COYNE
Electrical School
CHICAGO ~~ ILLINOIS

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ELECTRIC SIGNAL SYSTEMS AND CIRCUITS

Section One

SIGNAL SYSTEMS AND CIRCUIT WORK

Great Opportunities In Signal Field

The field of electric signalling is a very broad one, covering everything from simple door bells and call systems to elaborate burglar alarm, telephone and railway signal systems.

Every year many millions of dollars are spent in new installations and expansions in these branches, creating new jobs for several thousand more trained men yearly.

There are millions of homes with their door bell systems and some of them with burglar alarm equipment to be maintained, and hundreds of thousands more homes being built each year.

Hotels, office buildings, department stores, theatres and hospitals have elaborate signal systems. Banks, stores, and offices have their burglar alarm systems. Fire and police departments also have special signal networks.

Then there are the railroads with their block signals and crossing alarms, and the newer automatic train control equipment, to provide greater safety in the operation of trains.

The telephone and telegraph field is one of the largest branches of the electrical industry and employs many thousands of trained electrical men. So you see the general field of signal work is far greater than many people realize, and offers interesting work at good pay in all parts of the country, and also splendid opportunities for a business of your own.

Many men entering electrical work overlook this branch, thinking it is of small importance because of the small size of the equipment, and the low voltage it uses.

This however is a great mistake, and signal wiring and maintenance should not be overlooked just because one may be interested in wiring or power work.

You may plan or hope to have a business of your own some day, but feel that it takes a great amount of capital to start it.

This is one of the particular advantages of bell and alarm work.

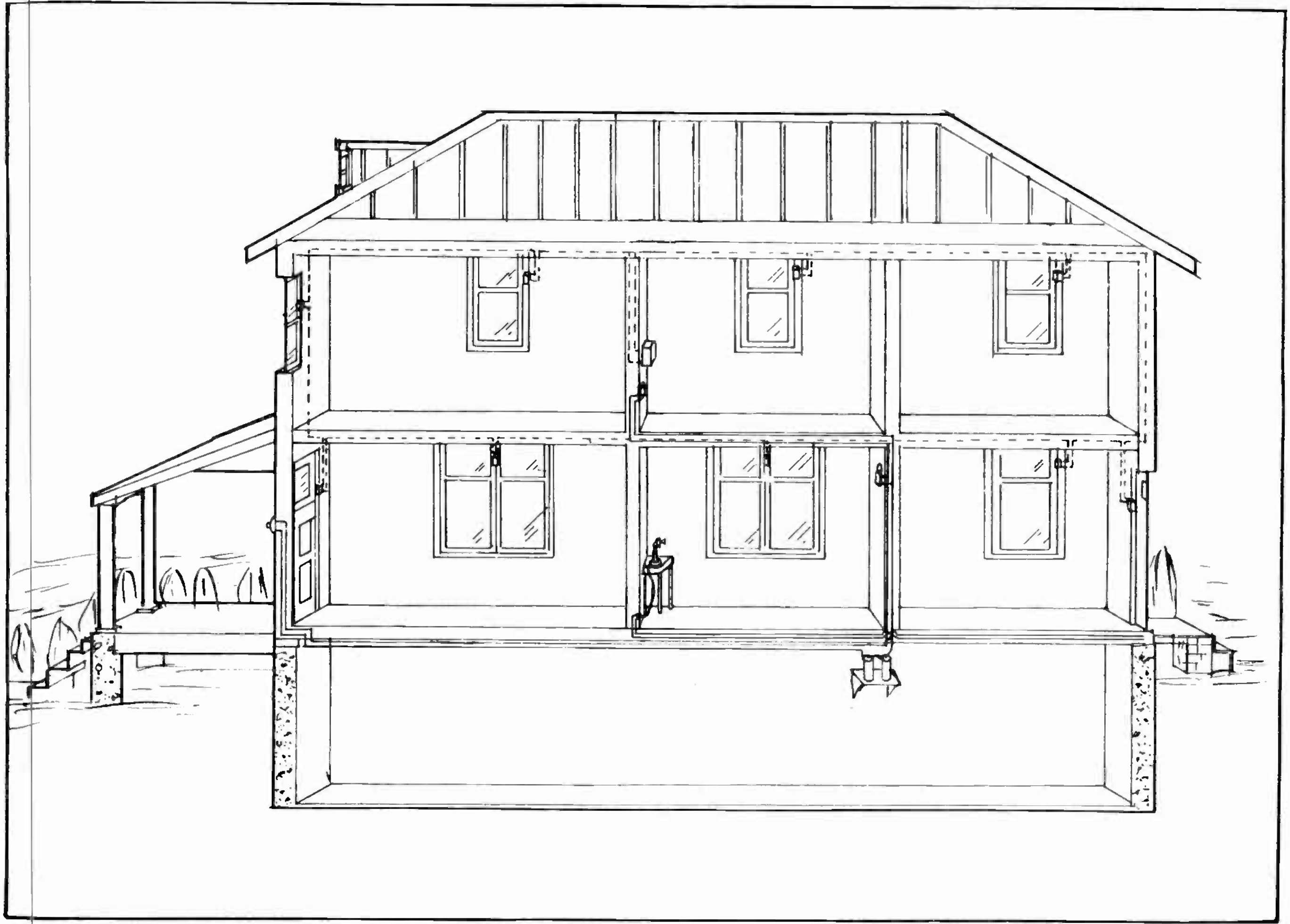
It requires but very little capital to start a business in this line, and many of our graduates are making big money specializing in this work in a business of their own. Others, who are working at some other line of electricity, do alarm and bell wiring jobs as a side line, and make a nice bit of extra money. Often in this way they gradually build up a full time business of their own.

Signal work of any kind requires a good knowledge of blue print reading and circuit tracing and testing, and needs men who know definite methods of wiring equipment from a print, and how to systematically "shoot trouble."

Even though you may not specialize in signal work, and no matter what line of electrical work you follow, the principles of these signal systems and the knowledge of circuit tracing and testing this section gives you will be very necessary and valuable.

The general electrician or foreman often encounters a job of installation or repair on some signal system, even though his principal work is on power equipment.

So make a very careful study of every part of this section if you wish to qualify for a real success and the bigger jobs.



Sectional view of a house showing the wiring for doorbells, burglar alarm and telephone. These are three of the most common signal conveniences in the home.

CALL AND SIGNAL SYSTEMS

In obtaining a knowledge of signal systems, we have to deal with the equipment or devices used, and also the circuits or methods of connection.

There are a number of very interesting devices used in this work and we want to become thoroughly acquainted with the operation, care, and purpose of each. With this knowledge and a good understanding of fundamental circuits you can lay out and install most any common signal system.

The more common pieces of equipment are batteries or transformers, switches of various types, bells, buzzers, relays, drop relays, annunciators, etc.

The circuits are series or parallel, which you already know something about, and "closed" and "open" circuits, which will be explained later.

1. SIMPLE CALL BELL

One of the simplest of all signal systems, is the ordinary door bell or call bell.

Such an installation requires an ordinary bell, a dry cell, a switch, and a few pieces of wire as shown in Figure 1.

Note how the three devices are connected together in a simple series circuit. One wire leads from the positive terminal of the cell to the right-hand bell terminal, one from the left bell terminal to the switch, and one returning from the switch to the negative cell terminal, thus completing the electrical circuit when the switch is closed.

In an actual installation, of course, these wires would be much longer, as the button would be located at the door, and the dry cell and bell probably near together somewhere in a rear room of the house.

Or this same system can be used for an office call with the button located on a certain desk, and the bell at another desk or office where a party is to be called. The battery can be located at either end of the circuit, equally well.

This circuit can also be used for a shop call, or a burglar alarm or fire alarm, by replacing the push button switch with a special door or window switch, or thermal switch, all of which will be explained later.

So we find that this very simple system has a variety of valuable uses.

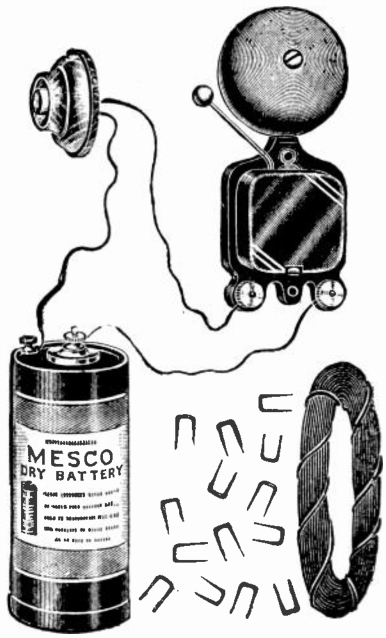


Fig. 1. Materials and parts for a simple doorbell or call system. Note how the dry cell, bell and button are connected.

2. USE OF PLANS AND SYMBOLS

When the equipment for any signal system is pictured as in Fig. 1, it is of course easy to recognize each part, and also to connect the wires as shown. But we must have some form of plan or sketch to do such work from, that can be made quicker and cheaper than photographs. So we have certain little marks or signs which we use to indicate the different pieces of equipment in blue prints or job plans and sketches. These marks are called **Symbols.**

As practically all new electrical installations now-a-days are made from prints or plans, the man who knows these symbols and can read prints has a great advantage over the untrained man who cannot.

In Figure 2 is shown a simple sketch of the same door bell system as in Figure 1.

This sketch uses the symbols for the various parts, and can be quickly and easily made, and also easily understood, with a little practice.

The part marked "A" is the symbol for a cell, the long line representing the positive terminal at which the current leaves, and the short line the negative terminal. "B" is the symbol for the bell, and "C" for the switch.

The heavy top line of the switch represents the movable contact. The arrow underneath represents the stationary contact. Note that the arrow does not touch the upper part, showing that the switch is open as it should be normally. Imagine that you were to press down on this top part causing it to touch the arrow and close the circuit. Current would immediately start to flow from the positive cell terminal to the bell, and back through the switch to the negative side of the cell. The arrows along the straight lines, representing wires, show the direction of current flow.

In **Reading** any electrical diagram from now on, practice **Tracing Out** the current flow in this manner. First locate and recognize all the parts by their symbols, and if there are any open switches, imagine that you close them. Then starting at the battery, trace the current flow along the wires and through the devices, always returning to the opposite side of the battery from the one at which you started. Remember that unless you have such a complete circuit no current will flow.

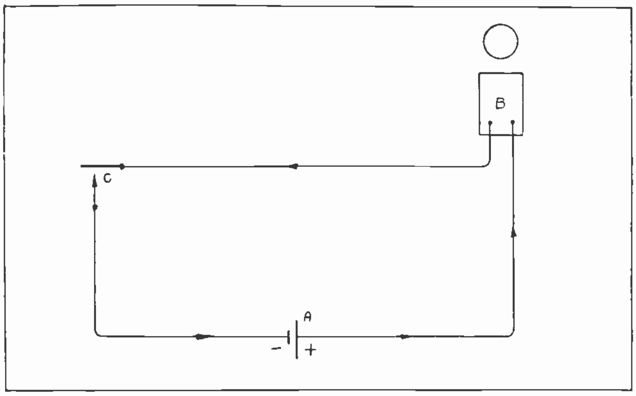


Fig. 2. Sketch showing the connections and circuit of simple doorbell system.

3. COMMON DEVICES IN SIGNAL CIRCUITS

Now let's find out more about each of the devices used in this simple system just covered, and also others.

We can readily see that the principal parts which we must have for any electric signal system are a source of current supply, a means of control, and a device to transform the electric energy into a signal.

4. BATTERIES FOR CURRENT SUPPLY

Dry cells are very commonly used to supply current to ordinary door bell and call systems of the "open circuit" type, where current is only required for occasional short intervals. Figure 3 shows two dry cells. You are already familiar with the care and operation of these cells from a previous section. (Elementary Section 6, Article 68.) When two or more cells are used they can be connected series or parallel according to the voltage and current requirements of the signal device. These connections were also covered in a previous section on Series and Parallel Circuits. Figure 4, however, shows two groups of three cells each, one group connected series, and the other parallel.

Dry cells should not be used in closed circuit systems, except where the current requirements are exceedingly small.

Primary cells of the "gravity" type or the "Edison" type are often used in closed circuit systems because they will stand the continuous current requirements much better than dry cells. The operation and care of these cells were also covered in a previous section. (Elementary Section 6.)

Fig. 3. Two common dry cells such as used extensively in signal systems. One is cut away to show terminal strip attached to the zinc.

Storage batteries are often used in signal systems where the current requirements are quite heavy. Their care and charging will be covered later.

5. MOTOR GENERATORS FOR SIGNAL SYSTEMS

In very large signal systems **Motor-Generator** sets are often used.

These consist of a motor operated from the usual 110 or 220 volt current supply in a building, and driving a generator which supplies the low voltage D.C. to operate the signals. (See Figure 5.)

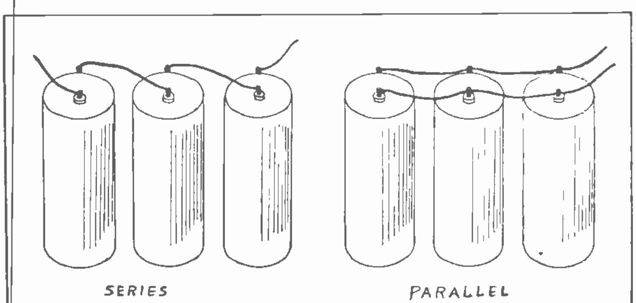


Fig. 4. Sketch showing method of connecting groups of dry cells in series or parallel, to obtain proper voltage or current for various signals.

Storage batteries are often used with motor generators, to supply current for short periods when the motor-generator might be shut down.

Figure 6 shows a storage battery connected in parallel with a D.C. generator so that the generator, while operating, will keep the battery fully charged. Then, when the generator is stopped for any reason, the battery supplies the current to the signals. The generator should be disconnected from the battery when it is stopped, so the battery will not discharge through the generator winding.

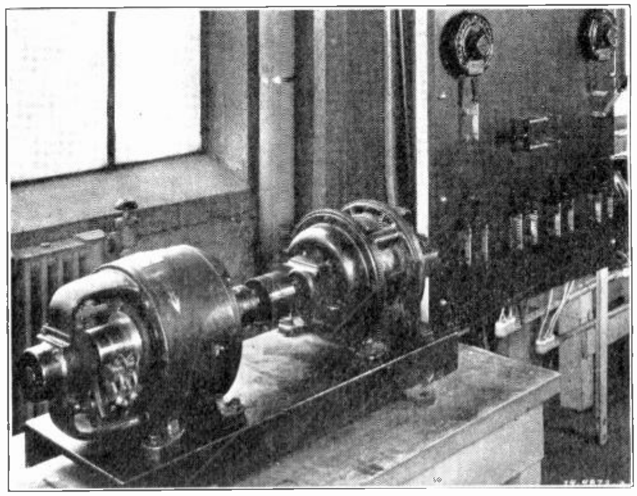


Fig. 5. Photo of low voltage motor generator set and switchboard, used for supplying energy to large signal systems.

6. BELL TRANSFORMERS

Bell Transformers are very commonly used to supply current to ordinary door bell and simple call systems. These transformers operate from the 110 volt A.C. lighting circuits and reduce the voltage to that required for the signal bells or lamps.

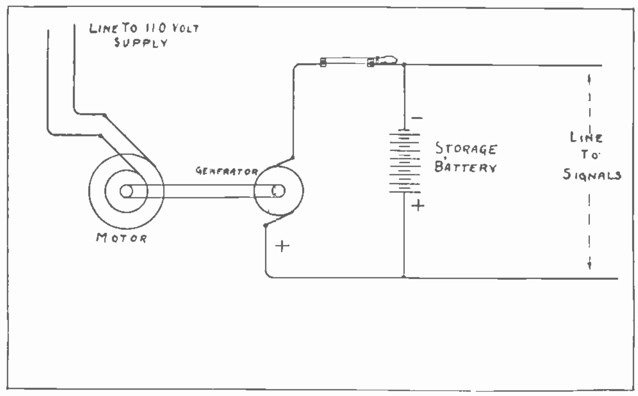


Fig. 6. Diagram of motor generator and storage battery connected together for dependable energy supply to large signal ystems.

Figure 7 shows two common types of door bell transformers.

A number of these transformers have three secondary wires, or "leads," giving 6, 8, or 14 volts with different connections. Others give still higher voltages. Where higher voltage bells or lamps are used, or where the line is long, the higher voltage "leads" on the transformer should be used.

In Figure 8 is shown a sketch of the windings and connections of a very common type of bell transformer. The primary winding "P" consists of about 1800 turns of No. 36 wire. The secondary winding consists of 235 turns of No. 26 wire, and has a "tap" or connection at the 100th turn. The core legs are about ½ in. x ¾ in. in size and 2¼ in. long.

Transformers can only be used where there is electric supply in the building, and only on A.C.

They will not operate on direct current supply, and in fact, will "burn out" quickly if connected to a D.C. line.

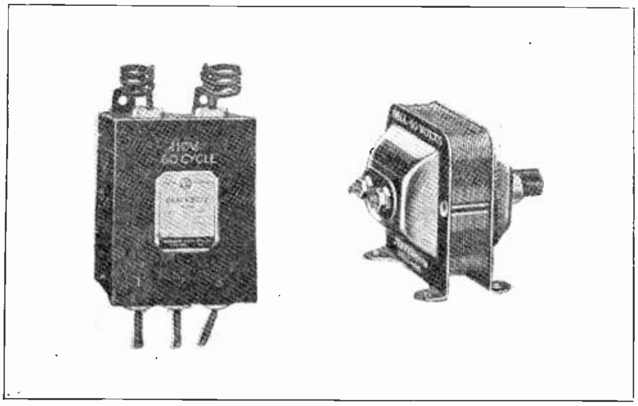


Fig. 7. Two different types of low voltage bell transformers. These reduce the voltage of an A. C. lighting circuit to 6, 8, and 14 volts for operation of bells.

For special uses transformers are obtainable with taps and a switch to vary the voltage in a number of steps. One of this type is shown in Figure 9.

Several other types are shown in Figure 10. Two of these, on the left, are mounted right on covers of "outlet boxes" for convenience in installing and attaching them to the lighting circuits, which are run in conduit, or protective iron piping. The other is built in a box with fuses.

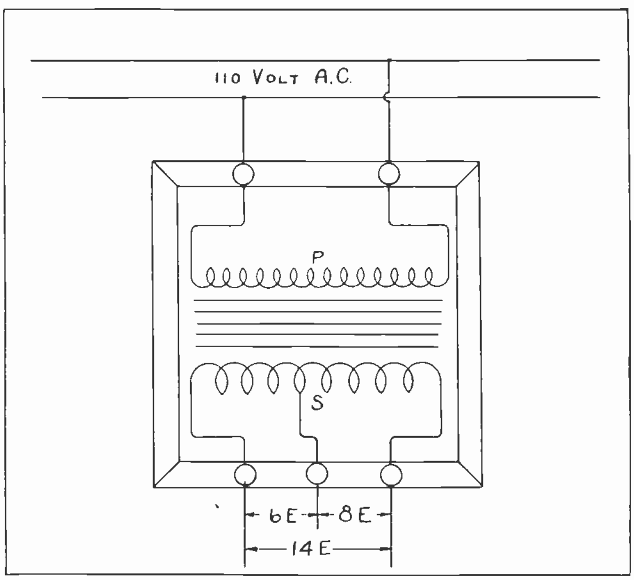


Fig. 8. Sketch showing windings and connections of a bell transformer.

All of the various sources of current supply above mentioned are low voltage devices, usually furnishing from 6 to 20 volts, as most bells and signal lamps are made to operate at these low voltages. Special bells are made, however, for 110 volt operation. But a low voltage bell should never be connected directly to a lighting circuit, as it will immediately burn out, and possibly blow the fuses or do other damage.

Certain types of signal systems using relays cannot be operated satisfactorily with transformers, as they require the continuous pull of D. C. on the relay magnets. Batteries or motor generators are required for such systems.

7. CURRENT SUPPLY TROUBLES

When signal systems fail to operate, the trouble can very often be traced to a weak or dead battery, burned out transformer, or blown fuse in the lighting circuit to which the transformer primary is connected. Cells and batteries can be quickly and easily tested right at their terminals with a bell or buzzer, low reading voltmeter, or battery ammeter.

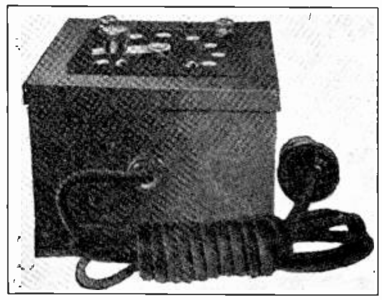


Fig. 9. Low voltage transformer with "taps" for obtaining various voltages.

A transformer can be tested with a bell, buzzer or low voltage test lamp for the secondary test, or a 110 volt test lamp for the primary test.

When "shooting" trouble on any defective signal system, you should never fail to check the source of current supply first of all.

8. SIGNAL SWITCHES

Now that we know something of the different sources of current supply for signal systems, let us consider the means of control or switches used.

Referring again to Figure 2, the purpose of the switch, as we have already mentioned, is to close and open the circuit, and start or stop the current flow, thus causing the bell to ring when desired.

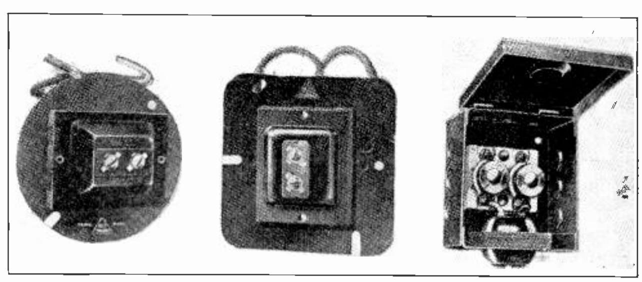


Fig. 10. Three types of bell transformers which are built in the covers of standard outlet boxes for conduit wiring.

This type of switch is called a **Push Button** switch. Figure 11 shows the operating parts of such a switch with the cover removed, and also the assembled switch. The upper left part shows the contact springs, mounted on an insulating base of hard fibre. The short lower contact is called the stationary one, and the longer upper spring is called the movable contact.

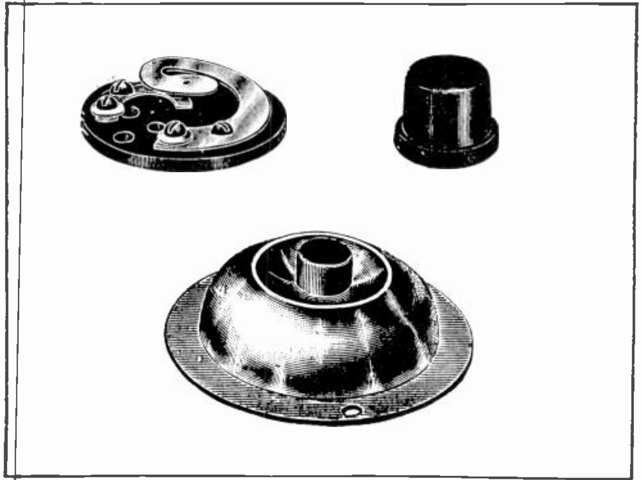


Fig. 11. View showing parts of a push button switch; also completely assembled button below.

When assembled, the button, which is also of insulating material, rests on the large spring and is held in place by the cover, as shown in the lower part of the figure. The springs are so shaped that they normally remain separated from 1/8 in. to 1/4 in., thus keeping the circuit open. But when the button is pressed it forces the movable spring down onto the stationary one, closing the circuit and allowing current to flow through the switch.

This type of push button switch is called an **Open Circuit Switch,** because it is normally open.

These switches are made for low voltages only, and should never be used for high voltage lighting circuits, or heavy currents, as they may arc and overheat badly.

When connecting such a switch in a circuit, one wire is attached to each of the screws which have the washers under their heads. This fastens one wire to each switch contact.

The two holes in the fibre base are for the wires to pass through, and the switch is held in place by the cover. The button is slipped in the hole in the cover before placing the cover on the switch. Some switches have metal covers that snap on, while others have wood covers that screw on. In addition to this common open circuit switch, we have "closed circuit" and "double circuit" push button switches.

A **Closed Circuit** switch is one that has its contacts normally closed, and some current flowing through it all the time except when it is pressed.

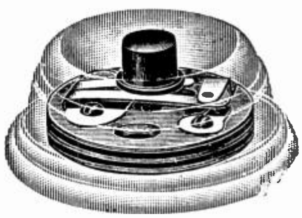


Fig. 12. Double circuit push button switch, showing clearly the arrangement of contacts and parts with respect to base and cover.

9. DOUBLE CIRCUIT SWITCHES

A **Double Circuit** switch is one that has both a closed contact and an open contact, and when pressed it breaks the closed circuit and closes the open circuit.

In Figure 12 is shown a double circuit switch. This switch is used in certain types of signal and alarm systems, where we wish to open one circuit and close another at the same time.

Referring to the figure, you will see that it has a large movable contact, and one open contact underneath, and also a closed contact above the movable spring.

The top spring is called the closed contact because it is normally touching the movable strip, keeping a circuit closed through them until the button is pressed. Then the movable spring leaves the top one and touches the bottom one, opening one circuit and closing the other.

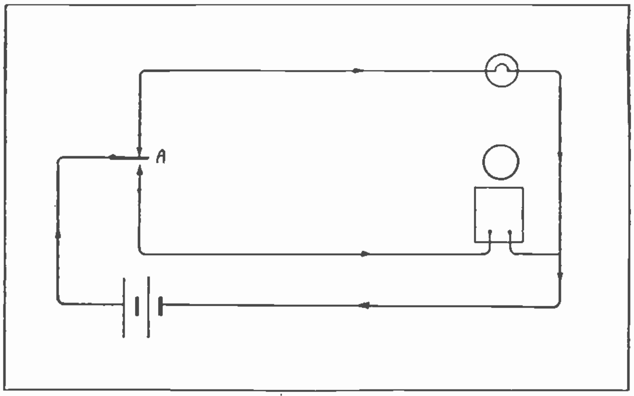


Fig. 13. Connections for a double circuit switch to operate a signal lamp and bell.

Figure 13 shows a double contact switch in use in a signal circuit. Normally the lamp burns continually and the bell is silent until the switch is pressed. Then the lamp goes out and the bell rings. Trace the circuit to note carefully this operation, and notice the symbol used to represent the double circuit switch at "A".

