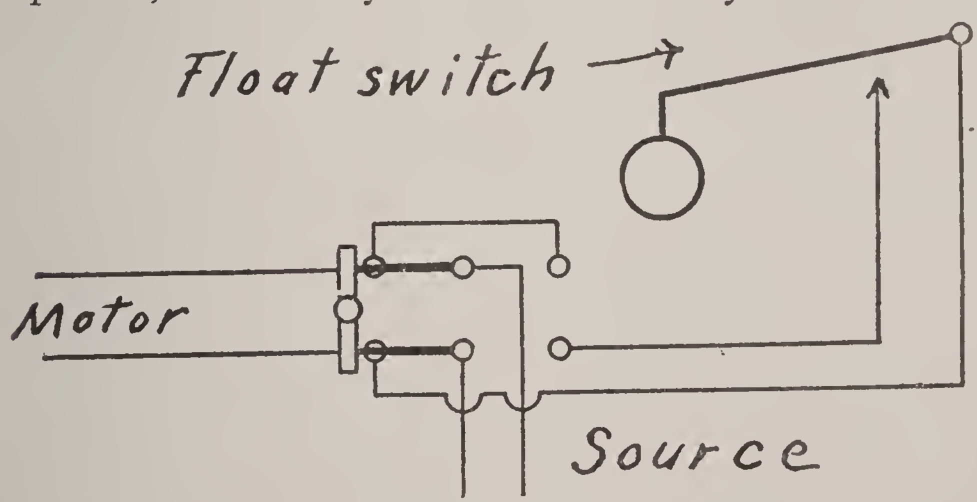


FIGURE 113.

while larger motors require resistance or reactance in the circuit. If a D. C. motor larger than one-quarter horse power, is used, a solenoidal or other form of remote starter must be used.

Fittings for Bathrooms and Damp Places.—As explained in another chapter, there is danger of an electric shock where metallic sockets or fixtures are installed in bathrooms, cellars, or any place where a person may come into contact with the ground while touching them. To avoid this danger, insulating sockets of porcelain or composition are used where their appearance is not objectionable. Also metallic fixtures are often placed high enough to be out of reach from the floor, and are controlled by wall switches. If, for special reasons, metal fixtures must be used and must be placed within reach from the floor, they should be grounded. In a bathroom this can easily and neatly be done by grounding the wire to the fixture and carrying it concealed to the ground on the water pipe. The commercial ground clamp makes the best connection to ground and should be used where conditions will permit.

Locating Troubles.—When a fuse plug on an existing branch circuit of wiring burns out, it is usually due to a short circuit or dead ground. The following is the method usually employed to locate and correct the trouble. If the system is a metallic system, or one in which there is any likelihood of a ground, remove both fuse plugs and screw a lamp into the socket of one of them. If the lamp burns, there is a ground on that wire, and it is most probably in a junction or outlet box. The connection in these boxes should be examined, and when the ground is opened the lamp will be extinguished. Should the lamp not light when screwed into one socket, it should, of course, be removed and be inserted into the other socket for the same test. This lamp method would show only low resistance grounds. The test for high resistance grounds must be made with a voltmeter or magneto.

Short Circuit.—To locate a short circuit screw a good fuse plug and a lamp in the cut-out, as shown in Fig. 114.

Turn off all the lamps and current-consuming devices on that circuit. If there is a short circuit, the lamp will remain lighted until the short circuit is removed. The most probable places where the short circuit will be found are where the wires are joined in the junction or outlet boxes, and are connected under binding screws in fixtures, rosettes and sockets.

Where it seems impossible to locate the short circuit by this method, because of the large number of poorly insulated connections, the circuit is sometimes sectional-

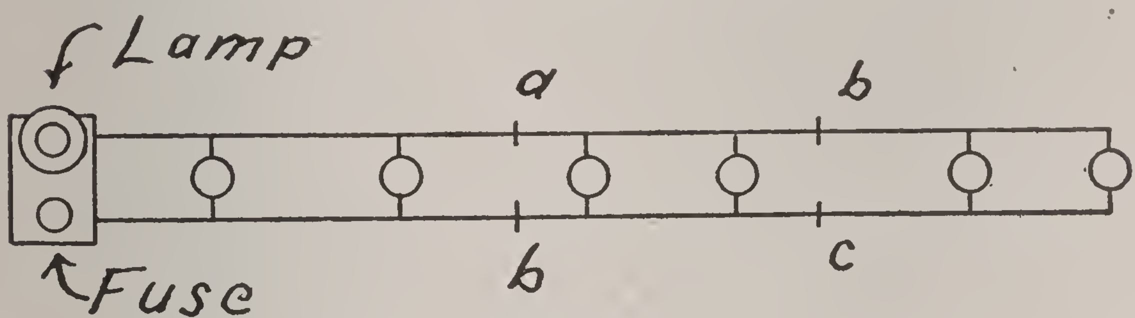


FIGURE 114.

ized. The circuit is opened near the middle, or between weak points, and the two parts thus divided are tested separately to determine on which of them the short circuit exists. It may be necessary to open the circuit wires and perform tests even a second or a third time to make a satisfactory location of the trouble. To illustrate, suppose that, in Fig. 114, the lamp burns, indicating a short circuit, and that, after opening the wires at a and b, the lamp is extinguished. This of course indicates that the wires between the cut-outs and a and b are free from short circuits. Then suppose the wires to be reconnected at a and b, and to be opened at b and c, the lamp will then indicate whether or not there is a short circuit between a and b and b and c. This testing by sections can be carried on until the exact point is located, but usually this is not necessary, as the probable trouble is evident.

The lamp method of locating a short circuit is the most convenient method, but, in rare instances, the lamp will not indicate the presence of a cross between wires because of its high resistance. In such cases it is necessary to use a magneto or to follow some other method of testing for high resistance contacts, and afterwards to perform the tests previously described.

QUESTIONS.

1. How are lamps or other current-consuming devices usually connected in interior wiring?
2. Make a diagram for a 2-wire wiring system from the service entrance to the lamps, showing all necessary fittings.
3. Make a diagram for a 3-wire single-phase alternating current system with all necessary fittings from service entrance to the lamps.
4. What is the advantage of the 3-wire system over the 2-wire system?
5. What is meant by a 3-wire convertible system?
6. Make a diagram of a switch for changing a 3-wire system to a 2-wire system.
7. How may 2-phase alternating current be used for lighting loads?
8. How may a 3-phase alternating current service be used to supply power for lighting loads?
9. Show by diagram the wiring for meter loops on the following systems:
   (a) 2-wire, A. C. or D. C.
   (b) 3-wire, with a 220-volt potential circuit.
   (c) 3-wire, with a 110-volt potential circuit.
   (d) 4-wire, 2-phase.
   (e) 3-wire, 3-phase.
10. What type of switch is generally used in controlling lamps on branch circuits? What is the current-carrying capacity of this switch for 110 volts?
11. Where wires are carried in conduit, and one wire of

the system is grounded, where is it advisable to connect a single-pole switch?

12. How are pendant switches usually connected in a line? Suggest a good substitute for a pendant switch.
13. How may a fuse block be connected into a line to prevent possible trouble?
14. What is the object of using 3- or 4-point switches?
15. Make a diagram for controlling four lamps with two 3-point switches.
16. Make a diagram for controlling four lamps with two 3-point and three 4-point switches.
17. Draw a diagram for controlling two lamps from three different points, using only 4-point switches.
18. Draw a diagram for the stairway control of two lamps, using four 3-point switches and five wires between floors.
19. Explain in detail a method of testing out 3-point and 4-point switch connections before power is available.
20. Explain the use and the operation of a 3-circuit snap switch.
21. Draw a diagram for twelve lights controlled in fours by a 3-circuit switch.
22. Draw a diagram for a burglar circuit in connection with four 3-light fixtures.
23. Explain the use of the remote-control switch.
24. Show by diagram an original method of opening the main switch to motors from several different points in a building.
25. Make a diagram for controlling a pump motor with a double-pole tank switch and a double-pole knife switch near the motor, knife switch to operate the motor independently of the float switch.
26. Mention three methods of preventing a person from receiving an electric shock from metallic sockets or fixtures in bathrooms or other places where the floor may be damp.
27. Explain a method of locating and removing a ground on a lighting system.
28. Explain the lamp fuse plug method of locating a short-circuit on a branch circuit.

CHAPTER IX

WIRING PRACTICE

Factors.—In the lighting of a house, sometimes as many as four different companies have a part in the work, each with a different duty to perform. They are as follows: a plumbing contractor, an electrical contractor, a fixture supply house, and the power company.

Duties.—The part of the work done by each factor may differ slightly in different localities. The writer gives the duties of each, based upon practical experience in wiring in Tennessee, Maryland and the District of Columbia.

It is the duty of the plumber or gas-fitter to install all gas pipes and locate gas outlets.

It is the electrical contractor's duty to do all the wiring in the house and install all drop cords, switches, baseboard and floor receptacles, etc.

It is the duty of the firm supplying the fixtures to install all fixtures and connect the fixture wires to the branch wires at the outlet.

It is the duty of the power company to run service wires from the street to the house and make connections with the main wires that have been extended through the walls by the wireman. It is also the duty of the power company to install and connect the wires to the electric meter. In rare instances, the power company will wire into the main-line cut-out, but it is unusual for them to do any work inside the building. The contractor should carry his mains out through porcelain bushings and leave about twelve inches for connections with the power company's wires outside the building.

The contractor does not install the meter, but he must leave a place in the mains, between the entrance switch and the branch blocks, where the meter may be installed.

The electric fixtures are usually supplied and installed under a separate contract, as the customer usually prefers to purchase them from a firm in the fixture business. In taking a contract, however, either verbal or written, a definite understanding should be had as to who is to supply and install the electric fixtures.

Size of Mains.—In deciding on the size of mains to be used in an installation, it is usually only necessary to choose a wire that is large enough to carry the current without heating.

The current to be carried by the mains is generally determined by the number of branch circuits.

As specified by the Code, no branch circuit must carry more than 660 watts. Then, dividing 660 watts, the maximum load on a branch circuit, by 110, the usual branch voltage, the quotient, 6, is the amperage of the branch. Then, to calculate the number of amperes that will pass over a main for a two-wire system, it is only necessary to multiply the number of branch circuits by six. Thus, if a two-wire system has connected two branch blocks, the current in the mains will be 2×6 or 12 amperes.

On a three-wire system, with a balanced load, as shown in Fig. 115, the current of e goes through wire a, then through b d to load f in series, and back to wire c, thereby requiring only six amperes for two branch circuits, instead of twelve, in a two-wire system. If the load is unbalanced, that is, if there are more branch circuits connected between b and a than between c and d, the excess of load on one side will return through the neutral wire g, as if it were a two-wire circuit.

To calculate the current in the mains, add the number of balanced branch circuits, multiply by six, and divide by two. To this amount add the excess of current in all branch circuits on one side over the balanced load. This sum gives the total current in the mains. Thus, for a 5-branch circuit, where four are balanced and one is unbalanced, $4 \times 6 = 24 \div 2 = 12$ amperes. $12 + 6 = 18$ amperes in wire c, while the neutral wire g will carry the difference, or six amperes.

After knowing the number of amperes to pass over the mains, their size is usually selected by referring to the

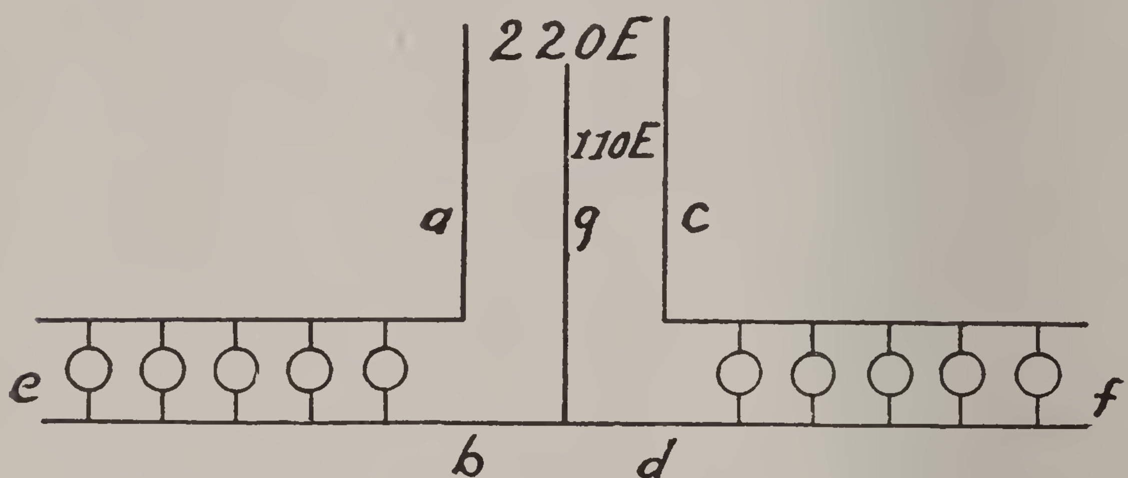


FIGURE 115.

carrying capacities of wires, as stated in the National Electrical Code. As a convenience to the reader, the part of the table most commonly used is given on page 169. Then, if by calculation it is found that the total number of branch circuits requires twelve amperes, a No. 14 wire which carries fifteen amperes would be used as mains. A method frequently employed is to use two No. 14 wires as mains for a system having only two branches on a 2-wire system and three No. 14 wires as mains for a system having four branches on a 3-wire system.

It is always necessary to use a wire for mains that will carry the current without heating, but the contract may call for a still larger wire. For instance, in a large installation, the contract may specify that wires of sufficient size must be used so that, when all lamps are

"Allowable Carrying Capacities of Wires."
1913 Code

B. & S. Gauge	Rubber Insulation Amperes	Other Insulation Amperes	Circular Mils
18	3	5	1,624
16	6	10	2,583
14	15	20	4,107
12	20	25	6,530
10	25	30	10,380
8	35	50	16,510
6	50	70	26,250
5	55	80	33,100
4	70	90	41,740
3	80	100	52,630
2	90	125	66,370
1	100	150	83,690
0	125	200	105,500
00	150	225	133,100
000	175	275	167,800
0000	225	325	211,600

turned on, the drop in voltage from the main line switch to the farthest lamp on the system shall not exceed 3 per cent. It is necessary to make a calculation to find the wire or wires required for mains and branches when the per cent. drop is specified.

The following wire formula may be used for direct current and for 2-wire and 3-wire single-phase alternating current where the load is a lamp load or of some other non-inductive nature. If the load is inductive, motors or arc lamps, it is recommended that a size be used which is 25 per cent larger than the one obtained from the wiring formula.

$$CM = \frac{L \times 22 \times I}{e}$$

Where:

L = length in feet one way
I = current in amperes

e = volts lost in line
CM = Size of conductor in circular mils
22 = constant

Example.—What size wire should be used on a 114-volt circuit when it is necessary to carry 70 amperes a distance of 100 feet with a loss of 3 per cent under full load? Three per cent. of 114 equals 3.42 volts which may be lost in the line.

$$\frac{100 \times 22 \times 70}{3.4} = 45{,}294 \text{ circular mils}$$

According to the table of allowable carrying capacities of wires, a No. 3 wire, which is the next heavier size, would be selected. As may be seen from the table of carrying capacity of wires, the wire selected is one size larger than would have been required by the Code. So in certain cases it may be necessary to use a larger wire than the Code calls for in order to prevent an excessive loss of potential in the line. On the other hand, a

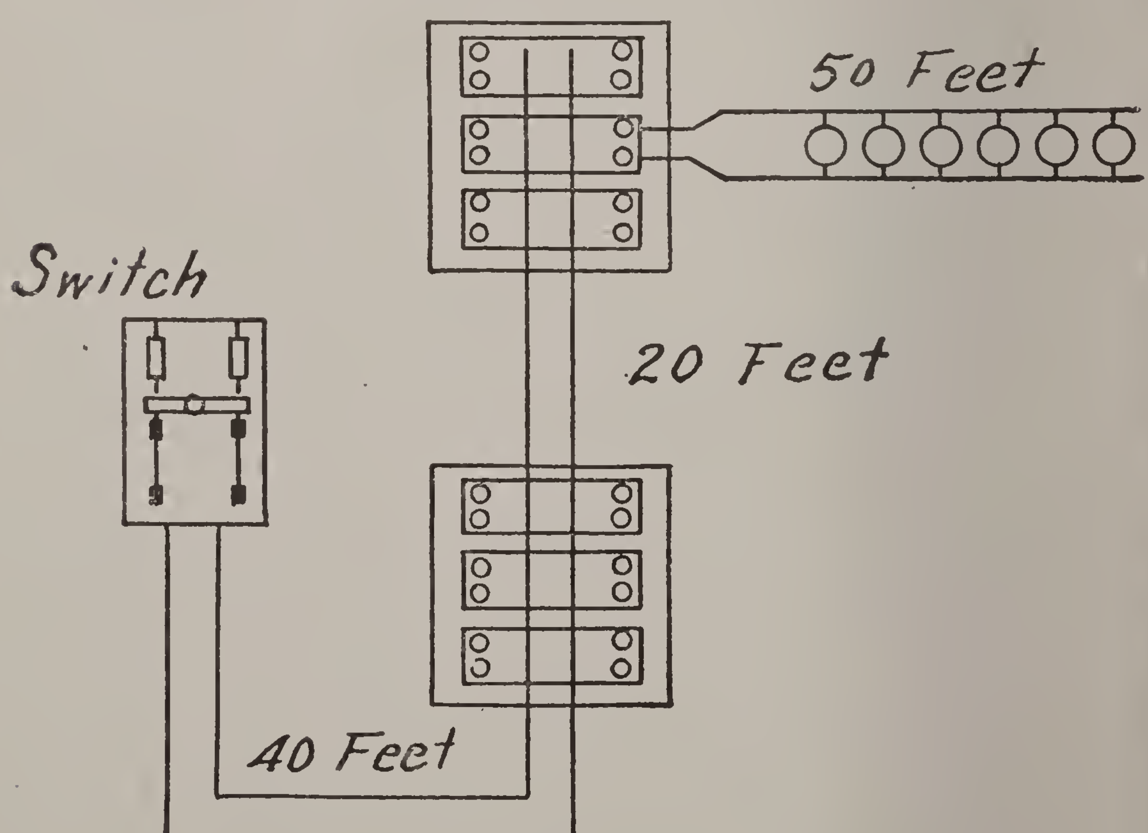


FIGURE 116.

wire smaller than the Code requirement should never be used under any circumstances.

In an interior wiring installation, the size of wire used and the current passing would probably differ in different parts of the circuit. In an installation consisting of two cabinet boxes or distributing centers, a large wire would be used between the main switch and the first cabinet box, and probably a smaller wire would be used between the first and the second cabinet box, while probably a still smaller wire might be used on the branch circuit.

As an example, suppose that with the wiring diagram shown in Fig. 116 the contract specifies not more than 3 per cent. drop under full load from the switch to the farthest lamp on the circuit. If the voltage at the main switch is 114, then 3 per cent of 114 = 3.4 volts which may be lost in the line. This voltage drop may be divided among the different sections to suit the contractor. In Fig. 116, suppose we allow 1.4 volts drop between the switch and the first cabinet box, and 1 volt between the second and the third cabinet box, and 1 volt between the last box and last lamp on the branch circuit; then with 12 branch circuits and 6 amperes to a circuit there are flowing between the switch and the first distribution center 12 × 6 or 72 amperes. Using the formula

$$\frac{40 \times 22 \times 72}{1.4} = 45{,}255 \text{ c.m. or No. 3 wire.}$$

Between the first and second cabinet box 6 × 6 or 36 amperes are passing. Then

$$\frac{20 \times 22 \times 36}{1} = 15{,}840 \text{ c.m. or No. 8 wire.}$$

On the branch circuit we will suppose the center of distribution to be 30 feet from the cabinet box.

Then,

$$\frac{30 \times 22 \times 6}{1} = 3{,}960 \text{ c.m. or No. 14 wire.}$$

Then with No. 5 wire for the first part of the main, No. 8 for the second part and No. 14 for the branch, the drop would not exceed 3 per cent under any load. Where a change in the size of the main is made, a cut-out must be installed, unless the fuse installed for the larger wire will also protect the smaller. In Fig. 116 a cut-out should be installed at the first cabinet box to protect the run of No. 8 wire. Where the run of mains after passing the first cabinet box is short, usual practice is to continue the mains with the larger wire and thereby save the expense and trouble of installing a cut-out.

Branch circuits on all systems are wired with No. 14 wire, except where the circuit is to be more than 100 feet long, when a No. 12 wire or larger size is generally used. This larger wire is employed to avoid too great a loss in candle power by the lamps at the remote end of the long circuit.

Number of Lights.—The National Electrical Code permits as many as twelve 50-watt lamps, or sixteen sockets for 40-watt lamps, on one branch circuit; but in most instances it is considered better practice to wire for ten instead of twelve sockets on a branch.

In residence wiring, some of the outlets have fixtures connected to them that have more than one light and the contractor should allow amply for these in laying out the branch circuits. When the contractor knows the number of lamps that are to be connected to an outlet, the outlet may be wired for the stated number of lamps. Otherwise, he should be guided by the rules that follow. The Code does not specify the number of lights allowed for different kinds of outlets. However, the following regulation, which prevails in the District of Columbia, is an excellent rule to follow:

Parlor ceiling outlet.........	4 lights or sockets
Sitting-room ceiling outlet...	4 " " "
Dining-room " " ...	4 " " "

Living-room ceiling outlet...	4 lights or sockets
Library " " ...	4 " " "
Reception hall " " ...	3 " " "
Bedroom " " ...	3 " " "
Bedroom toilet " " ...	1 light or socket
Kitchen outlets	1 " " "
Wall or bracket outlets.....	1 " " "
Hall, Pantry, Washroom, Bathroom } Ceiling or wall outlets, each..	1 " " "
Plug outlets	1 ampere each

Locating Outlets.—In locating the outlets in a residence, the following rules, which are usual practice, will probably assist the wireman:

Wall brackets in living-rooms, 5 feet 6 inches above the floor
Wall brackets in chambers, 5 feet above the floor
Wall brackets in halls and corridors, 6 feet 3 inches above the floor
Wall brackets in offices, 6 feet above the floor
Snap and flush switches, 4 feet 2 inches above the floor
Knife switches, 4 feet 6 inches above the floor
Cabinet and switch boxes, 5 feet above the floor
Sockets from drop cords, 6 feet above the floor

Knife Switches.—In the mounting of knife switches, the Code specifies that they must be so placed that gravity will not tend to close them when the switch is open. The switch may be mounted so that the blades stand either vertically or horizontally, but when mounted vertically the hinges of the blades should be below, so that gravity will tend to open instead of to close the switch.

Combination Switch and Cut-Out.—In the majority of small installations, the main line fuse block and the main line switch are combined into one fitting, called a combination entrance switch and cut-out. In installing this fitting, the cut-out must be installed on the line side of the switch to protect it in case of a short circuit across the blades. Usually a combination entrance switch and cut-out is constructed for entrance from the top, as shown in Fig. 117A. Where the entrance is made at the bottom, it is usually necessary to turn the switch blades around, as shown in Fig. 117B.

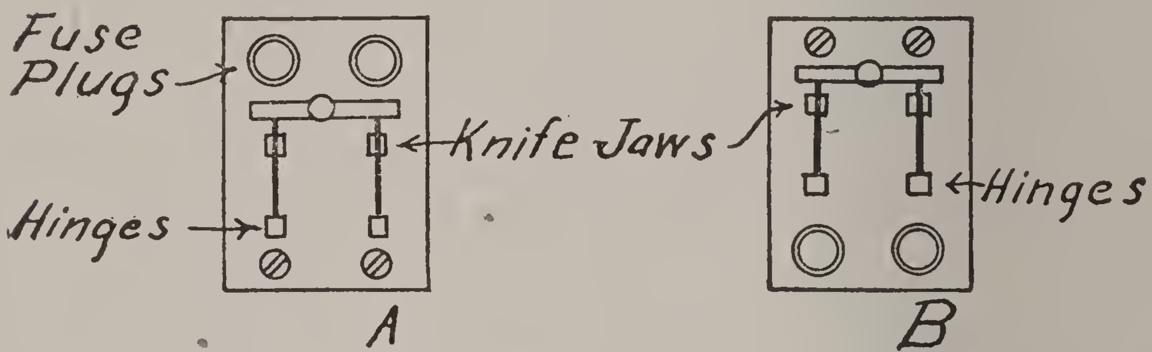


FIGURE 117.