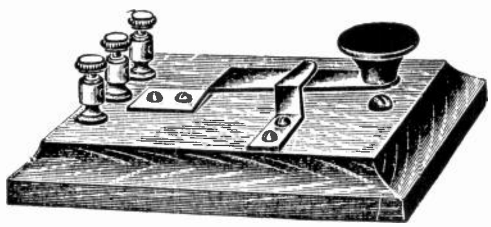


Fig. 14. Different type of double circuit switch, very convenient for code signalling because of its "key-like" construction.

It is quite important, in making a drawing of these switches, to have the top contact closed or touching the movable strip, and the bottom contact or arrow should not be touching, in normal position.

Also remember that in all these switches the movable part is a spring, so it goes back to normal as soon as released.

In Figure 14 is another type of double circuit switch, that has no cover, and is used for indoor work such as desk call systems.

Because of the shape of its spring and button, it is very convenient to use as a signalling key for certain code calls.

With either of the double contact buttons shown, we can remove the bottom contact or leave it unused, and then this switch will serve as a closed circuit switch.

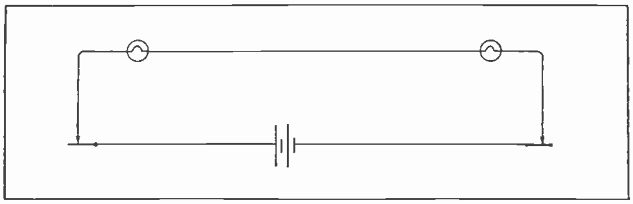


Fig. 15. Two closed circuit switches connected with lamps for a return call signal.

Figure 15 shows a sketch of two such switches used with two lamps, as a signal system for two parties to signal each other at a distance, by blinking the lamps.

Such a circuit should use a transformer, storage battery or gravity battery, because the continual current flow through the lamps would soon exhaust a dry cell.

One definite advantage of such a closed circuit signal system is the fact that any failure or defect, due to a dead battery or broken wire, is more likely to be noticed at once, than it is with an open circuit system. This is often of great enough importance to more than make up for the slight extra current cost.

Push button switches can be obtained with ornamental covers as shown in Figure 16.

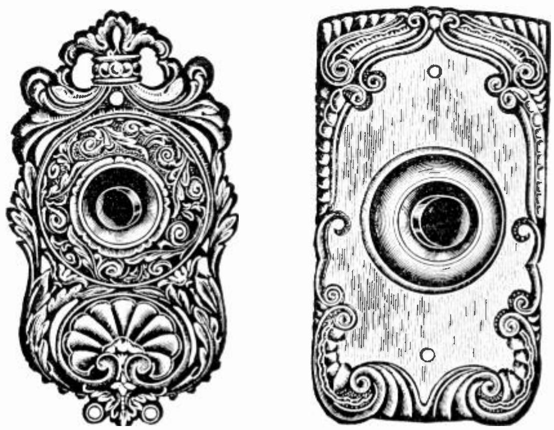


Fig. 16. Two types of ornamental covers for use with push button switches.

10. DESK BLOCKS AND SPECIAL PUSH BUTTON SWITCHES

For desk call systems a smaller push button switch is often required, so a number of them can be located in one small block or panel.

Figure 17-A shows a desk block with five of these small buttons, and marker plates to indicate which call each button operates. Figure 17-B shows a metal panel assembly of 10 switches, such as quite commonly used in office call systems.

In Figure 18 are shown several types of small push buttons that can be mounted in desk blocks, or in round holes drilled in a board or desk.

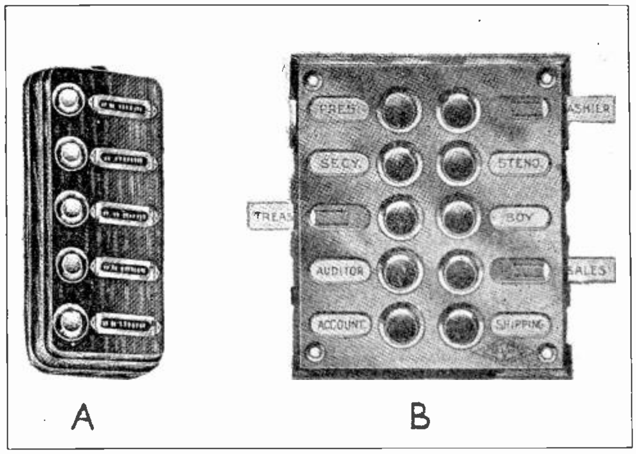


Fig. 17-A. Push buttons arranged in a desk block for office signal systems.
Fig. 17-B. Ten small push buttons with indicator tags, on a panel that can be used for wall or desk mounting.

For hospitals, and certain other uses, a very convenient push button can be arranged on the end of a flexible wire, so it can be laid on the pillow, or moved around somewhat. A button of this type, and also one to be clamped onto a bed or chair are shown in Figure 19.

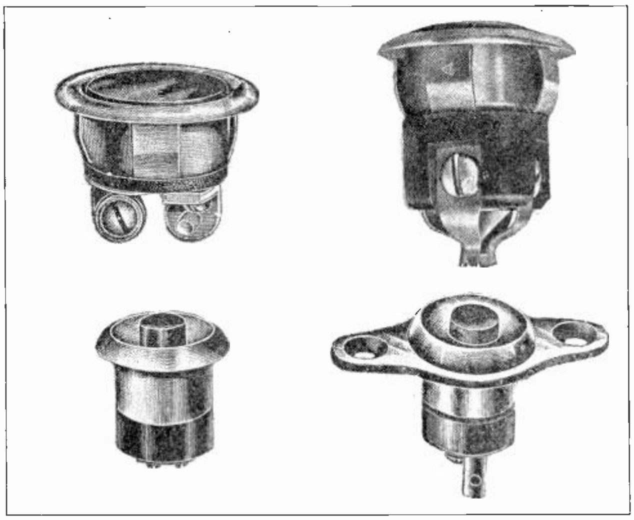


Fig. 18. Four different types of small push buttons for use in desk blocks or panels.

11. BURGLAR ALARM SWITCHES. DOOR AND WINDOW SPRINGS

In burglar alarm work we have special types of switches called **"Window Springs"** and **"Door Springs."** Figure 20 shows three views of common types of window springs which are made to fit in the window casing. These switches can be obtained in either open circuit or closed circuit types. They are mounted in the window casing in such a manner that when the window is closed, its frame rubs on the projecting slide of the switch and holds the switch open, so the bell does not operate. When the window is opened and its frame slides off the switch, the spring closes the circuit and causes the bell to operate. Or the

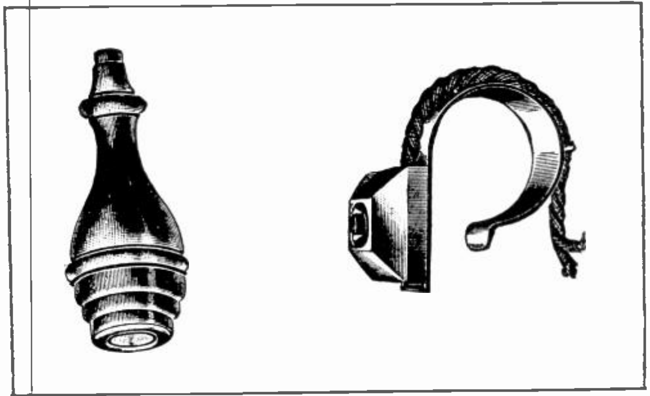


Fig. 19. Two types of push buttons commonly used in hospitals. The one on the left for attachment to pillow cord; the one on the right to be clamped to bed rail or chair arm.

reverse operation takes place where closed circuit switches are used.

Figure 21 shows two door spring switches. The one at the left is a closed circuit switch, and the one at the right is an open circuit type.

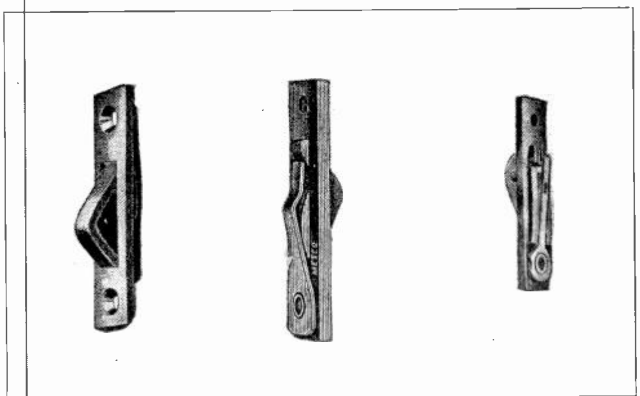


Fig. 20. Three different views of open and closed circuit window springs used in burglar alarm systems.

These switches are installed in the door casing, so that when the door is closed it holds the button compressed, and when the door is opened, the spring pushes the button out and closes or opens the circuit as desired, causing alarm to operate. Window and door springs can be obtained in both closed and open circuit types.

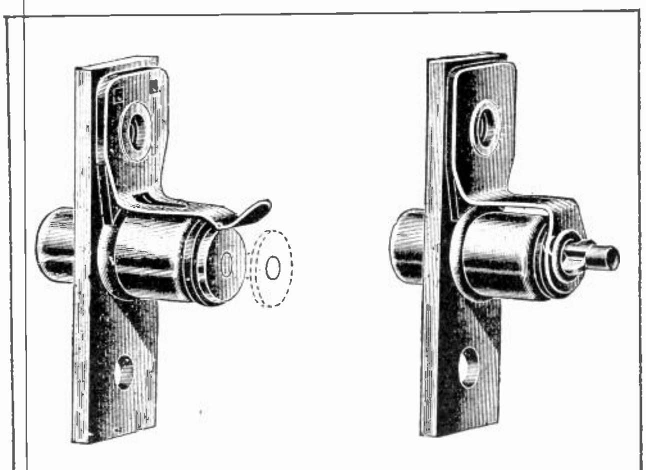


Fig. 21. Door springs of open circuit and closed circuit types to be mounted in door casings for burglar alarms.

Two types of **Door Trips** are shown in Figure 22. This type of switch is to be mounted above the door so that as it opens, the top of the door will strike the suspended lever, causing the bell to operate momentarily.

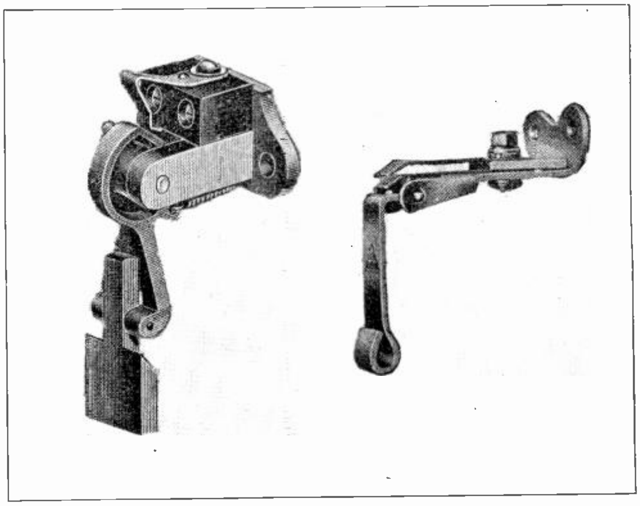


Fig. 22. Door trips to be mounted above a door, and ring a bell as the door is opened.

12. KEY OR LOCK SWITCHES

In burglar alarm systems a lock switch is often used so the owner can turn the system on at night and off during the day, or enter the building without tripping the alarm if he desires. These switches can only be operated with a special key. Figure 23 shows two switches of this type.

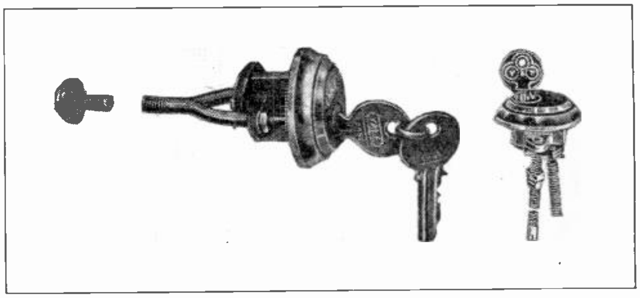


Fig. 23. Burglar alarm lock switches, used to turn the system off during the day, or when the owner wishes to enter the building without sounding alarm.

13. BURGLAR ALARM "TRAPS"

Another type of switch, often called a burglar alarm "**Trap**" is shown in Figure 24. This switch is arranged to be operated by a string attached to the door, window, or device to be protected.

Some of these "traps" will cause the alarm to operate if the lever is moved in either direction from the "set" position.

If the string is pulled it moves the lever in one direction, making contact on that side. If the string is cut, it releases the lever and a spring moves it in the opposite direction, making a contact on that side.

14. FLOOR SWITCHES

Often it is desired to have a signal system that can be operated from a concealed floor switch, under a carpet or rug. A switch of this type is shown in Figure 25-A. Pressure on any part of this switch will close a circuit through it, and operate a bell or other signal. Figure 25-B shows a special burglar alarm matting which is equipped with wires and contacts, to cause a bell to ring when the mat is stepped on.

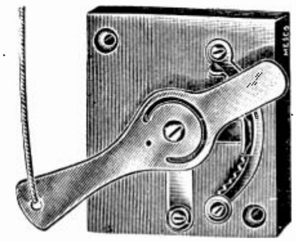


Fig. 24. Burglar alarm trap or switch to be operated by a string attached to door, window, or other object.

15. THERMAL OR HEAT SWITCHES

Another very interesting type of switch is the **Thermostat** type. One of these is shown in Figure 26. This switch is caused to operate by changes in temperature, and makes use of the different rates of expansion of different materials when they are heated. In the type shown here a strip of brass and one of hard rubber or composition are riveted together. When heated, the rubber or composition strip expands much faster than the brass, causing the whole strip to warp or bend downwards and close a circuit with the lower adjustable contact. When the strip is allowed to cool the contraction of the top strip causes the whole element to bend upwards again, and break the connection with the lower contact. If cooled beyond a certain point, it will bend upward still farther and close another circuit with the top adjustable contact.

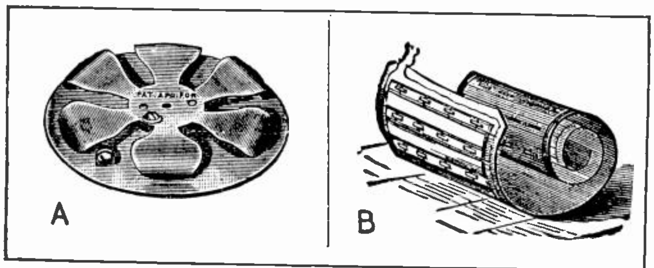


Fig. 25-A. Floor switch for use under carpets, near tables or desks.
Fig. 25-B. Burglar alarm mat to be placed under door mats or rugs, and close a circuit when stepped upon.

These thermostatic switches are made in several different styles, and are used in fire alarm systems, or to indicate high or low temperature in ovens, refrigerators, storage rooms and various places, by operating a bell or signal when certain temperatures are reached. Some of their applications will be more fully described later.

So you see there are switches for almost every need in signal work, but all are simply devices to open and close a circuit.

Switches for special alarm or signal needs can often be easily and quickly made from two or more strips of light spring brass mounted on a piece of wood or other insulation, and bent to the proper shapes.

A few other types of switches are shown in Figure 27. Snap switches of the type used in lighting circuits are sometimes used in signal circuits also.

16. SWITCH TROUBLES AND TESTS.

Some of the mysterious little troubles that cause failure of signal systems are often right at the switches, and nothing more than a loose connection, or dirty or burned contacts. Or possibly some small piece of insulating material such as a bit of string or fuzz from the wire insulation, or a bit of wood or sand, stuck to one of the contacts. A sure way to test any switch is to connect a dry cell and buzzer, or low voltage lamp, directly across its terminals; and then press the switch a number of times. If it does not operate the lamp or buzzer every time it is pressed, its contacts should be thoroughly cleaned with sandpaper, knife, or fine file, and its terminals carefully tightened. Remember a very small object or amount of dirt offers enough resistance to prevent current flow in low voltage circuits.

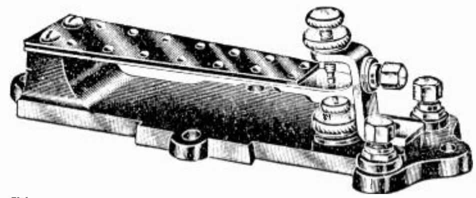


Fig. 26. Thermostatic switch which closes its contacts when heated, and is used in fire alarm systems.

We have seen many an "old timer" or electrician with considerable experience sweat and worry over something of this same nature. But with a knowledge of circuit principles, Ohms Law, and these simple definite tests, such troubles can be "cornered" and need not be so mysterious to the man with training.

Now that you understand the common types of switches or devices for controlling signal circuits, we will take up the bells and devices for producing the call or alarm.

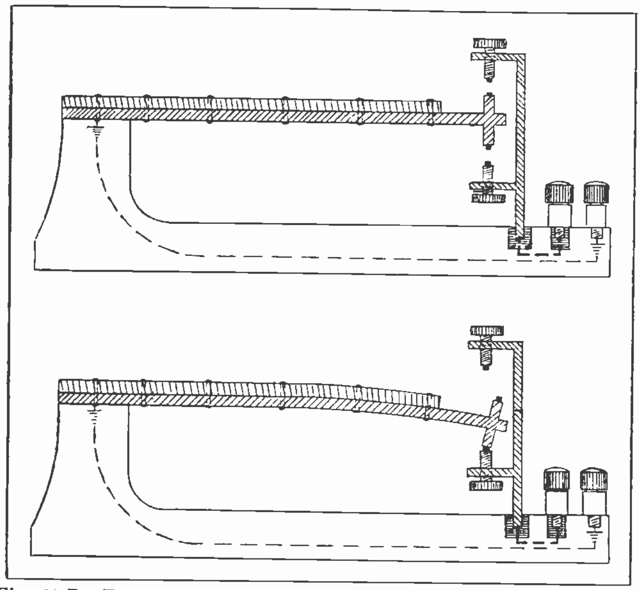


Fig. 26-B. Two sketches of thermostatic switch, showing the strip in normal position in the upper view, and warped to close the contacts in the lower view. Note how the circuit is completed through the metal frame of this device.

17. SIGNAL BELLS AND LAMPS

The purpose of any signal or alarm system, is to call the attention of someone. To do this we can use either an "audible" or "visible" signal, or quite often a combination of both. By an audible signal, we mean one that creates sound loud enough to be heard by those whose attention is desired. Bells, buzzers, and horns are used for this purpose. Visible signals are those that are to attract the eye, such as lamps, or semaphores. The term "semaphore" means a sort of moving flag or shutter.

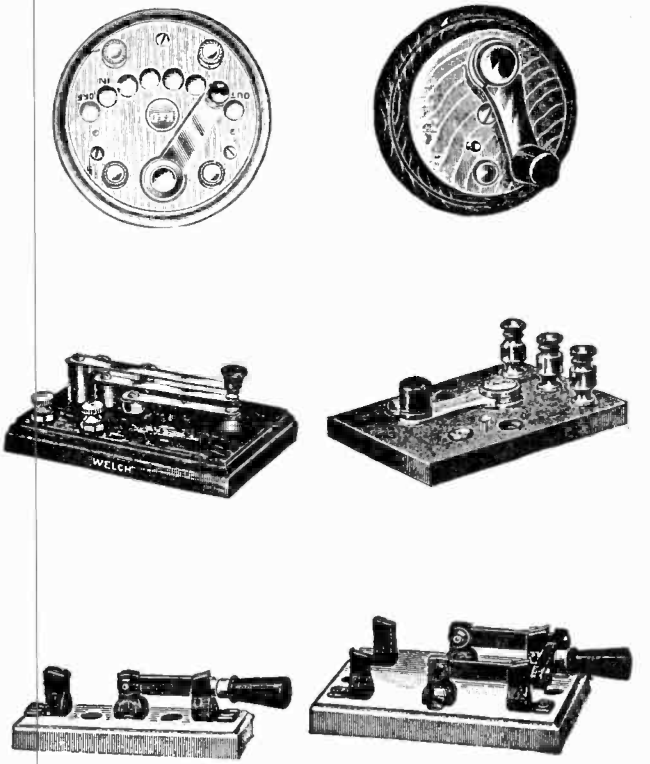


Fig. 27. Several different types of switches used in signal work. The two above are called Lever Switches. In the center on the left is a Multiple Key Switch; at the right double circuit Lever Switch. Below are two Knife Blade Switches.

Visible signals as a rule can only be used where they are in front of, or in line with the vision of those whose attention is desired, and are most commonly used where an operator or attendant is watching for them continually.

Electric bells are very commonly used in all types of signal systems.

Their construction and operation is quite simple and yet very interesting, and important to know.

18. VIBRATING BELLS.

There are several different types of bells, but the **Series Vibrating Bell** is the most commonly used of any. Figure 28 shows a good view of such a bell with the cover removed, showing the coils and parts.

Examine this carefully and compare it with Figure 29, which is a sketch of the same type of bell, and shows the electrical circuit and operating principle clearly. Note how easy it is to recognize each part in the photo, from the simple symbols in the sketch, and how the sketch really shows some things more clearly than the actual photograph. "A" and "A" are the bell terminals to which the wires are fastened. "B" "B" are the cores and coils or electro-magnets, which attract or operate the armature "C". "D" is a spring which supports the armature and also pulls it back every time the magnets release it. "E" is the end of the same spring, on which is mounted a piece of special alloy metal, which serves as a contact to close a circuit with the adjustable screw contact "F". These form the **Make and Break Contacts,** and are very necessary in the operation of the bell. "G" is the frame of the bell, "H" is the hammer which is attached to the armature, and strikes the gong "I", when the magnets attract the armature.

When a battery is connected to terminals "A", "A", current at once starts to flow through the bell. If the positive battery wire was attached to the left terminal, current would flow up through the armature, which, of course, is insulated from the frame, then through the "make and break" contacts, through the coils and back to the right hand terminal and the battery. As soon as current flows through the coils, the magnets attract the armature,

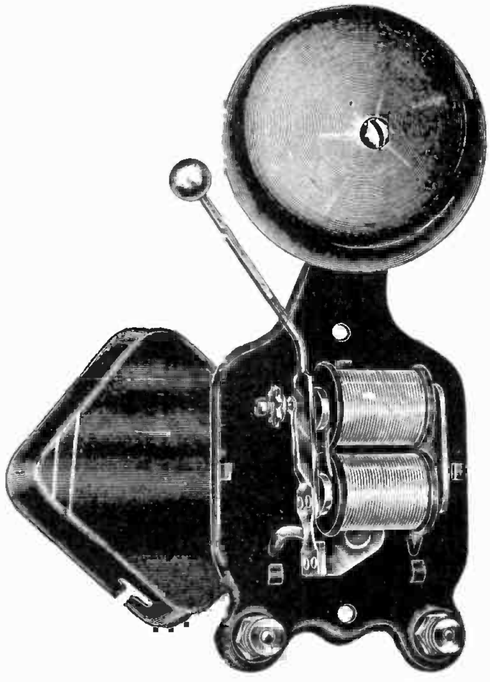


Fig. 28. View showing common vibrating bell with cover removed. Note carefully the construction and arrangement of coils, armature, and contacts.

causing the hammer to strike the gong, and also opening the "make and break" contacts. This stops the flow of current, demagnetizing the coils and releasing the armature. As soon as it falls back and closes the contacts, the magnets pull it away again. This is repeated rapidly as long as current is supplied to the bell; thus it is called a **Vibrating Bell.**

19. BELL TROUBLES

Most of these bells have their coils wound for 6 to 10 volts, and should not be operated on much

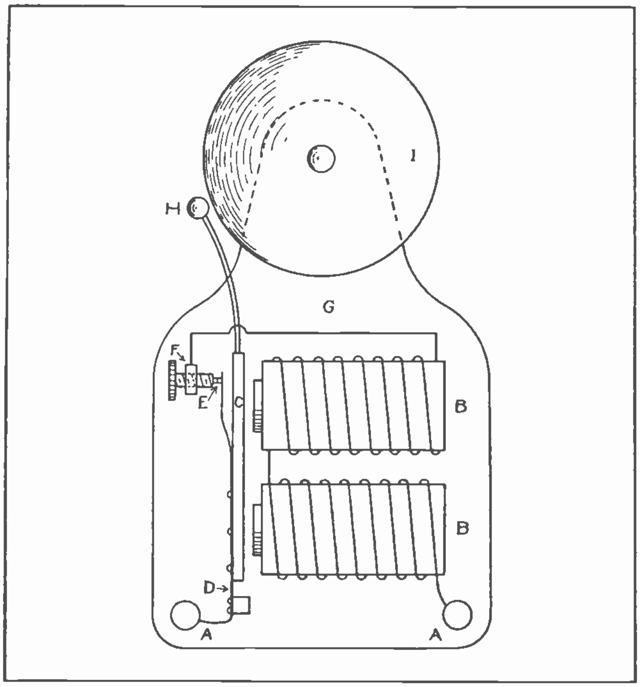


Fig. 29. Sketch showing electrical circuit and connections of common vibrating bell. Observe very carefully the parts of this diagram, and the explanation given.

higher voltage or the coils will overheat and burn their insulation off, which destroys them.

Most vibrating bells are made for short periods of operation only, and should not be allowed to operate continuously for long periods, or the arc at the contacts will heat and burn them. If these contacts become badly burned or dirty, they should be cleaned and brightened with a thin file. When a vibrating bell refuses to operate the trouble can usually be found at these contacts, or a loose terminal nut, or poorly adjusted armature spring.

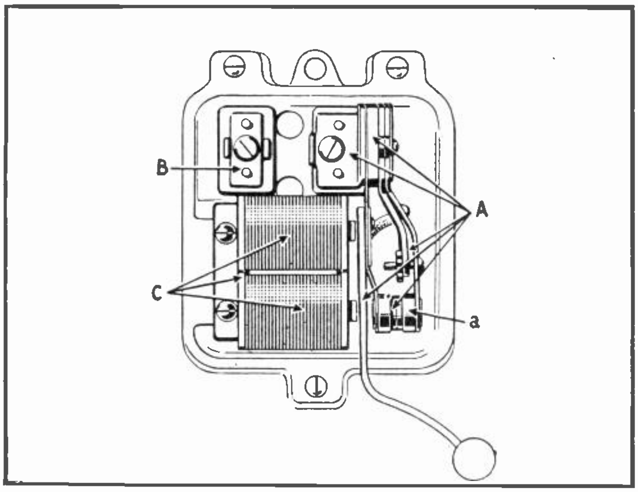


Fig. 30. Heavy duty bell frame and parts. Note the extra heavy carbon contacts for making and breaking the circuit at "A."