To turn the blade around, the sealing wax over the screw heads on the back side of the switch is broken out, the screws are removed and the positions of the jaws and blades are interchanged.

In the mounting of knife switches, fuse blocks and branch blocks, the best practice is to inclose them in iron or wooden boxes. This is not required by the Code, ordinarily, and often the boxes are omitted where the inspector having jurisdiction does not require them and the customer wishes a cheaper job. Switches and cut-outs should be placed in boxes because the boxes protect them and make a neater appearance.

Power Required for Illumination.—The amount of power required for general illumination may be ascertained by the use of the following table.

The rule for the application of the table given below is as follows:

Total watts = area of room in square feet × foot-candles × constant taken from table.

For general illumination, 3 or 4 foot-candles are usually sufficient.

As an example, a room 25 feet wide and 40 feet long, with a light ceiling and dark walls, is to have an illumination of 3 foot-candles throughout. This illumination is to be obtained by the use of metallized filament lamps and prismatic reflectors.

Substituting the area (1,000 square feet), the required foot-candles (3) and the proper constant (55),

Total watts = 1,000 × 3 × .55 = 1,650.

If 50-watt lamps are used, 33 will be necessary.

To secure approximately uniform illumination, the light sources should be separated by a distance not greater than twice their height above the plane where the illumination is desired.

The following table shows the number of watts per square foot of floor area required to produce an average of 1 foot-candle of illumination (Watts per lumen):

Tungsten Lamps rated at 1.25 watts per horizontal candle-power; clear prismatic reflectors, either bowl or concentrating; large room; light ceilings; dark walls; lamps pendant:

Height 8 to 15 feet	0.25
Same with very light walls	0.20

Tungsten Lamps rated at 1.25 watts per horizontal candle-power; prismatic bowl reflector enameled; large room; light ceilings; dark walls; lamps pendant:

Height 8 to 15 feet	0.29
Same with very light walls	0.23

Metallized Filament Lamps rated at 2.5 watts per horizontal candle-power; clear, prismatic reflector; either concentrating or bowl; large room; light ceiling; dark walls; lamps pendant:

Height 8 to 15 feet	0.55
Same with very light walls	0.45

Carbon Filament Lamps rated at 3.1 watts per horizontal candle-power; clear prismatic reflector, either bowl or concentrating; light ceiling, dark walls; lamps pendant:
Height 8 to 15 feet.......................... 0.65
Same with very light walls.................... 0.55

Bare Carbon Filament Lamps rated at 3.1 watts per horizontal candle-power; no reflectors; large room; very light ceiling and walls:
Height 10 to 14 feet..................... 0.75 to 1.5
Same, small room, medium walls........ 1.25 " 2.0

Carbon Filament Lamps rated at 3.1 watts per horizontal candle-power; opal dome or opal cone reflectors; light ceilings; dark walls; large rooms; lamps pendant:
Height 8 to 15 feet.......................... 0.70
Same with light walls....................... 0.60

Wooden Cabinet Boxes.—Wooden cabinet boxes were used extensively until recently. On account of the time required for the building of the box by the electrician, it is considered cheaper to use the iron box. For the benefit of wiremen in localities where wooden boxes are still used, suggestions for constructing them will be given.

The wood used in the box must be well seasoned and at least three-fourths of an inch thick and must be thoroughly filled and painted. The lining may be of $\frac{1}{4}$-inch slate, $\frac{1}{4}$-inch marble, $\frac{1}{4}$-inch approved composition or $\frac{1}{8}$-inch asbestos. Except in large installations, asbestos is generally used. One-eighth inch asbestos is secured to the sides of the box with screws or tacks, generally the latter. The box should have a neat door and some means of fastening the door when closed. Wooden or composition cabinets must not be used with metal conduit, armored cable or metal molding systems. This requirement is made mainly because the wooden box does not make a metallic connection between the different runs of conduit, cable or molding that pass into the box, which connection is necessary for the grounding of the system.

In a wooden cabinet box where the wires pass from the box, bushings or tubes through which they run to the connections, each wire should be encased in circular loom. Where such runs are short and the wires are not carried near other wires, loom may not be required; but where the runs are long, as from one side of the box to the other, or where they pass near other wires, all such wires should be encased in circular loom.

In iron cabinet boxes, the wires may be passed to the fittings without being encased or supported in any way. Some inspectors make an exception to this implied rule and require circular loom on the wires for the longer runs, such as a run from the top to the bottom of the box.

Insulation of Wire.—Wires with various kinds of insulation are sometimes permitted in different classes of wiring. Rubber-covered wire is now required almost entirely. It may be purchased with either single or double cotton braid; the former is cheaper but is not approved for some wiring systems.

Rigid conduit and armored cable systems require double-braid, rubber-covered wire, while single-braid, rubber-covered wire may be used in open-work wiring (cleats or knobs), concealed knob and tube work, wood molding and metal molding.

QUESTIONS.

1. Explain in detail the various portions of the work for which the plumber, power company and electrical contractor are responsible in wiring a house.
2. How many watts of energy are permitted on a branch circuit?
3. What is the largest current ordinarily that flows in a branch circuit?

4. What usually determines the size of wire to be used for mains in any system?
5. Explain the method of determining the size of wire to be used for mains with a given number of branch circuits:
   (a) For a two-wire system;
   (b) For a three-wire system.
6. In a 2-wire system with 84 lights and 7 branch cirsuits, how much current would be flowing in the mains under full load? What size mains would be required?
7. In a 3-wire system with 84 lights and 7 branch circuits, how much current would be flowing in each of the three main wires under full load? What size mains would be required?
8. State the current-carrying capacity for four different sizes of wire—rubber insulation.
9. What is meant by a certain "per cent. drop" in a line?
10. State the formula for determining the size of wire to be used with a specified drop in voltage. Indicate the meaning of the letters in the equation.
11. What sized wires would be required on a 115-volt circuit to furnish current for one hundred ½-ampere lamps a distance of 150 feet with a 4 per cent loss in voltage at full load?
12. What sized wires would be used on a 2-wire circuit to carry 50 amperes a distance of 200 feet with a drop of 2 per cent if the voltage between the wires is 225 volts?
13. With three wires of the same size on a 3-wire, 115- and 230-volt direct current system, what size mains would be required to supply current to 200 ½-ampere, 110-volt lamps a distance of 400 feet with a 4 per cent drop?
14. What sized wire would be used on a 115-volt wiring installation with one distribution center supplying 6 branch circuits 150 feet from the main switch, allowing a 3 per cent. drop in voltage?
15. What sized wire would be required for the same installation, using three-wire 115- and 230-volt mains?
16. Where should cut-outs be placed in main wires?

17. What size of wire is generally used on branch circuits? When is it advisable to use a larger wire?
18. How many sockets are permitted on a branch circuit?
19. What outlets in a residence should be wired for as if they were to have five sockets?
20. What outlets should be considered to take current:
    (a) For three sockets?
    (b) For two sockets?
    (c) For one socket?
21. How high above the floor should wall brackets be placed:
    (a) In dining-rooms?
    (b) In chambers?
    (c) In halls?
    (d) In offices?
22. What is the usual height of:
    (a) Flush switches?
    (b) Knife switches?
    (c) Cabinet boxes?
    (d) Sockets from drop cords?
23. How should knife switches be mounted?
24. How would a combination cut-out and switch, arranged for entrance from the top, be changed to an "enter from the bottom" fitting?
25. How many 40-watt Tungsten lamps would be required to furnish an illumination of three foot-candles in a room 30 feet wide and 50 feet long, if the room has light walls and light ceilings, and the lamps are to be twelve feet above the floor?
26. How many 50-watt, metallized filament lamps would be required in the foregoing problem?
27. Explain in detail the building of a wooden cabinet box.
28. Should circular loom be used on the wires in wooden cabinet boxes?
29. In what systems of wiring must double-braid, rubber-covered wire be used? In what systems may single-braid, rubber-covered wire be used?

CHAPTER X

WIRING FOR MOTORS

Wiring Systems.—The wiring for motors may be installed with any of the systems used for lights. It should be remembered in this connection, however, that metal molding must not be used for circuits carrying more than 1,320 watts of energy; therefore, its use is restricted to small motors.

The two most widely used systems in wiring for motors are open work on knobs, and rigid conduit. Open work is much cheaper and is much more extensively used. It serves the purpose very well if the motor is near the wall and if the wires on the side wall will not be subjected to mechanical injury. Rigid conduit is superior to all other systems of wiring for motors, because it protects the wires from mechanical injury and carries them in a compact form. Where motors are located away from the side walls or partitions, rigid conduit forms an excellent protection for the wires across the floor.

Some Code Requirements.—Some of the Code requirements for installing and wiring motors will be discussed, but the student should become familiar with this subject in the Code before undertaking any practical work. "Motors operating at a potential of 550 volts or less must be thoroughly insulated from the ground whenever feasible." "Wooden base frames and wooden floors are considered as sufficient insulation if they are kept filled to prevent the absorption of moisture and are kept clean and dry." "Motors when combined with ceiling fans must be hung from insulated hooks, or else there must be an insulator interposed between the motor and its support."

"Small motors may be grouped under the protection of a single set of fuses, provided the rated capacity of the fuse does not exceed 6 amperes." "Motors of this class seldom require a starting resistance and are thrown across the line when the switch is closed." With motors of $\frac{1}{4}$th horse power or less, on circuits where the voltage does not exceed 300, single-pole switches may be used.

Larger motors, varying in size from one-fourth to one-half horse power and upward must have a special branch circuit run from the mains, which wires must have a current-carrying capacity at least 25 per cent greater than the motor is rated to take, as motors, when starting, take momentarily more than their rated current. The motor, and resistance box, if any is used, must be protected by a cut-out and controlled by a switch which plainly indicates whether it is "on" or "off." The fuses used may be of the plug type if the current carried is not more than 30 amperes. If the current carried exceeds 30 amperes, the cartridge fuse must be employed.

Knife switches are used in controlling the larger motors for three reasons: First, all the wires leading to the motor may be opened by the switch; second, the switch indicates whether or not the current is passing to the motor; third, knife switches may be obtained for either large or small current-carrying capacities.

"The switch and rheostat must be located within sight of the motor." This enables the operator to see the performance of the motor while manipulating the switch or rheostat.

Direct Current Motors.—Direct current motors are designed to work on a constant potential; that is, the same potential that is ordinarily used for lights. They are built to be connected across 110, 220 and 550 volts and are usually wired with a resistance to be cut in the circuit, to limit the current when starting. The 110- and

220-volt motors are used extensively; the 550-volt motors are seldom used industrially, because a circuit with such a high potential is seldom permitted in buildings.

Types.—There are three different types of direct current motors in commercial use, namely, shunt, series, and compound motors. Each has its field and ar-

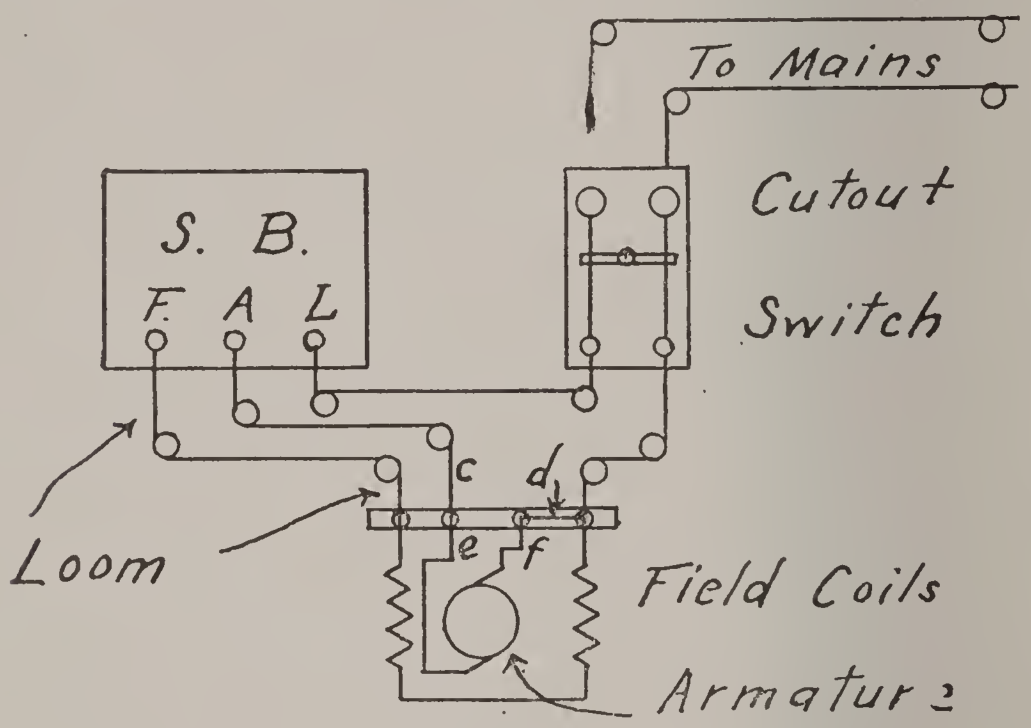


FIGURE 118.

mature windings connected differently and is suitable for a particular kind of service.

Shunt Motor.—The shunt motor has its field and armature connected in parallel, which fact causes it to give a speed that is practically constant under all variations in load. The starting torque or pull of the shunt motor is comparatively weak and for this reason the load is usually connected to the motor after it is up to speed. Friction clutches of various types are commonly used for connecting motors to their load. The shunt motor is used for running lathes and other machinery where a practically constant speed is desired. The wiring for such a motor, with the wires carried on split knobs, is shown in Fig. 118.

Mounting Switch and Starting Box.—The cut-out switch and starting box shown in the figure should be at least 4½ feet above the floor. The starting box, if mounted over combustible material, must be separated therefrom by a slab of soapstone, marble or slate, at least half an inch thick, and somewhat larger than the starting box in length and breadth. Slate is commonly used. The slate must be secured in its position independently of the rheostat supports. The following plan should be followed in mounting a starting box or other rheostat. Holes are drilled under the feet of the box through which bolts are to be passed that secure the box in place. These holes should be drilled with a larger drill for a short distance so that when the bolts are put into place, the heads are countersunk at least ⅛ inch below the surface of the back of the slab. The drill holes over the bolt heads should then be filled with sealing wax flush with the back surface of the slab. Other holes are then drilled for the wood screws and the slab is put into place.

Wiring.—In connecting the wires to the starting box and motor, as shown in Fig. 118, one wire from the switch connects to the armature and field connections joined. The other line wire connects to the binding post, at the box marked L; the binding post marked A on the box is connected to the armature of the motor and the terminal marked F on the box is connected to the field of the motor. The terminals of the motor may or may not be marked with the letters F and A, but it is usually an easy task to trace the wires. The terminals that connect to the brushes on the commutator are the armature connections and the terminals that connect to the field coils are, of course, the field connections.

If the motor has a potential of less than 300 volts, the wires must be kept 2½ inches apart and half an inch from the surface wired over. Where this distance between wires and from the surface wired over cannot be maintained, each wire must be protected by a separate casing, such as porcelain tubes or circular loom. Circular loom or some similar casing for the wires must be used at the motor and starting box. The casing should cover each wire in one continuous piece from the last knob to the connection on the motor or starting box.

Starting.—The object of the starting box is to limit

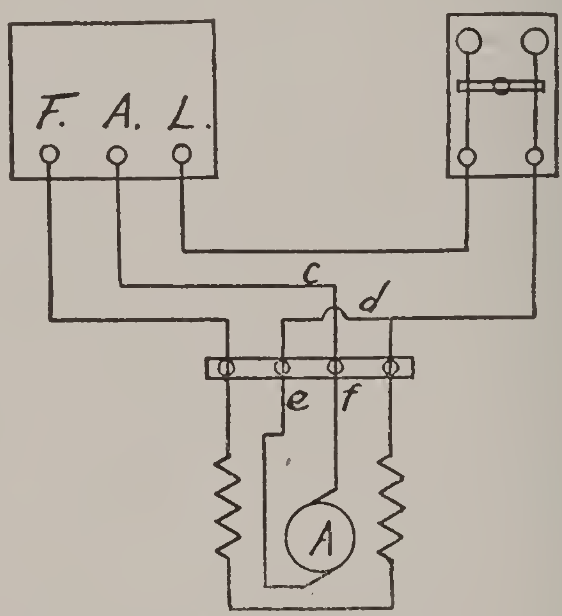


FIGURE 119.

the current taken by the motor when starting, and the handle which cuts out resistance should be brought over slowly. To start a motor, the knife switch is closed and the handle of the rheostat is carried over the contacts gradually until it has reached the last contact, at which time the motor should be running at almost full speed. The time required to perform this operation differs for different-sized motors, or for motors with different starting loads. However, for small motors, five to ten seconds are required for proper starting.

Reversing a Shunt Motor.—After a motor is installed, it often runs in the wrong direction. The direction of rotation of a direct current motor may be reversed by reversing the direction of the current in either the armature or the field coils. Having a motor with four binding posts, as shown in Fig. 119, the direction of rotation may be reversed by interchanging the connections of the wires c and d, to the binding posts e and f.

If the motor has only three places for connections it

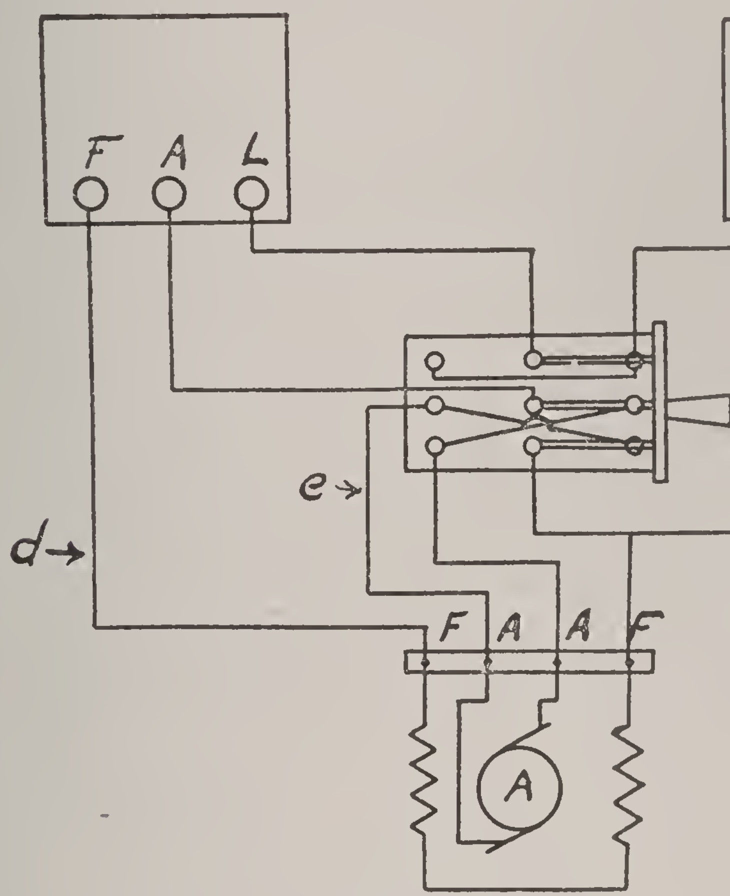


FIGURE 120.

is then necessary to reverse either the field or the armature leads within the motor. One of these three terminals has two wires connected under it, one from the armature and one from the field, and is usually marked L.

Often it is desirable to reverse the direction of rotation with a reversing switch. This may be done, as shown in Fig. 120.

A two-pole reversing switch may be used instead of a three-pole switch, but the motor is much less liable to injury with the latter because it opens the circuit to both the field and the armature circuit.

Controlling Speed of Motors.—Where it is desirable to vary the speed of the motor, this may be done by placing a variable resistance in either the field or the armature circuit. To speed up the motor, open the wire at d and connect in series a field rheostat. Turning the handle of the rheostat so as to put more resistance in the circuit will increase the motor's speed, and turning the handle so as to cut out resistance will slow the motor down. Too much resistance must not be placed in the field circuit, as it may cause the motor to spark at the brushes and burn out under a heavy load. To slow down the motor, open the armature wire at e and place a rheostat in series. Increasing the resistance in the circuit will decrease the speed of the motor, and decreasing the resistance will increase the speed of the motor. By this method, the speed may be varied from a standstill to the normal speed of the motor. Other methods of speed control are used which embody this same principle; that is, by varying the voltage applied to the brushes.

The Series Motor.—The series motor, as the name implies, has its field and armature windings connected in series. It has a strong starting torque and a variable speed; there is practically no limit to the speed of a series motor, when thrown across the line without any load. Some means must be provided to control the speed. This may be done by using a controller such as is employed on street cars, or by employing a load which increases as the speed rises, such as is found on a fan motor.

Wiring.—The wiring for a series motor with a controller is shown in Fig. 121.

The wiring for a series motor with a controller and reversing switch is shown in Fig. 122.

Compound Motors.—Compound motors are used where a motor is required that will start under a heavy load and run at practically constant speed. They are commonly used for elevators, hoists, etc. The compound motor has a field coil of coarse wire connected in series with the armature and a shunt winding in parallel with the armature The series field is here arranged to aid the shunt field and thus give a large starting torque.

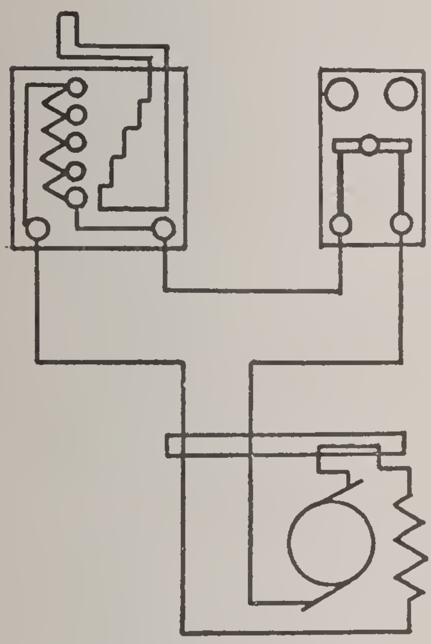


FIGURE 121.

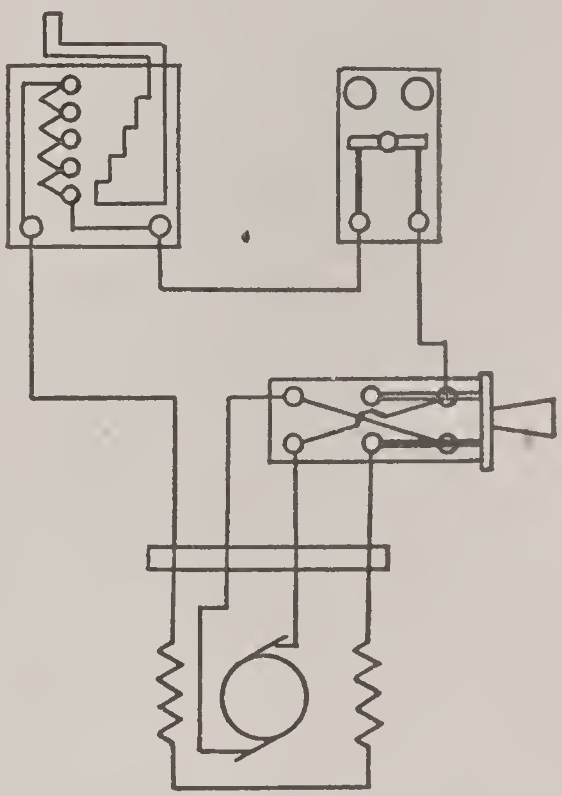


FIGURE 122.

When full speed is attained the series field is cut out, and the motor thereafter runs as a shunt motor at a constant speed. Were the series field not cut out, the motor would vary in speed under different loads, as does a series motor. This variation of speed would, of course, be prohibited for an elevator.

Wiring.—The wiring for a compound motor, with a starting box, is shown in Fig. 123. The wiring for a compound motor with a starting box and reserving switch is shown in Fig. 124.

Controlling Speed.—The speed of a compound motor may be varied by placing resistance in either or both the field and armature circuits. Placing a variable resistance in the wire b, Fig. 123, and in the wire c, Fig.

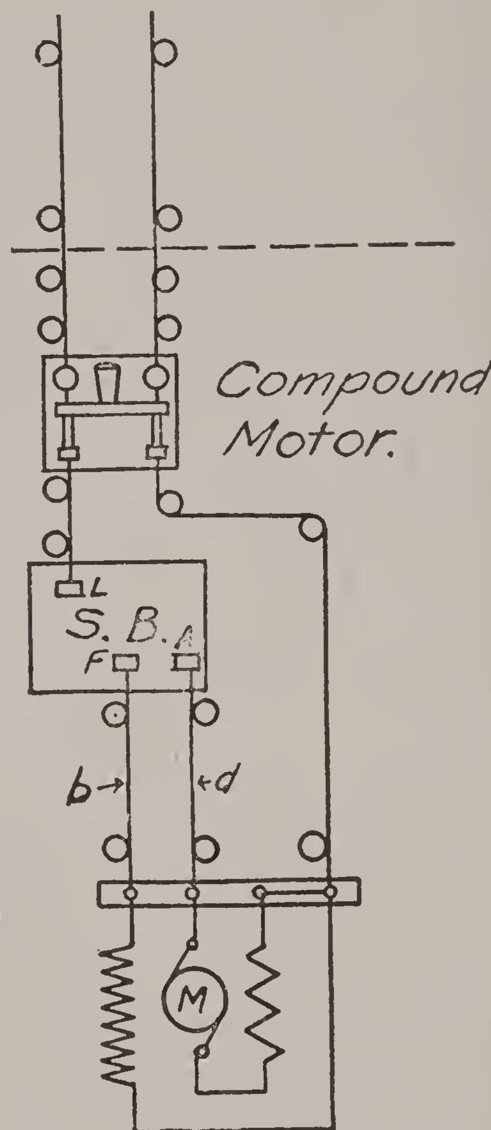


FIGURE 123.

124, will increase the speed of the motors; while placing a variable resistance in the wire d, Fig. 123, and in the wire e, Fig. 124, will decrease the speed of the motors. By combining these two resistances, a wide range of speed control may be obtained.

Alternating Current Motors.—The wiring for alternating current motors may be installed with any of the systems used for direct current motors. The same rules apply, except as to the size of branch circuits or leads to the motor. The wires for this purpose must be designed to carry a current at least 25 per cent greater than that for which the motor is rated. Also, "where wires under this rule would be overfused in order to

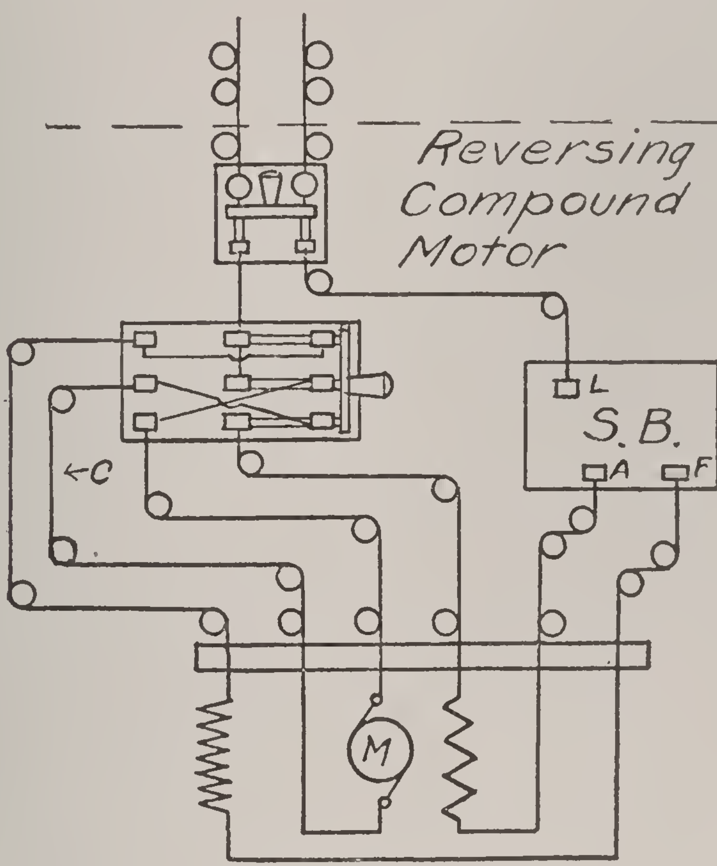


FIGURE 124.

provide for the starting current, as in case of many alternating current motors, the wires must be of such size as to be properly protected by these larger fuses."

Classes.—The motors used on alternating current circuits may be divided into two classes; namely, single-phase and polyphase. In the single-phase class, two kinds are obtainable—series and induction motors. Under the polyphase class come induction and synchronous motors. Single-phase motors require only two wires from the mains to the cut-out and switch. The number required from the switch to the motor will depend on the method of starting the motor.

Series Motor.—The series motor used on alternating current is similar to the direct current series motor, shown in Fig. 121. The motor has a commutator and brushes like those of the D. C. motor and the field and armature are connected in series, though it is a little smaller, for the same rating than the direct current, because less iron is used in its construction. In starting, small motors of this type are thrown directly across the line; while the larger motors are started with an external resistance or reactance connected in one wire leading to the motor as the starting box is connected in Fig. 121.

The use of the series motor is restricted almost entirely to fans, dental engines and similar work, and on a larger scale to street railways or electric locomotives.

Induction Motor.—The induction motor has its field and armature windings separate; that is, they are entirely insulated from each other. The current from the line is usually introduced into the field or stationary member and the current is induced in the armature or rotating member. The armature may be a wound or a squirrel-cage type of armature but no commutator is required for either, as the rotating effort is due to a combination of transformer and motor action between the two windings.

Starting.—Small single-phase motors and some larger ones are designed to be inherently self-starting. The wiring for such a motor would naturally only include carrying the two wires from the mains through a cut-out and switch to the motor.

The larger motors require such large currents for starting when thrown directly across the line that some method of limiting the initial rush of current to the motor must be used. Resistance or reactance may be placed in the circuit leading to the motor, though the most satisfactory plan is to use a combination of the two which is found in some of the standard starters. These starters usually have a double-throw switch, which is thrown into one position for starting and into another position for running. Such a starter for a single-phase induc-

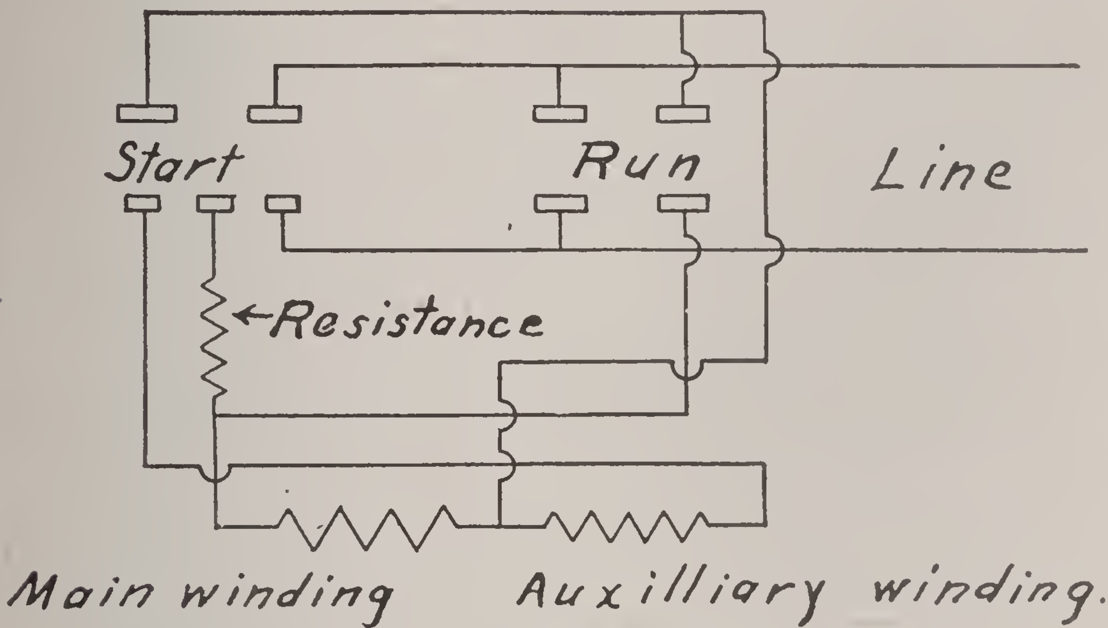


FIGURE 125.

tion motor, with a two-phase or with a single-phase and an auxiliary winding, is shown in Fig. 125.

The largest motors used on single-phase have their

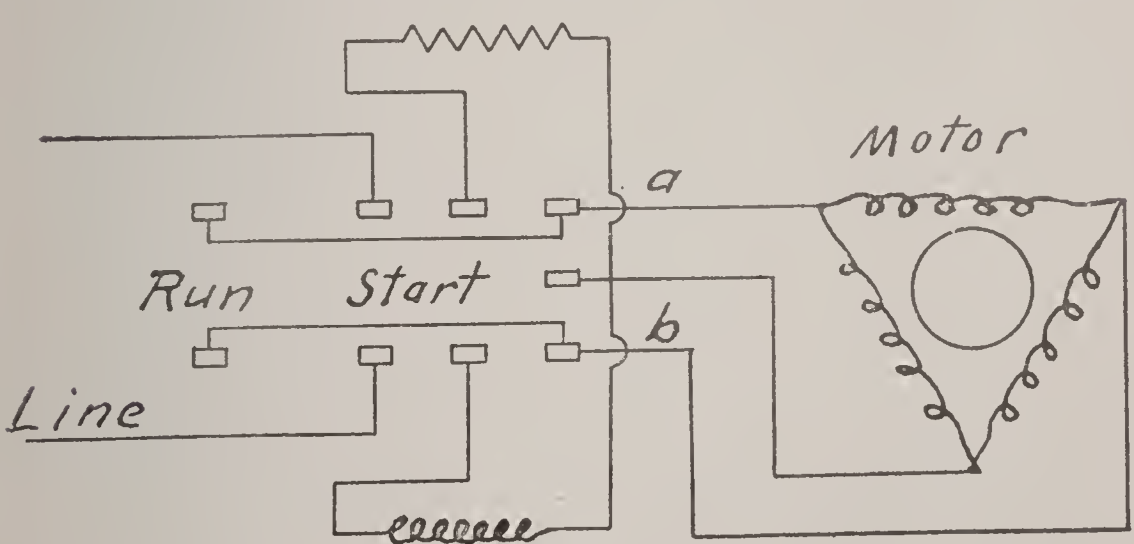


FIGURE 126.

windings separated into three parts as if they were to be used on three-phase. Fig. 126 shows the connections for starter and single-phase induction motors, with a three-phase winding.

Reversing.—To change the direction of the rotation of this motor, it is only necessary to reverse the wires a and b at the starting box, or at the motor.

The three windings of a motor are usually connected in what is called a "delta" for running, as shown in Fig.

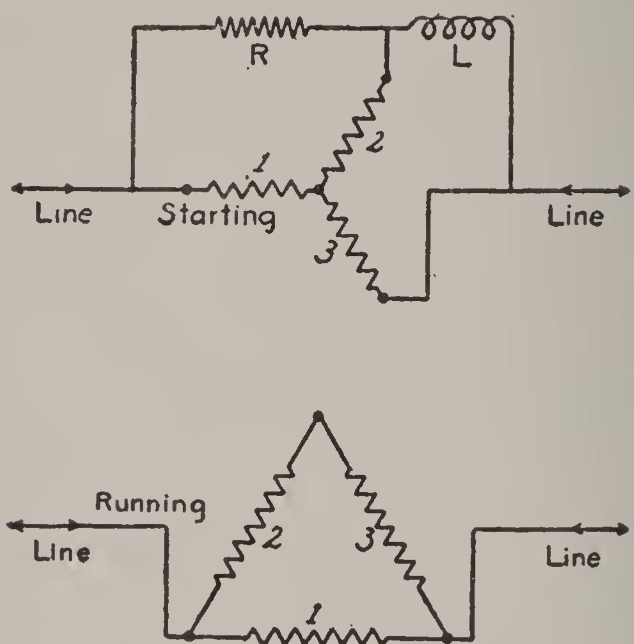


FIGURE 127.

127B, but where this connection is made permanently in the motor, the same connection must also be used for starting. If these windings can be connected in "star" for starting, as shown in Fig. 127A, the motor will take a much smaller starting current.

A starting box which uses both resistance and reactance and connects the windings in "star" when starting and in "delta" when running, is shown in Fig. 128. It is necessary in wiring for this box and motor to carry the two wires from each winding of the motor to the starting box, as shown in Fig. 128.

Reversing.—The direction of rotation of this motor may be reversed by reversing the position of the wires on the starter that comes from the resistance and reactance, as shown at R and L in the figure. The external connections for Fig. 128 are shown in Fig. 129.

In installing induction motors with starters, the wire-

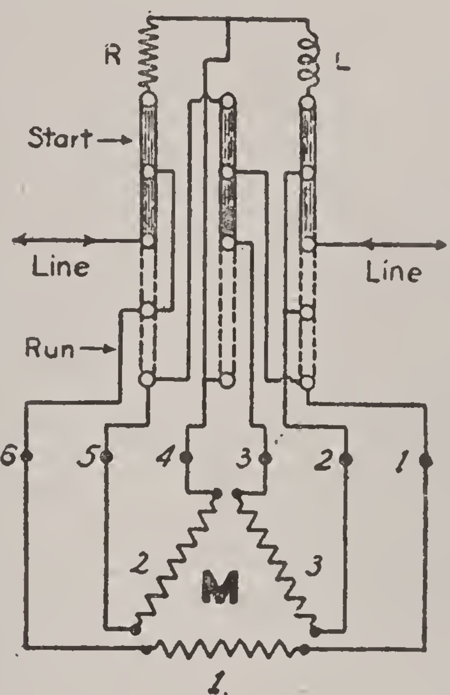


FIGURE 128.

man should be guided by the diagrams and instructions provided by the manufacturer.

Starting Polyphase Induction Motors.—Polyphase, or

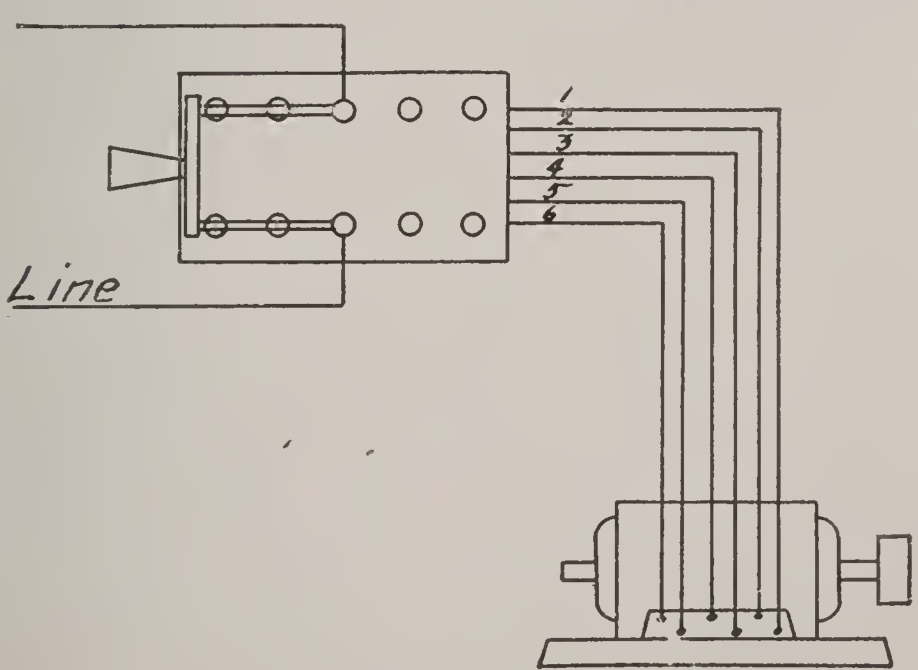


FIGURE 129.

two- and three-phase, induction motors are inherently self-starting; and small motors of this type may be thrown directly across the line. To limit the current taken by large motors of this type in starting, one of two types of starters is generally used. One type employs a resistance unit for each phase, which is placed in

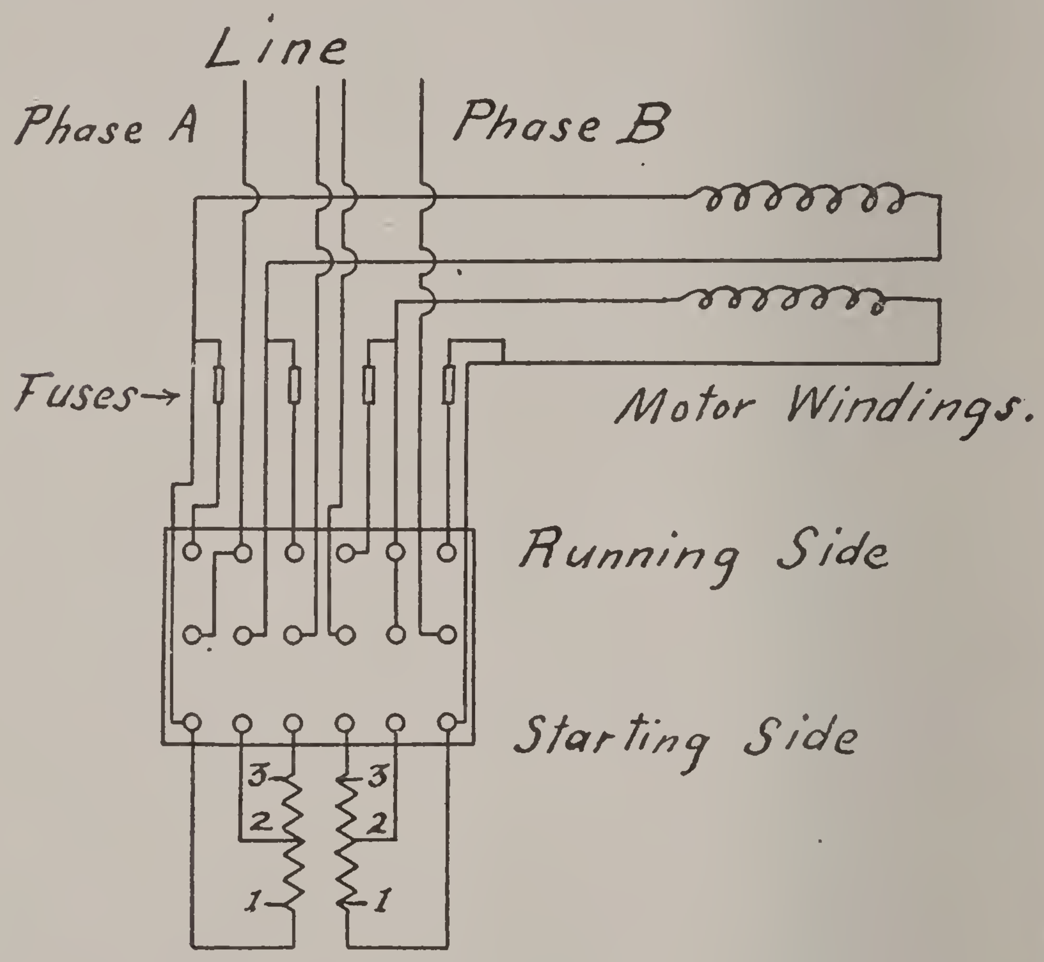


FIGURE 130.

series with the phases when starting and is cut out after the motor reaches full speed. A more expensive, but much more satisfactory, starter employs an auto-transformer for each phase. Taps are taken out from the transformer which make it possible to select a voltage for starting that is suitable for that particular motor. With a resistance starter, some form of double-throw switch is arranged to connect resistance in series with each phase for starting and to connect the motor directly across the line for running.

The connections of a self-contained auto-starter for a two-phase induction motor are shown in Fig. 130.

The auto-starter, or compensator shown in Fig. 130,

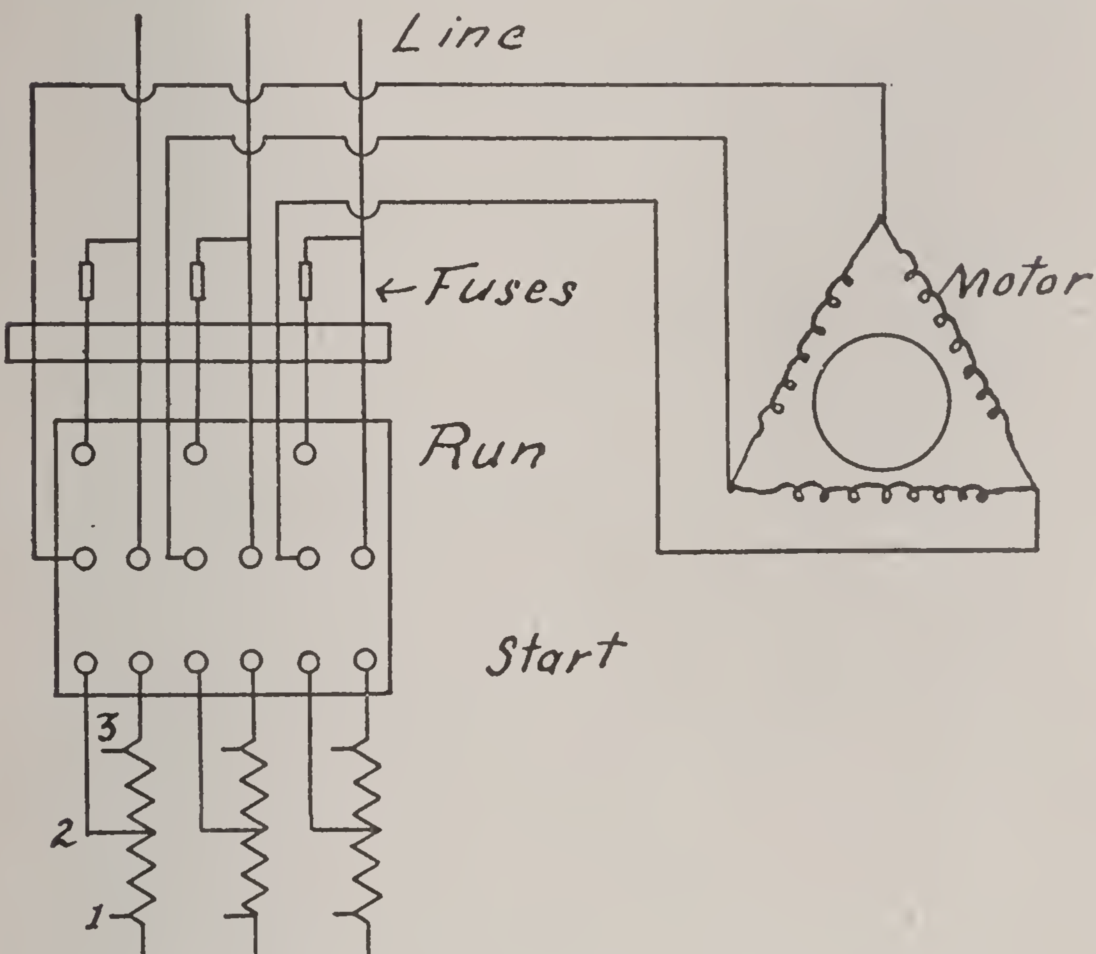


FIGURE 131.

gives the arrangement of all the internal connections. In practice it is only necessary to connect the marked terminals to the four wires from the line and the other four terminals to the motor.

Reversing.—To reverse the direction of rotation of a two-phase motor, reverse the wires of one phase. If the circuit used should be a 3-wire, 2-phase, instead of a 4-wire, 2-phase, the direction of rotation may be reversed by reversing the position of the two smaller wires.