When the contacts are worn out, they can be replaced on the more expensive bells, but on the cheaper bells it is difficult to remove them and the bells can be discarded more economically, because of their very low cost.

In the more expensive bells, the contact points are faced with platinum, silver or special alloys that resist corrosion and burning, as even a very small amount of burned metal or dirt in these contacts will prevent the operation of the bell.

In some vibrating bells both terminals are insulated from the frame by little fibre sleeves and washers, and must be kept so.

If this insulation becomes defective the current is shorted through the frame and the bell will not operate. Other bells have only one terminal insulated, and the other is intentionally grounded to the frame, passing the current through the frame to the armature, which in this case is also grounded to the bell frame.

Sometimes the hammer of a bell becomes bent so it will not touch the gong, or rests too tight against it, stopping the proper operation of the bell.

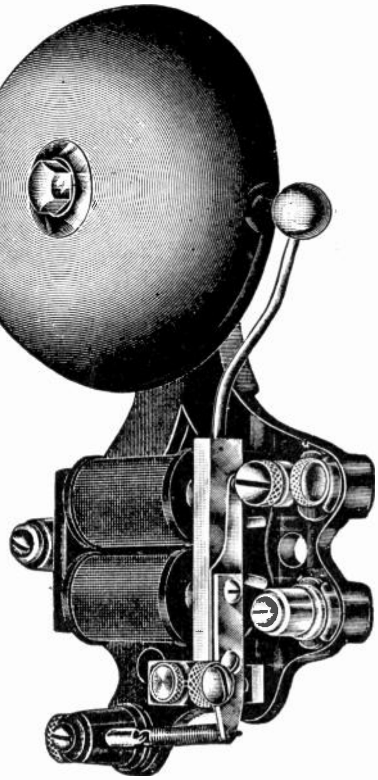


Fig. 31. Ruggedly constructed heavy duty bell. Bells of this type are often wound for 110-volt operation, and used where a very loud signal is desired.

A good undersanding of the parts and operation of these bells will enable anyone with a little mechanical ability, to easily locate and repair their most common troubles.

In Figure 31, is shown one of the larger types of vibrating bells which are often wound for 110 volt operation.

Series vibrating bells will operate on either D. C. or A. C. as it does not matter which way current flows through them; the magnets will attract the armature just the same. For this same reason, it makes no difference which way a battery is connected to these bells, as far as polarity is concerned.

20. SINGLE STROKE BELLS

Sometimes it is desired to have a bell that will give single taps each time the button is pressed, instead of the continuous vibration.

Such a bell is called a **Single Stroke Bell.** Figure 32 shows a sketch of a bell of this type. The only difference between this and a vibrating bell is that it has no make and break contacts, and therefore cannot vibrate. Each time the button is pressed and current supplied to this bell, its hammer strikes one tap on the gong. As long as the switch is kept closed the magnets hold the hammer quietly against the gong, after the first tap. When the switch is opened the hammer drops back ready for the next stroke.

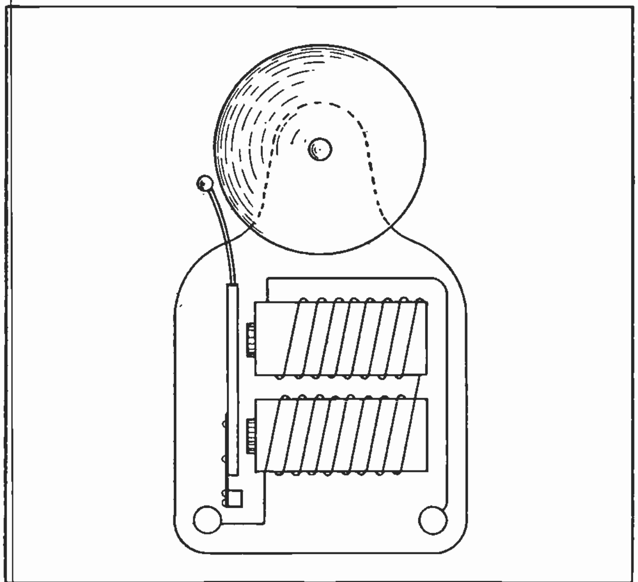


Fig. 32. Circuit diagram of a single stroke bell. Note that it does not have any "make and break" contacts.

These bells are very good for code calling, where a certain number of distinct strokes are used for each different call. They should be operated on D. C., as alternating current will cause the hammer to chatter slightly if held against the gong. This is due to the regular variations in value of alternating current.

21. COMBINATION BELLS

There are also combination bells which are arranged to be used either vibrating or single stroke.

Figure 33 shows a sketch of such a bell connected to a battery and two switches, to be operated either as a single stroke or vibrating bell as desired. If button "A" is pressed, the current will flow directly through the coils without having to pass through the make and break contacts at "C", and the bell will operate single stroke. The arrows show the path of current flow, during single stroke operation. If button "B" is pressed the current will flow through the armature and make and break contacts, and then to the coils, and the bell will vibrate because the magnets can now break the circuit rapidly as they pull the contacts apart at "C".

In emergencies or when a combination bell of this type cannot be obtained conveniently, you can easily convert an ordinary vibrating bell to single stroke or combination operation, by attaching an extra wire to the stationary contact of the breaker. See Figure 34, and the extra wire "A".

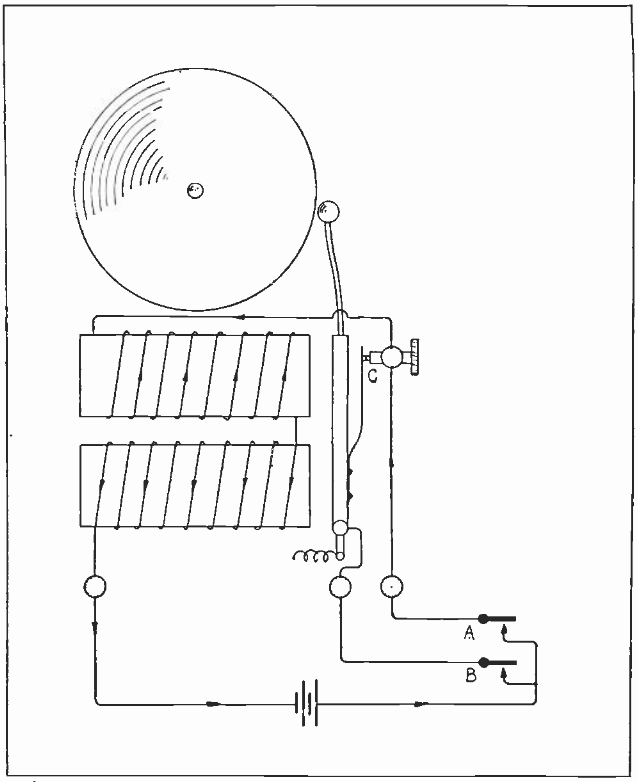


Fig. 33. Connections for a combination bell to be used either single stroke or vibrating. Trace this circuit carefully.

There are several other types of bells that are slightly different from the series vibrating type with principles very similar, but they are little used and can be easily understood with a little close observation and a knowledge of general principles covered here.

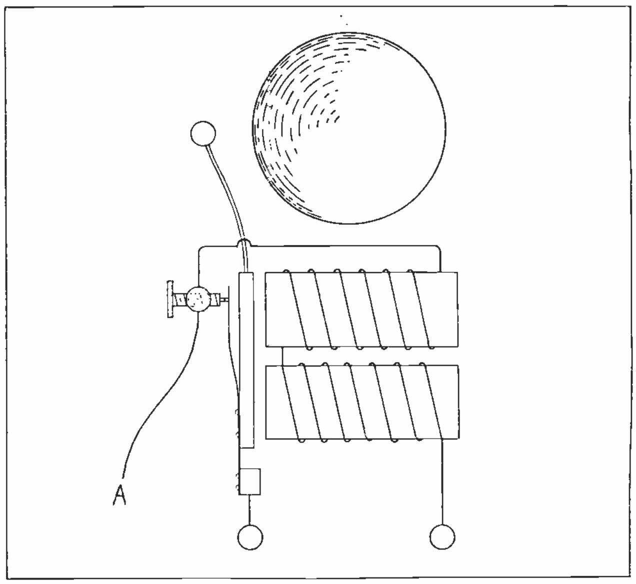


Fig. 34. Sketch showing method of attaching an extra wire to the stationary contact to convert an ordinary vibrating bell for single stroke or combination operation.

Another type of bell used extensively in telephone work, and operated on alternating current, will be taken up in a later section.

22. SIGNAL BUZZERS

In certain places such as hospitals and offices where noise is undesirable, a bell is too loud, and some device to give a softer note is needed.

For this purpose we have buzzers. These buzzers are almost exactly the same in construction and operation as the bells, except that the hammer and gong are left off entirely. The vibration of the smaller and lighter armature makes a sort of low buzzing sound which is sufficient to attract the attention of anyone near it. Figure 35 shows a common type of office buzzer enclosed in its metal case, and Figure 36 shows a sketch of the electrical circuit and parts of this buzzer. Buzzers can be obtained in different sizes, and some have an adjustment screw on them to change the tone and volume of sound. Figure 37 shows four buzzers of different sizes.

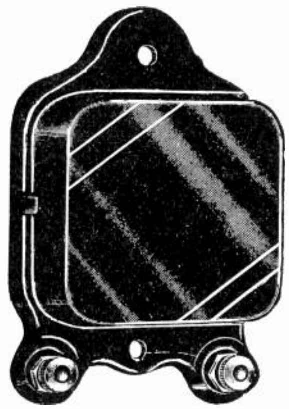


Fig. 35. Common office type buzzer, very similar to a vibrating bell, except that it has no hammer or gong.

23. "MUFFLING" OF BELLS

Sometimes when a buzzer is not available it is desirable to partly silence a bell, without putting it out of service entirely. This can be done by plugging the back of the gong with paper, or by removing the hammer ball, or bending it back so it does not strike the gong.

24. CARE AND TESTS OF BELLS AND BUZZERS

When any bell or buzzer fails to operate, a quick test to find out whether the trouble is in the bell or some other part of the circuit, can be made by connecting a cell or battery of proper voltage directly to the bell terminals.

If the bell does not operate then, be sure its terminals are tight, and its armature free to move. Clean the make and break contacts carefully with a thin file, or fine sand paper, and you will probably cure the trouble. If it still does not operate, examine the coils and the wires leading to them and, if necessary, test the coils as explained in previous sections. Usually the trouble will be found at the contacts, loose terminals, or armature adjustment.

25. SILENT SIGNALS

In some places an entirely silent signal is desired, and a visual indication is used instead of a bell or buzzer.

For this purpose we have low voltage signal lamps of various types. These can be obtained in voltages from two to twenty, and with colored bulbs, in white, red, blue, green, amber, etc. The different colors can be used to indicate different signals or to call different parties.

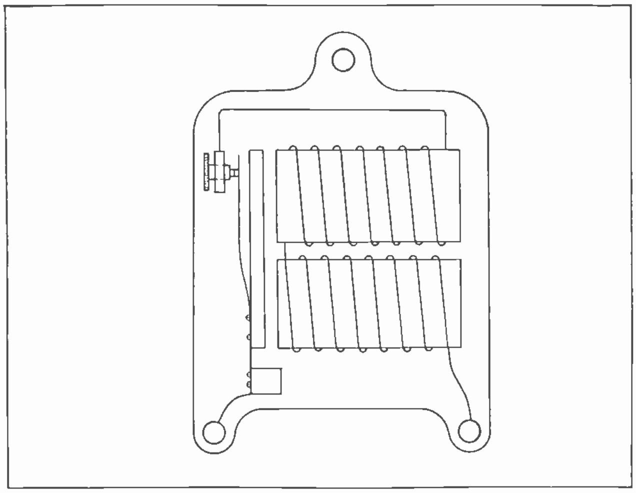


Fig. 36. Sketch showing coils and circuit of a buzzer of the type shown in Fig. 35.

Some of these lamps can be obtained with miniature threaded bases, to screw into small porcelain sockets, and can be conveniently located most anywhere desired. Others are made in special sizes and types, such as those used in telephone switchboards, etc.

When regular signal lamps are not available, automobile lamps and flashlight lamps can often be used to good advantage.

In many cases both a lamp and bell are used, or a lamp in the daytime, and a bell at night to arouse a sleeping person.

Danger signals often use both a red lamp and a bell. Railway crossing alarms are good examples of this.

Lamps of proper size and voltage rating can often be connected in parallel with a bell as in Figure 39-A, or in series as in Figure 39-B.

Figure 40 shows a circuit which enables the caller to use either the lamp or bell as desired.

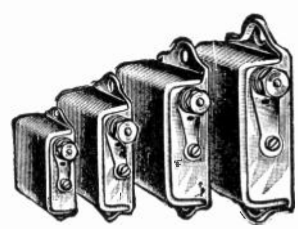


Fig. 37. Four office buzzers of different sizes. Each size gives a signal of a different tone and volume.

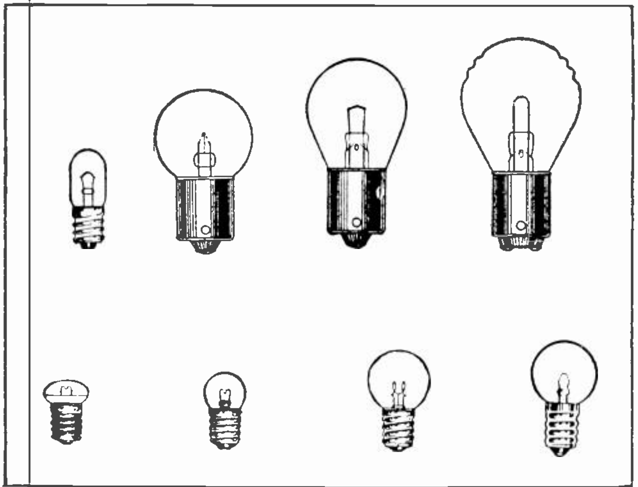


Fig. 38. Several types of low voltage lamps which can be used for signal circuits.

26. MAGNETIC DOOR OPENERS

A device quite commonly used in connection with door bells is a **Magnetic Door Opener,** shown in Figure 41. These devices will unlock the door by use of magnets, when a button inside is pressed. They are particularly popular and useful in apartment buildings where the door bell may call someone several floors above. Such buildings usually have speaking tubes or telephones in connection with the door bells, and after the bell is rung and the party in the house finds out who is calling, they can unlock the door if they wish to by merely pressing a button in their apartment. Thus they are a

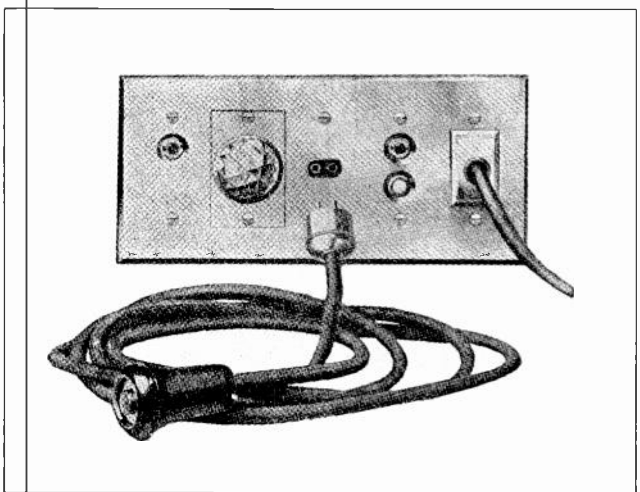


Fig. 38-A. Panel and cord for silent hospital signal. The lamp is located behind the glass "bulls-eye" at the left.

great convenience and time saver. Figure 42 shows a sketch of a magnetic door lock in connection with a door bell system. Note how the same battery and the center wire are used for both circuits. Many worth while economies can be effected in wiring signal systems, by such simple combinations of circuits. A number of these will be shown a little later in this section.

27. DROP RELAYS FOR CONSTANT RINGING SIGNALS

In certain alarm and signal systems it is often

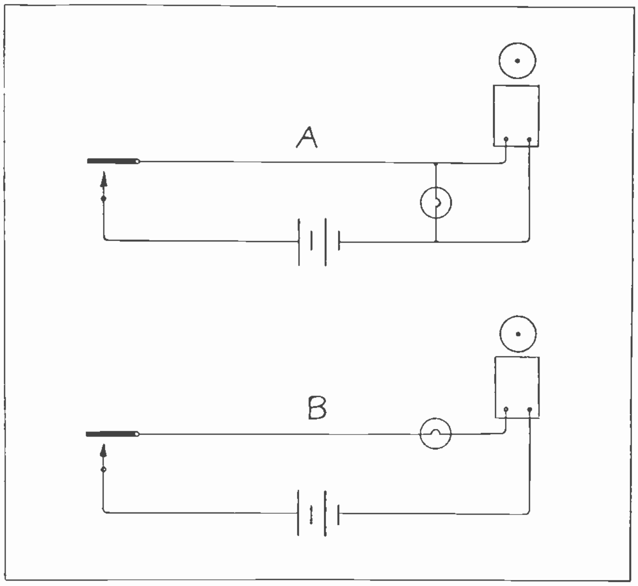


Fig. 39-A. Signal lamp connected in parallel with a bell so they both operate at once.
Fig. 39-B. Signal lamps can also be connected in series with bells if they are of the proper resistance.

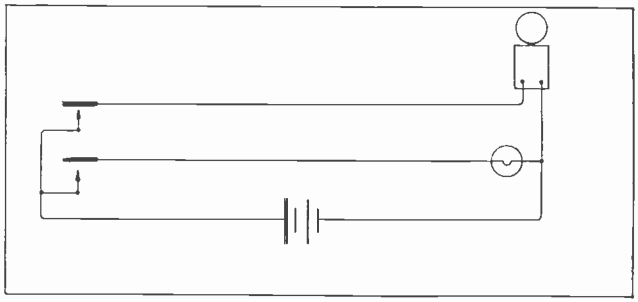


Fig. 40. Connections for operating either a bell call or silent lamp signal, as desired.

an advantage to have the bell continue to ring until it is shut off by the person it is to call. For example a burglar alarm in order to give a sure warning, should not stop ringing if the burglar stepped in through the window and then closed it quickly. To provide continuous ringing of a bell once the switch is closed, we use a device called a **drop relay.** Figure 43 shows one of these devices, and Figure 44 shows a sketch of the connections of a drop

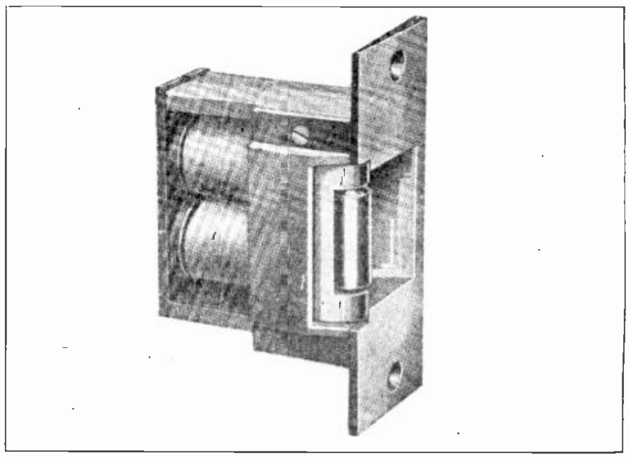


Fig. 41. Magnetic door opener, used to unlock doors in apartment houses or buildings from a distance, by the use of a push Button and low voltage circuit.

relay with a bell, battery, and switch, ready to operate. Trace each part of this circuit and examine the parts of the device carefully, and its operation will be easily understood.

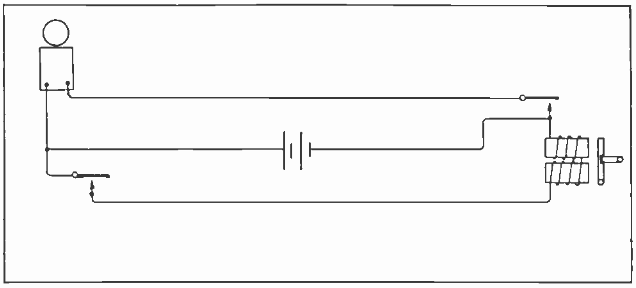


Fig. 42. Sketch showing connections for a door bell and magnetic door opener.

When the switch is closed, current first flows through the circuit as shown by the small arrows, causing the coils to become magnetized and attract the armature. This releases the contact spring which flies up and closes the circuit with the stationary contact to the bell. Before being tripped, the contact spring is held down by a hook on the armature, which projects through a slot in the spring. The button "B" extends through the cover of the relay, and is used to push the contact spring back in place, or reset it, and stop the bell ringing.

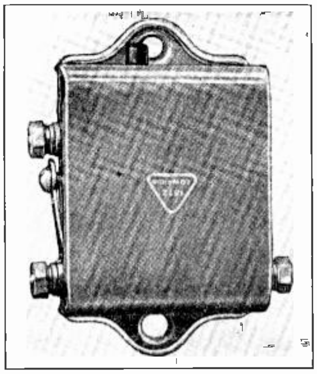


Fig. 43. Common type of drop-relay to provide constant ringing in alarm or signal circuits.

In tracing the bell operating circuit shown by the large black arrows, we find the current flows through the frame of the device from "C" to "D." The marks or little group of tapered lines at "C" and "D" are symbols for **Ground** connections. From this we see that a ground connection as used in electrical work does not always have to be to the earth. But instead a wire can be **Grounded** to the metal frame of any electrical device, allowing the current to flow through the frame, saving one or more pieces of wire and simplifying connections in many cases. It is a very common practice in low voltage systems, and extensively used in telephone and automobile wiring. So remember what that symbol means whenever you see it from now on. Another type of drop relay is shown in Figure 45, and its circuit and connections with a bell and battery are shown in Fig. 46.

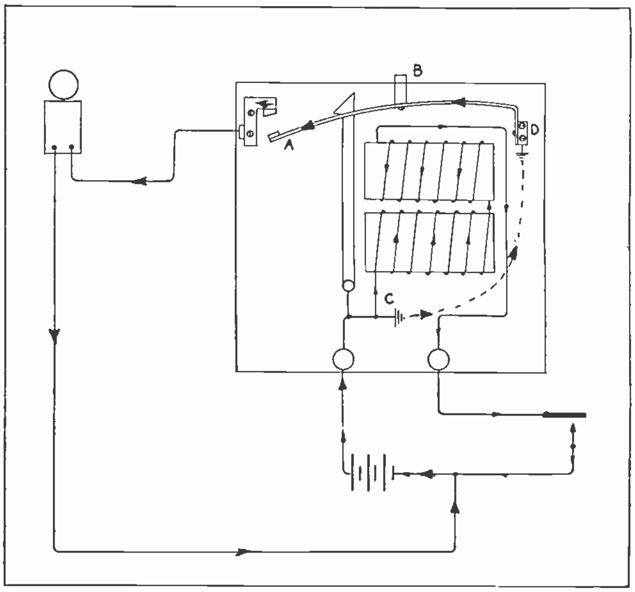


Fig. 44. Sketch showing complete circuit and connections of drop-relay of the type shown in Fig. 43. Examine this sketch and trace the circuit very carefully.

This relay is a little different in construction than the one in Figure 43, but it performs the same function of causing the bell to ring constantly when the relay is tripped. Trace this circuit carefully and compare the terminals "C," "D" and "E" with their position on the relay in Figure 45, and this will show you how to properly connect the device in a circuit.

Drop relays are used very extensively in burglar alarms, and also in other forms of signals. Some special bells are made with an extra release spring and switch to make them ring constantly until reset. This is a sort of drop relay built right into the bell.

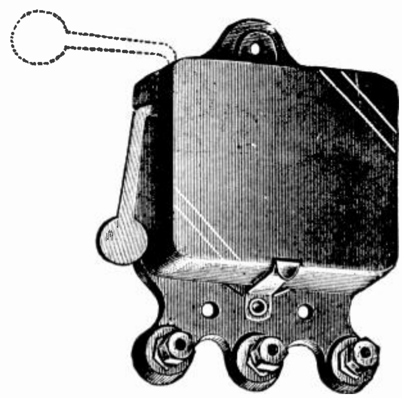


Fig. 45. Another type of drop-relay of slightly different construction, but also providing constant ringing.

28. RELAYS

Earlier in this section it was mentioned that a closed circuit system is much more reliable than an open circuit system, because any fault such as a broken wire or dead battery would make itself known at once by causing the signal to operate. So closed circuit systems are much better for burglar alarms, fire alarms, etc., where it is very important

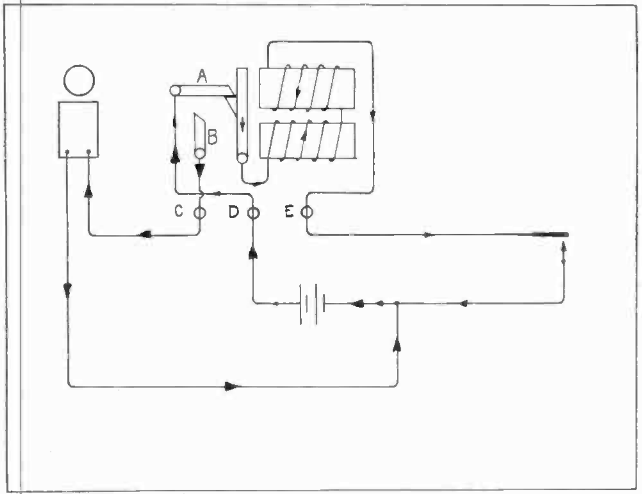


Fig. 46. This sketch shows the method of connecting a drop-relay such as shown in Fig. 45 to a bell battery and push button for constant ringing signals.

not to have a fault in the system go unnoticed until just when the signal is most needed.

We cannot, of course, connect a bell directly in a closed circuit, or it would ring continually. So we have an interesting device which can be connected in the closed circuit, using very little current, and making no noise until its circuit is disturbed. Then it immediately gets busy and closes a second circuit to the bell, causing it to ring.

This device is called a **Relay.** Its name gives a good idea of its function. When it receives an impulse or has its current interrupted, it passes on an impulse of current to a bell or other device, similar to the man in a relay race who passes his stick to the next man to carry on.