On such a circuit the wire that is common to both phases must be one and one-half times larger than either of the other two wires. This wire remains as connected and the other two are reversed.

Three-phase induction motors are started by an auto-starter or compensator similar to the one used for two-

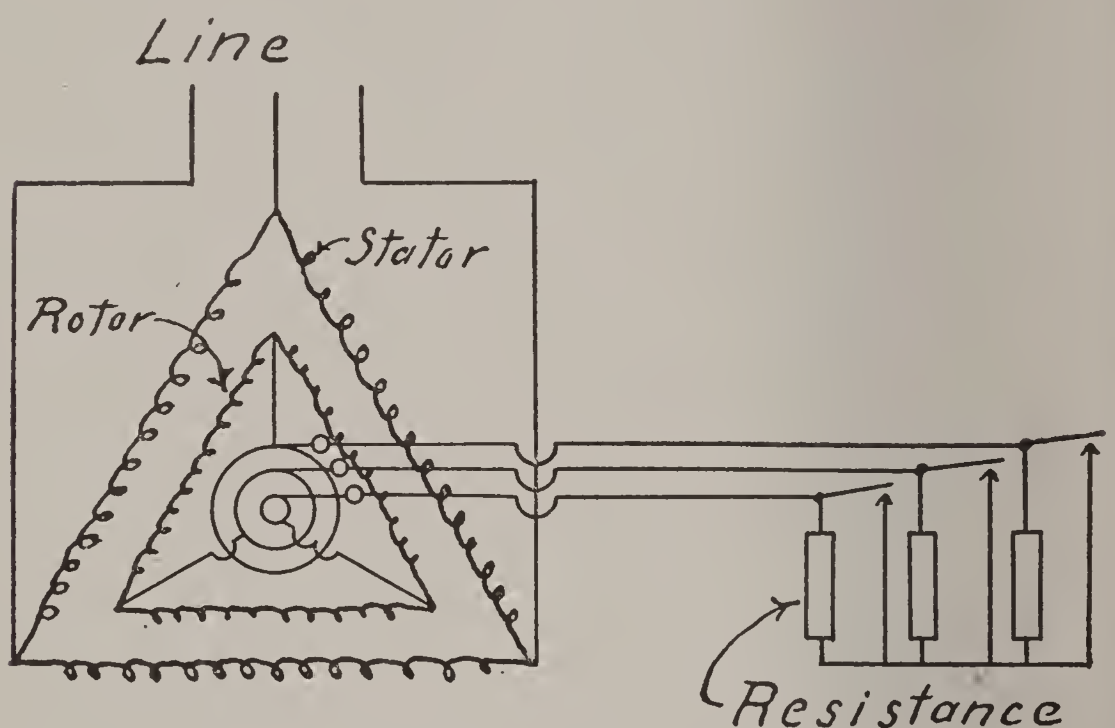


FIGURE 132.

phase motors. Fig. 131 shows the connections for such a starter.

This starter is self-contained. To install it, it is only necessary to connect to the marked terminals the three wires from the motor.

To reverse the direction of rotation of a three-phase motor, reverse the connections of any two wires.

Three-phase induction motors are on the market which employ a wound stator and a wound rotor. This wound rotor is sometimes used for starting by taking taps from the winding and connecting them to a resistance which may be either internal or external to the motor. This resistance is placed in circuit with the winding for starting and is short-circuited while running. The resistance may be cut in and out of circuit by a lever on the machine or by an external switch. Fig. 132 shows the connections for such a motor.

Where the resistance used is external to the motor, the speed of the motor is sometimes regulated by placing part of the resistance in the rotor circuit.

Synchronous Motors.—Synchronous motors of the

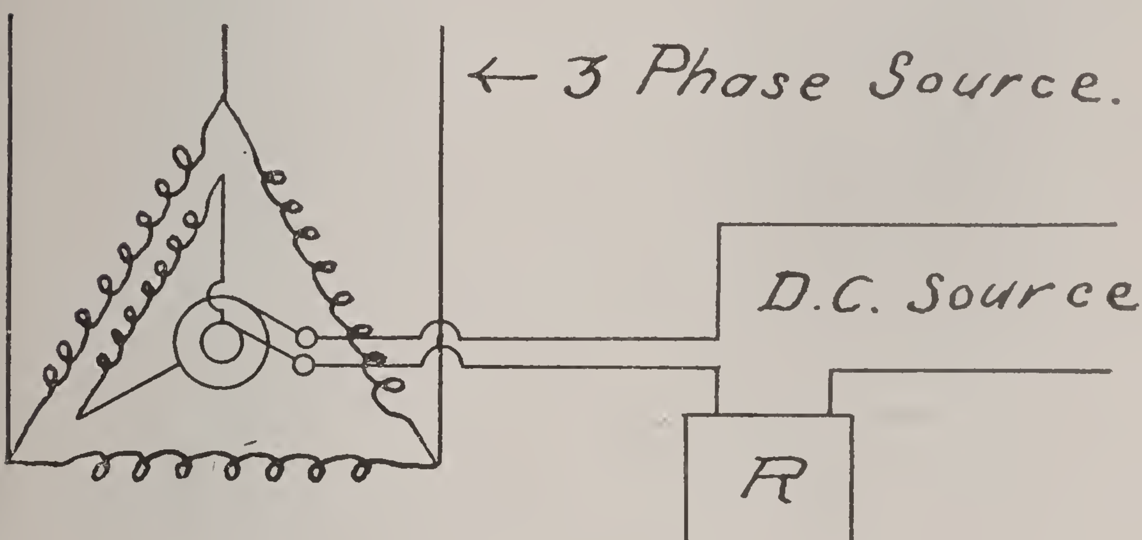


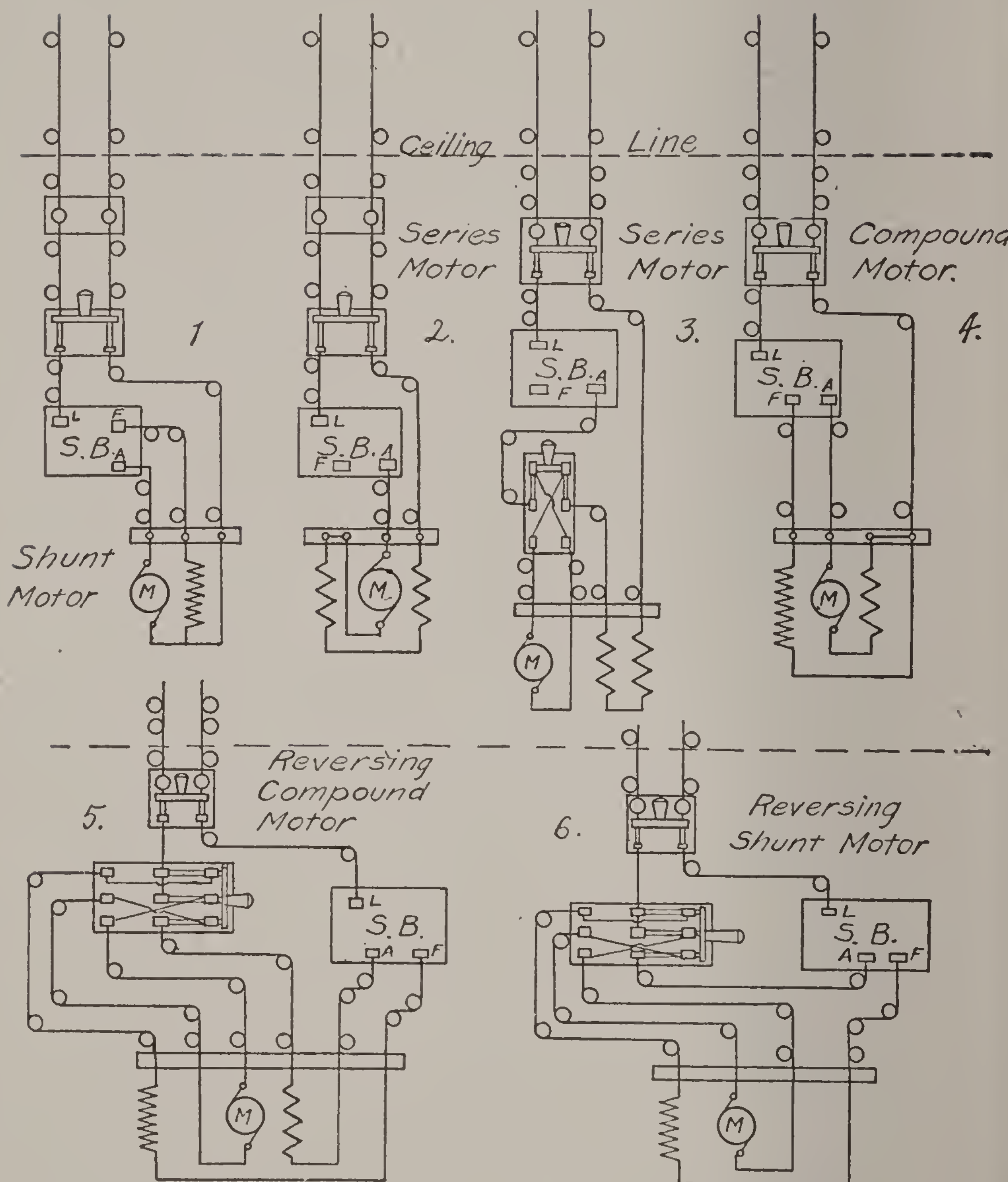
FIGURE 133.

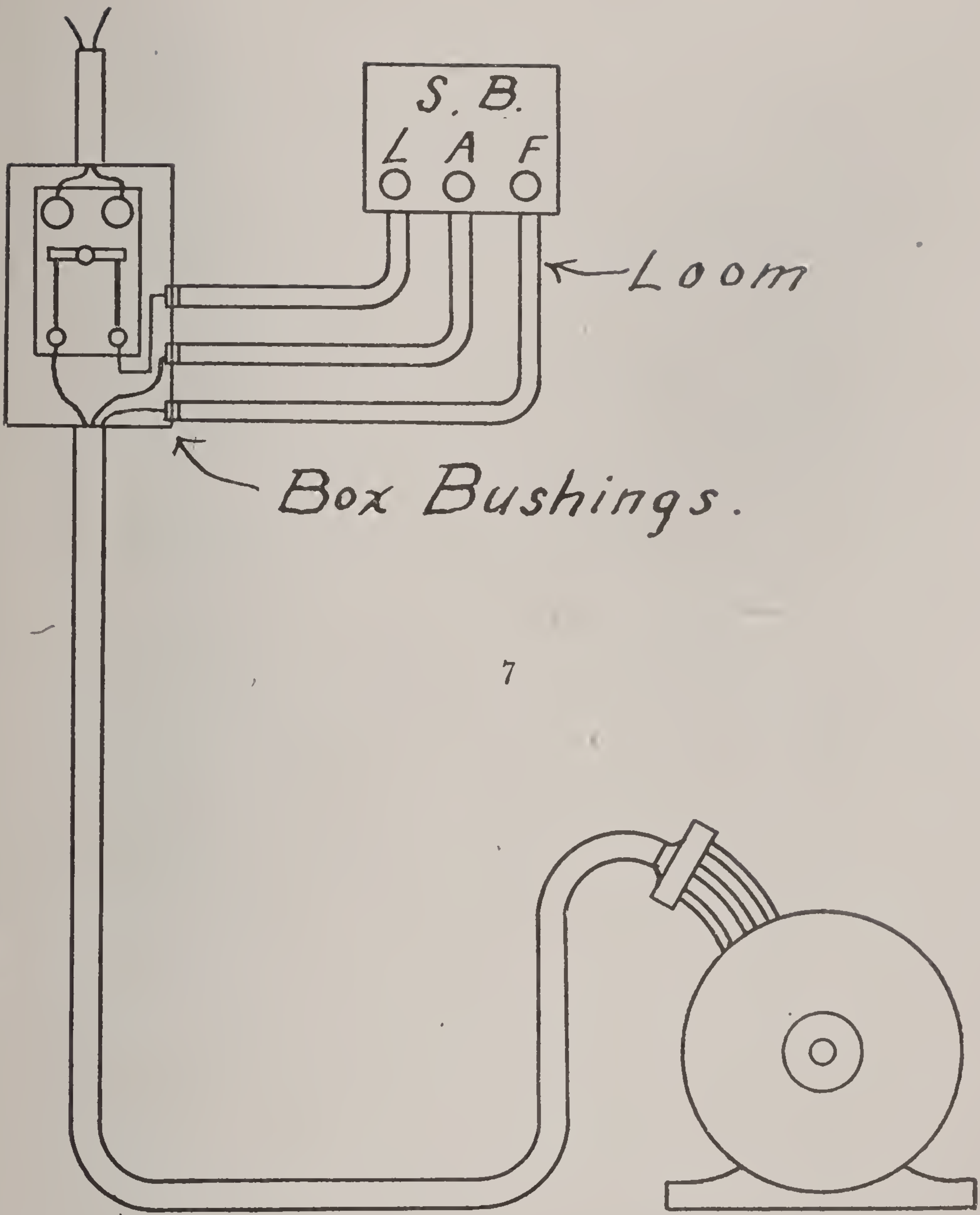
larger size are sometimes used on alternating current circuits. They run at the same speed, pole for pole, as the alternator furnishing the current and have the advantage that they improve the power factor of the line. They may be used on single-phase, two-phase or three-phase circuits, though in practice they are seldom used except in three-phase circuits. The synchronous motor requires a direct current source of power to excite one of the windings, which is called the field of the motor. The field may be the stationary or the revolving member. Fig. 133 shows a three-phase synchronous motor with a revolving field.

QUESTIONS.

1. What wiring systems may be used in wiring for motors?
2. What two systems are most widely used in wiring for motors? Which is the better, and why?
3. What are the Code requirements in regard to insulating motors from the ground?
4. Under what conditions may single-pole switches be used for motors?
5. What sized wire is required for motors?
6. What is the largest current which plug fuses are permitted to carry?
7. What kind of switches are usually employed in controlling the larger motors? Why?
8. Where must the switch and rheostat be placed in respect to the motor?
9. Explain the connection of the field and armature windings of a shunt motor.
10. For what purpose are shunt motors used in practice?
11. How high above the floor should a motor's switch and starting box be placed?
12. Explain in detail a method of mounting a starting box or rheostat.
13. In wiring for motors with open work, where is circular loom required on the wires?
14. Explain the method of starting a direct current motor.
15. How may the direction of rotation of a shunt motor be reversed?
16. How may the speed of a shunt motor be increased? Be decreased?
17. Explain the connection of the field and armature windings in a series motor.
18. For what purpose are series motors used in practice?
19. How may the direction of rotation of a series motor be reversed?
20. How are the field coils and the armature of a compound motor connected?
21. For what purposes are compound motors used in practice?

22. How may the direction of rotation of a compound motor be reversed?
23. What types of motors are used on alternating current circuits?
24. For what purposes are series A. C. motors used in practice?
25. Explain the different methods of starting single-phase induction motors.
26. Explain the method of reversing the direction of rotation of a three-phase motor used on single-phase.
27. Show by diagram the windings of a three-phase motor connected in "delta." In "star."
28. What forms of starters are employed for starting large polyphase induction motors?
29. How may the direction of rotation of a 2-phase, 4-wire induction motor be reversed? A 2-phase, 3-wire?
30. How may the direction of rotation of a 3-phase motor be reversed?
31. What method is sometimes employed for regulating the speed of a 3-phase induction motor?


Ceiling Line
1
Shunt Motor
S.B.
L
F
A
M
2.
Series Motor
S.B.
L
F
A
M
3.
Series Motor
S.B.
L
F
A
M
4.
Compound Motor.
S.B.
L
F
A
M
5.
Reversing Compound Motor
S.B.
L
A
F
M
6.
Reversing Shunt Motor
S.B.
L
A
F
M



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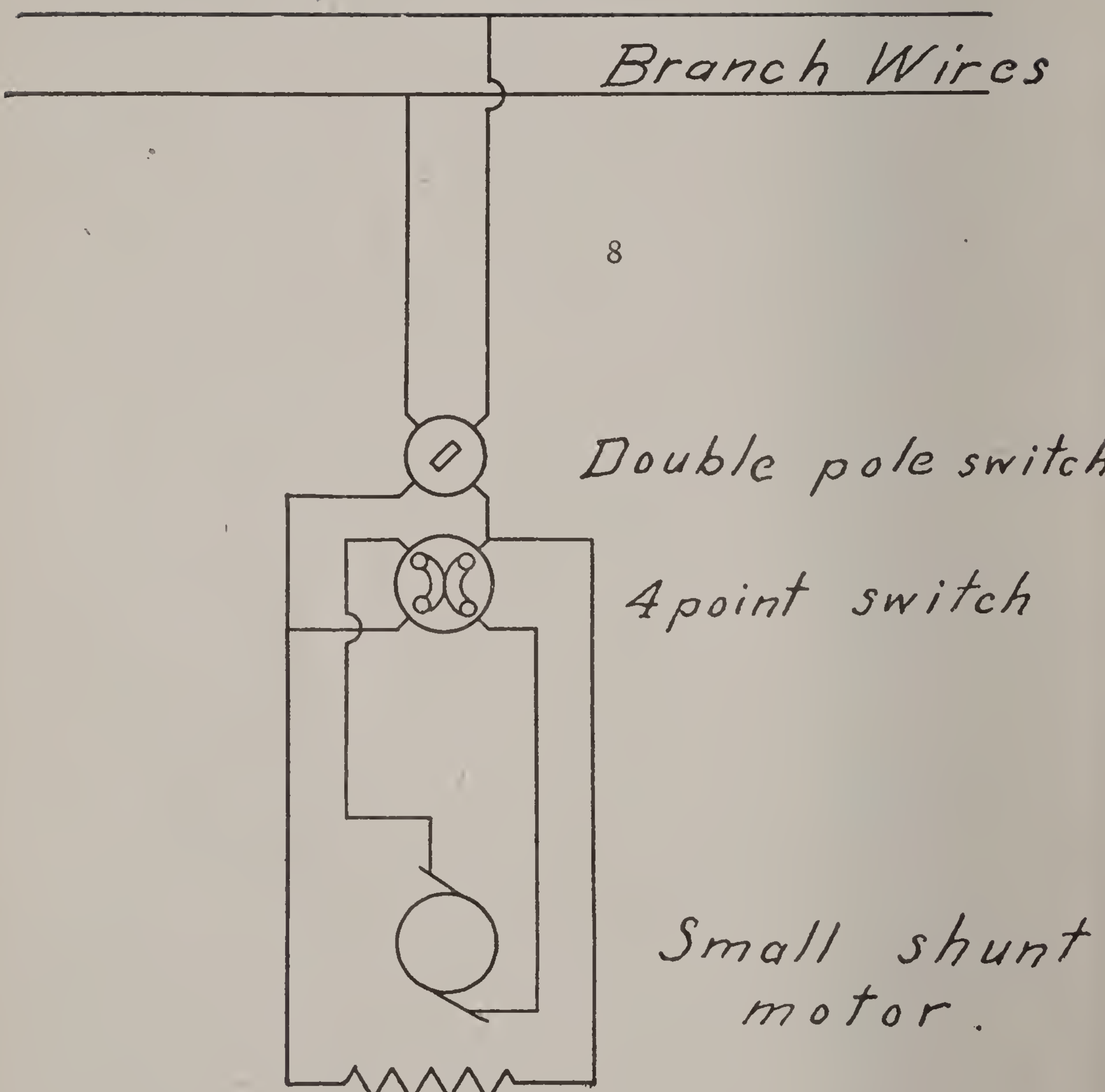
Branch Wires
8
Double pole switch
4 point switch
Small shunt motor.

CHAPTER XI

TELEPHONES

Important Requirements.—The wiring for telephones, like other low voltage wiring, is covered by only a few Code requirements. The reason for these requirements is chiefly the possibility of the telephone wires' coming into contact with heat, light or power wires. The requirements for telephones in the Code are given under signaling systems, and as a convenience to the reader the rules that apply especially to telephones will be given.

Rule No. 85, Section A.

(a) Outside wires should be run in underground ducts or strung on poles, and kept off the roofs of buildings, except by special permission, and must not be placed on the same cross-arm with electric light or power wires. They should not occupy the same duct, man-hole or hand-hole of a conduit system with electric light or power wires. Single manholes, or hand-holes separated into sections by means of partitions of brick or tile will be considered as conforming with the above rule.

When the entire circuit from central station to building is run in underground conduits the following rules do not apply.

(b) When outside wires are run on the same pole with electric light or power wires, the distance between the two inside pins of each cross-arm must not be less than twenty-four inches.

When the wires are carried in approved cables the next three sections, c, d, and e, do not apply.

(c) When wires are attached to the outside walls of buildings, they must have an approved rubber insulating covering, and on frame buildings or frame portions of other buildings shall be supported on glass or porcelain insulators, or knobs.

(d) The wires from last outside support to the cut-outs or protectors must be of copper, and must have an approved rubber insulation, and must be provided with drip loops immediately outside the building and at entrance.

(e) Wires must enter building through non-combustible, non-absorptive, insulating bushings sloping upward from the outside; and both wires may enter through the same bushing if desired.

Telephone Protectors.—Installations where the current-carrying parts of the apparatus are not capable of carrying indefinitely a current of 10 amperes:

The installation must be provided with an approved protective device located as near as possible to the entrance of the wires to the building. The protector must not be placed in the immediate vicinity of easily ignitible stuff, or where it is exposed to inflammable gases or dust or flyings of combustible materials.

Wires from entrance to building to protector must be supported on porcelain insulators, so that they will not come into contact with anything except their designed supports.

The ground wire of the protective device shall be run in accordance with the following requirements:

1. It shall be of copper and not smaller than No. 18 B. & S. gauge.

2. It must have an insulating covering approved for voltages from 0 to 600, except that the preservative compound may be omitted.

3. It must run in as straight a line as possible to a good permanent ground. This may be obtained by connecting to a water or gas pipe connected to the street mains or to a ground rod or pipe driven into permanently damp earth. When connections are made to pipes, preference shall be given to water pipes. If attachment is

made to a gas pipe, the connection in all cases must be made between the meter and the street mains. In every case the connection shall be made as near as possible to the earth.

When the ground wire is attached to a water pipe or a gas pipe, it may be connected by means of an approved ground clamp fastened to a thoroughly clean portion of said pipe, or the pipe may be thoroughly cleaned and tinned with resin flux solder, and the ground wire then be wrapped tightly around the pipe and thoroughly soldered to it.

When the ground wire is attached to a ground rod driven into the earth, the ground wire shall be soldered to the rod in a similar manner.

Steam or hot water pipes must not be used for a protector ground. The protector, referred to in the preceding rules, consists of a fuse, a lightning arrester and a heat coil. Though a lightning arrester is usually provided on the telephone, this is not considered as sufficient protection. A standard arrester and fuses should be added to the circuit, as the protector and heat coils should also be inserted, where the circuit, normally closed, through the magnet windings cannot indefinitely carry a current of at least five amperes. The fuses must be so placed as to protect the arrester and the heat coils.

Telephone Wiring.—The wires from the fuses and arrester may be run concealed or open. When it is practical the wires should be concealed and this is very desirable if there are a number of wires. The wires may be grouped into a cable and passed in partitions or between floors; however, a more substantial and satisfactory plan is to run them in a conduit raceway. Such conduits should be installed during the construction of the building.

Open Wiring.—Open wiring is usually done with a twisted pair held in place with nails having insulated heads. Such wires are usually passed around window facings, door jambs, and along baseboards to make them less conspicuous. The wires should be insulated by a substantial covering from each other and from any non-conducting surfaces wired over. Where a space of at least two inches cannot be maintained between telephone wires and electric light and power wires, or iron pipes, steel girders, etc., an extra insulation such as a porcelain tube should be placed over the wires.

Caution.—Telephone wires should never be placed in the same duct with or run near light or power wires,

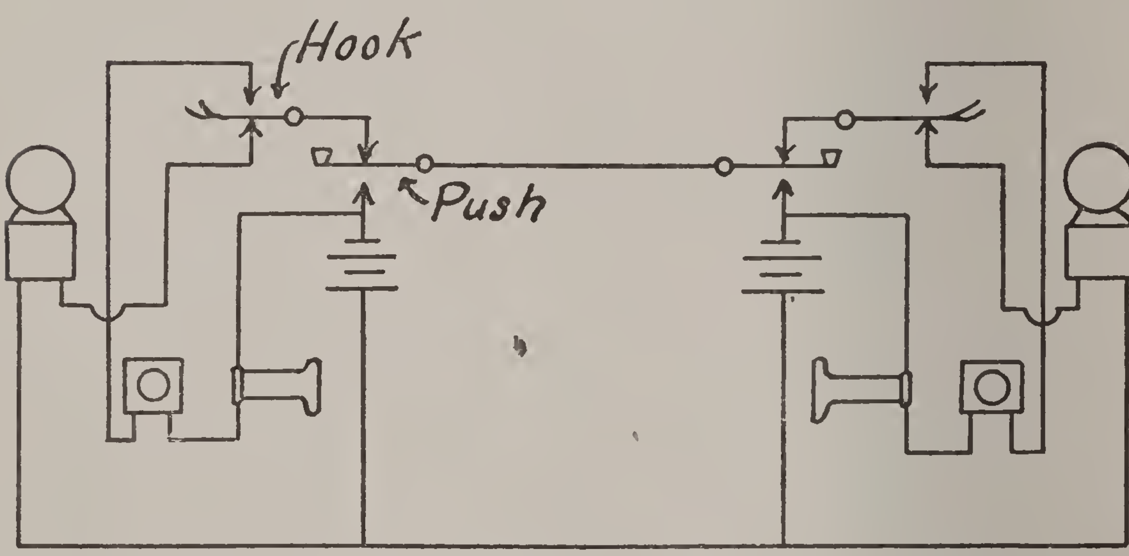

FIGURE 134.

not only because of the possibility of the wires' coming in contact with each other, but because parallel power wires often produce by induction objectionable noises in the telephone receivers.

Kinds of Telephone Systems.—Telephone wiring may be roughly divided into two classes; namely, that done by the owner of a building and that done by the telephone company. Under the former should come the installing and wiring for any telephones that may be required in the establishment, such as private or inter-communicating systems. Under the latter should come the installing and wiring for any telephones placed on the premises by the local telephone company, including extensions and private branch exchanges.

Two-party System.—Perhaps the simplest example of

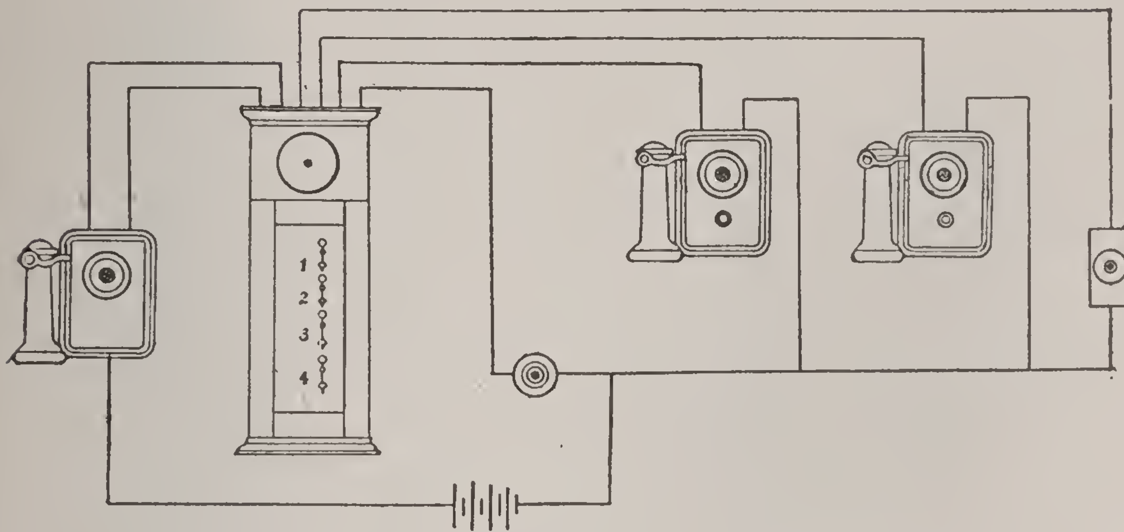

FIGURE 135.

an interior telephone system is a battery system between two parties, as shown in Fig. 134.

As shown in the figure, signaling is done with a bat-

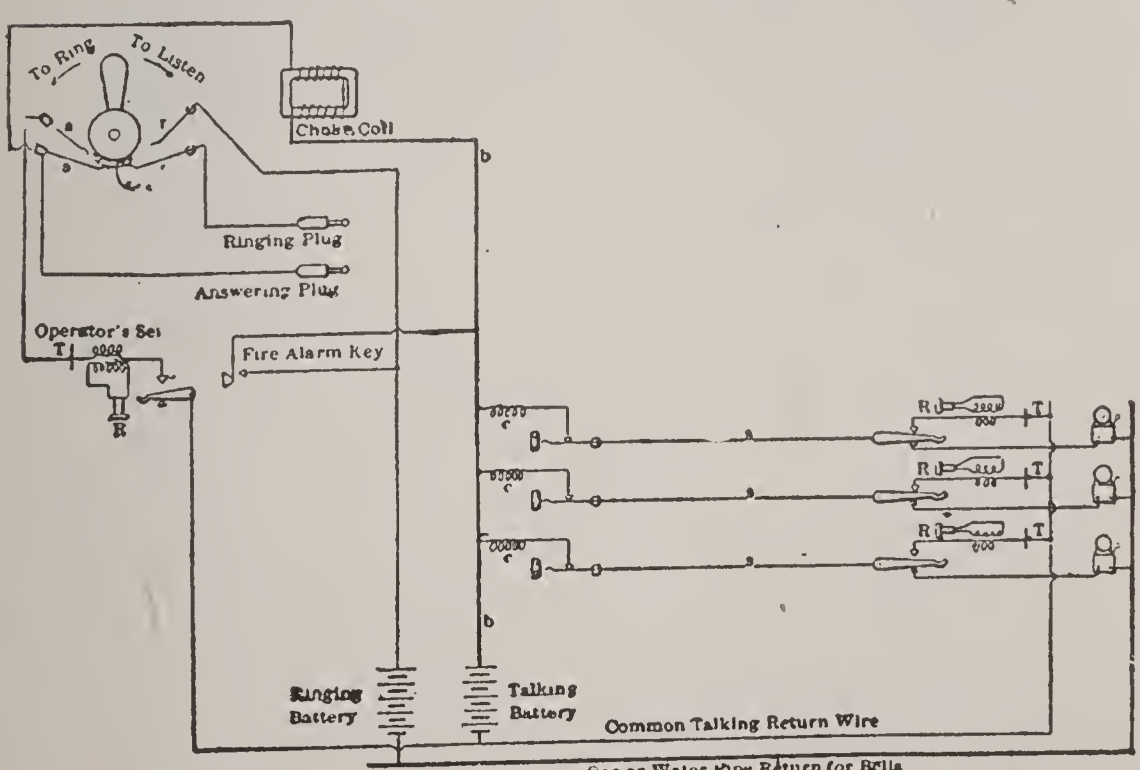

FIGURE 136.

tery, double contact push buttons and a vibrating bell. When the receivers are taken from the hooks the circuit is closed through both transmitters, receivers and

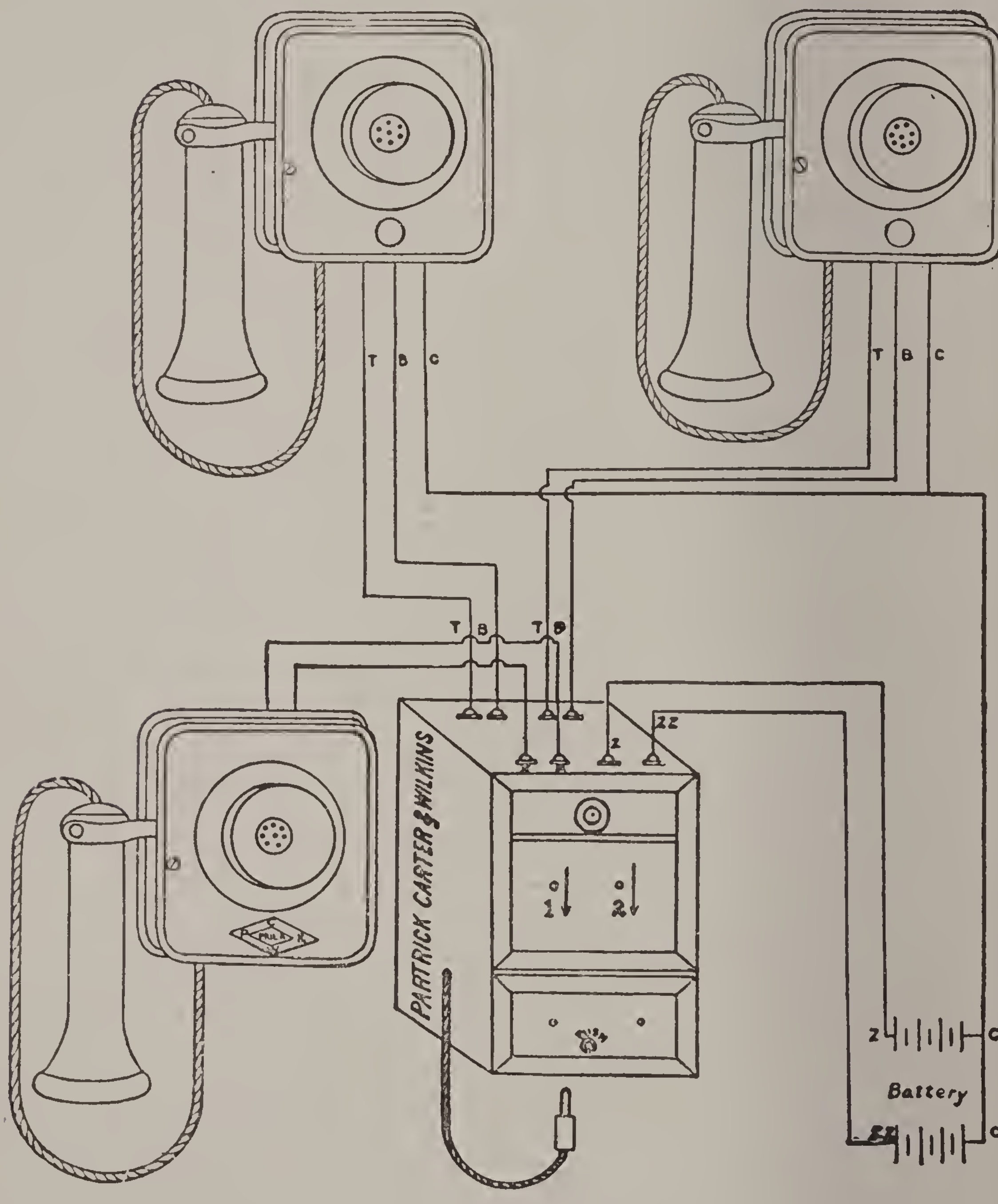

FIGURE 137.

batteries. The batteries should be connected so as to aid each other when the talking circuit is made. This type of telephone when wired with No. 18 wire is very satisfactory for distances up to 500 feet.

Kitchen Annunciator System.—Often it is desirable to install a telephone annunciator system, instead of an existing return call annunciator system, in a private resi-

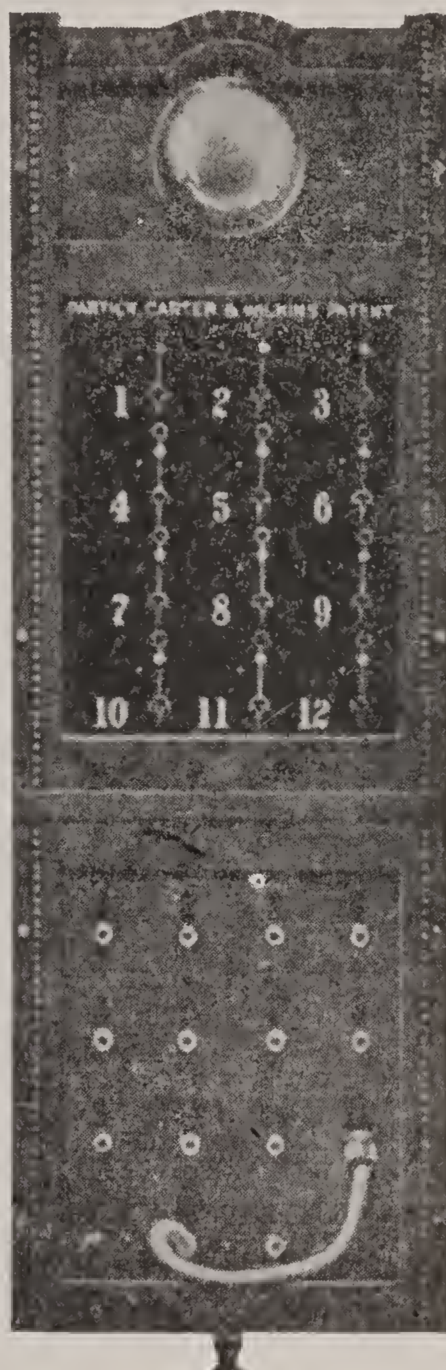

FIGURE 138.

dence or hotel. The existing wiring may be used for this system by installing telephones instead of the bells and buttons in the rooms and replacing the old annunciator with one employing a telephone. Fig. 135 shows this plan applied to a kitchen annunciator telephone system. With this arrangement the room can call the annunciator but the servant cannot call the room.

Hotel Annunciator System.—The same plan is applied on a larger scale to hotel telephone annunciators. The connections of such a system using three-room telephones and employing the existing wiring for a return call annunciator is shown in Fig. 136. Each room telephone is

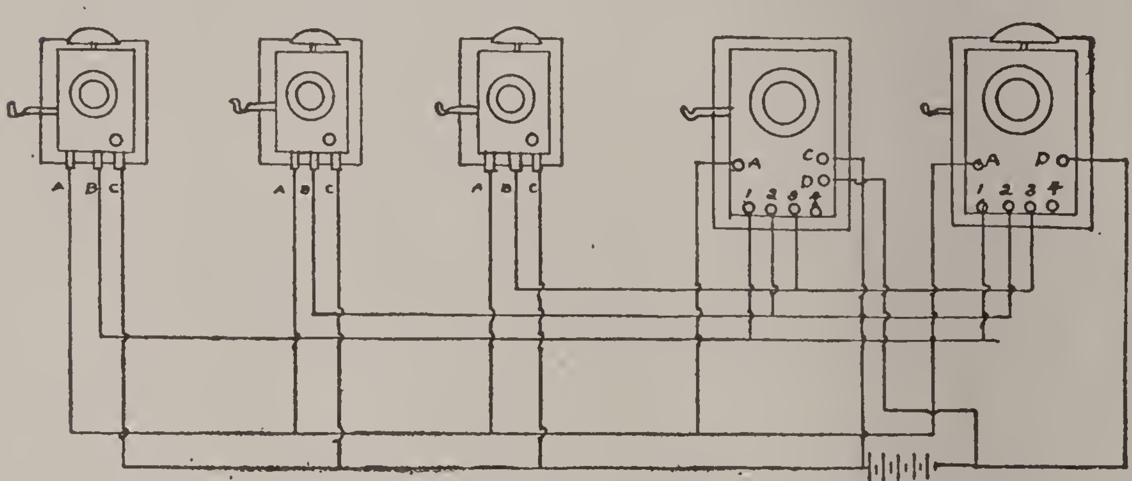

FIGURE 139.

connected to one individual wire that runs to the annunciator and to the two common return wires.

The diagram for a similar system employing two-room telephones is shown in Fig. 137. An illustration of a telephone annunciator to be used with this diagram is shown in Fig. 138. The operation of the system is as follows:

To call the office from a room, press the button on the room set. This indicates on the annunciator the point from which the call is made. The attendant at the annunciator inserts a plug in the corresponding room number on the telephone board and answers call by pushing button located on the annunciator. Upon the room bell's ringing, the person in the room takes the receiver off the hook and proceeds with the conversation. When the plug is in position on the board, no other room can hear the conversation, but should a call come in from any room it would be indicated on the annunciator.

To call a room, insert a plug in the hole corresponding to the point desired and press the push on the annunciator.

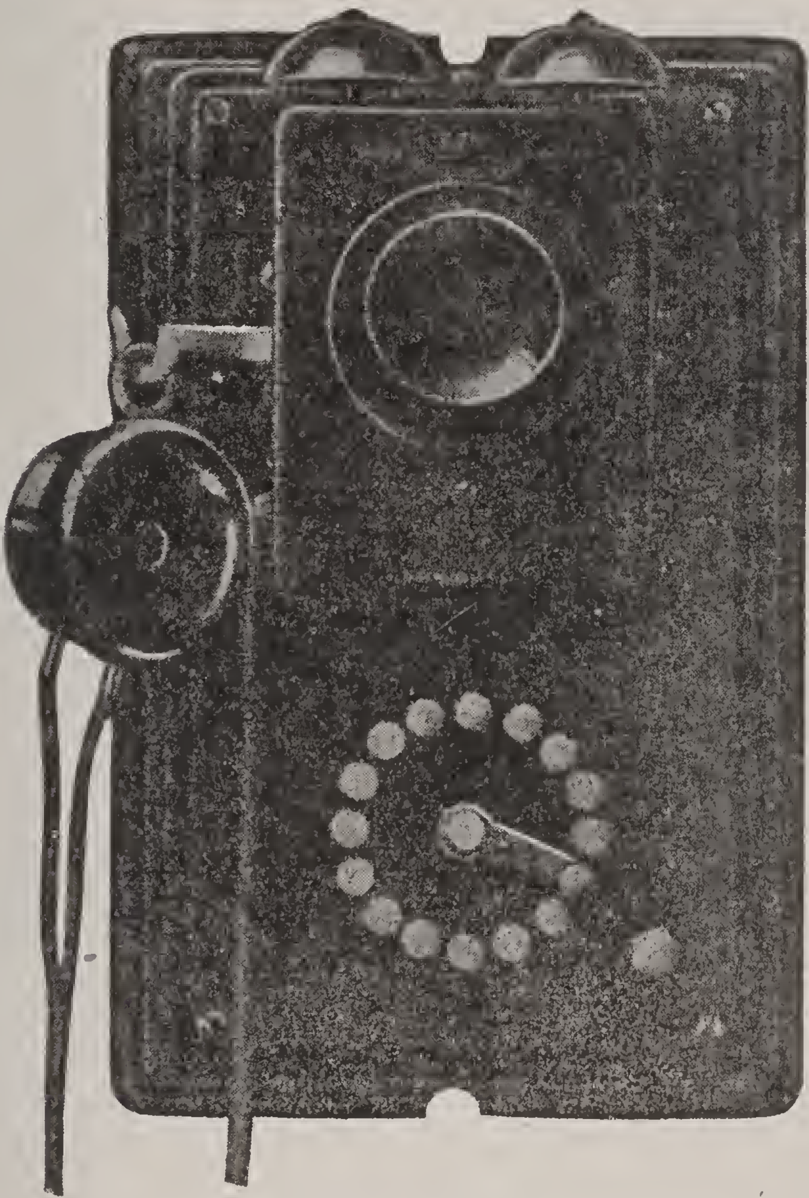

FIGURE 140.

This can be made intercommunicating by using an extra set of plugs and an extra battery. When used for intercommunicating it does not interfere with the calling or talking on any other portion of the system. No conversation can be heard outside of those in communication.

Six to eight cells of battery are usually ample for an ordinary house or hotel annunciator. This system is arranged for 2 leading wires and 1 battery wire; in other words, for a hotel of 100 rooms there would be 201 wires required.

Apartment House System.—A type of telephone system designed to take the place of speaking tubes in apartment houses is shown in Fig. 139. This system permits

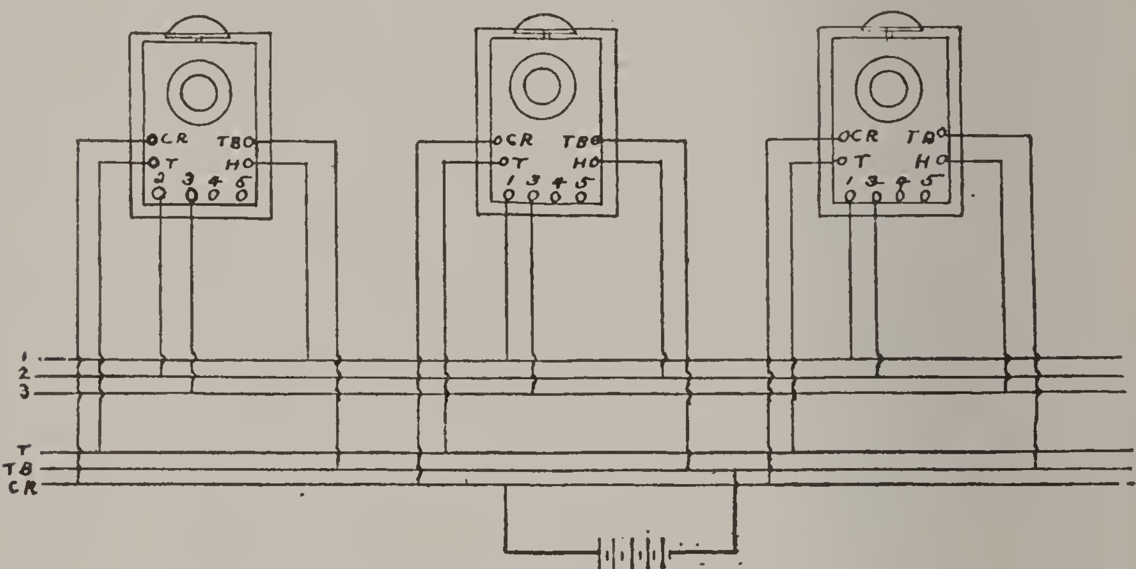

FIGURE 141.

communication between the entrance and the rooms and between the janitor and the rooms. One set of battery is employed for both ringing and talking circuits.

Intercommunicating System.—Where it is desired to converse between the different parts of an establishment without using a common switch board, a type of telephone called intercommunicating is employed. This type of telephone employs some switching arrangement on each case by means of which the circuit to any telephone in the system may be closed for signaling and conversation. Fig. 140 shows the instrument and Fig. 141 the wiring for three such telephones.

Much time will be saved in the wiring if wires with different colored insulation are used for this class of installation. For instance, it is a good plan to use red for the common return wire, blue for the talking battery wire, yellow for the telephone wire, and white for the switch wires to the telephones. An objection sometimes made to this system is that there may be cross-talk when more than one pair of telephones are being used. Such cross-talk will not occur on a full metallic system, as shown in Fig. 142. Four cells of battery connected as

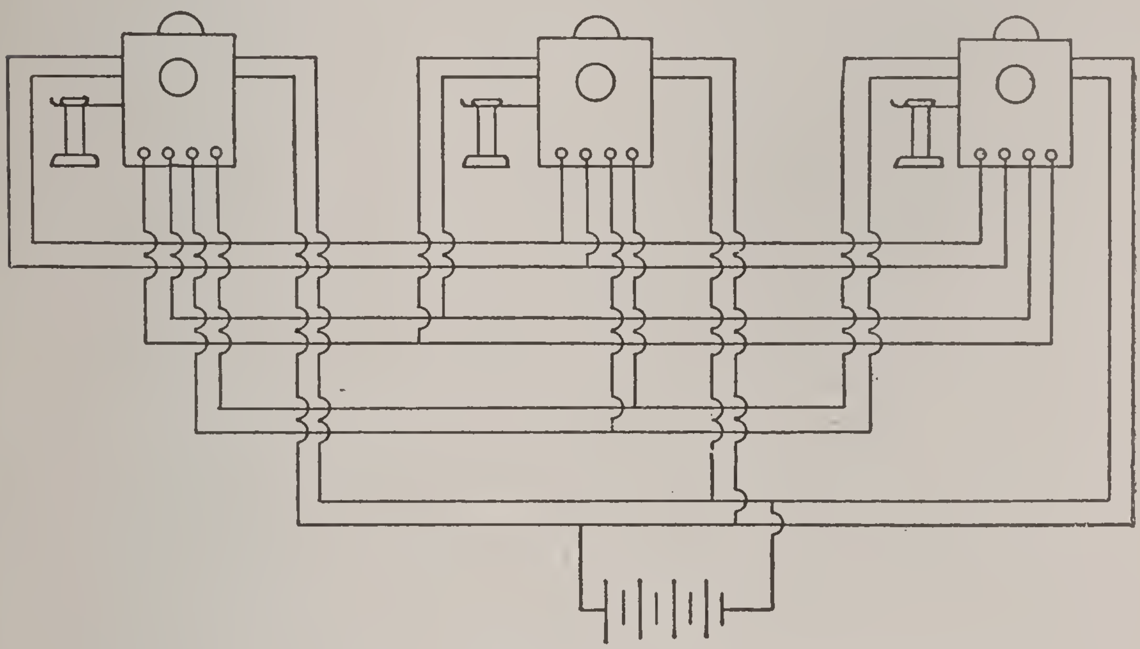

FIGURE 142.

shown in the figure are usually sufficient to operate such a system.