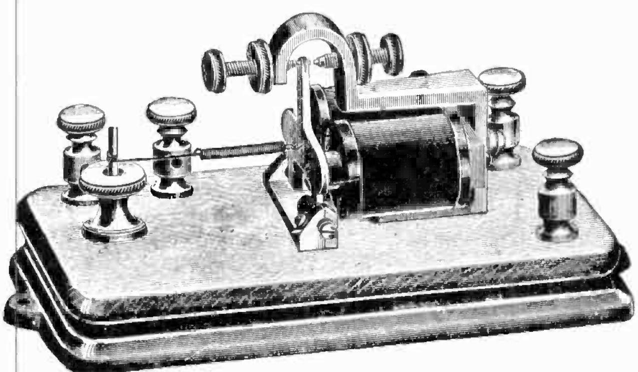


Fig. 47. Common Pony Relay such as used in burglar alarm and telegraph systems. Examine the construction and parts, and compare with description given.

A relay is in reality a **Magnetically Operated Switch.** Figure 47 shows a common type of Pony Relay, which is used extensively in alarm, signal, and telegraph work.

Examine this relay very closely. You will note the **Coils** or electro magnets, which are to attract the **Armature** or movable part of the switch. The armature is the vertical metal piece set in pivot hinges at the left end of the magnets. Then there is a coil spring attached to it and having its other end fastened to an adjusting screw to vary the spring tension on the armature. This spring is to pull the armature back each time the magnets release it. The large piece of brass with the curved arch above the armature is called the **Bridge,** and supports two adjustable bridge contacts. These screw contacts have hollow tips, in which we can place plugs of metal, hard rubber, or wood, according to which contact we wish to use in the circuit. Note that the armature tip also has small points of good contact metal on each side where it touches the bridge contacts.

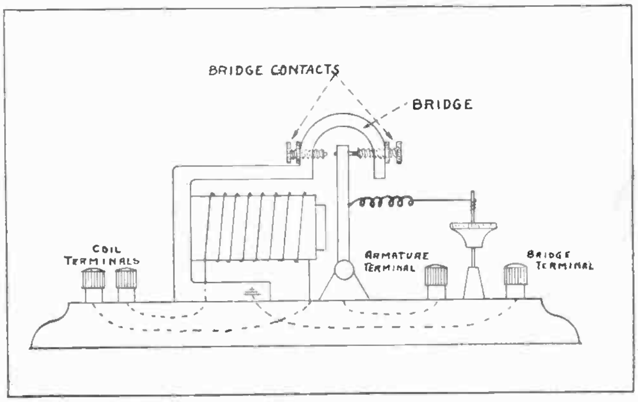


Fig. 48. Diagram showing the arrangement of the electrical circuits and terminals of a Pony Relay.

29. RELAY TERMINALS AND CONNECTIONS

The two connection posts or terminals on the right end of the base in Fig. 47 connect to the coils. And of the two on the upper left corner, the right-hand one nearest the armature is connected to the armature, and the left one connects to the bridge. These connections are made under the relay base. It is very important to remember which of these terminals are for the coils, armature, and bridge.

Figure 48 is a sketch of this relay showing its electrical parts and circuits from the opposite side to the one shown in Figure 47. Compare this very closely with the picture in Figure 47, and locate the coils, armature, bridge, contacts, and terminals, so you know the location of each and the operating principle of the relay. Figure 49 shows another relay of slightly different construction but same general principle as Figure 47.

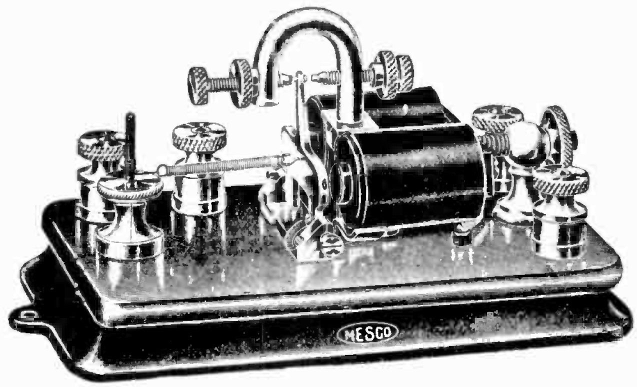


Fig. 49. Another type of Pony Relay similar to the one in Fig. 47, but of slightly different mechanical construction.

30. OPEN, CLOSED, AND DOUBLE CIRCUIT RELAYS

Relays can be used in several different ways in circuits, and according to their use they are called **Open Circuit, Closed Circuit, and Double Circuit Relays.**

To use a relay as an open circuit device, we place the metal tipped bridge contact screw on the left side of the bridge arch, and the insulated contact on the right, or the side away from the coils, as in Fig. 50-A.

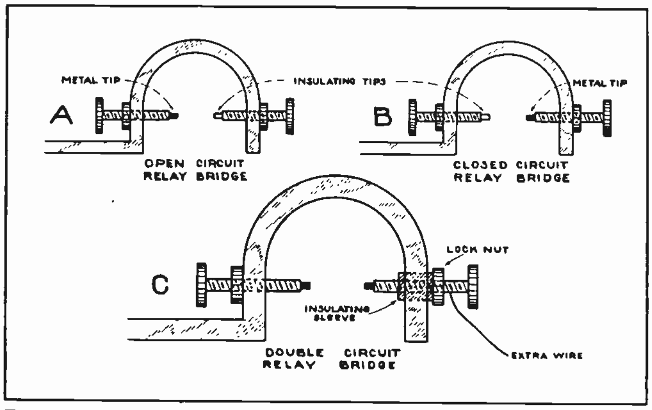


Fig. 50. This sketch shows in detail the manner of arranging and insulating relay bridges for open circuit, closed circuit, and double circuit operation.

For closed circuit operation we reverse them. For double circuit use we fit both bridge screws with metal tips, but remove one screw and insulate it from the bridge arch, by enlarging the hole and fitting it with an insulating sleeve, then replacing the screw in this sleeve. Then we attach an extra wire to this screw for the extra circuit. See Figs. 50-A, B, and C. With a drill to enlarge the hole in the bridge, and piece of fibre or hard rubber, or even hard wood, for the insulating sleeve, any ordinary pony relay can be easily changed to a double circuit relay in this manner in a few minutes. This is a very important thing to remember, because some time you may not be able to get a double circuit relay, and it may be very handy to know how to change over a single circuit relay in this manner.

31. RELAYS USED IN BURGLAR ALARMS

Figure 51 shows a closed circuit relay connected up for operating a simple closed circuit burglar alarm. Here we have used just the symbol for the relay instead of a complete sketch. Note what a time saver this symbol is, and practice making a sketch of it until you are sure you can make it any time, when laying out a plan for a system using relays.

Trace out the circuit in Figure 51 until you understand its operation thoroughly. Note that current will normally be flowing all the time in the closed circuit "A". For this reason most relays of this type have high resistance coils, wound with many turns of very fine wire, so they will not use much current from the battery. Many of these

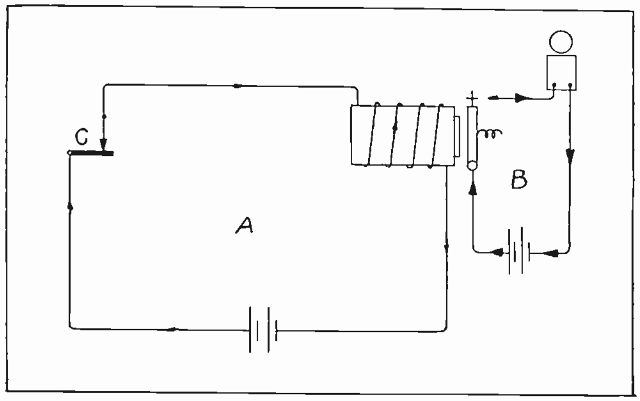


Fig. 51. Connections for a closed circuit relay used to operate a bell in a simple bulglar alarm system.

common relays have coils of 75 ohms, and they can be obtained with higher or lower resistance for various uses. Recalling the use of Ohms law formula, we find that if a 75 ohm relay is used in a circuit with a 3 volt battery, only .04 ampere will flow. Or as $E \div R = I$, then $3 \div 75 = .04$.

Many relays are made so sensitive and with such high resistance coils, that .001 ampere or less will operate them. But even with the small current flow of .04 ampere, it will be best to use a gravity cell, Edison cell, or storage battery, for the closed circuit "A", so the continuous current flow will not exhaust it quickly.

As long as this system is not disturbed, the current flowing in the closed circuit "A" and through the relay coils, will hold the armature away from the bridge contact, and the bell will remain silent.

But if a burglar disturbs the window or door to which the closed circuit switch "C" is attached, this will open the circuit and stop the current through the relay coils, and they will release the armature. Its spring will pull it against the bridge contact and close the circuit to the bell giving the alarm.

32. PROPER LOCATIONS OF PARTS FOR DEPENDABLE CLOSED CIRCUIT SYSTEMS

In installing such a system, the relay, bell, and batteries would usually all be grouped close together, possibly all on one shelf, so the wires between them and in circuit "B," would be short and have little chance of being damaged. The wires of circuit "A" would be the long ones running through the building to the part to be protected.

If these wires should be cut or damaged, or this battery go dead, the relay would immediately cause the bell to operate, calling attention to the fault. While with an open circuit system the wire could be cut, or the battery dead, and the system out of order, without any one knowing it, and thus fail to operate when needed the most.

The battery in circuit "B" is not likely to go dead so often, as there is very seldom any current required from it. But it should be tested occasionally to make sure it is in good condition. Any important alarm system should be tested daily, or every evening, before being switched on for the night.

In Figure 51, in the relay symbol, we only show the one bridge contact which is in use.

When we desire to operate a bell or signal sounder at a considerable distance, an open circuit relay can be used to good advantage to save sending the heavier current required by the bell over the long line.

If we were to send the heavy current over the long line, it would cause considerable voltage drop and we would have to use larger, more expensive wires, or higher voltage supply. But the relay current being very small can be sent over the line more economically, and the relay will act as a switch at the far end of the line, to close a **Local** circuit to the bell. See Figure 52.

This circuit uses an open circuit relay, and the bridge contact on the side opposite to the one used in Figure 51. This method of using a relay to operate on a feeble impulse of current, and close a circuit to a larger device requiring more current, is one of their most common applications.

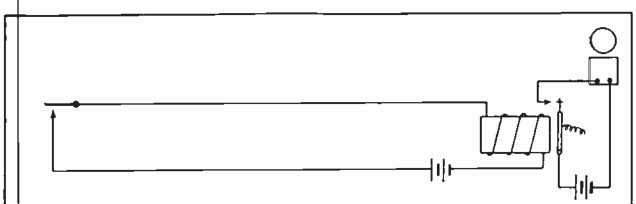


Fig. 52. Connection diagram for an open circuit relay used to operate a bell at a considerable distance from the push button.

33. USE OF RELAYS IN TELEGRAPH SYSTEMS. GROUND CIRCUITS

Figure 53 shows two relays at opposite ends of a line, and operating **Sounders** in local circuits, in a simple telegraph system. The primary circuit includes two line batteries, two key switches, and two high resistance relay coils. The secondary circuits each consist of a local battery and sounder, and include the relay armature and bridge contacts as their switches. You will note that only one line wire is used in the primary circuit, and the earth is used for the other side of the circuit, by grounding the batteries at each end as shown. This saves considerable expense in line wire, and is quite commonly done in telegraph, telephone, and certain classes of signal work.

If the ground connections are well made of buried metal plates, or rods driven deep into moist soil, the resistance of the earth is low enough so the losses are not very high with such small currents. Such ground circuits are not used to transmit electric power in large amounts, however.

Both of the telegraph keys in this system have extra switches that are normally kept closed when the keys are idle. This allows a very small amount of current to flow through the line and relay coils continually, when the system is not in use.

This keeps the relays energized, and the local sounder circuits closed also, through the relay armatures and bridges. This may seem like a waste of current, but the batteries, being of the closed circuit type, stand this current drain very well and do not cost much to renew when exhausted.

When an operator wishes to send a message, he opens the auxiliary switch on his key, thus opening all circuits. Then each tap of his key sends a feeble impulse or very small current over the line, causing the relays to operate and give similar impulses, but of much heavier current, to the sounders from their own local batteries.

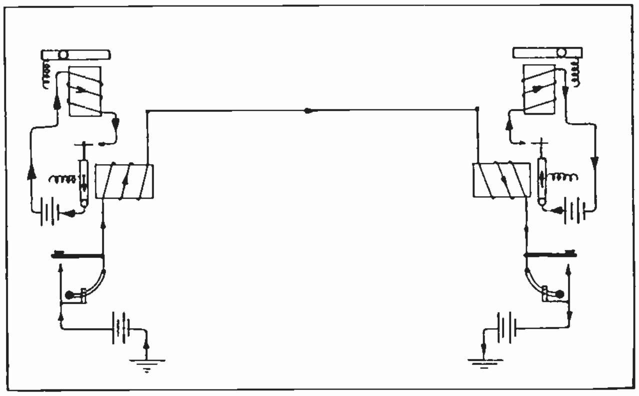


Fig. 53. Sketch of simple telegraph system showing line and ground circuit for the relays and keys, and local battery circuits for the sounders.

The operator at the other end of course hears the signals from his sounder. When the sending operator finishes, he closes his key switch, and waits for an answer. Then the other operator opens his switch and uses his key to signal back. Sometimes a number of such relays at various stations are all connected to one line, so they all operate at once, when any key is used.

Figure 54 shows a double circuit relay. In this system, as long as the switch "A" is closed the relay armature is attracted and closes a circuit through the lamp, showing that the circuit is in normal condition. But when switch "A" is opened the relay armature is released, allowing the lamp to go out and causing the bell to ring.

These double circuit relays have many uses, some of which will be shown a little later.

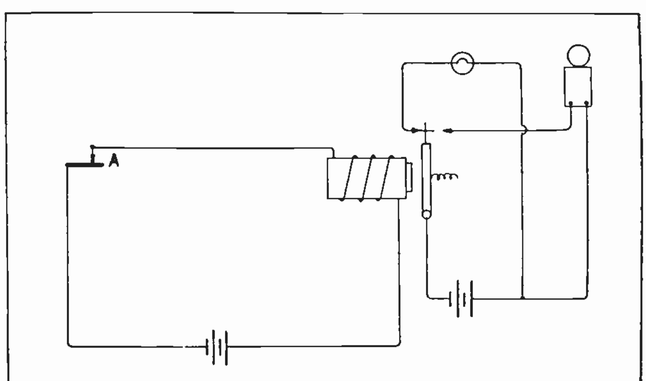


Fig. 54. Diagram and connections for a double circuit relay to operate a lamp when the system is undisturbed, and to ring a bell when the closed circuit is molested in any way.

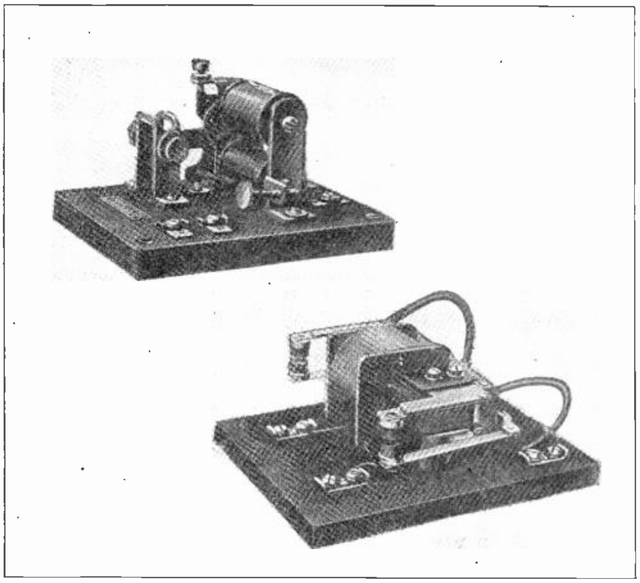


Fig. 54-B. Two additional types of relays used in various classes of signal circuits.

34. RELAY TERMINAL TESTS

If you are ever in doubt as to the correct terminals on a relay, a quick test with a dry cell and two test wires will soon locate the coil terminals. When the cell is connected to the coil wires the armature will snap over toward the magnets. Connecting a cell and buzzer or small low voltage test lamp, to the armature and bridge terminals, and then moving the armature back and forth by hand, will soon show which terminal connects to the closed bridge contact and which to the open one.

35. ADJUSTMENT AND CARE OF RELAYS

Relays require careful adjustment to secure good operation. The pivot screws supporting the armature and acting as its hinges, should be tight enough to prevent excessive side play of the armature, but not too tight or they will interfere with its free movement. By turning one of these screws in, and the other one out, the contact points on the armature can be properly lined up with the bridge contacts. The bridge contacts should be adjusted to act also as stops for the armature. The contact on the magnet side should be adjusted to allow the armature to come very close to the core ends, to reduce the air gap and strengthen the pull as much as possible. It should not, however, allow the armature to touch either core end, or it is likely to stick, due to slight residual magnetism, even after the coil current is turned off. Some relays have thin brass or copper caps over the iron core ends of the magnets, to prevent any possibility of this sticking. The contact on the side away from the magnets should be adjusted to allow the armature just enough swing to effectively break the circuit at the other contact; but not too far, or it will be very hard for the magnets to pull it back, due to the increased air gap between the armature and cores.

This would require more current to operate the relay. Usually the gap or travel of the armature contacts should be from 1/32 in. for breaking circuits at very low voltage and small currents, to $\frac{1}{16}$ in. or $\frac{1}{8}$ in. for slightly higher voltages and heavier currents; as these have a tendency to arc more, when the circuit is opened and the points must separate farther to extinguish the arc quickly.

The armature spring should be adjusted just tight enough to pull the armature away from the magnets quickly when it is released, but not too tight, or the magnet will not be able to pull up the armature.

The contacts on both the armature and bridge should be kept clean and occasionally polished with a thin file or fine sandpaper, as the slight arcing often burns and blackens them, greatly increasing their resistance.

When contacts become too badly burned or damaged to repair, they can easily be replaced with new ones, obtained from the relay manufacturers.

Dust and dirt should be kept off from all parts, and all terminal nuts should be kept tight. Cores of magnets should be kept tight on keeper bar support.

Occasionally, but not often, a relay coil may become open, grounded, or shorted, or completely burned out. Simple tests as given in the elementary section on electro-magnets will locate any such faults. (See Article 101.) In addition to these pony relays, there are numerous other types used in telephones, railway signals, power plants, etc. Some of these differ in mechanical construction and shape, from the ones just described, but their general purpose and principle are very much the same. So if you have a good understanding of the relays in this section and always remember that **any relay is simply a magnetically operated switch,** you should be able to easily understand most any type. Some of the others will be explained in later sections.

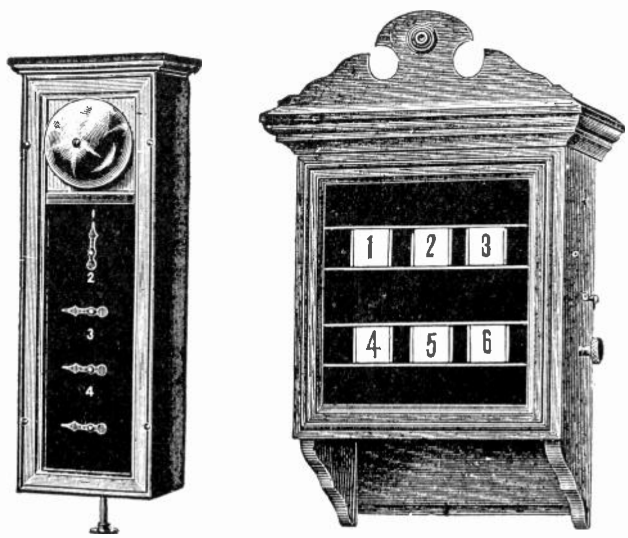


Fig. 55. Annunciators of these types are used to indicate where various calls on signal circuits come from.

36. ANNUNCIATORS

In alarm or signal systems where calls may come from several different points, it is often necessary to have some device to indicate which place the signal comes from. For this purpose we use an **Annunciator.** These devices indicate which circuit is operated, by arrows or numbers which are dropped into view by electro-magnets. Figure 55 shows two types of annunciators, and Figure 56 shows the electrical circuit of a 4 point annunciator.

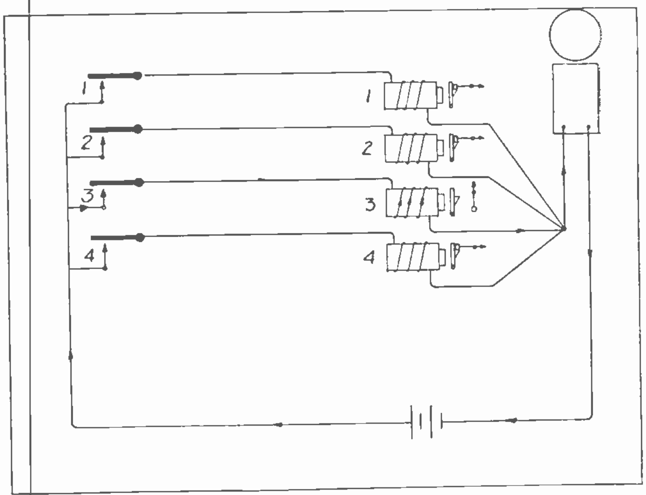


Fig. 56. Circuit diagram of the connections for a four-drop annunciator. Note that the drop number 3 has been operated.

Here we have four switches that may be used, for example, for office calls, burglar alarms, or hotel room calls. When any one of the switches is pressed it will send current through the respective annunciator magnet, and on through the bell. When a magnet is energized its armature is attracted, allowing the weighted end of the arrow to fall off the catch, and the arrow to fly up, as on magnet 3.

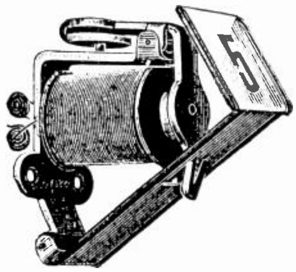


Fig. 57. This view shows the mechanical construction of one type of annunciator drop. Note how the drop is held up by a small hook on the end of the armature.

In Figure 57 are shown one of the magnets and "number drops" of an annunciator. When this magnet is energized, its armature is attracted and releases its catch from the slot in the drop arm. Gravity then causes the drop number to fall. Annunciators usually have a system of rods and hooks, all attached to one lever, to push the drops back in place after any of them are tripped. Some are equipped with a strong electro-magnet to operate this "reset" lever, from a switch on the annunciator case, or a short distance away.

Figure 58 shows a back view of an annunciator, and the magnets and reset mechanism.

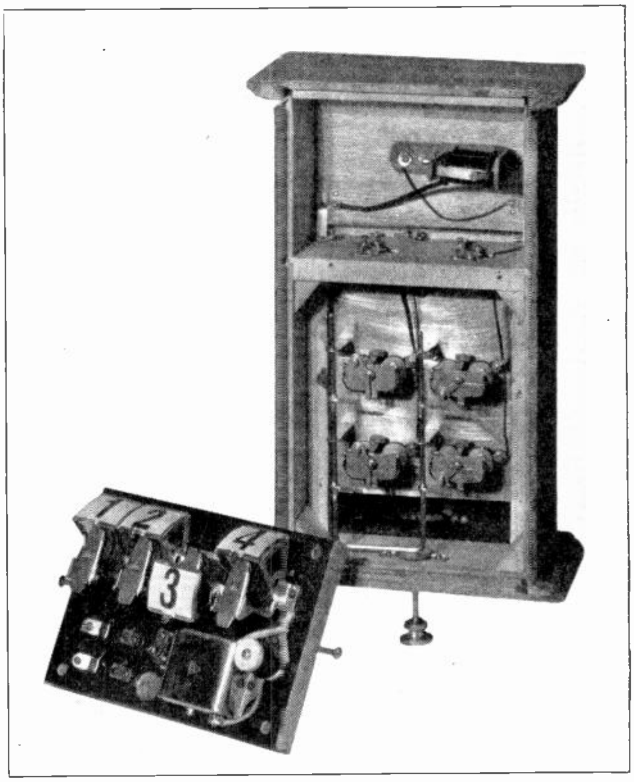


Fig. 58. Photographs showing the inside parts and construction of two common types of annunciators.

Referring to Figure 56 again, note how one wire from each magnet attaches to a common terminal or wire leading to the bell. This is called a **Common Return Wire,** as it makes a common path for current from any magnet to return to the battery. This is the wire that should go to the bell, so all coil circuits will operate the bell when they are tripped. Some annunciators have the bell built in them, and others do not.

37. ANNUNCIATOR CONNECTIONS AND TERMINAL TESTS

When installing annunciators it is very important to get the proper wires connected to the separate circuits, and to the bell. Sometimes they are marked with numbers on the box where they enter, but when they are not marked, they can be found by a simple test. Using a dry cell or source of supply, and two test wires, as in Figure 59-A, place one wire on one of the annunciator terminals at the end of the row or group, and hold it there while touching the other wire to the remaining terminals in rotation. If this causes the drops to operate in proper rotation then mark the wire to which your stationary test lead was connected, as the common lead, and the rest according to the numbers of the drops they each operate.

If touching the free test lead to certain ones of the terminals causes two or more drops to trip at once, the stationary lead is not on the common wire, and should be tried on the terminal at the opposite end of the row, because the common lead is usually at one end or the other. Sometimes, however, it may be somewhere else in the group.

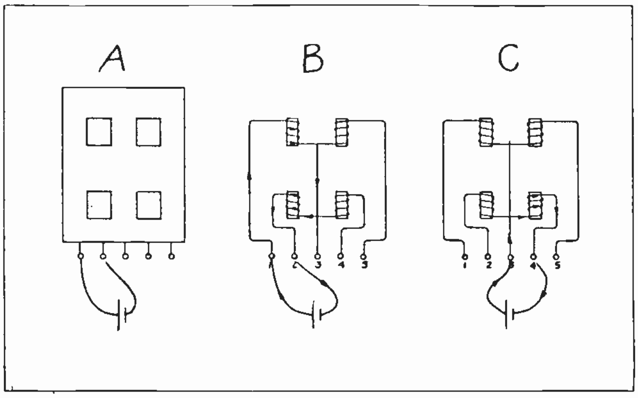


Fig. 59. Observe these test diagrams very carefully with the instructions given for locating annunciator terminals.