Standard Wall Sets.—Telephones for longer distance service including party lines, exchanges and long distance communication, commonly employ a hand magneto generator and a polarized bell for ringing and an induction coil to increase the magnitude of the talking current. Such a standard wall set with a list of important parts used in its construction is shown in Fig. 143.

The usual internal wiring for such a standard wall set, when connected from an exchange or on a party line, is shown in Fig. 144.

As shown in the diagram, when the receiver is on the hook the external circuit is closed through the bells, the generator being open-circuited by a switch operated from the crank. When the crank is turned, a switch is closed

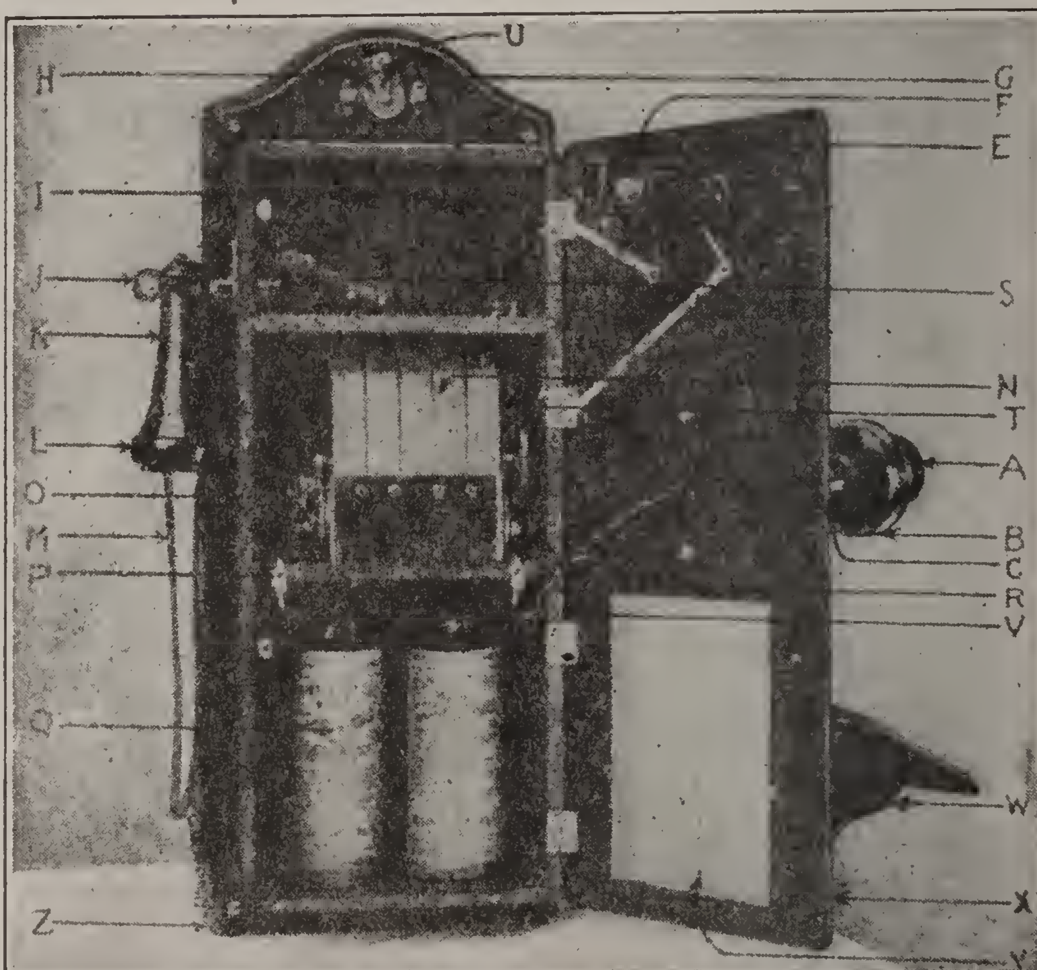

FIGURE 143.

A—Transmitter mouthpiece; B—Transmitter back shell; C—Enameled transmitter arm complete; E—Ringer coil; F—Ringer magnet; G—Line binding posts complete with plates; H—Carbon disc for lightning arrester; I—Induction coil complete; J—Hook lever; K—Receiver shell or body; L—Receiver cap; M—Receiver cords; N—Magnet for generator; O—Generator shunt springs complete; P—Wire terminal; Q—Dry batteries; R—Transmitter cord; S—Springs for hook switch; T—Large gear wheel; U—Ground spring complete with binding post; V—Small gear wheel for generator; W—Writing shelf with bracket; X—Front door for cabinet; Y—Diagram card; Z—Complete telephone cabinet.

through the generator, which places the generator in parallel with the home bell and the distant bell for signaling purposes. Removing the receiver from the hook allows the hook switch to rise, placing the receiver on the line in series with the secondary of the induction coil. At the same time the local circuit for talking purposes is closed through the battery transmitter and primary of the induction coil. Use of the induction coil has the advantage of removing the transmitter from the line cir-

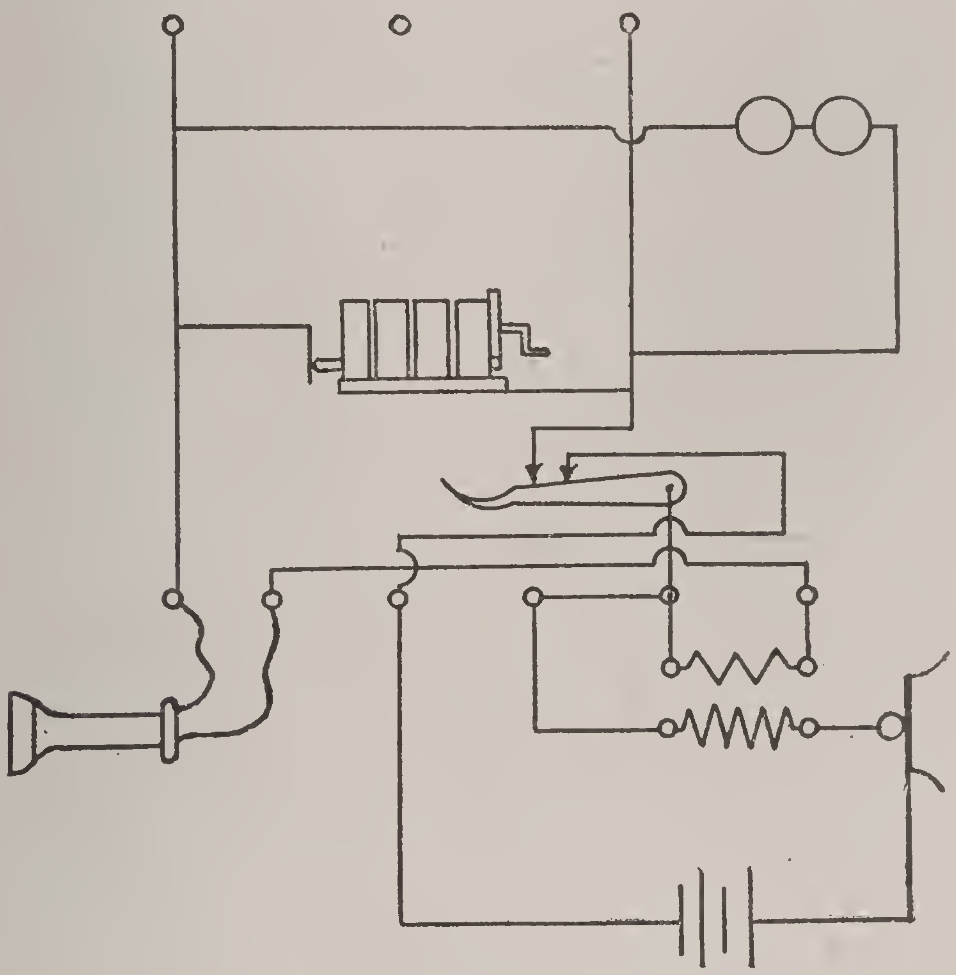

FIGURE 144.

cuit where a given change in resistance would produce a small alteration of current, and of placing it in a local circuit where the same amount of variation in resistance will cause a large alteration of current. Through the inductive action of the coil this effect is transferred in its magnified form to the secondary circuit which is connected in the main line. At the same time it transforms the talking current from a low voltage and large current to a higher voltage and smaller current, which can more readily be transmitted to a distant receiver.

Such telephones, when connected upon individual lines from an exchange, usually employ two wires from the exchange to the telephone. This is generally known as a full metallic circuit. They may be connected by using one wire and a ground return, but this is not considered

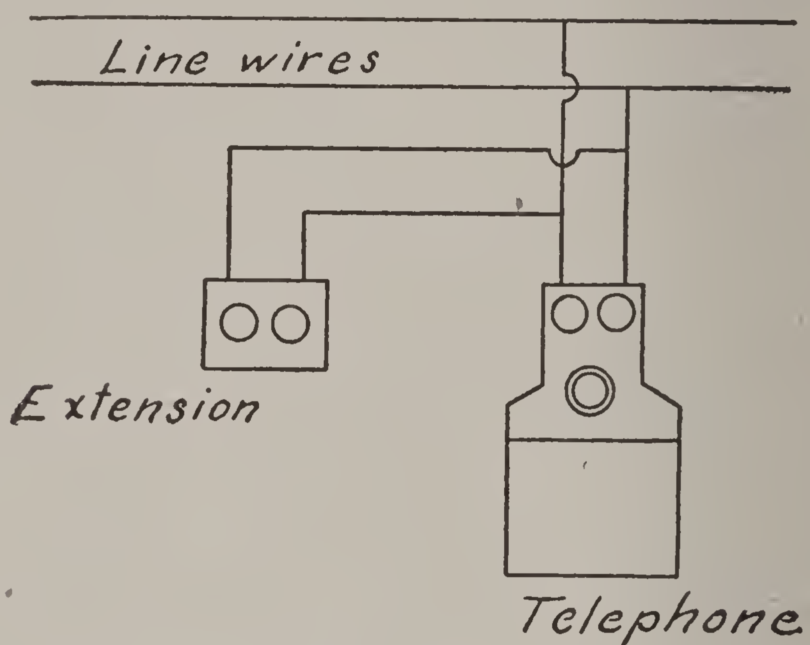

FIGURE 145.

good practice as other currents flowing through the earth may cause a noisy system.

Extension Bells.—Extension bells are sometimes connected to telephones for signaling. These are for calling only and have no telephones attached thereto. The wiring for such a bell on a bridging phone consists in connecting the two wires from the extension bell to the telephone line wires, either on the terminal block of the telephone itself or to another part of the line, as shown in Fig. 145.

For a series telephone line, where two or more telephones are connected in series, an extension bell may be placed in circuit by connecting it in series with the generator and bell on such a wall set, as shown in Fig. 146.

For either the bridging or series telephone the extension bell used should be of the same type and have the same resistance as the telephone bell.

Party Lines.—Where two or more telephones are con-

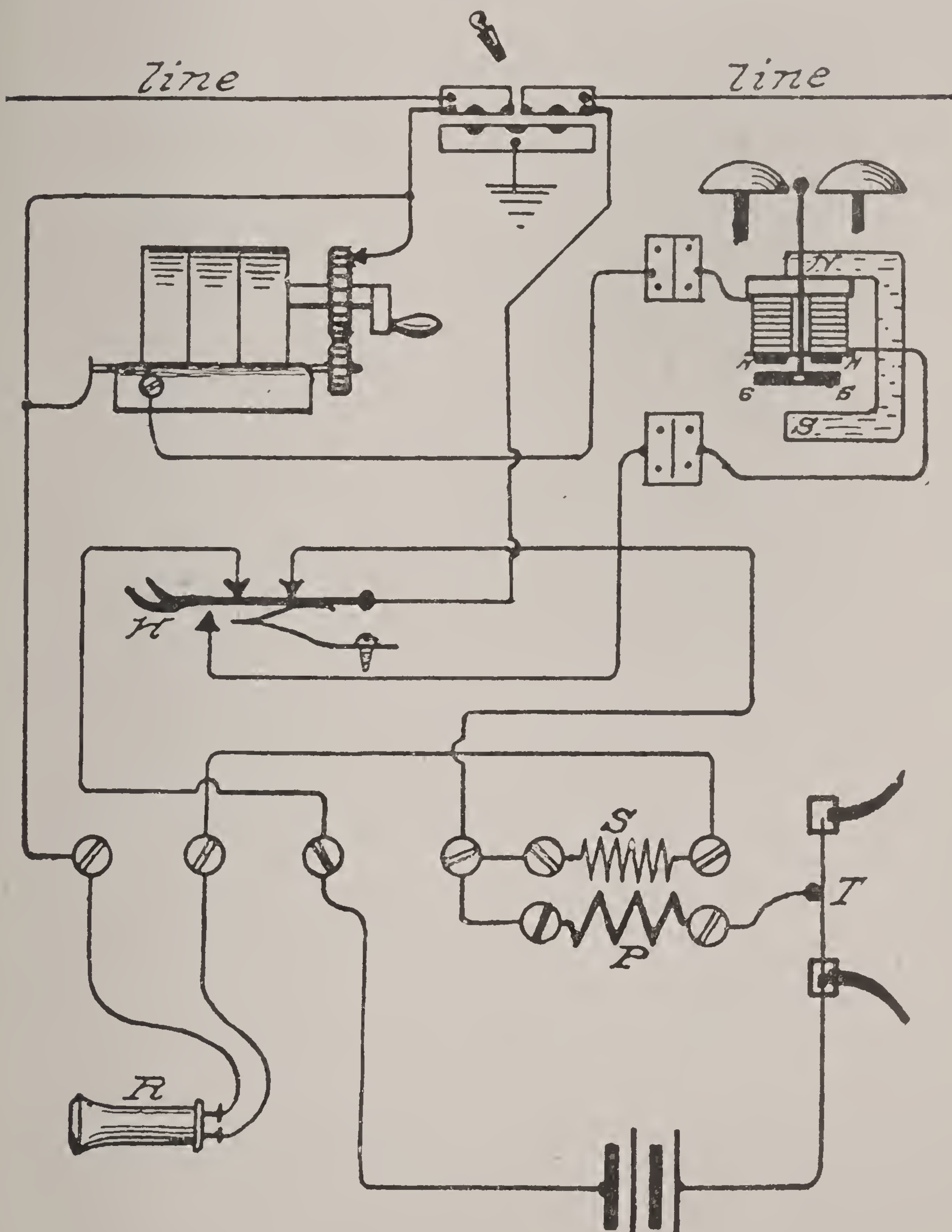

FIGURE 146.

nected to the same wire or pair of wires either in series or in multiple, it is called a party line. The internal wiring for a telephone employed on a party line is shown

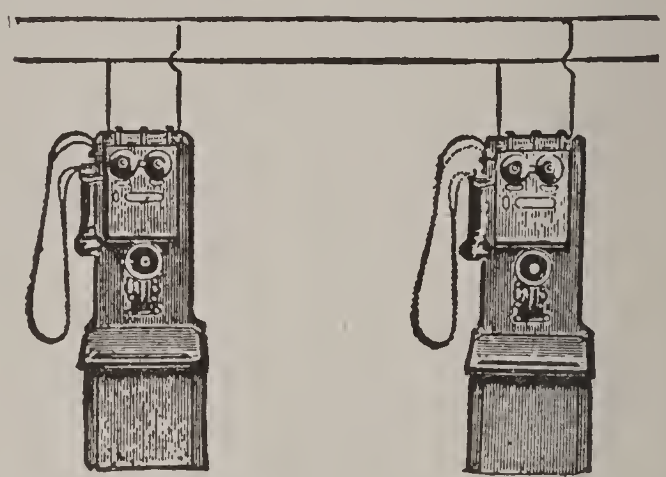

FIGURE 147. BRIDGING METALLIC LINE

in Fig. 144 for the bridging line and No. 146 for the series line. When two or more telephones are connected together in series, as shown in Fig. 149, the circuit is designated as a series metallic line. Instruments used for

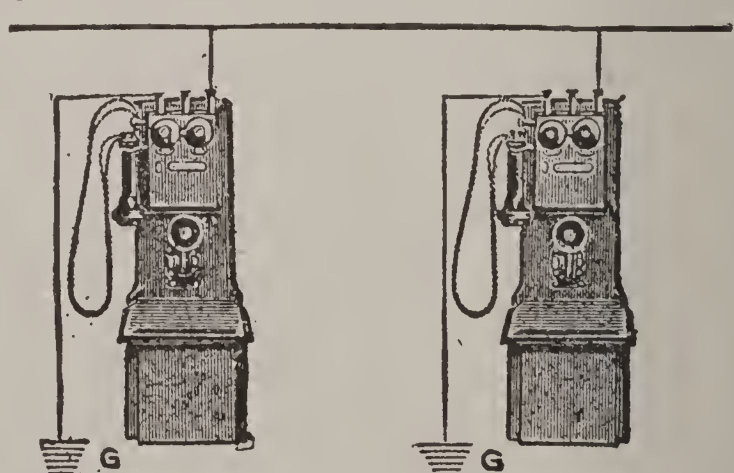

FIGURE 148. BRIDGING GROUNDED LINE

this purpose must be alike, and the bells and magnetos must be of suitable resistance for series operation.

When a number of telephones are connected together in multiple, as shown in Fig. 147, the circuit is designated a bridging metallic line. Here also, all instruments must be alike and the bells and magnetos must be of similar resistance for multiple operation. The bells should have a resistance of from 1,000 to 1,200 ohms and the magnetos, about 350 ohms. In addition to the

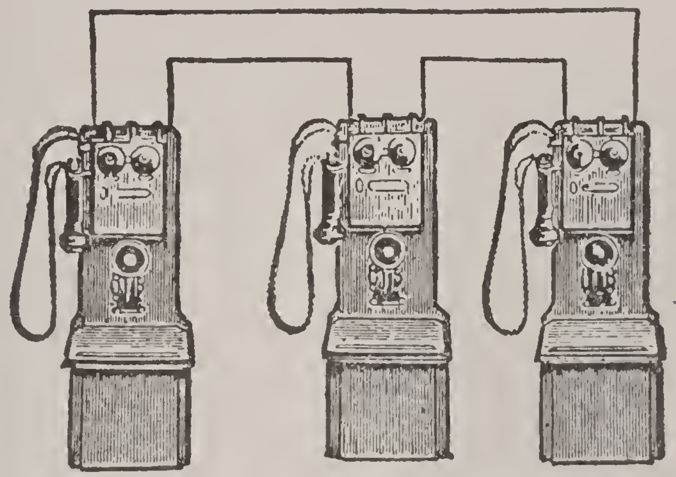

FIGURE 149. SERIES METALLIC LINE

metallic circuit, series and bridging lines shown in Figs. 149 and 147, the same result may be accomplished with grounded returns as shown in Figs. 150 and 148.

Of the four different connections the series grounded

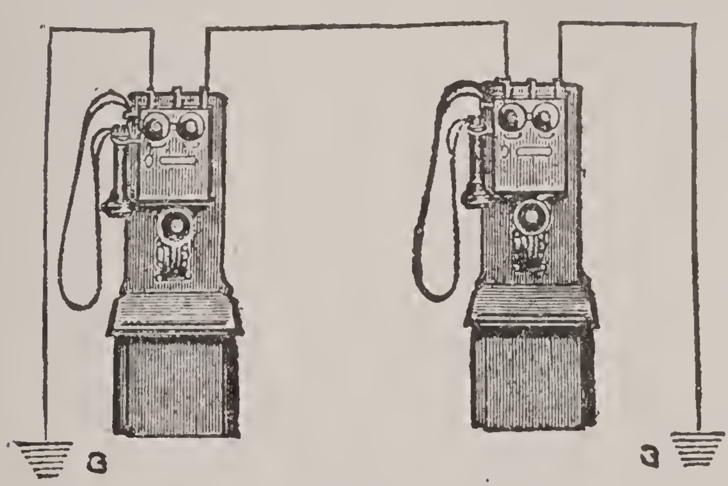

FIGURE 150. SERIES GROUNDED LINE

and the bridging grounded are the cheapest to install, though the number of telephones that will give satisfaction on such a circuit is usually limited to from four to six. With a series metallic line a few more telephones

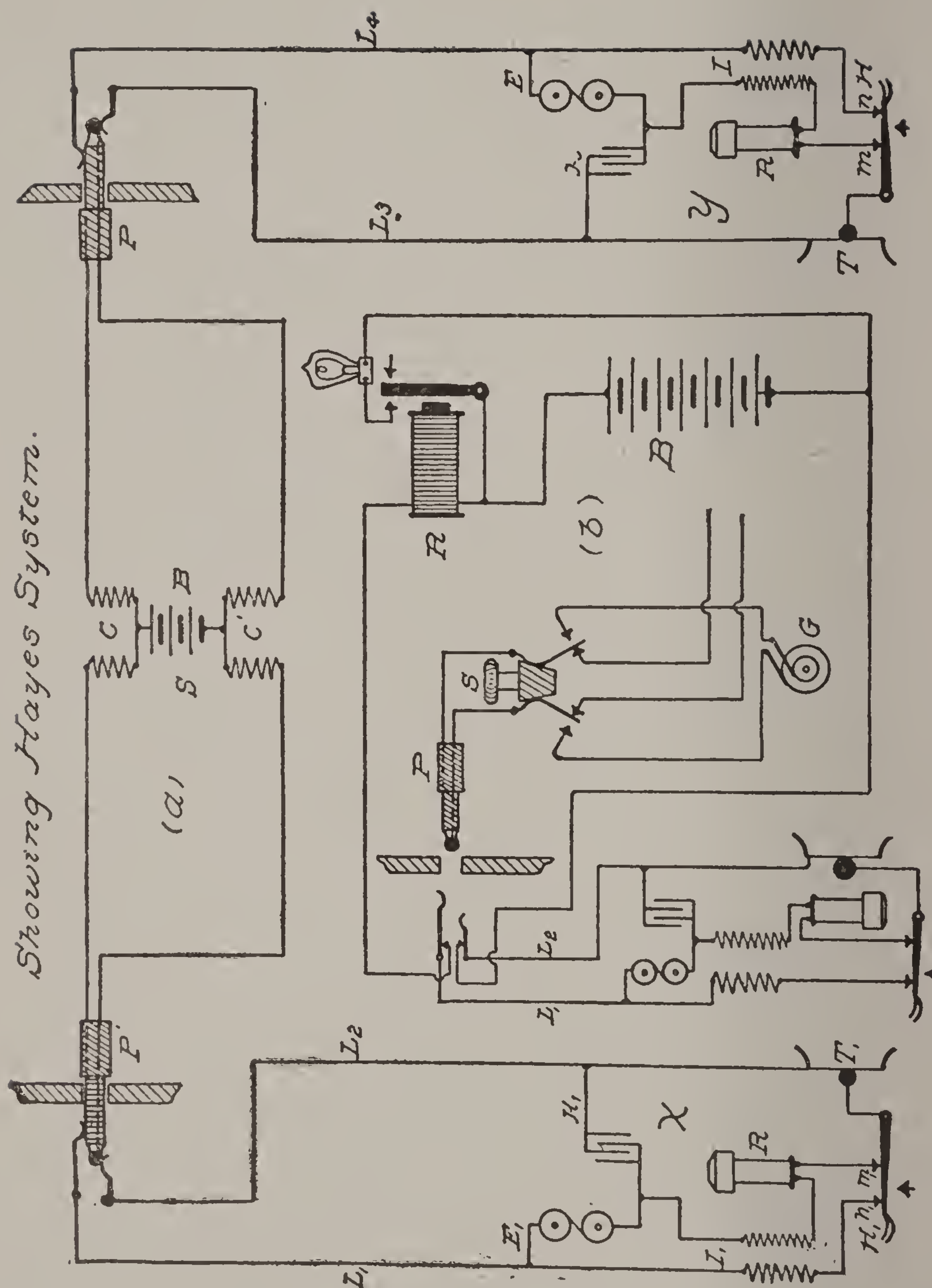

FIGURE 151.

may be placed in circuit but the number is kept low because of the high resistance of the telephone bells. The bells of the telephone in use are disconnected from the talking circuit when the receiver is removed from the hook but all the other telephone bells are left connected in the talking circuit.

The bridging metallic line is the most satisfactory of all the party lines in use. The bells possess a high resistance and reactance which cause them to use a very small amount of the talking current that is passing on the line wires.

Central Energy System.—The most widely used telephone system for exchange purposes in all large cities is the central energy system. With this system, instead of having a battery and a magneto in each subscriber's telephone, the current for both talking and ringing purposes is supplied from the exchange. An alternating current of 75 volts and 15 cycles is furnished from a generator as the ringing current for all the telephones. A 24-volt storage battery serves the double purpose of supplying the talking current for all the telephones and of supplying the current for signaling from the subscriber's telephone to the central exchange. When the subscriber takes the receiver from the hook, he thereby closes a circuit from the battery through a relay, which in turn closes another circuit from the battery to a small lamp on the board, causing it to light and indicate the number that is calling. The connection of the Hayes central energy system for conversation between the two subscribers' telephones is shown in Fig. 151.

Though other central energy systems are in use, the general scheme for connecting the battery and the private telephones is very similar to the one here shown.

QUESTIONS.

1. May telephone wires be carried in the same duct with light or power wires?
2. How may telephone wires be run on the outside walls of buildings?
3. What kind of wire must be used from the last outside support to the cut-out or protectors?
4. Describe the method of entering the building with the wires.
5. Where should the protective device be located?
6. State the requirements for the ground wire, to be run from the protector.
7. How should the ground wire be fastened to the ground pipe?
8. Of what does the protector consist?
9. How may wires be carried, concealed, from the protector to the telephone?
10. Describe the usual method of carrying the wires in open work.
11. How should the wires be insulated from power wires, iron pipes, etc.?
12. Why should telephone wires never be placed in the same duct or near light or power wires?
13. Into what two classes may telephone wiring be divided?
14. Sketch a battery telephone connection between two parties.
15. Draw a diagram of wiring for a kitchen annunciator system and explain its operation.
16. Sketch a similar system used for hotels.
17. Explain the operation of a standard hotel annunciator system.
18. Sketch a battery system for an apartment house.
19. What is an intercommunicating system?
20. Sketch the wiring plan for three intercommunicating telephones.
21. What are some of the most important parts of a standard wall set?
22. Sketch the internal wiring plan of a standard wall set for a bridging system.

23. What is the object of the induction coil?
24. What is meant by a full metallic circuit?
25. Sketch the wiring plan for an extension bell connected to a bridging telephone.
26. Sketch the internal wiring plan of a standard wall set for a series system.
27. What is a party line?
28. Sketch three telephones connected
    (a) On a bridging metallic system,
    (b) Bridging grounded system,
    (c) Series metallic system,
    (d) Series grounded system.
29. Which of the four different systems is the most satisfactory?
30. Describe the operation of a central energy system.
31. Sketch the wiring plan for a conversation between two subscribers on a central energy system.

APPENDIX.

WIRING TABLES

CONDUCTIVITIES.

Metals.	At 0° C. At 32° F.	At 100° C. At 212° F.
Silver, hard	100.	71.56
Copper, hard	99.95	70.27
Gold, hard	77.96	55.90
Zinc, pressed	29.02	20.67
Cadmium	23.72	16.77
Platinum, soft	18.00	
Iron, soft	16.80	
Tin	12.36	8.67
Lead	8.32	5.86
Arsenic	4.76	3.33
Antimony	4.62	3.26
Mercury, pure	1.60	
Bismuth	1.245	0.878

CONDUCTORS AND INSULATORS IN ORDER OF THEIR VALUE.

Conductors.	Insulators (Non-conductors).	
All metals	Dry air	Ebonite
Well-burned charcoal	Shellac	Gutta-percha
Plumbago	Paraffin	India-rubber
Acid solutions	Amber	Silk
Saline solutions	Resins	Dry paper
Metallic ores	Sulphur	Parchment
Animal fluids	Wax	Dry leather
Living vegetable substances	Jet	Porcelain
Moist earth	Glass	Oils
Water	Mica	

According to Culley the resistance of distilled water is 6,754 million times as great as that of copper.

MELTING POINT AND RELATIVE ELECTRICAL CONDUCTIVITY OF DIFFERENT METALS AND ALLOYS.

Metals.	Relative Conductivity.	Melting Point ° F.
Pure silver	100.	1873
Pure copper	100.	2550
Refined and crystallized copper	99.9	
Telegraphic silicious bronze	98.	
Alloy of copper and silver (50%)	86.65	
Pure gold	78.	2016
Silicide of copper, 4% Si	75.	
Silicide of copper, 12% Si	54.7	
Pure aluminum	54.2	1160
Tin with 12% of sodium	46.9	
Telephonic silicious bronze	35.	
Copper with 10% of lead	30.	
Pure zinc	29.9	773
Telephonic phosphor-bronze	29.	
Silicious brass, 25% zinc	26.49	
Brass with 35% zinc	21.5	
Phosphor tin	17.7	
Alloy of gold and silver (50%)	16.12	
Swedish iron	16.	4000
Pure Banca Tin	15.45	442
Antimonial copper	12.7	
Aluminum bronze (10%)	12.6	
Siemens steel	12.	
Pure platinum	10.6	4100
Copper with 10% of nickel	10.6	
Cadmium Amalgam (15%)	10.2	
Dronier mercurial bronze	10.14	
Arsenical copper (10%)	9.1	
Pure lead	8.88	630
Bronze with 20% of tin	8.4	
Pure nickel	7.89	2800
Phosphor-bronze, 10% tin	6.5	
Phosphor-copper, 9% phos	4.9	
Antimony	3.88	840

CURRENT REQUIRED TO FUSE WIRES OF COPPER, GERMAN SILVER AND IRON.

B. & S. Gauge.	Copper, Amperes.	German Silver, Amperes.	Iron, Amperes.
10	333.	169.	101.
11	284.	146.	86.
12	235.	120.7	71.2
13	200.	102.6	63.
14	166.	85.2	50.2
15	139.	71.2	42.1
16	117.	60.	35.5
17	99.	50.4	32.6
18	82.8	42.5	25.1
19	66.7	34.2	20.2
20	58.3	29.9	17.7
21	49.3	25.3	14.9
22	41.2	21.1	12.5
23	34.5	17.7	10.9
24	28.9	14.8	8.76
25	24.6	12.6	7.46
26	20.6	10.6	6.22
27	17.7	9.1	5.36
28	14.7	7.5	4.45
29	12.5	6.41	3.79
30	10.25	5.26	3.11
31	8.75	4.49	2.65
32	7.26	3.73	2.2
33	6.19	3.18	1.88
34	5.12	2.64	1.55
35	4.37	2.24	1.33
36	3.62	1.86	1.09
37	3.08	1.58	.93
38	2.55	1.31	.77
39	2.20	1.13	.67
40	1.86	.95	.56

TABLE SHOWING DIFFERENCE BETWEEN WIRE GAUGES IN DECIMAL PARTS OF AN INCH.

No. of Wire Gauge	American or Brown & Sharpe	Birmingham or Stubs	Washburn & Moen Mfg. Co., Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	New British	Old English from Brass Mfrs. List	No. of Wire
000000	......	....	.46	....	....	....	000000
00000	......	....	.43	.45	....	....	00000
0000	.46	.454	.393	.4	.4	....	0000
000	.40964	.425	.362	.36	.372	....	000
00	.3648	.38	.331	.33	.348	....	00
0	.32495	.34	.307	.305	.324	....	0
1	.2893	.3	.283	.285	.3	....	1
2	.25763	.284	.263	.265	.276	....	2
3	.22942	.259	.244	.245	.252	....	3
4	.20431	.238	.225	.225	.232	....	4
5	.18194	.22	.207	.205	.212	....	5
6	.16202	.203	.192	.19	.192	....	6
7	.14428	.18	.177	.175	.176	....	7
8	.12849	.165	.162	.16	.16	....	8
9	.11443	.148	.148	.145	.144	....	9
10	.10189	.134	.135	.13	.128	....	10
11	.090742	.12	.12	.1175	.116	....	11
12	.080808	.109	.105	.105	.104	....	12
13	.071961	.095	.092	.0925	.092	....	13
14	.064084	.083	.08	.08	.08	.083	14
15	.057068	.072	.072	.07	.072	.072	15
16	.05082	.065	.063	.061	.064	.065	16
17	.045257	.058	.054	.0525	.056	.058	17
18	.040303	.049	.047	.045	.048	.049	18
19	.03589	.042	.041	.039	.04	.04	19
20	.031961	.035	.035	.034	.036	.035	20
21	.028462	.032	.032	.03	.032	.0315	21
22	.025347	.028	.028	.27	.028	.0295	22
23	.022571	.025	.025	.024	.024	.027	23
24	.0201	.022	.023	.0215	.022	.025	24
25	.0179	.02	.02	.019	.02	.023	25
26	.01594	.018	.018	.018	.018	.0205	26
27	.014195	.016	.017	.017	.0164	.01875	27
28	.012641	.014	.016	.016	.0148	.0165	28
29	.011257	.013	.015	.015	.0136	.0155	29
30	.010025	.012	.014	.014	.0124	.01375	30
31	.008928	.01	.0135	.013	.0116	.01225	31
32	.00795	.009	.013	.012	.0108	.01125	32
33	.00708	.008	.011	.011	.01	.01025	33
34	.006304	.007	.01	.01	.0092	.0095	34
35	.005614	.005	.0095	.009	.0084	.009	35
36	.005	.004	.009	.008	.0076	.0075	36
37	.004453	....	.0085	.00725	.0068	.0065	37
38	.003965	....	.008	.0065	.006	.00575	38
39	.003531	....	.0075	.00575	.0052	.005	39
40	.003144	....	.007	.005	.0048	.0045	40

"Code" Wire and Cords

The grade of wire and cord used in most indoor electric light and power work is known as "Code." These wires and cords are made in accordance with the requirements of Underwriters' Laboratories which inspects and tests them as they are made at the wire factories.

Such "approved" products may be identified by the Laboratories' labels found on the tags attached to the coils of rubber-covered wire, fixture wire and flexible cords. The labels on armored cable are placed around the armor about every fifty feet.

The Laboratories have a large inspection force and are continuously making inspections at factories throughout the country, authorizing the use of labels on materials that conform to the standard requirements. The label is thus a valuable asset to the purchaser and user, indicating as it does that the material has been inspected and tested by an entirely disinterested inspection force and that its quality is up to standard. Labeled products are not necessarily uniform in quality or merit, but at least they all meet certain minimum requirements necessary for protection against fire.

Each manufacturer uses a marking of a thread or group of threads by means of which his product may be identified. The Underwriters' Laboratories List of Inspected Electrical Appliances gives the list of manufacturers of "Code" wire with the marking used by each. Copies of the List may be obtained in most cities from the Laboratories' office or from the local insurance inspector.

"Approved Fittings"

Only fittings which have been tested and listed by Underwriters' Laboratories should be used in electric light and power work. Nearly all standard wiring devices are submitted by their makers for such tests and listing so that the choice available is very large and there is little excuse for using others. The use of approved fittings is required by all insurance inspectors and by most city inspectors as well.

All of these approved fittings, or "listed" fittings, as they are called by the Laboratories, have been carefully investigated as to their fire hazard. Only those devices are listed which are found by test to be built in a reasonably safe manner, so that when properly installed they are unlikely to cause fire from overheating, arcing or defective insulation.

Copies of the Laboratories' List may be obtained from the Laboratories' offices and from inspection departments.

BROWN & SHARPE'S GAUGE.

The B. & S. Gauge is standard for copper wire and is understood to apply in all cases where size of copper wire is mentioned in any wire gauge number.

By referring to the table it will be seen that in the B. & S. gauge, for all practical purposes, the area in circular mils is doubled for every third size heavier, by gauge number, and halved for every third size lighter, by gauge number.

Every tenth size heavier by gauge number has ten times the area in circular mils.

No. 10 B. & S. gauge wire has an area of approximately 10,000 circular mils, and from this base the other sizes can be figured, if a table should not be at hand.

CLASSIFICATION OF GAUGES.

In addition to the confusion caused by a multiplicity of wire gauges, several of them are known by various names.

For example:

Brown & Sharpe (B. & S.) = American Wire Gauge (A. W. G.).

New British Standard (N. B. S.) = British Imperial, English Legal Standard and Standard Wire Gauge and is variously abbreviated by S. W. G. and I. W. G.

Birmingham Gauge (B. W. G.) = Stubs, Old English Standard and Iron Wire Gauge.

Roebling = Washburn Moen, American Steel & Wire Co.'s Iron Wire Gauge.

London = Old English (Not Old English Standard).

As a further complication:

Birmingham or Stubs' Iron Wire Gauge is not the same as Stubs' Steel Wire Gauge.

GENERAL USES OF VARIOUS GAUGES.

B. & S. G.—All forms of round wires used for electrical conductors. Sheet Copper, Brass and German Silver.

U. S. S. G.—Sheet iron and steel. Legalized by act of Congress, March 3, 1893.

B. W. G.—Galvanized iron wire. Norway iron wire.

American Screw Co.'s Wire Gauge.—Numbered sizes of machine and wood screws, particularly up to No. 14 (.2421 inch).

Stubs' Steel Wire Gauge.—Drill rod.

Roebling & Trenton.—Iron and steel wire. Telephone and telegraph wire.

N. B. S.—Hard drawn copper. Telephone and telegraph wire.

London Gauge.—Brass wire.

EQUIVALENTS OF WIRES: B. & S. GAUGE.

0000	=	2–0	=	4–3	=	8–6	=	16–9	=	32–12	=	64–15
000	=	2–1	=	4–4	=	8–7	=	16–10	=	32–13	=	64–16
00	=	2–2	=	4–5	=	8–8	=	16–11	=	32–14	=	64–17
0	=	2–3	=	4–6	=	8–9	=	16–12	=	32–15		.....
1	=	2–4	=	4–7	=	8–10	=	16–13	=	32–16		.....
2	=	2–5	=	4–8	=	8–11	=	16–14	=	32–17		.....
3	=	2–6	=	4–9	=	8–12	=	16–15	=	32–18		.....
4	=	2–7	=	4–10	=	8–13	=	16–16		.....		.....
5	=	2–8	=	4–11	=	8–14	=	16–17		.....		.....
6	=	2–9	=	4–12	=	8–15	=	16–18		.....		.....
7	=	2–10	=	4–13	=	8–16		.....		.....		.....
8	=	2–11	=	4–14	=	8–17		.....		.....		.....
9	=	2–12	=	4–15	=	8–18		.....		.....		.....
10	=	2–13	=	4–16		.....		.....		.....		.....
11	=	2–14	=	4–17		.....		.....		.....		.....
12	=	2–15	=	4–18		.....		.....		.....		.....
13	=	2–16	=	4–19		.....		.....		.....		.....
14	=	2–17		.....		.....		.....		.....		.....
15	=	2–18		.....		.....		.....		.....		.....
16	=	2–19		.....		.....		.....		.....		.....

OHM'S LAW.

The Electrical Units—Volt, ohm and ampere, which are most frequently used, have fortunately been established so as to bear simple but important relations to one another, based upon the current increasing and decreasing with the voltage, but increasing when the resistance decreases, and decreasing when the resistance increases.

Using the Symbols mentioned above, this is expressed in the following equations:

$$I = \frac{E}{R} \quad E = I.\,R. \quad R = \frac{E}{C} \quad E.\,I.\ (\text{or watts}) = I^2\,R.$$

$$E.\,I.\ (\text{or watts}) = \frac{E^2}{R}$$

ELECTRICAL UNITS.

The electrical units are derived from the following mechanical units of the metric system:

Centimeter. Unit of Length—One thousand millionth part of a quadrant of the earth's surface.

Gramme. Unit of Weight—Weight of a cubic centimeter of water at a temperature of 4 degrees centigrade.

Second. Unit of Time—The time of one swing of a pendulum making 86,400 swings in a solar day.

The unit of area is the square centimeter. The unit of volume is the cubic centimeter.

Volt—Unit of electro-motive force; pressure of potential. Symbol E.

Ohm—Unit of resistance. Symbol R.

Megohm—1,000,000 ohms.

Ampere—Unit of current. Symbol I.

Ampere Hours—Current in amperes × time in hours.

Watt—Unit of power. Product of 1 volt × 1 ampere. Symbol W. or E. I (746 watts equal one horsepower).

Horsepower—746 watts.

Kilowatt—1000 watts. Written K. W.

Kilowatt Hours—Kilowatts × time in hours.

Farad—Unit of capacity.

Microfarad—One-millionth of a farad. Written M. F.

Coulomb. Unit of Quantity—Quantity of current which, impelled by one volt, would pass through one ohm in one second.

Joule. Unit of Work—The work done by one watt in one second.

MILS AND CIRCULAR MILS.

The one-thousandth part of one inch, written .001, and usually called one mil, is taken as the unit of diameter, from which one square mil would be the unit of area. If you measure the diameter of a round wire in thousandths of an inch, or mils, by means of a micrometer, and multiply this number by itself, i.e., square it, you obtain in square mils the cross-sectional area of a square wire having four sides, each the same length as the diameter of the round wire that you have calipered.

Circular mil (usually written C. M.) applies to all round wires, and has a value .785 times that of the square mil.

Consequently the square of the diameter of any round wire, measured in mils, gives its cross-sectional area in circular mils, without any further multiplication.

Conversely, if you extract the square root of the number of circular mils, by which a round wire is listed, you obtain its diameter in mils.

ELECTRICAL UNITS AND MECHANICAL EQUIVALENTS.

AMPERES PER HORSEPOWER.

The following table shows number of amperes required per horsepower when the percentage of efficiency of the motor is known.

Efficiency of Motor	75 Per Cent	80 Per Cent	85 Per Cent	90 Per Cent
At 110 Volts....	9 Amp.	8.4 Amp.	7.9 Amp.	7.5 Amp.
At 220 Volts....	4.5 Amp.	4.2 Amp.	3.95 Amp.	3.75 Amp.
At 500 Volts....	1.98 Amp.	1.86 Amp.	1.75 Amp.	1.66 Amp.

AMPERES PER GENERATOR.

K. W.	125 Vs.	250 Vs.	500 Vs.	Appx. H. P.
1.	8	4	2	1.3
2.	16	8	4	2.7
3.	24	12	6	4.0
5.	40	20	10	6.7
7.5..........	60	30	15	10.
10.	80	40	20	13.
12.5..........	100	50	25	17.
15.	120	60	30	20.
20.	160	80	40	27.
25.	200	100	50	3 .
30.	240	120	60	40.
37.5..........	300	150	75	50.
40.	320	160	80	53.
50.	400	200	100	67.
60.	480	240	120	80.
75.	600	300	150	100.
100.	800	400	200	134.
125.	1000	500	250	167.
150.	1200	600	300	201.
200.	1600	800	400	268.

AMPERES PER MOTOR.

H. P.	Per Cent Eff.	Watts Input.	50 Volts.	100 Volts.	220 Volts.	500 Volts.
¾	70	800	16	7	4	2
1½	70	1600	32	15	7	3
3	75	2980	60	27	14	6
5	80	4660	93	42	21	9
7½	85	6580	132	60	30	13
10	85	8780	176	80	40	18
15	85	13200	264	120	60	26
20	85	17600	352	160	80	35
25	85	21900	438	199	100	44
30	90	24900	498	226	113	50
40	90	33200	664	301	151	66
50	90	41400	828	376	188	83
60	90	49700	994	452	226	99
70	90	58000	1160	527	264	116
80	90	66300	1330	603	302	133
90	90	74600	1490	678	339	149
100	90	82900	1660	755	377	166
120	90	99500	1990	905	453	199
150	90	124000	2480	1130	564	248

I = Current in Amperes.
HP = Horsepower.
E = Voltage.
K = Efficiency of Motor.

$$I = \frac{HP \times 74600}{E \times K}$$

WIRE DATA

DIMENSIONS AND RESISTANCES OF COPPER WIRES.

B. & S. Gauge No.	Diameter in Mils or Thousandths of an Inch.	Area in Circular Mils.	Ohms Per 10,000 Ft.	Lbs. Per 1,000 Ft. W. P. Ins.
....	1,000	1,000,000	.01038	3,550
....	894	800,000	. 01297	2,880
....	775	600,000	.0173	2,210
....	707	500,000	.02076	1,875
....	632	400,000	.02596	1,530
....	548	300,000	.0346	1,185
0000.........	460	211,600	.04906	750
000.........	410	167,805	.06186	600
00.........	365	133,079	.07801	500
0.........	325	105,592	.0983	400
1.........	289	83,694	.1240	300
2.........	258	66,373	.1564	250
3.........	229	52,633	.1972	200
4.........	204	41,742	.2487	160
5.........	182	33,102	.3136	140
6.........	162	26,250	.3955	110
8.........	128	16,509	.6288	75
10.........	102	10,381	1.	50
12.........	81	6,530	1.590	35
14.........	...	4,107	2.591	25
16.........	51	2,583	4.019	16
18.........	40	1,624	6.391	12

GALVANIZED IRON WIRE—WEIGHT AND RESISTANCE CALCULATED AT 68° F.

Iron Wire Gauge.	Diameter in Mils.	Pounds Per Mile.	Ohms Resistance Per Mile — E. B. B.	B. B.	Steel.
4...........	.225	730	6.44	7.53	8.90
6...........	.192	540	8.70	10.19	12.04
8...........	.162	380	12.37	14.47	17.10
9...........	.148	320	14.69	17.19	20.31
10...........	.135	260	18.08	21.15	25.00
11...........	.120	214	21.96	25.70	30.37
12...........	.105	165	28.48	33.33	39.39
14...........	.080	96	48.98	57.29	67.71

FINE MAGNET WIRE

No. B. & S. Gauge.	Diameter.	Ohms, Per Pound Single Cotton.	Ohms, Per Pound Double Cotton.	Feet, Per Pound Single Cotton.	Feet, Per Pound Double Cotton.
20	.0319	3.15	3.02	311	298
21	.0284	4.97	4.72	389	370
22	.0253	7.87	7.44	491	461
23	.0225	12.45	11.7	624	584
24	.0201	19.65	18.25	778	745
25	.0179	30.9	28.45	958	903
26	.0159	48.5	44.3	1188	1118
27	.0142	76.5	68.8	1533	1422
28	.0126	120.	106.5	1903	1759
29	.0112	190.5	164.	2461	2207
30	.0100	294.5	252.	2893	2534
31	.0089	461.	384.5	3483	2768
32	.0079	717.	585.	4414	3737
33	.0070	1115.	880.	5688	4697
34	.0063	1715.	1315.	6400	6168
35	.0056	2640.	1960.	8393	6737
36	.005	4070.	2890.	9846	7877
37	.0044	6180.	4230.	11636	9309
38	.0039	9430.	6150.	13848	10666
39	.0035	14200.	8850.	18286	11907
40	.0031	21300.	12500.	24381	14222

RUBBER COVERED WIRE—SOLID CONDUCTORS

Size B. & S.	Diam. of Conductors, Mils.	Capacity Circular, Mils.	Single Braid Diam. Over All.	Single Braid Weight Per 1,000 Ft.	Double Braid Diam. Over All.	Double Braid Weight Per 1,000 Ft.
0000	460	211600	47/64	809	55/64	832
000	410	167803	11/16	666	13/16	690
00	365	133079	5/8	546	47/64	568
0	325	105524	19/32	453	45/64	476
1	289	83695	33/64	355	5/8	376
2	258	66373	29/64	275	9/16	295
3	230	52634	27/64	227	33/64	245
4	204	41743	25/64	186	15/32	200
5	182	33102	23/64	160	7/16	170
6	162	26250	5/16	128	25/64	135
8	129	16510	17/64	80	11/32	86
10	102	10382	15 64	58	19/64	64
12	81	6530	7/32	43	9/32	48
14	64	4107	13/64	32	1/4	37
16	51	2583	3/16	20	.....	...
18	40	1624	11/64	16	.....	...
19	36	1288	5/32	15	.....	...
20	32	1022	9/64	14	.....	...