By touching the test wires to adjacent terminals two at a time, when two are found that cause only one drop to operate, one of these leads should be the common return. In Figure 59-B, with the stationary test lead on wire No. 1, touching the other test lead to wires No. 2, 4, and 5, should cause two drops to fall each time, if they are reset before each test. But when No. 3 is touched only one drop should fall, as No. 3 is the common terminal. Then when the stationary lead is placed on wire No. 3, and the free lead touched to the others, each one should cause one drop to operate.

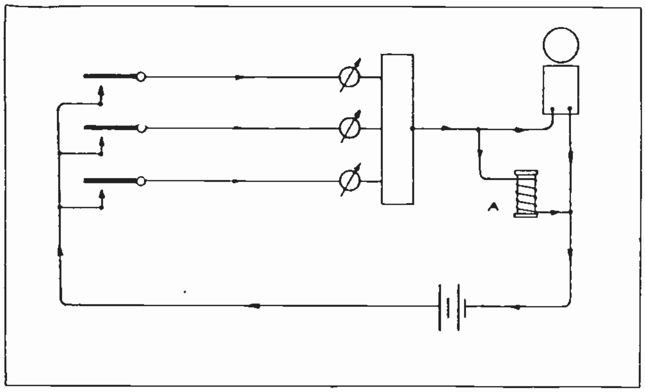


Fig. 60. Diagram showing connections of a three-drop annunciator in an opened circuit signal system. This annunciator uses a ballast coil shown at "A," and connected in parallel with the bell to allow the proper amount of current to flow to operate the drops.

With annunciators that are equipped with a bell or buzzer permanently connected, it is easier to locate the common wire, as it is the only one that will cause the bell to operate when the test battery is applied. For example, when the test wires touch two terminals and cause the bell to ring, one of these terminals must be the common return lead. Trying each one with another wire will quickly show which one operates the bell.

Some annunciators have a ballast coil connected in parallel with the bell, as at "A" in Figure 60. This coil carries part of the current when the bell is of high resistance and not able to carry quite all the current required to operate the drop magnets. Figure 60 also shows a different symbol which is often used for the annunciator in plans or diagrams.

Some large annunciators have a separate reset magnet for each drop magnet, as in Figure 61-A and B. In Figure "A" the reset coil has been operated, and has drawn the armature toward it, carrying the number on the disk out of view from the annunciator window. In Figure 61-B the trip coil has operated, drawing the armature toward it and bringing the number on the disk into view, in vertical position in the annunciator window. (Window and case not shown in this sketch.)

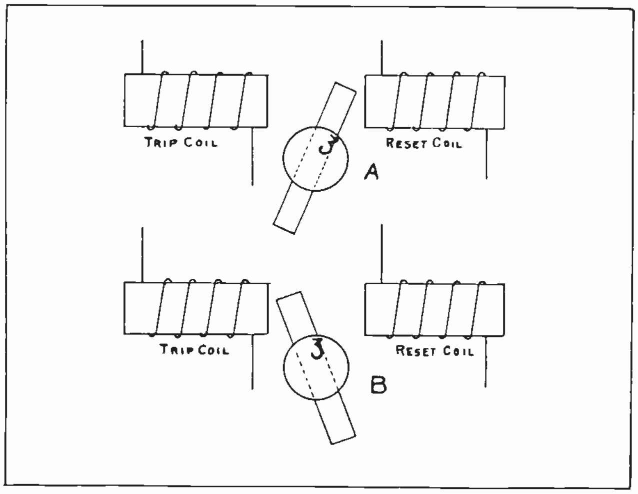


Fig. 61. Sketch illustrating arrangement of coils and number disks on an "electrical reset" annunciator.

Figure 62 shows both sets of coils for a four point annunciator and their connections. Each trip coil can of course be operated separately, but when the reset button is pressed all reset coils operate at once, resetting all numbers that have been tripped.

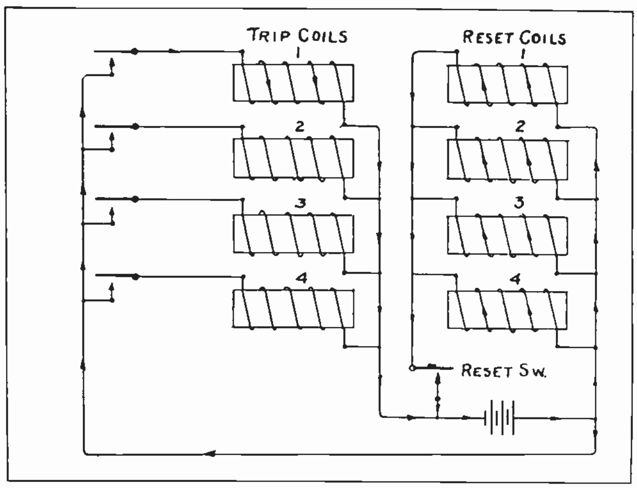


Fig. 62. Complete diagram of a four-drop annunciator using "electrical reset" magnets.

Hotels, hospitals, and steamships often have annunciators with several hundred numbers each. Elevators also use thousands of these devices.

38. LOCATING FAULTS IN ANNUNCIATORS

When annunciators fail to operate, careful checking and tightening of all terminals will usually locate the trouble. If none of the drops operate, and the supply battery to the system is tested and found O.K., and all circuits good up to the annunciator, then the trouble is almost sure to be in the common return wire, bell, or ballast coil, if one is used. If only one drop fails, then its own wire, coil, or mechanism is at fault, and careful checking and testing with a dry cell and buzzer should locate it. Here again the rules for testing electro-magnets, given in Section 1, Article 101, should be useful.

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ESTABLISHED 1899

ELECTRIC SIGNAL SYSTEMS

PLAN READING
AND
INSTALLATION

Section Two

PLAN READING
AND
VARIOUS TYPES OF SIGNAL CIRCUITS

Now that you understand some of the more common devices used in signal circuits, you will want to learn how they are arranged and connected in the larger and more complete systems.

But first, in order to be able to more easily understand and trace out these advanced circuits, we will cover some of the more definite methods of plan reading and circuit tracing.

Remember this is one of the most valuable things any electrical man can know, and nothing will give you any more confidence, or be of greater help to your success on the job, than a good knowledge of plan reading and circuit tracing. Once you have learned the real system or "trick" of this, it is really very enjoyable and satisfying to trace out almost every circuit or blue print you come across, and you will be surprised how much better understanding you can get of any device or system in this way.

39. SYMBOLS USED IN SIGNAL DIAGRAMS.

The chart in Fig. 62-A gives a review of all the most common symbols used in the following diagrams and signal systems, and you should study these carefully, so you will be able to recognize them quickly when tracing any circuit. You will also want to be able to quickly select and use the proper symbol for any device, when laying out a plan for a job yourself.

40. METHOD OF TRACING CIRCUITS, OR READING PRINTS.

In each of the following systems shown, make a practice of first examining the plan in general, locating and recognizing all of the devices by their symbols. Then get a general idea of the layout, number and arrangement of separate circuits which may be combined in the one system. Next start with the primary or first operating circuit, and trace it out carefully until you can imagine every step of its operation clearly, then the next circuit, or the one which is operated by the first, tracing its operation and so on until you are sure you thoroughly understand the entire system.

At first this may seem like quite a job, but after a little persistent practice you get the trick or method of it, and then you can read most any plan almost at a glance. The ability to do this will be worth more in the field than any beginner can realize, until he finds out what a great help it is on the job, in any kind of electrical construction work or "trouble shooting" and maintenance.

Don't forget that every principle and bit of practice you get in tracing signal circuits will apply to practically any other kind of work as well.

Also remember that most electrical wiring nowadays is done from plans, and not by guesswork. And when we have a difficult trouble shooting problem in a large machine or system, looking over the plan furnished, or making a sketch of the wiring, will often speed up the location of the trouble more than anything else. The man who can do this and save the most time is the man who gets the best jobs.

Then too, as you carefully trace out and study each of the following systems you will also be gaining a knowledge of the principles and operation of common signal, alarm, and call systems.

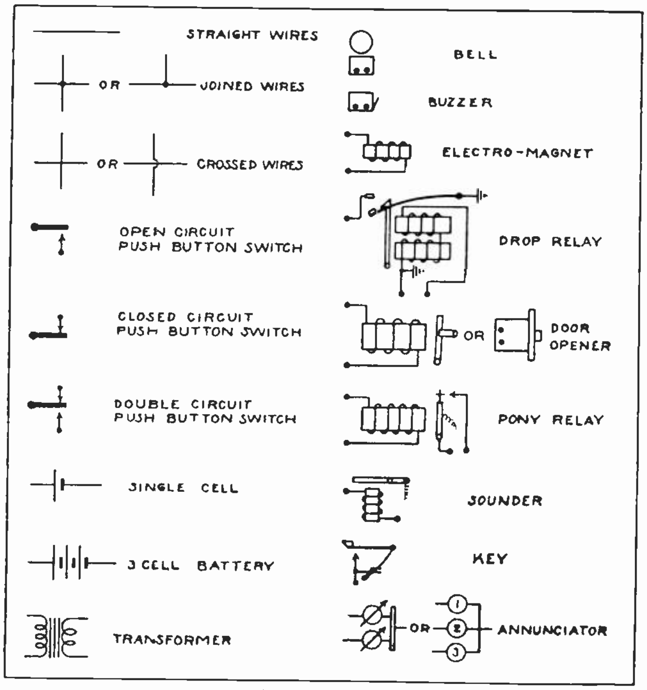

Fig. 62-A. These are some of the most important symbols used in signal diagrams and circuits. They should be memorized so you can easily recognize them when tracing any diagram in the future.

41. OPEN CIRCUIT SYSTEMS.

Fig. 63 shows an open circuit call or signal system, in which any one of three switches will operate the bell. Note that the switches are all connected in parallel. **Open Circuit Switches must always be connected in parallel, if each one is to be able to close the circuit.**

If they were connected in series then they would all have to be closed at once, in order to close the circuit. Make a sketch of this same circuit, but with the switches in series, and prove this out for yourself, because it is very important, and making a sketch will help you remember it.

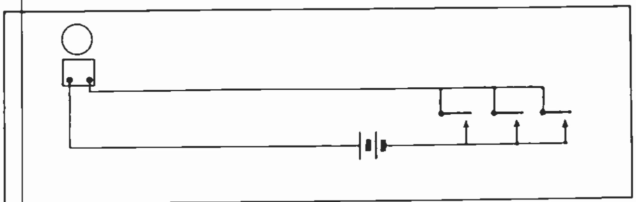

Fig. 63. Simple signal system using three buttons in parallel, any one of which will ring the bell.

Fig. 63 shows only three buttons in use, but any number can be connected in this manner to operate the same device. Such a circuit can be used for the signals on street cars or busses, for an office call where several different parties are to be able to call one person, or for a simple burglar alarm system, by connecting the window and door contacts of open circuit type, to the bell and battery as shown.

42. SELECTIVE CALL CIRCUIT.

Fig. 64 shows a selective call system, in which switch number 1 rings bells 1 and 2, and switches 2 and 3 both operate bell number 3.

Bells 1 and 2 are connected in parallel and both controlled by button 1. Buttons 2 and 3 are connected in parallel, and either one will operate bell number 3.

The lower wire leading from the positive terminal of the battery to the stationary contacts of the switches, can be called a **Common Feeder Wire,** as it carries current to any of the buttons as they are closed.

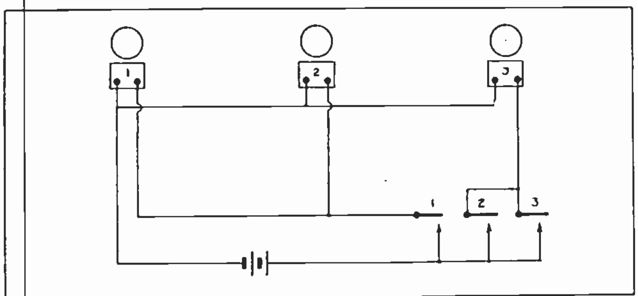

Fig. 64. Selective call system. Button No. 1 will ring bells 1 and 2; buttons Nos. 2 and 3 will ring bell No. 3.

Trace this circuit carefully. When switch number 1 is closed, current will flow from the battery through the switch, and then divide, part of it flowing through each bell. A good rule to remember in tracing such circuits is as follows: **Electric current will flow through all paths provided from positive to negative of the source of pressure. It also tends to follow the easiest path, or the greater amounts of current will flow over the lower resistance paths.**

In the case of Fig. 64, both bells being of equal resistance, and the circuits to them about the same length, the current will divide about equally.

The wire which leads from the left terminal of all three bells, back to the negative battery terminal, can be called a **common return wire,** as it serves to carry the current back to the battery, from any or all of the bells.

43. RETURN CALL SYSTEMS.

Fig. 65 shows a return call system using two bells and two single contact buttons. This is called a return call system because either party can signal the other, or can answer a call by a return signal if desired.

Button number 1 rings bell number 2, and button number 2 rings bell number 1. When button number 1 is closed current flows as shown by the small arrows, and the large arrows show the path of current when button number 2 is pressed.

Note that three main wires or long wires are used in this system.

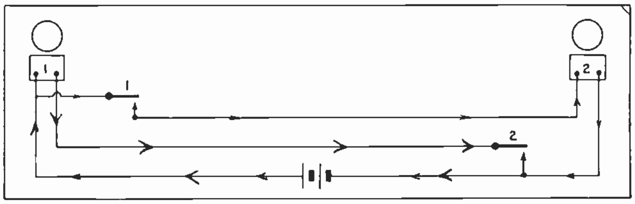

Fig. 65. Return call system. Button No. 1 will ring bell No. 2; button No. 2 rings bell No. 1.

In Fig. 66 is shown another method of connecting a return call system, which causes both bells to ring when either button is pressed.

This system uses two batteries, one at each end, but it saves one main wire, using only two instead of three, as in Fig. 65.

When button number 1 is pressed current flows from battery number 1 as shown by the small arrows, dividing through both bells. When button number 2 is pressed, the current flows from battery number 2 as shown by the large arrows, also operating both bells.

In this system, if the line is very long the bell nearest the button pressed, may ring a little the

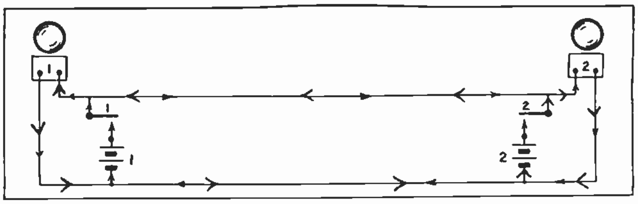

Fig. 66. Return call system using two batteries, thereby saving one wire.

loudest, because its circuit is shorter and lower resistance. Trace this carefully in the sketch.

If the far bell does not ring loud enough, then higher voltage batteries, or larger wires should be used.

Fig. 67 shows a return call system, using double circuit switches.

Here also, button number 1 rings bell number 2, and button number 2 rings bell number 1.

When button number 1 is pressed the current flow is shown by the small arrows, and the large arrows show the path of current when number 2 is pressed. If both buttons should be pressed at once neither bell would ring. Check this on the diagram.

This system also uses three main wires.

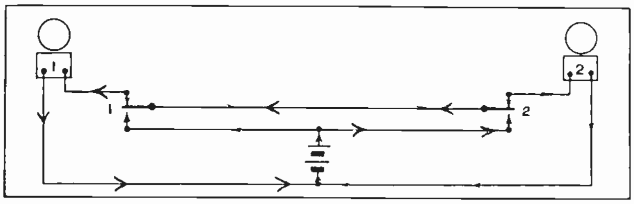

Fig. 67. Return call system using double circuit switches. Trace this circuit carefully.

44. SAVING WIRES BY USE OF DOUBLE CIRCUIT SWITCHES OR "GROUNDS".

Fig. 68 shows how double circuit switches can be used to save considerable wire in connecting a return call system.

By using two separate batteries and the double circuit switches, one main wire can be eliminated and the system operated with only two as shown.

When button number 1 is pressed, current (shown by small arrows) flows from battery number 1, and operates bell number 2. When button number 2 is pressed, current (shown by large arrows) flows from battery number 2, and operates bell number 1.

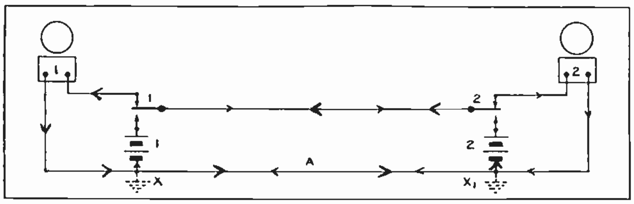

Fig. 68. Return call system showing how wires can be saved by the use of double circuit switches, two separate batteries, and a ground circuit.

When such a return call system is to be installed where the bells are a long distance apart and it is convenient to make good ground connections at each end, we can eliminate still another wire, by the use of ground connections as shown by dotted lines at "X" and "X^1," in Fig. 68. Then we do not need wire "A", current flowing through the ground instead. Sometimes a piping system can be used for these grounds, and no connection to earth is needed.

Trace this circuit over very carefully, and be sure you understand its operation, as it is often very important to be able to save these extra wires, where the line between bells is long.

45. CALL SYSTEM WITHOUT SWITCHES.

Fig. 69 shows a system of signaling that is often very convenient for use on temporary construction jobs, where workmen need to signal each other; or in mines or mine shafts.

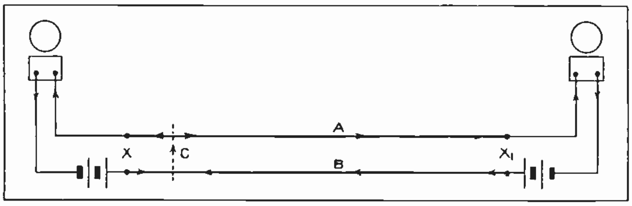

Fig. 69. Mine signal or alarm circuit which uses no switches. The bells are caused to ring by short circuiting wires "A" and "B".

No switches are used in this system, and instead wires "A" and "B" are bare or uninsulated, so any metal object can be used to "short" them or connect them together as shown by the dotted line at "C." Then if the wires "A" and "B" are strung tight and parallel to each other, a few inches apart and supported on insulators, a shovel, pick or piece of wire or metal touching both wires anywhere between points "X" and "X^1", will cause both bells to ring.

You may wonder at first why current does not flow all the time in this circuit, as it is always closed. Note how the batteries are connected positive to positive, or opposing each other, so if they are of equal voltage no current can flow normally. Of course if one battery was dead the other would cause both bells to ring continuously.

When a circuit is made between the two wires as at "C" the current starts to flow from both batteries as shown by the arrows, up through the connection "C" and then dividing through both bells, and returning to both battery negatives.

Such a system as this can also be operated from moving cars or elevators, by running the bare wires along close to the track or in the shaft.

46. SELECTIVE AND MASTER CALLS.

Fig. 70 shows a selective call system, with a master control, using one battery, three bells, and three single circuit switches.

Button number 1 operates bell number 1. Button number 2 operates bells number 2 and 3 in series. And button number 3, which is called the master button, operates all three bells in series. Trace each circuit carefully.

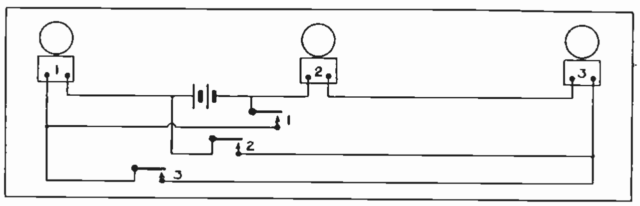

Fig. 70. Selective signal circuit. Check its operation carefully with the instructions.

Another method of arranging a selective call system with a **Master Switch**, is shown in Fig. 71. In this system any one of the double circuit switches 1, 2, 3 or 4, will operate its respective bell of the same number only, but the single circuit switch number 5, will operate all bells when all the other switches are in normal position.

When any one of the double switches is pressed, its movable contact is disconnected from the upper, or normally closed contact, so when the movable contact touches the lower one, current can only flow through them to its own bell, and not to any of the others.

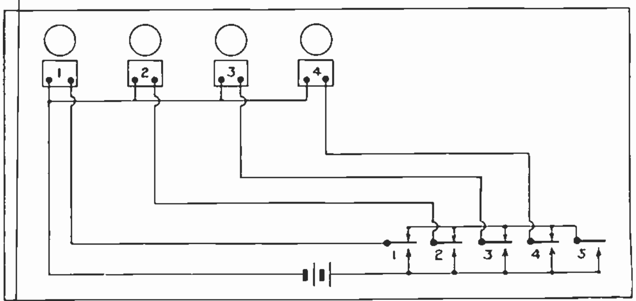

Fig. 71. Selective call system with Master Switch. This is a type of system very often used in executives' offices.

When button number 5 is pressed current flows from the positive of the battery through this button, then divides through the closed contacts of all the other switches and to all bells. Trace this on the sketch until you can clearly imagine this operation.

Note how the wire from the positive of the battery is again used as a **Common Feeder** for all switches, and also the common return wire used for all bells. Of course one separate wire is required feeding from each switch to its bell, if we are to operate them separately at times, but a great amount of wire can be saved by proper use of **Common Feeder** and **Common Return** wires.

This is where a sketch or plan laid out in advance helps to save materials.

47. CONNECTING VIBRATING BELLS FOR SERIES OPERATION.

When several bells are to be operated in series as in Fig. 70, or other systems for which they are connected this way, they will usually not operate very loudly or steadily without a special connection. This is because they do not all vibrate evenly or in synchronism, and the make and break contacts of one bell will open the circuit just as another goes to close for its power impulse. This results in rather irregular and weak operation, and the greater the number of bells in series, the worse it usually is.

This can be overcome by arranging one bell only as a vibrator, and all the rest as single stroke bells. This is done by shunting out the make and break contacts of all bells except the one, as in Fig. 72. Here the current will flow through the make and break contacts of bell number 1 only, and on the others it flows directly through the coils. Number

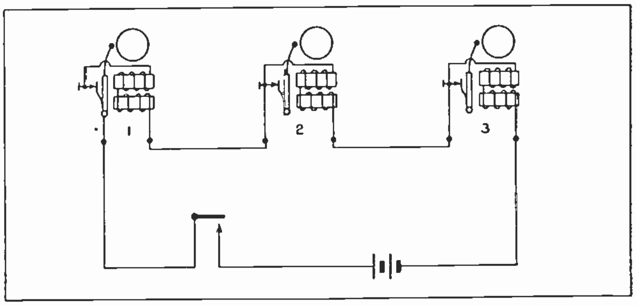

Fig. 72. This sketch shows the proper method of connecting vibrating bells in series, to secure best results.

1 bell then acts as a **Master Vibrator**, making and breaking the circuit for all the others, robbing them of the power to interrupt the circuit, and forcing them to operate in synchronism.

A series connection of bells is often desirable where they are all to be rung at once and are located a long distance apart, as it saves considerable wire in many cases.

48. ECONOMICAL BARN OR GARAGE ALARM.

Fig. 73 shows a method of connecting a bell as a combination single stroke and vibrator, and obtaining a closed circuit call or alarm system.

When we recall that a closed circuit system usually requires a relay to operate the bell, we find that this trick or connection effects quite an economy by saving the cost of a relay.

Tracing the circuits we find that as long as the switches are all closed, the current will flow continuously as shown by the small arrows, through the bell coils, then through the switches and back to the battery. This keeps the coils energized and holds the hammer quietly against the gong, after the first single stroke when it is connected.

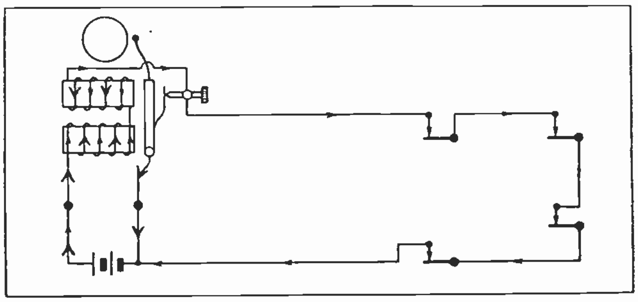

Fig. 73. Simple and economical barn or garage alarm of closed circuit type.

Then when any one of the switches is opened, the circuit is momentarily broken, allowing the hammer to fall back and close the circuit again at the make and break contacts of the bell.

The bell will then continue to vibrate, current flowing as shown by the large arrows, until the switch in the line is again closed. This is a very good circuit to keep in mind when the dependability of a closed circuit system is desired, but must be had at low cost.

A bell with high resistance coils should be used, to keep the amount of current flow small. A closed circuit battery should also be used, as dry cells would soon be exhausted by the constant current flow.

This system makes a very good barn or garage alarm, where long wires are to be run in the open, between the protected buildings and the house. Then if anyone attempts to cut these wires, the alarm will operate just as though the window or door switches of the building were disturbed and opened.

49. OFFICE OR SHOP CALL SYSTEM.

Fig. 74 shows a selective master control call system that would be very convenient for an office executive or shop or power plant superintendent, to signal their various foremen or workmen. Any one at a time can be called, by pressing the proper double circuit switch, or all can be called at once by pressing the single circuit master switch.

The small arrows show the path of current flow when one of the double switches is operated, and the large ones show the current flow to all bells when the master switch is operated.

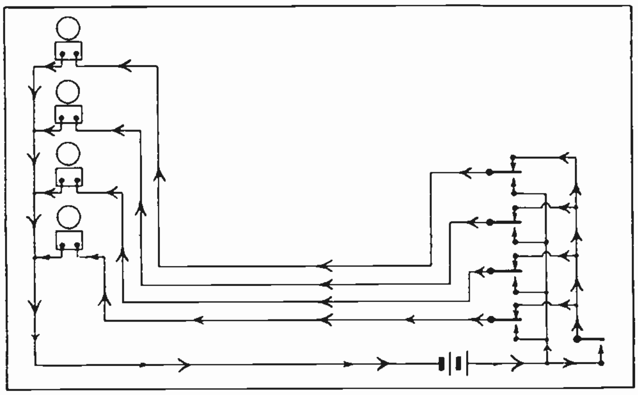

Fig. 74. Another type of selective call system with Master Control.

At first glance this circuit does not look much like the one in Fig. 71, does it? But look at it again and compare the two closely, and you will find they are exactly the same as far as parts and operation are concerned. The only difference is in the position or arrangement of these parts.

This comparison is made to show you that it does not matter how or where the bells or switches are to be located, as long as certain general principles of connection are followed.

Note that in each of these sketches a common feeder runs from the positive of the battery to all the lower or open contacts of the switches. Another common wire leads from the top of the master switch to the top or closed contacts of all double circuit switches. Then the individual bell wires are each attached to the movable contacts of the double switches in each case, and a common return from the bells back to the battery.

These are the principle points to note and follow in connecting up any such selective, master, call system.

50. APARTMENT DOOR BELL AND OPENER SYSTEMS.

Fig. 75 shows a door bell and magnetic door opener system for a three apartment building.

This sketch is arranged a little differently to show how the wires running up to the various floors can all be grouped together and run in one conduit or cable, and then branches taken off to each bell and switch.

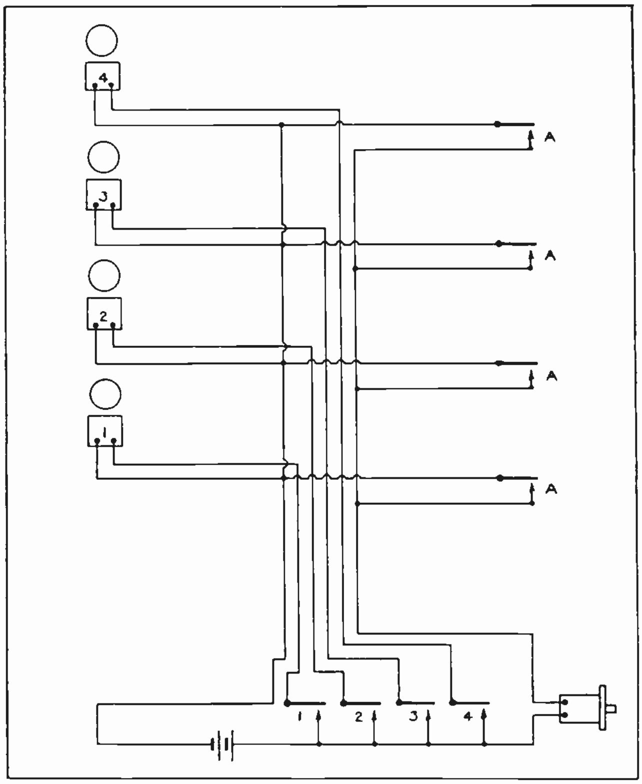

Fig. 75. Combination doorbell and magnetic door-opener system. Note the use of certain wires as common "Feeder" and "Return" wires.

Such a system is commonly used in connection with speaking tubes and telephones in apartment buildings, and could be extended to take in as many more floors or apartments as desired, just following the same scheme of connection as shown.

Any one of the buttons in the lower hall will ring its own bell of the same number. Then if the party is at home and wishes to admit the caller, any one of the apartment buttons marked "A" will operate the door lock.

Fig. 76 shows a similar system of apartment building calls and door opener, including also a buzzer at each apartment door, for parties within the building to use when calling at any other apartment, and without going down to the front door buttons. Trace the circuit and operation carefully.

51. HOTEL OR OFFICE CALL SYSTEM WITH ANNUNCIATOR.

Fig. 77 shows a selective, master call system that could be used very well in an office or hotel and many other places.

With this system a party at "A" can call any one of the parties "B", "C", or "D", by pressing

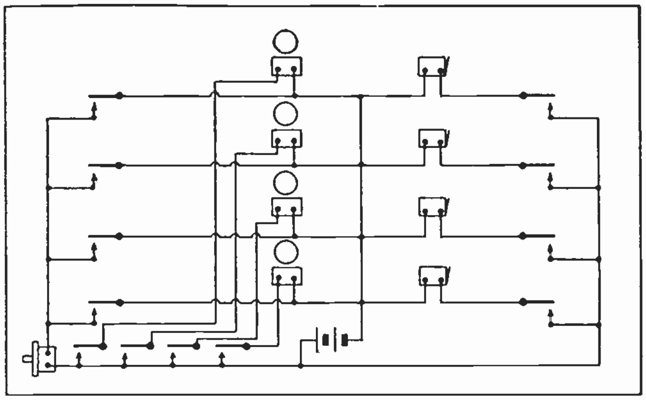

Fig. 76. Doorbell and door-opener system, including separate local buzzer circuits.

the proper buttons; or he can call them all at once by pressing the master button.

The party called can also answer back or acknowledge the call with their button, and the annunciator and buzzer show the response to party "A".

Or if "B", "C", or "D", wish to signal "A" at any time, the annunciator shows which one is calling.

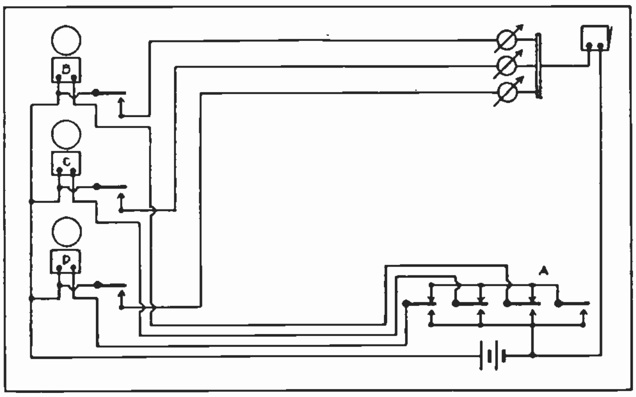

Fig. 77. Selective signal circuit with Master Control, return call and annunciator features. This is a very popular form of signal system.

52. SAVING WIRES BY SPECIAL GROUP CONNECTION, and SEPARATE BATTERIES.

Fig. 78 shows a method of connecting a large number of bells and switches in an extensive call system, and using separate batteries and a grouping system to reduce the number of main wires.

Any one of the buttons will ring its corresponding bell of the same letter, and by the use of the three separate batteries and **Cross Grouping** connection of the bells and switches, this can be done with seven vertical line wires, while with one battery it would require thirteen wires.

53. CLOSED CIRCUIT BURGLAR ALARM FOR TWO FLOORS OR APARTMENTS.

Fig. 79 shows a closed circuit burglar alarm system for two apartments or floors of a building, using an annunciator to indicate which floor the intruder has entered, and also a drop relay to keep the bell ringing constantly until some one is aroused and shuts it off.

Normally, when the system is in operation, current flows continually in the two relay circuits as shown by the small arrows. This keeps both relay armatures attracted, and no current flows in the annunciator, drop relay, or bell circuits.

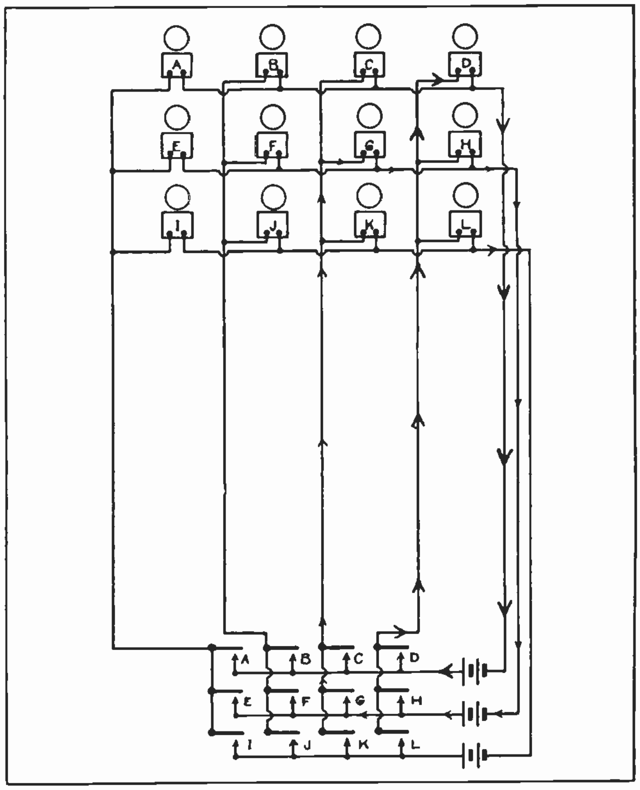

Fig. 78. "Group" method of connecting a large number of bells and switches to secure independent operation of each, with the least number of wires.

But as soon as any switch in either circuit "A" or "B", is disturbed, the relay current stops flowing, releasing the armature, and closing a circuit to the drop relay as shown by the dotted arrows. This trips the drop relay, starting the bell in operation. The bell circuit is shown with large arrows.

A system of this type using several separate circuits gives one an excellent chance to practice step by step tracing of each circuit, and the operation of all parts of the system.

54. SPECIAL ARRANGEMENT OF VIBRATING BELL FOR CONSTANT RINGING.

Fig. 80 shows a rather novel method of arranging a vibrating bell for a constant ringing alarm, without the use of a drop switch or relay. This is done by placing a piece of hard cardboard, fibre or hard rubber, between the make and break contacts of the bell. The spring tension of the armature should hold it there normally, but if cardboard is used it should not be too soft, or it may stick in place when it is released.

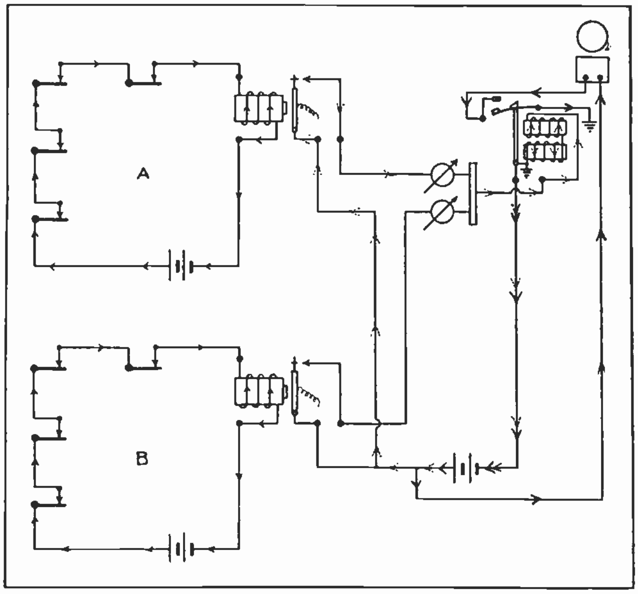

Fig. 79. Two section alarm system using a drop relay for constant ringing, also an annunciator to show which section of the building the alarm was disturbed in.

When one of the three open circuit alarm switches is closed, current will flow directly through the coils of the bell, attracting the armature and releasing the cardboard.

This starts the bell ringing until the switch "A" is opened. Swith "A" should be a lever switch or snap switch.

This system of course does not give the positive protection of a closed circuit system, or of one using a relay, but is very good for an emergency job, or one where the cost must be kept very low.

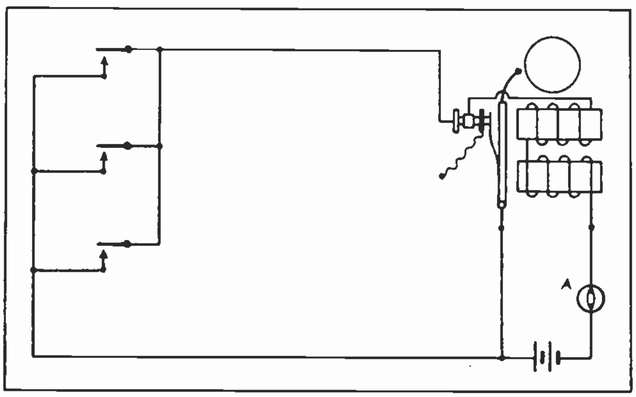

Fig. 80. Simple method of arranging an ordinary vibrating bell to secure constant ringing feature.

55. STICK RELAY CIRCUITS.

It is possible to connect an ordinary pony relay in an alarm circuit, so that it will provide constant ringing of the bell, without the use of a drop relay. This is done by connecting the relay to operate as a **Stick Relay.**

This term comes from the manner in which the relay armature closes a circuit to its own coil, and causes itself to stick and continue to feed the coil until it is forced away, or its circuit broken by another switch. (See Figure 81.)

This relay has its armature and bridge connected in series with its coil and the battery. Imagine you were to push the armature to the left with your finger, until it touched the bridge contact. What would happen? The armature would stick there, because as soon as it touches the bridge contact, it closes a circuit for current to flow through the coil to hold it.

Then to get the armature to go back to its normal position it would be necessary to force it away, in spite of the pull of the magnets, or to open the closed circuit switch at "A". This would stop the current flow through the coils, and allow the armature to release.

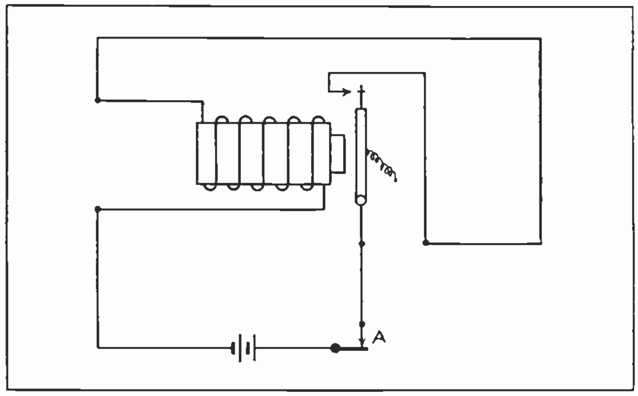

Fig. 81. Diagram illustrating the principle of a closed circuit stick relay.

Remember that to connect up a "stick relay," its armature and bridge must be connected so they will close and hold a circuit through the coils when the armature is attracted.

56. OPEN CIRCUIT STICK RELAYS.

Now let's see how we connect this stick relay in a simple open circuit, constant ringing alarm or call system, as in Fig. 82.

Here again we notice that the armature and bridge are in **Series** with the coils, and the bell is connected in **Parallel** with the coils. These are the

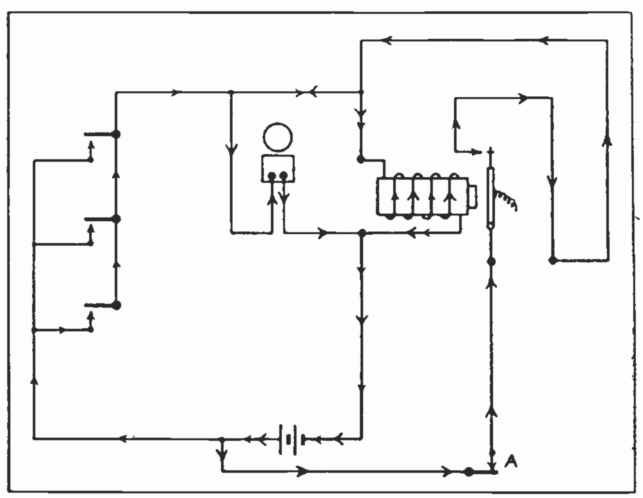

Fig. 82. Open circuit alarm system using a stick relay for constant ringing when alarm is tripped.

two principle rules to follow in arranging such a system.

The parallel group of open circuit switches is connected in series with the battery and relay coil.

Normally there is no current flowing in any part of this system, and the relay armature is not touching the bridge until the switches are disturbed. If any one of the open circuit switches is closed even for an instant, current will start to flow through the relay coils and bell in parallel, as shown by the small arrows.

This causes the armature to be attracted, and then it feeds current to both the coil and bell, even though the first switch is opened in case the burglar closes the window quickly.

The larger arrows show the path of current which keeps the relay coil energized and the bell ringing, after the system is tripped.

To stop the ringing of the bell and restore the system to normal "set" condition, we press the **Reset Switch "A".**

This stops the current flow through the coils long enough to release the armature; then we allow switch "A" to close again, and if the open circuit switches are again normal or open, the system remains quiet until again tripped.

57. DOUBLE CIRCUIT STICK RELAY.

In Fig. 83 is shown a double circuit "stick relay" system, which gives both the advantages of constant ringing and closed circuit reliability.

Here we have the relay armature, bridge, coils, closed circuit alarm switches and battery, all connected in series. An open circuit reset switch at "A" is used in this system. To set the system in order, this switch is pressed and current starts to flow at once, as shown by the dotted arrows. This energizes the relay coil and attracts the armature. Then the reset switch can be released, and the armature will stick in place, as it now feeds the coils, and a small current will flow continually as shown by the small solid arrows.

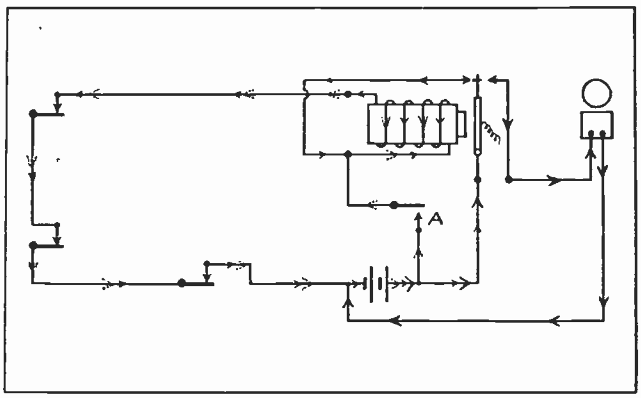

Fig. 83. Double circuit stick relay used in a closed circuit burglar alarm system. This is a very simple and efficient alarm circuit.

Now if any one of the closed circuit alarm switches is opened, the current stops flowing through the coil, releasing the armature, which closes a circuit to the bell, as shown by the large arrows.

This is a very simple and dependable alarm system, and one you may often have use for.

58. THREE SECTION ALARM SYSTEM.

Fig. 84 shows a system of this same type, with three separate sections for three different floors or apartments, and an annunciator to indicate which section is disturbed.

When an alarm switch in any one of the sections is opened, the relay sends current through the proper annunciator coil and keeps the bell ringing constantly until the reset button is pressed.

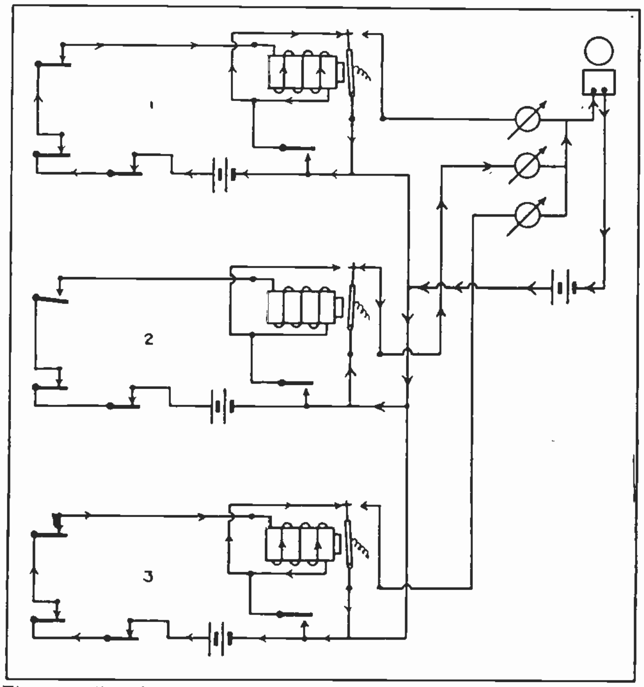

Fig. 84. Closed circuit burglar alarm system of three sections, each using stick relays for constant ringing; and an annunciator to indicate point of disturbance.

The relay armatures in this Figure and also the arrows, are shown as the system would be if sections 1 and 3 were normal, but section 2 has been disturbed causing the alarm to operate. Observe the armatures and arrows, and trace all circuits carefully to be sure you understand them.

At first glance such a diagram as Fig. 84 looks quite complicated and appears hard to understand, but you have probably found by now, that taking one section at a time, it can be traced out quite easily. This is true of even the largest circuit plans of telephone or power plant systems, and if you practice tracing each of these diagrams carefully, you will soon have confidence and ability to read any circuit plan.

59. COMBINATION CLOSED AND OPEN CIRCUIT ALARMS.

Fig. 85 shows a method of using double circuit switches to operate both the relay and annunciator in a closed circuit constant ringing system.

When any one of the alarm switches is pressed, it opens the relay coil circuit and closes the annunciator circuit at the same time.

In this system the annunciator shows exactly which window or door is disturbed.

A number of such circuits could be arranged to protect separate floors or apartments in a building, and then all connected together through one annunciator and alarm bell as in Fig. 84. The additional annunciator would then indicate to the watchman, janitor or owner, which floor or apartment the alarm came from.

The small arrows in Fig. 85 show where current will normally flow when the system is "set". The large arrows show where current would flow through both the annunciator and bell circuits, if switch number 2 was disturbed.

After this system is tripped and the bell is ringing what would you do to stop the bell and reset the alarm?

60. BURGLAR ALARM FOIL FOR WINDOW PROTECTION.

In addition to window and door contacts, switches and alarm traps, some alarm systems use tinfoil strips for the protection of glass windows or thin wood panels that could be easily broken.

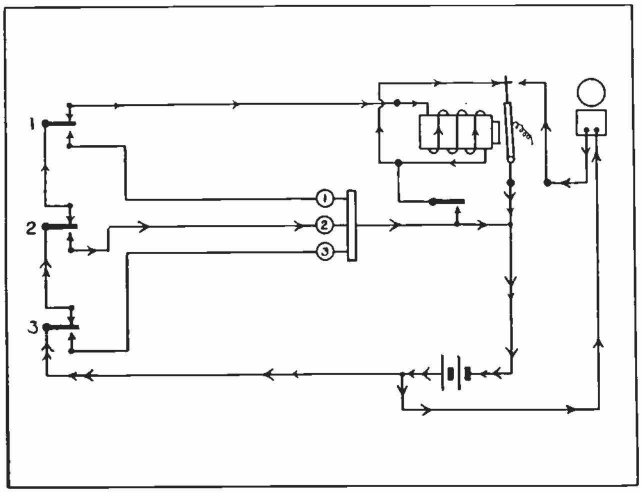

Fig. 85. Combination alarm system using double circuit switches to operate both the stick relay and the annunciator.

Tinfoil for this purpose can be bought in rolls, prepared for cementing to the inner surface of the glass or panel to be protected. It is then connected into the regular alarm circuit by attaching wires to its ends.

If the glass is broken it will crack the tinfoil and open the circuit, causing the alarm to operate.

Fig. 86 shows a large show window and small window above the door protected by burglar alarm foil, and the door and two small windows by door and window springs. All are connected in series to form the closed circuit for the relay coil.

Disturbance of any one will cause the bell to ring.

61. BALANCED ALARM SYSTEMS.

Burglar alarms can be arranged so that it is nearly impossible for even an expert to disturb or tamper with them without giving the alarm.

Fig. 87 shows a system using circuits of balanced resistance and a specially wound relay.

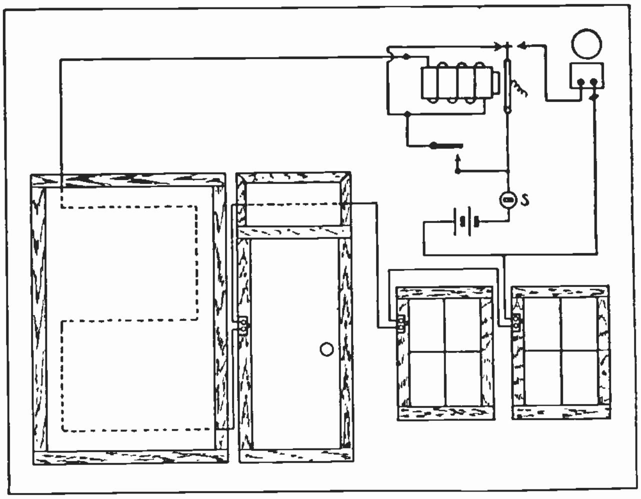

Fig. 86. This diagram shows the use and application of burglar alarm foil for the protection of glass windows and doors.

This relay has two coils wound in opposite directions on each core, so when current flows through them equally they create opposing magnetic flux and do not attract the armature.

The variable resistance at "A" is used to balance the current flow through coil "R", with that of coil "L", by being adjusted so that its resistance is equal to that of the entire alarm circuit. This circuit includes the wire, switches, and the resistance unit "B" which is in series with the closed circuit switches.

As long as the alarm circuit remains of equal resistance to that of the balancing circuit, the current from the battery divides evenly through coils "L" and "R". But if any switch is opened or closed, or the wires are changed, the resistance of the alarm circuit will be changed and more current will flow through one coil or the other, and magnetize the relay core.

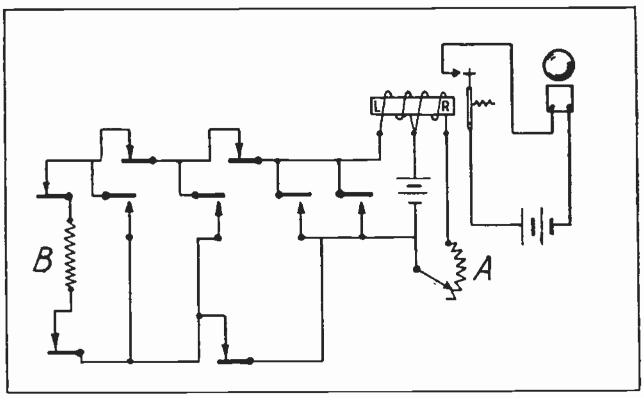

Fig. 87. Balanced resistance alarm circuit. This is a very dependable alarm system, as it is almost impossible to tamper with it without causing the alarm to sound.

For example, if any closed circuit switch is opened, the current through coil "L" stops flowing, leaving the flux of coil "R" unopposed and strong enough to attract the armature and cause the bell to ring. Or, if any open circuit switch is closed, it affords a much easier path than the normal one through resistance "B", and more current at once flows through coil "L", overcoming the opposing flux of coil "R", and again attracting the armature and ringing the bell.

Variations of this principle can be used in several ways in different types of alarm circuits, making them very dependable and safe from intentional or accidental damage.

62. LOCK SWITCH CONNECTIONS.

Fig. 88-A shows how a lock switch can be connected in a burglar alarm system, to allow the owner or watchman to enter the building without sounding the alarm, and also to turn off the system during the day.