DATA ON SOLID WIRES LARGER THAN 4/0

No. B. & S. Gauge.	Diameter, Mils.	Circular Mils.	Feet Per Pound.	Pounds Per Foot.	Ohms, Per Mile.
5/0	515	265,225	1.29	.80	.206
6/0	575	330,625	1.00	1.00	.165
7/0	640	409,600	.81	1.24	.133
8/0	710	504,100	.66	1.53	.108
9/0	785	616,225	.54	1.86	.089
10/0	865	748,225	.44	2.25	.073
11/0	950	902,500	.37	2.73	.060
12/0	1040	1,081,600	.21	3.27	.050

STRANDED CONDUCTORS.

Size B. & S.	Concentric Strands		Diam. of Conductors, Mils.	—Single Braid—		—Double Braid—	
	No. Wires.	Diam. Each.		Diam. Over All.	Weight Per 1,000 Ft.	Diam. Over All.	Weight Per 1,000 Ft.
2000000 C.M.	91	148	1650	2	7246	2 9/64	7385
1750000 C.M.	91	139	1550	1 29/32	6394	2 3/64	6525
1500000 C.M.	91	128	1430	1 51/64	5539	1 15/16	5658
1250000 C.M.	91	117	1308	1 43/64	4678	1 13/16	4783
1000000 C.M.	61	128	1166	1 1/2	3754	1 5/8	3849
900000 C.M.	61	121	1104	1 7/16	3404	1 9/16	3491
800000 C.M.	61	115	1049	1 3/8	3058	1 1/2	3138
750000 C.M.	61	111	1013	1 11/32	2881	1 15/32	2956
700000 C.M.	61	107	978	1 5/16	2709	1 7/16	2880
650000 C.M.	61	103	943	1 17/64	2534	1 25/64	2600
600000 C.M.	61	99	906	1 1/4	2355	1 3/8	2418
550000 C.M.	61	95	870	1 13/64	2182	1 21/64	2240
500000 C.M.	37	116	821	1 1/8	1959	1 1/4	2010
450000 C.M.	37	110	779	1 3/32	1791	1 7/32	1840
400000 C.M.	37	104	738	1 3/64	1608	1 11/64	1650
350000 C.M.	37	97	688	1	1431	1 1/8	1468
300000 C.M.	37	90	639	15/16	1250	1 1/16	1285
250000 C.M.	37	82	583	7/8	1071	1	1103
0000	19	.105	530	13/16	899	15/16	942
000	19	.094	475	3/4	740	7/8	782
00	19	.083	425	45/64	607	13/16	647
0	19	.074	380	5/8	492	47/64	526
1	19	.066	329	9/16	387	43/64	417
2	19	.059	296	1/2	303	39/64	329
3	7	.086	263	29/64	249	9/16	272
4	7	.077	233	7/16	204	17/32	227
5	7	.068	209	13/32	175	1/2	192
6	7	.061	185	3/8	141	29/64	156
8	7	.048	147	21/64	90	13/32	103
10	7	.039	118	19/64	65	3/8	72
12	7	.031	94	17/64	48	21/64	55
14	7	.024	75	15/64	36	19/64	40

RUBBER COVERED DUPLEX.

Size B. & S.	Solid: Diameter Over All.	Solid: Weight Per 1,000 Ft.	Stranded: Diameter Over All.	Stranded: Weight Per 1,000 Ft.
1	.....	...	1 1/4	810
2	.....	...	1 1/8	638
3	.....	...	1 1/32	528
4	.....	...	31/32	442
5	.....	...	29/32	375
6	.....	...	53/64	307
8	11/16	170	49/64	203
10	37/64	125	5/8	143
12	1/2	94	9/16	107
14	27/64	73	15/32	78

All Weights are Approximate but are Exact Enough for all Practical Purposes.

COPPER FOR VARIOUS SYSTEMS OF DISTRIBUTION.

Power transmitted, distance, line loss and voltage of lamps constant. All wires of each system, same size.

System.	Copper Required.
2-Wire, single-phase or direct current	1.000
3-Wire, single-phase or direct current	.375
4-Wire, single-phase or direct current	.222
4-Wire, two-phase	1.000
4-Wire, three-phase with neutral	.333
3-Wire, three-phase Delta	.75

TABLE 1. TWO-WIRE AND THREE-WIRE SYSTEMS

Size of Conductor B. & S. Gage	Number of Conductors 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
200000 C. M.	1¼	2	2½	3	3	3	3½	3½	4
225000	1¼	2½	2½	3	3	3½	3½	4	4
250000	1¼	2½	2½	3	3	3½	3½	4	4½
300000	1¼	2½	3	3	3½	3½	4	4½	4½
350000	1¼	2½	3	3½	3½	4	4½	4½	5
400000	1¼	3	3	3½	4	4	4½	5	5
450000	1½	3	3	3½	4	4½	4½	5	6
500000	1½	3	3	3½	4	4½	5	5	6
550000	1½	3	3½	4	4½	5	5	6	6
600000	2	3	3½	4	4½	5	6	6	6
650000	2	3½	3½	4	4½	5	6	6	6
700000	2	3½	3½	4½	5	5	6	6	...
750000	2	3½	3½	4½	5	6	6	6	...
800000	2	3½	4	4½	5	6	6	6	...
850000	2	3½	4	4½	5	6	6	...	...
900000	2	3½	4	4½	5	6	6	...	...
950000	2	4	4	5	6	6	6	...	...
1000000	2	4	4	5	6	6	...	...	...
1100000	2½	4	4½	6	6	...	...	...	...
1200000	2½	4½	4½	6	6	...	...	...	...
1250000	2½	4½	4½	6	6	...	...	...	...
1300000	2½	4½	5	6	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	...	...	...	...	...	...

SIZE OF CONDUITS FOR THE INSTALLATION OF WIRES AND CABLES

The following tables apply only to complete conduit systems and do not apply to short sections of conduit used for the protection of exposed wiring from mechanical injury.

For sizes not greater than No. 10 B. & S. gage, one more conductor than permitted by the opposite table may be installed in the specified conduit provided the conduit is not longer than 30 feet, and has not more than the equivalent of two quarter bends from outlet to outlet, the bends at the outlets not being counted.

TABLE 2. THREE CONDUCTOR CONVERTIBLE SYSTEM

Size of Conductors B. & S. Gage				Size Conduit, In. Electrical Trade Size
two	14	and one	10	¾
"	12	"	8	¾
"	10	"	6	1
"	8	"	4	1
"	6	"	2	1¼
"	5	"	1	1¼
"	4	"	0	1½
"	3	"	00	1½
"	2	"	000	1½
"	1	"	0000	2
"	0	"	250000	2
"	00	"	350000	2½
"	000	"	400000	2½
"	0000	"	550000	3
"	250000	"	600000	3
"	300000	"	800000	3
"	400000	"	1000000	3½
"	500000	"	1250000	4
"	600000	"	1500000	4
"	700000	"	1750000	4½
"	800000	"	2000000	4½

The following table must not be used for other than Stage Pocket and Border Circuits, except by special permission of the Inspection Department having jurisdiction.

TABLE 3. STAGE POCKET AND BORDER CIRCUITS

Size of Conductor B. & S. Gage	Maximum Number of Conductors in Conduit Ins. 1	Ins. 1¼	Ins. 1½	Ins. 2	Ins. 2½	Ins. 3
14	11	19	26	43	61	95
12	..	15	21	34	50	77
10	..	12	16	27	38	60
8	..	..	13	22	31	49
6	..	..	..	..	14	22

For groups or combinations not included in the above tables, consult the Inspection Department having jurisdiction. For such groups or combinations, it is recommended that the conduit be of such size, that the sum of the areas of the several conductors will not be more than 40 per cent. of the area of the conduit.

USEFUL TABLES

THE METRIC SYSTEM

WEIGHTS.

Metric Denominations and Values. Name.		No. Grams.		Equivalents in Denominations in Use—Weight of What Quantity of Water at Maximum Density.
Millier or tonneau	=	1,000,000	=	1 cubic meter.
Quintal	=	100,000	=	1 hectoliter.
Myriagram	=	10,000	=	10 liters.
Kilogram or Kilo	=	1,000	=	1 liter.
Hectogram	=	100	=	1 deciliter.
Dekagram	=	10	=	10 cu. centimeters.
Gram	=	1	=	1 cu. centimeter.
Decigram	=	.1	=	.1 cu. céntimeter.
Centigram	=	.01	=	10 cu. millimeters.
Milligram	=	.001	=	1 cu. millimeter.

Name.		No. Grams.		Avoirdupois Weight.	
Millier or tonneau	=	1,000,000	=	2,204.6	pounds.
Quintal	=	100,000	=	220.46	pounds.
Myriagram	=	10,000	=	22.046	pounds.
Kilogram or Kilo	=	1,000	=	2.2046	pounds.
Hectogram	=	100	=	3.5274	ounces.
Dekagram	=	10	=	0.3527	ounce.
Gram	=	1	=	15.432	grains.
Decigram	=	.1	=	1.5432	grains.
Centigram	=	.01	=	0.1543	grain.
Milligram	=	.001	=	0.0154	grain.

MEASURES OF LENGTH.

Myriameter	=	10,000 meters	=	6.2137 miles.
Kilometer	=	1,000 meters	=	0.62137 m. or 3,280 ft. 10 in.
Hectometer	=	100 meters	=	328 ft. and 1 inch.
Dekameter	=	10 meters	=	393.7 inches.
Meter	=	1 meter	=	39.37 inches.
Decimeter	=	.1 of a meter	=	3.937 inches.
Centimeter	=	.01 of a meter	=	0.3937 inch.
Millimeter	=	.001 of a meter	=	0.0394 inch.

MEASURES OF SURFACE.

Hectare	=	10,000 sq. meters	=	2.471 acres.
Are	=	100 sq. meters	=	119.6 sq. yards.
Centare	=	1 sq. meter	=	1,550 sq. inches.

MEASURES OF CAPACITY.

Name No.		Liters.		Cubic Measure		Dry Measure
Kiloliter	=	1,000	=	1 cubic meter	=	1.308 cu. yds.
Hectoliter	=	100	=	.1 cubic meter	=	2 bu. 3.35 pks.
Decaliter	=	10	=	10 cu. decimeters	=	9.08 quarts.
Liter	=	1	=	1 cu. decimeter	=	0.908 quart.
Deciliter	=	.1	=	.1 cu. decimeter	=	6.1022 cu. ins.
Centiliter	=	.01	=	10 cu. centimeters	=	0.6102 cu. in.
Milliliter	=	.001	=	1 cu. centimeter	=	0.061 cu. in.

Name No.		Liters.		Cubic Measure		Wine Measure
Kiloliter	=	1,000	=	1 cubic meter	=	264.17 gals.
Hectoliter	=	100	=	.1 cubic meter	=	26.417 gals.
Decaliter	=	10	=	10 cu. decimeters	=	2.6417 gals.
Liter	=	1	=	1 cu. decimeter	=	1.0567 quarts.
Deciliter	=	.1	=	.1 cu. decimeter	=	0.845 gill
Centiliter	=	.01	=	10 cu. centimeters	=	0.388 fluid oz.
Milliliter	=	.001	=	1 cu. centimeter	=	0.27 fluid oz.

Unit.	Equivalent Value in Other Units.
1 H. P. =	746 watts. .746 K. W. 33,000 ft.-lbs. per minute. 550 ft.-lbs. per second. 2,545 heat-units per hour. 42.4 heat-units per minute. .707 heat-unit per second. .175 lb. carbon oxidized per hour. 2.64 lbs. water evaporated per hour from and at 212° F.
1 H. P. Hour =	746 K. W. hours. 1,980,000 ft.-lbs. 2,545 heat-units. 273,740 k. g. m. .175 lb. carbon oxidized with perfect efficiency. 2.64 lbs. water evaporated from and at 212° F. 17.0 lbs. water raised from 62° to 212° F.
1 Kilowatt =	1,000 watts. 1.34 H. P. 2,654,200 ft.-lbs. per hour. 44,240 ft.-lbs. per minute. 737.3 ft.-lbs. per second. 3,412 heat-units per hour. 56.9 heat-units per minute. .948 heat-unit per second. .2275 lb. carbon oxidized per hour. 3.53 lbs. water evaporated per hour from and at 212° F.

1 Watt per sq. in.	=	8.19	heat units per sq. ft. per minute.
		6,371	ft.-lbs. per sq. ft. per minute.
		.193	H. P. per sq. ft.
1 Kilogram Metre	=	7.233	ft.-lbs.
		.00000365	H. P. hour.
		.00000272	K. W. hour.
		.0093	heat-units.
1 lb. Water Evaporated from and at 212° F.	=	.283	K. W. hour.
		.379	H. P. hour.
		965.7	heat-units.
		103,900	k. g. m.
		1,019,000	joules.
		751,300	ft.-lbs.
		.0664	lb. of carbon oxidized.
1 Heat-unit	=	1,055	watt seconds.
		778	ft.-lbs.
		107.6	kilogram metres.
		.000293	K. W. hour.
		.000393	H. P. hour.
		.0000688	lb. carbon oxidized.
		.001036	lb. water evaporated from and at 212° F.
1 Heat-unit per sq. ft. per min.	=	.122	watts per sq. in.
		.0176	K. W. per sq. ft.
		.0236	H. P. per sq. ft.
1 Watt	=	1	joule per second.
		.00134	H. P.
		3,412	heat-units per hour.
		.7373	ft.-lb. per second.
		.0035	lb. water evaporated per hour.
		44.24	ft.-lbs. per minute.
1 K. W. Hour	=	1,000	watt hours.
		1.34	H. P. hours.
		2,654,200	ft.-lbs.
		3,600,000	joules.
		3,412	heat-units.
		367,000	kilogram metres.
		.235	lb. carbon oxidized with perfect efficiency.
		3.53	lbs. water evaporated from and at 212° F.
		22.75	lbs. of water raised from 62° to 212° F.

1 Joule	=	1	watt second.
		.000000278	K. W. hour.
		.102	k. g. m.
		.0009477	heat-units.
		.7373	ft.-lb.

1 ft.-lb.	=	1.356	joules.
		.1383	k. g. m.
		.000000377	K. W. hours.
		.001285	heat-units.
		.0000005	H. P. hour.

1 lb. Carbon Oxidized with Perfect Efficiency	14,544	heat-units.
	1.11	lb. anthracite coal oxidized.
	2.5	lbs. dry wood oxidized.
	21	cu. ft. illuminating gas.
	4.26	K. W. hours.
	5.71	H. P. hours.
	11,315,000	ft.-lbs.
	15	lbs. of water evaporated from and at 212° F.

DECIMAL EQUIVALENTS.

Of eighths, sixteenths, thirty-seconds and sixty-fourths of an inch.

Fractions of an Inch.		Decimals of an Inch.	Fractions of an Inch.		Decimals of an Inch.	Fractions of an Inch.		Decimals of an Inch.
1/64	=	.015625	11/32	=	.34375	43/64	=	.671875
1/32	=	.03125	23/64	=	.359375	11/16	=	.6875
3/64	=	.046875	3/8	=	.375	45/64	=	.703125
1/16	=	.0625	25/64	=	.390625	23/32	=	.71875
5/64	=	.078125	13/32	=	.40625	47/64	=	.734375
3/32	=	.09375	27/64	=	.421895	3/4	=	.75
7/64	=	.109375	7/16	=	.4375	49/64	=	.765625
1/8	=	.125	29/64	=	.453125	25/32	=	.78125
9/64	=	.140625	15/32	=	.46875	51/64	=	.796875
5/32	=	.15625	31/64	=	.484375	13/16	=	.8125
11/64	=	.171875	1/2	=	.5	53/64	=	.828125
3/16	=	.1875	33/64	=	.515625	27/32	=	.84375
13/64	=	.203125	17/32	=	.53125	55/64	=	.859375
7/32	=	.21875	35/64	=	.546875	7/8	=	.875
15/64	=	.234375	9/16	=	.5625	57/64	=	.890625
1/4	=	.25	37/64	=	.578125	29/32	=	.90625
17/64	=	.265625	19/32	=	.59375	59/64	=	.921875
9/32	=	.28125	39/64	=	.609375	15/16	=	.9375
19/64	=	.296875	5/8	=	.625	61/64	=	.953125
5/16	=	.3125	41/64	=	.640625	31/32	=	.96875
21/64	=	.328125	21/32	=	.65625	63/64	=	.984375

FEET EXPRESSED IN DECIMAL PARTS OF A MILE.

	Units.	Tens.	Hundreds.	Thousands.
1	.000189	.001893	.01893	.1893
2	.000378	.003787	.03787	.3787
3	.000568	.005681	.05681	.5681
4	.000757	.007574	.07574	.7574
5	.000946	.009468	.09468	.9468
6	.001136	.011362	.11362	
7	.001325	.013255	.13255	
8	.001514	.015148	.15148	
9	.001704	.017042	.17042	

GENERAL EQUIVALENTS.

CM = Circular mils.
SqM = Square mils.
1 CM = .7854 SqM.
1 SqM. = 1.2732 CM.
1 Sq. in. = 1,000,000 SqM.
1 Sq. in. = 1,273,200 CM.
1 Sq. in. = area of a circle 1.128″ diam.
Area of circle 1″ diam. = 1,000,000 CM.
Area of circle 1″ diam. = 785,400 SqM.

TABLE OF MULTIPLES.

Diameter of a circle × 3.1416 = Circumference.
Radius of a circle × 6.283185 = Circumference.
Square of the radius of a circle × 3.1416 = Area.
Square of the diameter of a circle × 0.7854 = Area.
Square of the circumference of a circle × 0.07958 = Area.
Half the circumference of a circle × by half its diameter = Area.
Circumference of a circle × 0.159155 = Radius.
Square root of the area of a circle × 0.56419 = Radius.
Circumference of a circle × 0.31831 = Diameter.
Square root of the area of a circle × 1.12838 = Diameter.
Diameter of a circle × 0.86 = Side of inscribed equilateral triangle.
Diameter of a circle × 0.7071 = Side of an inscribed square.
Circumference of a circle × 0.225 = Side of an inscribed square.
Circumference of a circle × 0.282 = Side of an equal square.
Diameter of a circle × 0.8862 = Side of an equal square.
Base of a triangle × by ½ the altitude = Area.
Multiplying both diameters and .7854 together = Area of an ellipse.
Surface of a sphere × by 1/6 of its diameter = Solidity.
Circumference of a sphere × by its diameter = Surface.
Square of the diameter of a sphere × 3.1416 = Surface.
Square of the circumference of a sphere × 0.3183 = Surface.
Cube of the diameter of a sphere × 0.5236 = Solidity.
Cube of the radius of a sphere × 4.1888 = Solidity.
Cube of the circumference of a sphere × 0.016887 = Solidity.
Square root of the surface of a sphere × 0.56419 = Diameter.

Square root of the surface of a sphere × 1.772454 = Circumference.

Cube root of the solidity of a sphere × 1.2407 = Diameter.

Cube root of the solidity of a sphere × 3.8978 = Circumference.

Radius of a sphere × 1.1547 = Side of inscribed cube.

Square root of (1/3 of the square of) the diameter of a sphere = Side of inscribed cube.

Area of its base × by 1/3 of its altitude = Solidity of a cone or pyramid, whether round, square or triangular.

Area of one of its sides × 6 = the surface of a cube.

Altitude of trapezoid × ½ the sum of its parallel sides = Area.

PULLEY TABLES.

PULLEYS AND GEARS.

For single reduction or increase of speed by means of belting where the speed at which each shaft should run is known, and one pulley is in place:

Multiply the diameter of the pulley which you have by the number of revolutions per minute that its shaft makes; divide this product by the speed in R. P. M. at which the second shaft should run. The result is the diameter of pulley to use.

Where both shafts with pulleys are in operation and the speed of one is known:

Multiply the speed of shaft by diameter of its pulley and divide this product by diameter of pulley on the other shaft. The result is the speed of the second shaft.

Where a countershaft is used, to obtain size of main driving or driven pulley, or speed of main driving or driven shaft, it is necessary to calculate, as above, between the known end of the transmission and the countershaft, then repeat this calculation between the countershaft and the unknown end.

A set of gears of the same pitch transmits speeds in proportion to the number of teeth they contain. Count the number of teeth in the gear wheel and use this quantity instead of the diameter of pulley, mentioned above, to obtain number of teeth cut in unknown gear, or speed of second shaft.

RULE FOR FINDING SIZE OF PULLEYS.

$$d = \frac{D \times S}{S'} \qquad D = \frac{d \times S'}{S}$$

d = diameter of driven pulley.
D = diameter of driving pulley.
S = number of revolutions per minute of driving pulley.
S′ = number of revolutions per minute of driven pulley.

GEAR TABLE—DIAMETRAL PITCH. (Nuttall.)

Diametral Pitch is the Number of Teeth to Each Inch of the Pitch Diameter.

To Get	Having	Rule
The Diametral Pitch	The Circular Pitch	Divide 3.1416 by the Circular Pitch.
The Diametral Pitch	The Pitch Diameter and the Number of Teeth	Divide Number of Teeth by Pitch Diameter.
The Diametral Pitch	The Outside Diameter and the Number of Teeth	Divide Number of Teeth plus 2 by Outside Diameter.
Pitch Diameter	The Number of Teeth and the Diametral Pitch	Divide Number of Teeth by the Diametral Pitch.
Pitch Diameter	The Number of Teeth and Outside Diameter	Divide the product of Outside Diameter and Number of Teeth by Number of Teeth plus 2.
Pitch Diameter	The Outside Diameter and the Diametral Pitch	Subtract from Outside Diameter the quotient of 2 divided by the Diametral Pitch.
Pitch Diameter	Addendum and the Number of Teeth	Multiply Addendum by the Number of Teeth.
Outside Diameter	The Number of Teeth and the Diametral Pitch	Divide Number of Teeth plus 2 by the Diametral Pitch.
Outside Diameter	The Pitch Diameter and the Diametral Pitch.	Add to the Pitch Diameter the quotient of 2 divided by the Diametral Pitch.
Outside Diameter	The Pitch Diameter and the Number of Teeth	Divide Product of Number of Teeth plus 2 and Pitch Diameter by the Number of Teeth.
Outside Diameter	The Number of Teeth and Addendum	Multiply the Number of Teeth plus 2 by Addendum.
Number of Teeth	The Pitch Diameter and the Diametral Pitch.	Multiply Pitch Diameter by the Diametral Pitch.
Number of Teeth	The Outside Diameter and the Diametral Pitch	Multiply Outside Diameter by the Diametral Pitch and subtract 2.
Thickness of Tooth	The Diametral Pitch	Divide 1.5708 by the Diametral Pitch.
Addendum	The Diametral Pitch	Divide 1 by the Diametral Pitch, or $s = \frac{D}{N}$
Root	The Diametral Pitch	Divide 1.157 by the Diametral Pitch.
Working Depth	The Diametral Pitch	Divide 2 by the Diametral Pitch.
Whole Depth	The Diametral Pitch	Divide 2.157 by the Diametral Pitch.
Clearance	The Diametral Pitch	Divide .157 by the Diametral Pitch.
Clearance	Thickness of Tooth	Divide Thickness of Tooth at pitch line by 10.

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