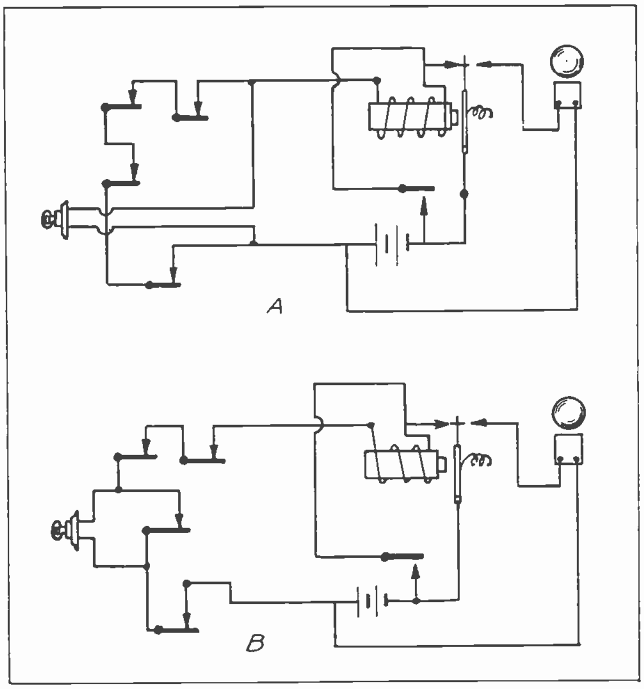

Fig. 88. These circuits "A" and "B" show two different methods of connecting a lock switch to a burglar alarm circuit.

This switch is connected in parallel with the entire line of switches here, and when it is locked closed, any of the others can be opened without tripping the alarm.

Or we can connect it to one switch only as in Fig. 88-B. In this case only the one door and switch can be opened. Then when the lock switch is again locked open, the alarm will operate if any other switch is opened.

63. FIRE ALARM DEVICES AND CIRCUITS.

Fire alarms are very similar in many ways to burglar alarms, using many of the same parts such as relays and bells; and also many of the same types of circuits.

The principle difference is in the types of switches used.

There are manually operated fire alarms and automatic ones; the manual alarms being merely a signal system by which someone sends a warning of fire when he sees it. The automatic alarms are those that are operated by the heat of the fire, and sends in the alarm without the aid of any person.

A very common type of manual fire alarm switch is the "break glass" type, in which the switch is held in a closed normal position by a small pane or window of glass. In case of fire the person sending the alarm merely breaks the glass, which allows the switch to open by spring action and give the alarm.

One of these devices is shown in Fig. 89. The illustration at the left, with the box closed, shows clearly how the glass holds the switch button compressed against a spring, and also the small iron hammer provided for convenience in breaking the glass. At the right the box is shown open and the switch button can be seen in the center.

Fig. 89. Fire alarm box of the "break glass" type. Note the hammer used for breaking the glass, and the location of the push button in the box which has the cover open.

64. PULL BOXES AND CODE CALL DEVICES

Figs. 90 and 91 show two different types of fire alarm "pull boxes". To send an alarm from this type of box, the operator opens the door and pulls the hook or crank down as far as it will go and then releases it.

When it is pulled down it winds a spring inside, and when released the spring operates a wheel or notched cam that opens and closes a switch several times very rapidly. These notches or cams can be arranged to send a certain number of impulses in the form of dots and dashes, or numbered groups of dots, to indicate the location of any particular pull box.

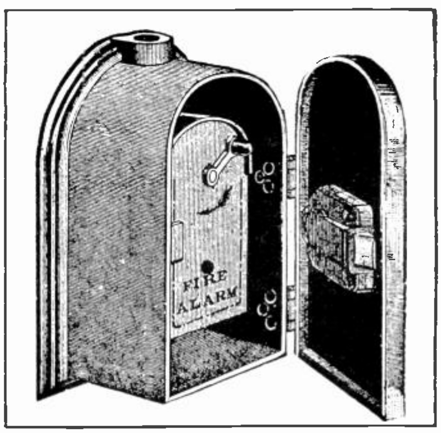

Fig. 90. This is a fire alarm "pull box" which sends in numerical or code signals to indicate its location.

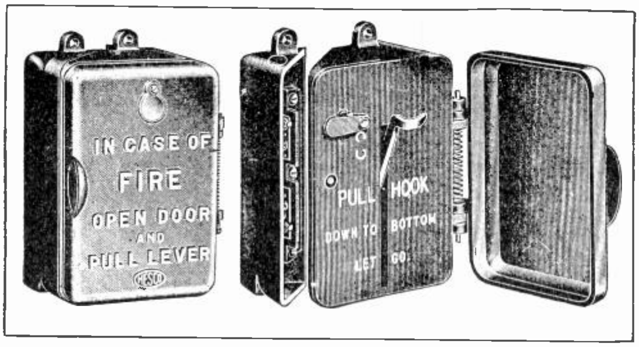

Fig. 91. Another type of fire alarm pull box which also sends code signals.

This enables the fire department crews to proceed direct to the location of the fire.

Fig. 92-A shows how a notched wheel can be arranged to open the contacts of a closed circuit fire alarm, giving a series of short signals and sounding the number 241. Fig. 92-B shows a cam wheel arranged to close the contacts of an open circuit system and send call number 123.

From this we see that such boxes are merely mechanically operated switches or sending keys.

Certain types of industrial or shop "code call" systems use a mechanism similar to these to send number calls for different parties in the plant. These will be explained later.

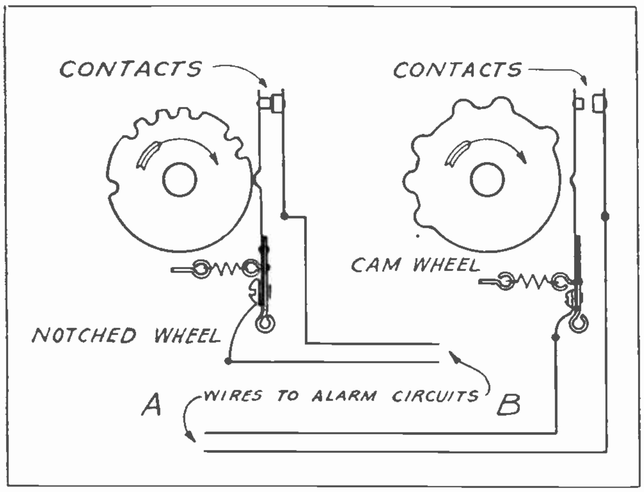

Fig. 92. This sketch shows the arrangement of the code wheel and contacts of closed and open circuit code call systems.

Fig. 93 shows a fire alarm control cabinet, which is used to control and check the condition of such systems. These cabinets are equipped with relays which receive the small impulses of current from the alarm box lines, and in turn close circuits sending heavier currents to the gongs or horns located near the cabinets.

Meters are also often provided for indicating the amount of current flow through closed circuit systems, and thereby show the condition of the circuits.

Note the diagram of connections which is in the cover of this cabinet, and is usually furnished by the manufacturer of such devices. So you can readily see what an advantage it is to know how to read these diagrams.

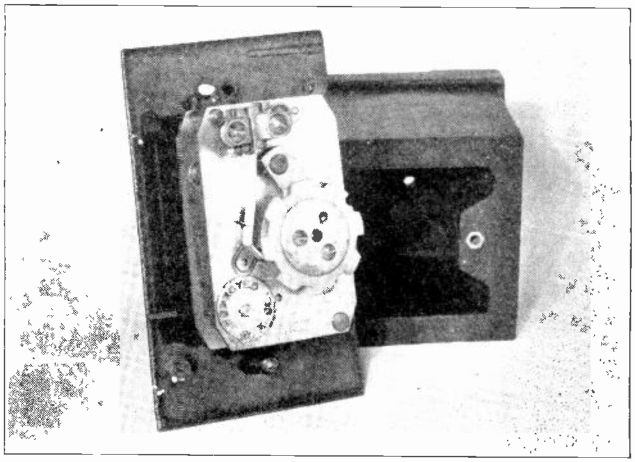

Fig. 92-C signal or alarm box of the code calling type, showing code wheel and contact springs.

65. SIGNAL RECORDERS

In fire alarm, bank burglar alarm, and police call systems, it is often desired to keep a record of the numerical code call sent in by the signal box, in addition to hearing the call sounded on the bell or horn. This helps to prevent mistakes in determining where the call comes from.

For this purpose we have recording machines which mark or punch the call on a moving paper tape as the signal comes in, thus giving an accurate and permanent record of it. Such a device is shown in Fig. 94.

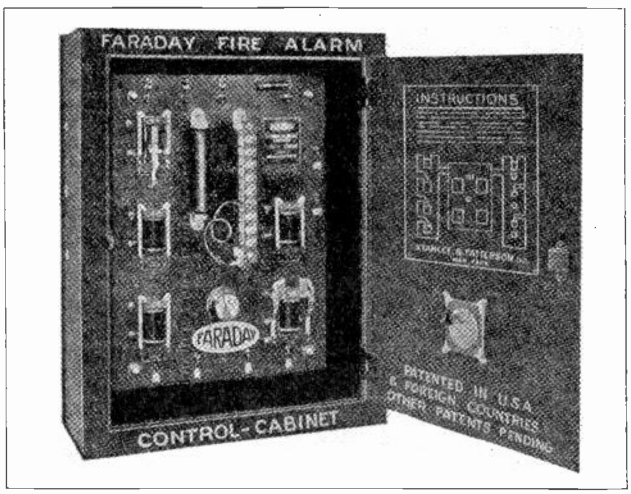

Fig. 93. Fire alarm control cabinet, showing relays, test meter, and connection diagram.

There is a spring and clockwork mechanism kept wound and ready to pull the tape through, at a definite speed. The first impulse of the signal operates a relay or magnetic trip that releases or starts the spring and tape.

Then another magnet operates a small pen arm, shown on the outside of the box in this case, and marks every impulse on the tape in the form of dots and dashes.

Automatic fire alarms use thermostatic switches or fusible links, to open or close circuits and send an alarm as soon as a certain temperature is reached. This type of system is very valuable in warehouses and buildings where no people or watchman are about to notice a fire immediately.

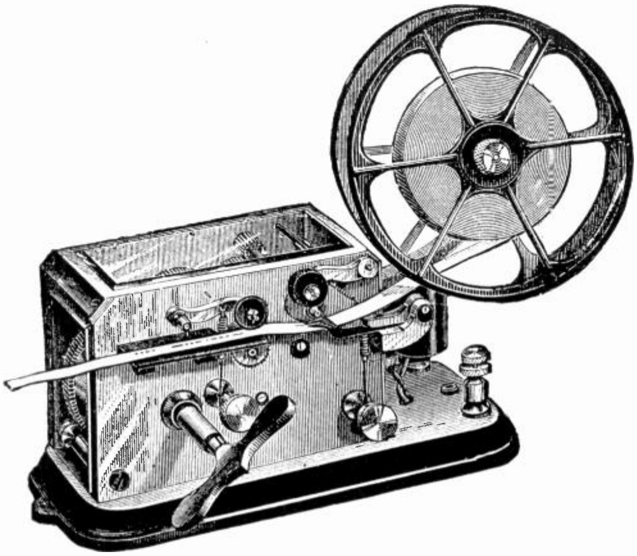

Fig. 94. Recording device for receiving code calls on paper tape. Fire and police departments use such recorders extensively.

Thermostatic switches can be set or adjusted so a rise of even a few degrees above normal temperature will cause them to close a circuit almost immediately.

One switch of this type was explained in Art. 15 of this section. Another type is shown in Fig. 95. There are various types in use but all are quite simple and merely use the expansion of metals when heated, to close or open the contacts.

Any number of such thermostats can be connected on a fire alarm circuit to operate one general alarm, through the proper relays.

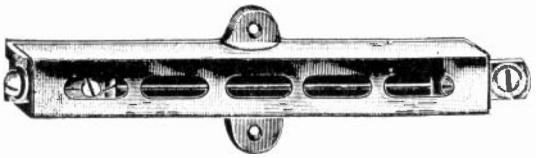

Fig. 95. One type of thermostatic fire alarm switch, that can be adjusted to open or close an alarm circuit by expansion at temperatures above normal.

66. FUSIBLE LINKS FOR FIRE ALARMS

The fusible link fire alarm is made of a soft metal alloy something like electrical fuse material. Some of these metals are made which will actually melt in warm water, or at temperatures of 125 degrees and up. Such fusible links can be located at various points where fire might occur, and all connected in series in the alarm circuit. If any one is melted by fire or excessive heat near it, the circuit will be broken and the alarm operated.

Fig. 96 shows a fire alarm system in which all three types of switches are used. The "break glass" switches can be located where they are easily accessible to persons who might observe the fire, and the thermostats and links installed in other places in the building where no one is likely to be.

In this sketch, "A" and "A-1" are fusible link switches. "B" and "B-1" are "break glass" switches, and "C" and "C-1" are thermostatic switches. All of these are of the closed circuit type. In addition to these, an open circuit thermostat switch is shown at "D" to operate the bell direct in case of fire near the relay and alarm equipment. Fig. 96-A shows a fire alarm fuse or link.

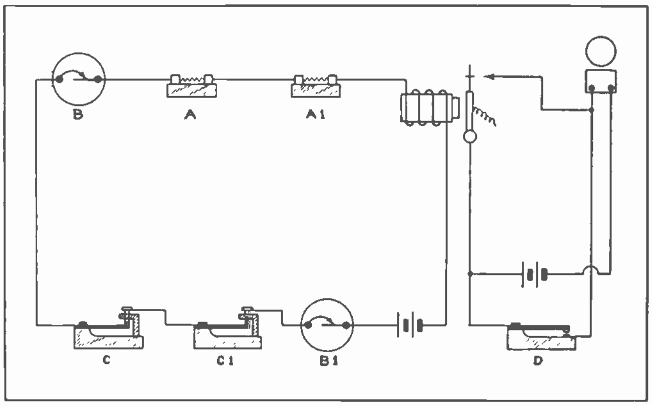

Fig. 96. This sketch shows the connection of several different types of fire alarm switches in one system.

67. INDUSTRIAL SIGNALS AND HEAVY DUTY BELLS

In factories, industrial plants and power plants, where signals are used to call department foremen and various employees, and the noise would make ordinary small bells difficult to hear, large heavy duty bells or horns are used.

The bells used for such work are very similar to the smaller ones, but are much larger and are usually wound to operate on 110 volts. Instead of using the vibrating armature pivoted on one end, they often use a rod for the hammer. This rod is operated by the magnets in the case. Two bells of this type are shown in Fig. 97, and the hammer rod can be seen under the gong of the larger bell.

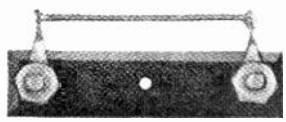

Fig. 96-A. Fire alarm fuse which melts when heated above normal temperature, opening the circuit and causing alarm to sound.

68. SIGNAL HORNS OR "HOWLERS"

Horns have a very penetrating note and for very noisy places are often preferred to bells. They are made to operate on either D. C. or A. C., and at

110 volts, or can be obtained for any voltage from 6 to 250.

Some such horns are made with a vibrator which strikes a thin metal diaphragm at the inner end of the horn. Others have small electric motors which rotate a notched wheel against a hard metal cam on the diaphragm, causing it to vibrate or "howl" loudly. Many of these horns are called "howlers".

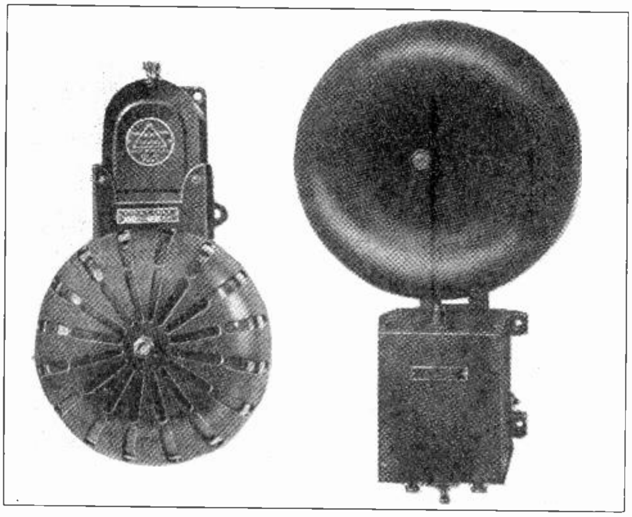

Fig. 97. Two types of large heavy duty bells for use in industrial plants or noisy places.

Fig. 98 shows two horns of the vibrator type, and Fig. 99 shows one of the motor operated type.

Fig. 100 is a sectional view of a motor horn, showing all its parts.

Heavy duty bells and horns require more current to operate them, than can be handled by the ordinary small push button, and these low voltage push buttons should not be used on 110 volts.

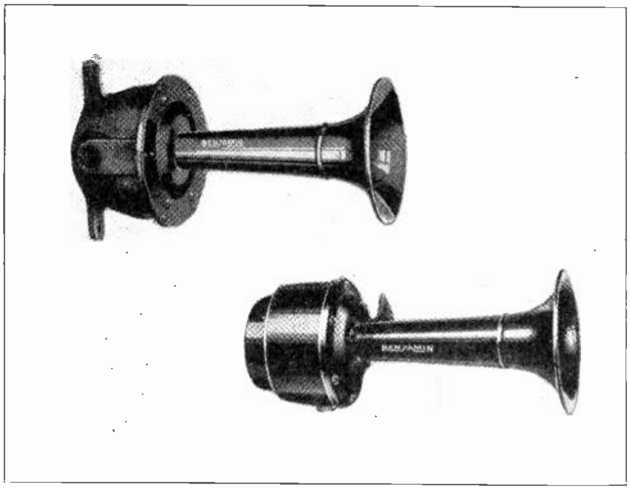

Fig. 98. Two styles of signal horns using magnetic vibrators to produce a loud note.

So we usually connect the switches to a special relay which has heavy carbon contacts, to close the high voltage and heavier current circuit to the bells or horns.

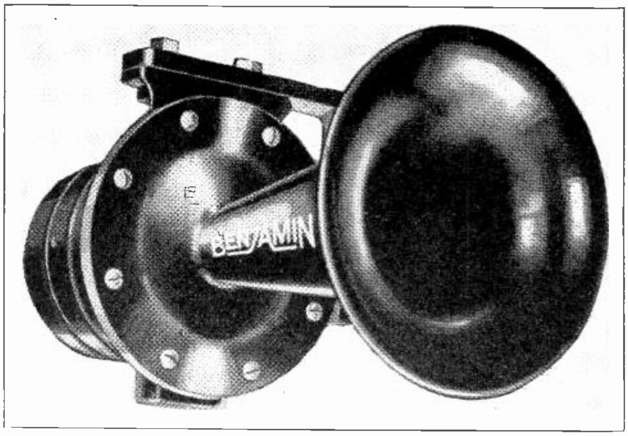

Fig. 99. Motor operated signal horn which produces a very penetrating note, and is excellent for industrial and power-plant use. *(Photo courtesy of Benjamin Electric Company.)*

Fig. 101 shows the connection diagram for a group of horns with such a relay.

69. AUTOMATIC SIGNALING MACHINES

In large plants where a great number of different numerical or code calls are used for signaling different parties, an automatic signaling machine is often used. With this device, the operator simply pushes a button for a certain call, and this releases or starts a spring or motor operated disk or code wheel, which sends the proper signal or number of impulses properly timed, in a manner similar to the fire alarm already explained.

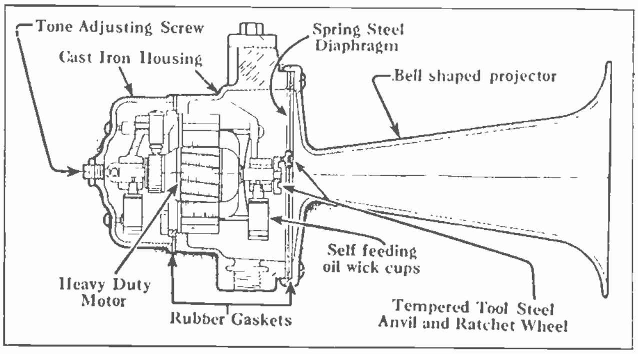

Fig. 100. Sectional view showing parts and construction of motor operated horn. *(Sketch courtesy of Benjamin Electric Company.)*

A box with a number of these buttons and wheels can be used to conveniently call any one of a number of parties, by just pressing the proper button once, and this does not require the operator to remember a number of code calls.

A diagram for connecting such a device to signal horns operated from a transformer is shown in Fig. 102.

Extra push buttons are also shown for sending special calls not included on the automatic signal box.

A time clock is also connected in this system to sound the horns at starting and quitting periods for the employees.

These clocks have two program wheels, one of which revolves with the hour hand, and one with

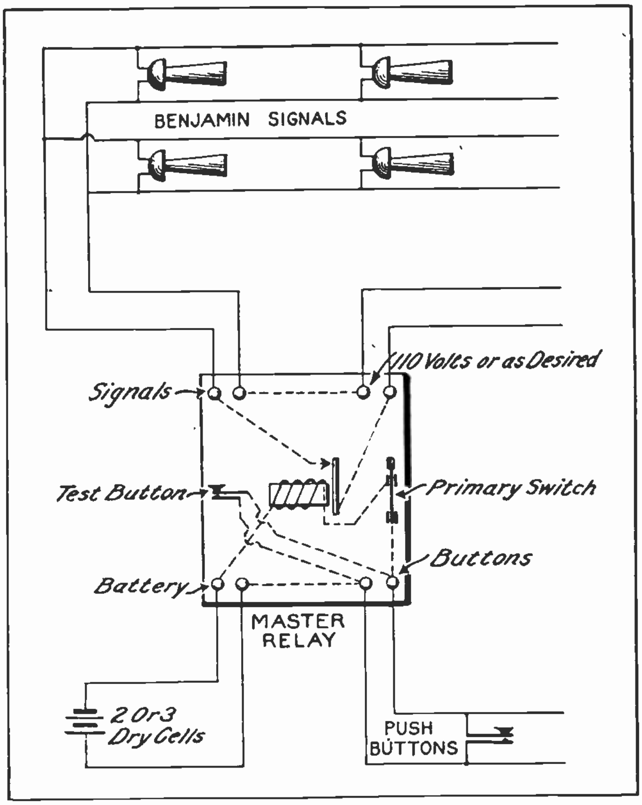

Fig. 101. Connection diagram for signal horns and Master relay. This relay operates on low voltage and very small current, and closes a high voltage, heavy current, circuit to the horns. *(Courtesy Benjamin Electric Company.)*

the minute hand. These wheels carry adjustable lugs or projections which open or close electrical contacts as they come around.

Schools often use these program clocks with signal systems, to start and dismiss various classes.

70. INSTALLATION OF CALL AND SIGNAL SYSTEMS

Now that you have learned the operating principles of these signal devices and circuits, and know how to trace and understand the diagrams and plans, you will want to know more about how to install them.

In making any electrical installation, the first thing should be the plan or layout, and circuit diagram. So as soon as we have decided upon the type of system desired and how it should operate to give best service, we should decide on the location of the various parts, and then lay out the circuits accordingly.

Of course in many cases a complete plan is furnished for new installations, by the architects in case of new buildings, or the engineering or construction departments of large power or industrial plants. But if such plans are not furnished, you should at least make up a rough layout before any work is started.

This can be drawn approximately to scale for the various distances between devices, or length of wire runs, and this will enable you to estimate and select the required materials with best economy.

Then, by following a circuit diagram, many mistakes and time losses can be avoided in making the final connections.

In drawing up plans, or in copying them from other prints, it is usually much easier to locate the parts and devices on the paper first, in about the same location and proportional spacing as in the original plan, or as they are to be installed in the building. Then draw in the wires and circuits one at a time, keeping them as straight and simple as possible. Make the wires and connections first to get the desired operation and results. Then go over the plan again, and possibly redraw it to simplify it and shorten wires, making use of "common wires" eliminating unnecessary crossed wires, etc.

71. LAYOUT OR LOCATION OF PARTS IN THE BUILDING

By going carefully over the building with these plans, and using good common sense in choosing the location for the various devices and wire runs, you can also help to make the most satisfactory job and save additional time and labor in the installation.

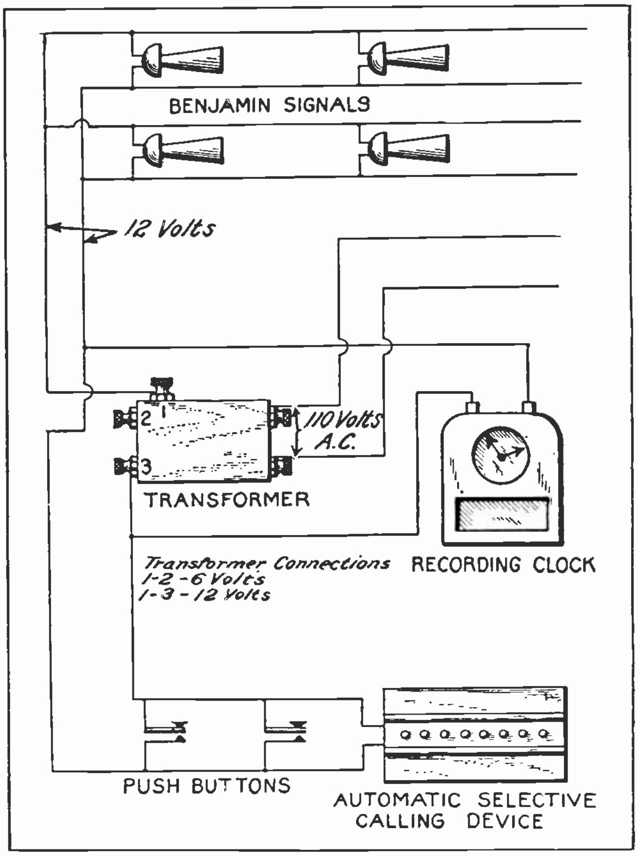

Fig. 102. This diagram shows the connections for signal horns operated from a transformer, and controlled either by a time clock or automatic signal device. *(Courtesy Benjamin Electric Company.)*

For example, when installing a simple door bell system in a home, the bell should be located in a rear room, probably the kitchen, because both its noise and appearance would likely be objectionable in the parlor or dining room. Usually some "out of the way" place can be found in a corner or hall or behind a door, and preferably quite high from the floor, so it is out of reach of children and safe from accidental damage. By considering where the wires can best enter the room and placing the bell on this side if possible, time and material may be saved.

The battery or transformer should usually be located in the basement or attic near to the bell or wires. However, the battery or transformer can sometimes be located on a small shelf or attached to the wall right with the bell, or in a small box.

The buttons of course must be located at the proper doors, and preferably on the door casing. Their height should be carefully chosen to be within convenient reach of grown-ups, but usually not low enough for small children to reach, unless by special request of the owner.

72. RUNNING THE WIRES

All wires should be run concealed whenever possible. Very often it is possible to drill two small holes in the door casing strip directly beneath the button and, by loosening the strip, run the wires under it to the basement or attic.

If it is not possible to get behind the strip, perhaps the holes can be drilled at an angle to get the wires into the edge of a hollow wall. Or, if necessary, they can be run in the corner at the edge of the door casing and covered with a strip of wood or metal moulding.

Where wires can be run through the basement or attic they can usually be stapled along the basement ceiling or attic floor. Care should be taken to run wires where they will be least likely to receive injury, and they should always be run as straight and neatly as possible.

Sometimes it is advisable to lay a narrow board to run the wires on across ceiling or floor joists in unfinished basements or attics, or even to cover the wires with a board.

When making long runs of wire always keep in mind the saving of time and material that can be made by using a common feeder wire to a number of switches, or a common return wire from bells to battery. This should also be carefully considered when laying out the diagram and plans.

Where it is desired to run wires vertically through walls, they can be **"Fished"** through by dropping a weight on a string from the upper opening to the lower one. This device is often called a **"Mouse"**. If the weight or "mouse" does not fall out of the lower hole, the string can be caught with a stiff wire hook and pulled out of the hole.

Then the wires can be pulled through with this string, or if necessary another heavier cord can be pulled through first, if the wires are too long and numerous to be drawn in by the light cord on the "mouse".

In horizontal runs through walls a steel **"Fish Tape"** can be pushed through first, and hooked or snared at the outlet opening, then drawn through with the signal wires attached.

A little "kink" that often comes in very handy in either signal or light wiring is as follows:

When you desire to locate the exact spot to drill up or make the hole in the basement ceiling, so that it will come directly under the center of the partition above, or some other certain spot, stick the point of a magnetized file in the floor above or ceiling below, and then use a pocket compass to locate this spot on the other side.

The compass needle will be attracted by the file tip. Moving the compass around will locate the center of attraction, which should be the point directly opposite the file tip. Then measure the distance between the spot located by the compass and to the edge of the partition, and add one-half the thickness of the partition. Measure off this distance in the same direction from the file and you should have a point about in the center of the partition.

In other cases measurements in two directions from certain outside walls may be accurate enough.

Sometimes an exact spot can be located best by drilling through the wall or floor with a long thin feeler drill, 1/8 or 3/16 in diameter.

If the hole does not come near the exact spot desired, it will serve as an accurate point to measure from, and can be easily plugged and concealed afterward.

Fig. 103-A shows how to use the magnetized file and compass and make the measurements to locate the center of partition. Fig. 103-B shows by the dotted lines how the small "feeler" holes can be drilled for the same purpose. The first hole should be drilled down at the proper angle and the second one drilled up, to try to strike the center of the

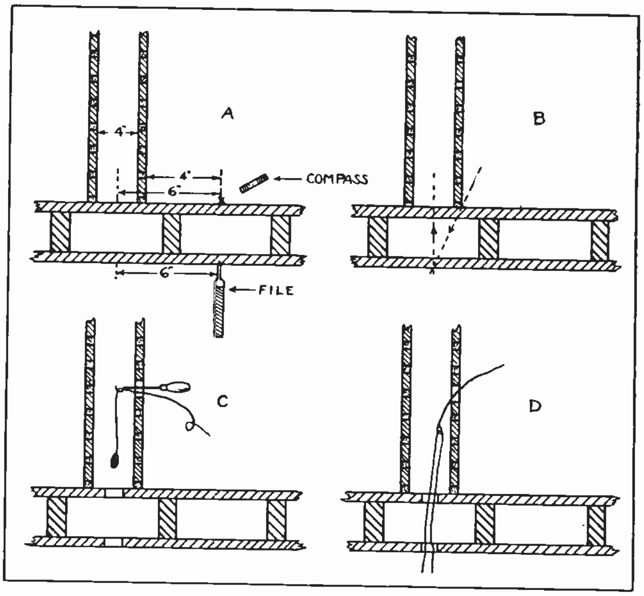

Fig. 103-A. Sketch showing uses of magnetized file and compass to locate spot to drill for wires. "B," dotted lines show how the "feeler drill" can be used. "C," dropping a "mouse" on a string, through holes in wall and floor. "D," pulling the wires in with the cord which was attached to the "mouse."

partition. Or, the first one can be drilled straight down and then the proper distance measured over to partition.

Figs. 103-C and 103-D show the method of dropping a "mouse" through the holes and pulling the wires in.

73. RUNNING SIGNAL WIRES IN CONDUIT

In some cases, especially in modern fireproof office or factory buildings, signal wires are run in conduit. Conduit, as previously mentioned, is iron pipe in which the wires are run for protection from injury and to provide greater safety.

Signal wires should always be run in separate conduits of their own, and never with wires of the higher voltage lighting system.

A fish tape is usually pushed through the conduit first, and used to pull the wires in.

74. TESTING TO LOCATE PROPER WIRES FOR CONNECTIONS

When a number of wires all alike and without color markings are run in one conduit, cable or group, it is easy to find the two ends of each wire by a simple test with a battery and bell, or test lamp.

Simply connect one wire to the conduit at one end, and then attach the bell and battery to the conduit at the other end, and try each of the wires on the bell, until the one that rings it is found. This is the same wire attached to the conduit at the other end. (See Fig. 104-A.) Mark or tag these ends both No. 1 or both "A", and proceed to locate and mark the others in the same manner.

When testing or "ringing out" wires in a cable or open group with no conduit in use, very often some other ground to earth or some piping system, can be obtained at each end, making it easy to test the wires. (See Fig. 104-B.)

75. TROUBLE TESTS

When troubles such as grounds, opens or shorts occur in wires in conduit, the fault can be located as follows:

Suppose one wire is suspected of being broken or "open." Connect all the wire ends to the conduit at one end of the line, as in Fig. 104-C. Then test with the bell and battery at the other end, from the conduit to each wire. The good wires will each cause the bell to ring, but No. 2, which is broken at "X" will not cause the bell to ring, unless its broken end happens to touch the conduit.

When testing for short-circuits between wires, disconnect all wires from the devices at each end of the line and test as in Fig. 104-D.

When the bell is connected to wires Nos. 1 and 2 it will ring, as they are shorted or touching each other at "X", through damaged insulation. Connecting the bell to any other pair will not cause it to ring.

Sometimes one wire becomes grounded to the conduit because of defective insulation as in Fig. 104-E.

For this test we again disconnect the devices from the wires, and connect the test bell and battery as shown.

With one test lead on the conduit, try the other lead on each wire. It will not ring on Nos. 1, 2, or 3, but will ring on No. 4 which is touching the pipe at "X", thus making a closed circuit for the test bell.

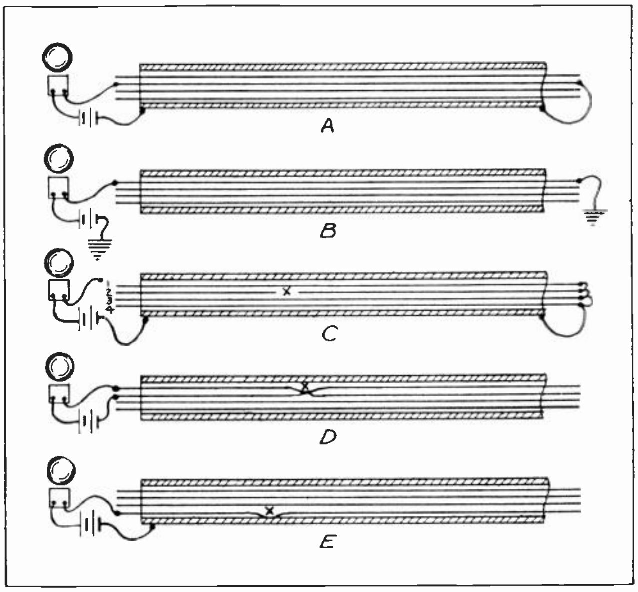

Fig. 104. Sketches showing methods of testing for various faults in wires run in conduit. Compare carefully with test instructions given.

76. EMERGENCY WIRES, AND PULLING-IN REPLACEMENTS

Where long runs of wires are installed in conduit or signal cables, it is common practice to include one or more extra wires for use in case any of the others become damaged.

This is especially good practice with cables, because it is difficult to remove or repair the broken wire. In a conduit system, where no extra wires are provided and a new wire must be run in to replace a broken or grounded one, it is sometimes easier to pull out all wires, and pull a new one back in with them.

Where this is not practical or possible, it sometimes saves time and money to pull out the broken or bad wire, and then attach two good wires to the end of one of the remaining wires, and pull it out, pulling in the two good ones with it. This replaces both the bad wire and the one good wire pulled out.

If the bad wire was not broken but only grounded, it can be used to pull in the new wire; but, of course, a broken wire cannot be used for this purpose. Therefore, it is often advisable to sacrifice one good wire, to pull in two new ones.

The several tests and methods just explained are very valuable and should be thoroughly understood, for they can be used on other wiring systems besides signal wiring.

While some of these tests were explained for wires in conduit, they can be also used on groups of open wires or cabled wires, by using in place of the conduit, some other ground or an extra wire, run temporarily for the tests.

77. SIGNAL WIRING MATERIALS

Now for the materials. In addition to the bell, battery or transformer, and push button switches, we will need the proper amount of wire, and in case of open wiring, staples to fasten it.

Ordinary bell or annunciator wire as it is called, is usually No. 16 or No. 18, B. & S. gauge, and is insulated with waxed cotton covering. It can be bought in small rolls of ½ lb. and up, or on spools of 1 lb., 5 lbs. or more. It can also be bought in single wires, or twisted pairs, and with various colored insulation.

Where several wires are to be run together, the use of different colors helps to easily locate the proper ends for final connection.

For damp locations, where the cotton insulation might not be sufficient, wire can be obtained with a light rubber insulation and cotton braid over it.

As ordinary door bells use only very low voltage, it is not necessary that the wires be so heavily insulated. In many cases they can be run with no other protection, such as conduit or mouldings.

To fasten the wires we use staples which have paper insulation to prevent them from cutting into insulation of the wire. However, these staples should not be driven too tightly down on the wires, and never over crossed wires, or they may cut through the insulation, causing a short circuit. Such a "short" under a staple is often hard to locate, and great care should always be used in placing and driving the staples.

Small cleats with grooves for each wire, and holes for screws to fasten them, are sometimes used. In other cases where twisted pairs of wires are run, a small nail with a broad insulating head is driven between the two wires, so the head holds them both. Fig. 105 shows several sizes of insulated staples, and Fig. 106 shows the nail and cleats mentioned.

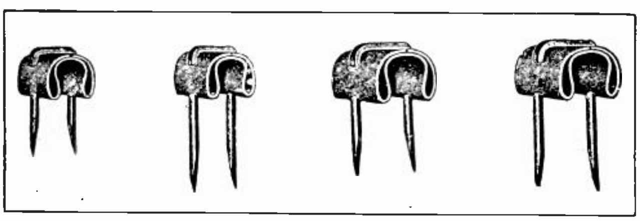

Fig. 105. Several different sizes and styles of insulated staples used in bell wiring.

On installations where a large number of wires are to be run in a group, cables with the desired number of wires can be obtained. These wires are usually marked by different colored insulation, so that the ends of any certain wire can be quickly and easily located at each end of the cable. Such cables simplify the running of the wires, save space and time, and make a much neater job in offices and places where numerous separate wires would be undesirable.

In large signal installations terminal blocks are used on some of the equipment, and all wires of the devices are brought to numbered terminals on these blocks. Then with the plans, on which the wires can also be numbered, it is very simple to make proper connections of cables with dozens or even hundreds of wires.

This is common practice with telephone installations and elevator signals, and also on modern radio sets, as well as for office and industrial call systems.

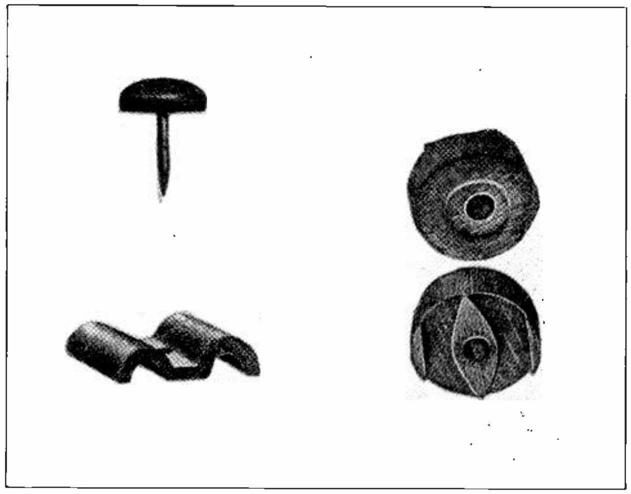

Fig. 106. Bell wires can also be fastened with the large headed nails and cleats shown here.

78. CAUTION NECESSARY FOR SAFE AND RELIABLE WIRING

Considerable care should be used when drawing bell wires through holes and openings, or the insulation may be damaged. Where the wires are left against the edge of a hole they should be protected from damage by vibration and wear, by means of a piece of hollow "loom" or insulating tubing slipped over the wires and taped in place. Also, where wires cross pipes or other wires, they should be well protected with such extra insulation.

Even though signal and bell wires carry low voltage and small current, they are capable of creating sparks and starting fires if carelessly installed.

So, for this reason and also that the finished system will give good service, all signal work should be done with proper care.

Low voltage signal wires must never be run in the same conduits with higher voltage lighting or power wires as it is very dangerous, and is also a violation of the National Electric Code, which will be explained in later sections.

If such wires were run with high voltage ones, and a defect should occur in the high voltage wires and allow them to touch the signal wires with their thinner insulation, it would create a serious fire and shock hazard.

When installing bell transformers, the wires from the lighting circuit to the transformer primary must be regular No. 14 rubber covered lighting wire, and must run in conduit, B X, or approved fashion for 110 volt wiring, according to the code of that particular town or territory they are in.

When making splices or connections to devices all wires should be well cleaned of insulation and all connections carefully made and well tightened. Splices in wires should be carefully soldered and well taped, to make secure and well insulated joints.

Any bell or signal system should be thoroughly tested before leaving it as a finished job. Pride in your work and neatness and thoroughness in every job should be your rule in all electrical work. That will be the surest way to make satisfied customers and success, in your job or business.

79. TROUBLE SHOOTING

In each section of this work on signal devices and circuits, common troubles and methods of locating them have been covered. In order to apply your knowledge of these things to solve any troubles in signal systems, your first step should be to get a good mental picture of the system, either from the plan or by looking over the system and making a rough sketch of the devices and connections.

Then go over it one part at a time **Coolly** and **Carefully,** and try to determine from the faulty action or symptoms of the system where the trouble may be.

80. KEEP COOL AND USE A PLAN AND A SYSTEM

A great mistake made by many untrained men in trouble shooting, is that they get rattled and worried as soon as they encounter a difficult problem of this nature. They forget that a plan or rough sketch of the wiring will usually be of the greatest help, and they make a few wild guesses as to what the trouble is. If these don't hit it, they often get still more rattled and indefinite in their efforts, and as a result sometimes mess up the system making it worse instead of improving it.

Remember that **Every Trouble Can Be Found,** and **Someone Is Going to Find It.** If you can do it, it will be to your credit and often put money in your pocket, or get you a promotion.

And you can find any fault, by thoughtful systematic testing of each circuit and device and applying the knowledge you have of this work.

In general, a good rule to follow is to first test the source of current supply. See that it is alive and at proper voltage. A test lamp or voltmeter will do this nicely.

Then test the devices that fail to operate, using a portable battery and test wires to make sure the device itself is not at fault, or has no loose terminals.

If both the supply and all bells, relays, and switches are tested and O. K., then start testing the main wires and circuits with the proper switches closed to energize them. Use a test lamp of the proper voltage, or a voltmeter, to make sure the current can get through the lines.

Any time you are not sure just how to test the wires, just refer back to Article 75 of this section and refresh your memory on the various steps.

No one can remember all these things perfectly the first time, but referring back to them and trying them out on the job at every opportunity is the quickest and surest way to fix them in your mind.

Never be ashamed to refer to a plan or notes when you have a problem of connection or other trouble. The most successful electricians and engineers do it daily.

When a system has several separate circuits, test them one at a time and mark them off on the plan or sketch as each is proven O. K. In this manner you know at all times how far you have gone, and where to look next, and can feel sure of cornering the trouble in one of the circuits or devices.

Remember a portable battery and bell, buzzer, or test lamp, and a few pieces of test wire, used with a knowledge of the purpose and principles of the circuits and devices, and plain common sense, will locate almost any signal trouble.

When any certain device is found to be out of order, you also have its troubles and repairs covered in the section on that device, in this Reference Set. Refer to it if you need to.

Welcome every "trouble shooting" job as a chance to get some excellent experience.

81. PUTTING YOUR TRAINING INTO PRACTICE

Now, if you have made a careful study of this section so far, and have properly completed your shop work in the department, you should be able to install almost any ordinary call or signal system.

You may doubt your ability to do this, but that is natural at first, as most of us have felt this way on our first jobs. But the thing to do is to get out and try it the first time you have an opportunity after graduation.

Start with a small job if you wish, and you will quickly find that you can apply every principle covered in this Set and in your shop work. After the first job or two, your confidence will grow and you will be ready to tackle any work of this nature.

Many hundreds of our graduates have started their present successful contracting businesses by a few bell wiring jobs at first.

Fig. 107 shows a floor plan of a house equipped with a modern bell call system, that affords great convenience in any home. Here are shown front and back door buttons, and buttons to call a maid from the parlor, bedroom, or dining room. An annunciator indicates which door or which room any call comes from. The switch in the dining room can be a floor switch under the table for foot operation, while those in the other rooms can be neat push buttons in convenient locations on the walls.

In homes where no maid is kept, several of these buttons may not be necessary, but practically every home should have a door bell.

They are becoming quite popular in many rural and farm homes. And in these homes a call bell from the house to the barn or garage is often a great convenience.

In Fig. 107 the wires are shown in a simple layout to be easily traced, but they should be run through the basement or attic, or through the walls where necessary.

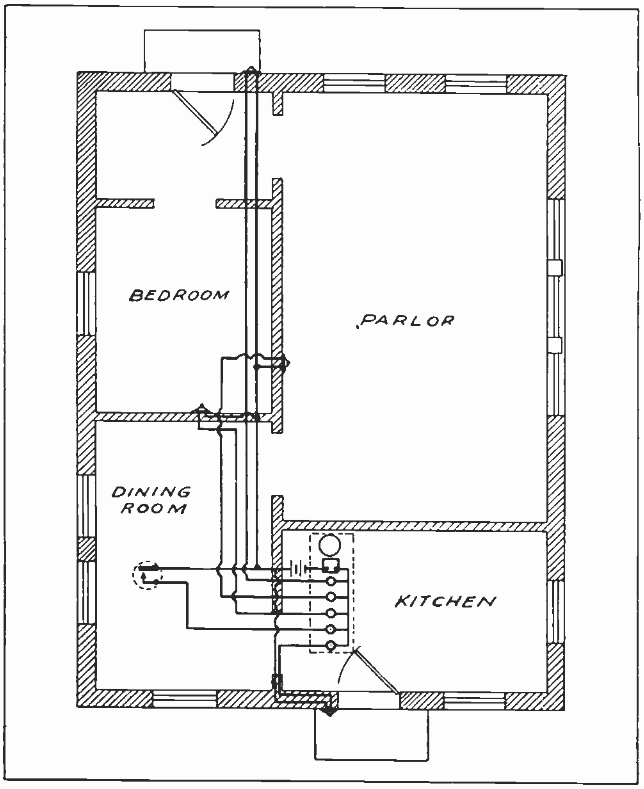

Fig. 107. Diagram showing layout of wiring for doorbell and convenience call system with annunciator. Such systems are commonly used in modern homes and are very well worth their cost of installation.

82. STARTING A BUSINESS OF YOUR OWN

To start a business of your own or side line jobs for extra money in bell and signal wiring, as mentioned before, very little capital or material is required.

Many men have started big businesses with only a few pounds of annunciator wire, a box of staples, a few push button switches, and a couple of bells and buzzers, along with a few tools, such as pliers, knife, screw driver, hammer, brace and bit, keyhole saw, star drill for brick walls, etc.

You may not even need to buy any materials, and only a few tools, until you get your first jobs lined up.

A little salesmanship will often convince the owner of a home, shop, or store that a door bell or signal system would be a great improvement and convenience, and well worth the very small expense, or that a burglar alarm system would be excellent protection for their property, or perhaps fire alarms from shops, garages, barns, etc., to the houses.

Both practice in salesmanship, and electrical practice are extremely valuable to every beginner.

83. GOOD WORKMANSHIP IMPORTANT

In every job you do, from the smallest door bell system to the most elaborate burglar or fire alarm system, make a practice of doing nothing but first class work—work that will be a credit to your profession, your school, and yourself.

Whether working for a customer or an employer, start building your reputation with your first job, and keep this thought in mind on all the rest.

84. ESTIMATING JOB COSTS

Try to do all work at a fair price to the customer, and a fair wage, plus a reasonable profit for yourself.

A good plan on the first job or two, is to do them on a "time and material" basis. After determining the type of system desired and parts and materials needed, let the customer buy them, and then charge for your time on installing them by the hour.

Keep a record of your time, wages, materials, and costs, and these will help you estimate future jobs quite accurately. Then you can buy your own materials, and charge 25 per cent or more for handling them and for overhead or miscellaneous expense; in addition to a good wage for your time, all in the estimate figure.

In many cases, time and money can be saved on alarm installations by arranging the relays, bells, batteries, and reset switch all on one panel or shelf board, in advance at your home or shop. Then when you go to the job, it is only necessary to mount this assembled unit and install the wires and proper switches.

And again let us emphasize the value of doing all work neatly and with good workmanship, both for the appearance of the job, and for its quality and dependability of operation.

A customer is usually better satisfied in the end, to have a first class job done at a fair price, than to have a poor job at a cheap price.

85. VALUE OF ADVERTISING

Don't hesitate to let the people in your neighborhood know of your training and ability. With just a little confidence and real ambition you can do these things you want to. Prove it to them and to yourself, and be proud of your training, and every job well done.

Very often the repair of bell and signal systems already installed, will bring you some extra money.

After completing your entire course you will be able to do repair and installation work, not only on signal and alarm systems, but also on radios. lighting systems, electric motors, appliances, etc.

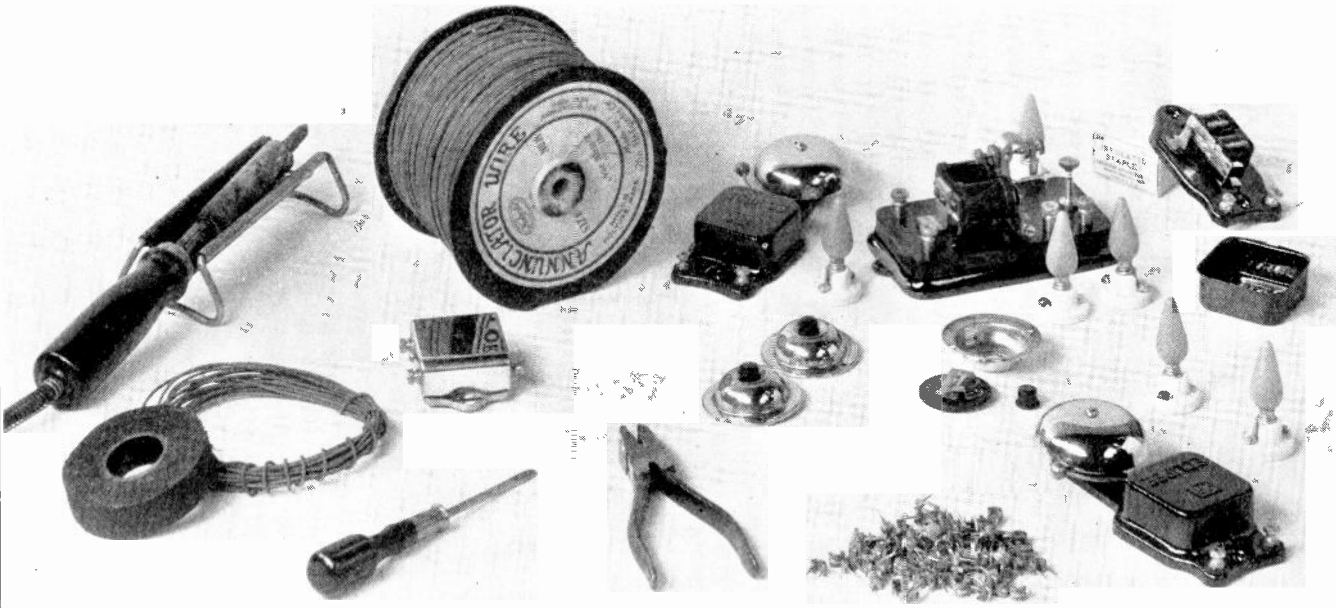

Fig. 107-B This photo shows a view of the more common parts and materials used in signal and alarm wiring.

If you have spare time evenings and week ends, and wish to do such work aside from your regular job, or to make a business and specialty of it, it will usually pay to do a little advertising. An advertisement in your local newspaper, and printed cards left at houses and shops will call attention of people to yourself, as a trained man available to install or service such equipment for them. In many cases this will bring all the work of this kind that you can handle, especially after you have done some work and have a few satisfied customers boosting for you.

Small advertisements and a few hundred cards of the type mentioned can often be gotten out at as low a cost as five to ten dollars.

If you should make a specialty of this line of work, and build up quite an active shop and business, then you can add to your tools and materials to make a more complete equipment for greatest time saving and convenience.

For a more complete list of tools and materials in case you want them later, see the following list.

Remember, however, that you can make a good start in this work with probably no more than one tenth of this amount.

1 2″ screw driver for bell adjustments.
1 4″ screw driver for small screws.
1 6″ screw driver for small screws.
1 ratchet for wood bits.
6 assorted wood bits.
3 long electrician's bits, 24″ to 36″, for long holes through walls and floors, and through mortar joints in brick walls.
1 pair side cutter pliers.
1 pair long nose pliers.
1 pair diagonal pliers.
1 claw hammer.
1 light machine hammer.
1 staple driver.
1 compass saw.
1 hack saw.
1 carpenter's saw.
1 small pipe wrench.
1 small set of socket wrenches.
2 small star drills.
1 Yankee drill.
2 ignition point files, for bell contacts.
20-ft. of steel fish tape.
1 wood chisel.
1 cold chisel.
1 doz. assorted push button switches.
3 to 6 vibrating bells.
3 to 6 vibrating buzzers.
3 drop relays.
3 bell transformers.
12 dry cells, No. 6.
5 lbs. No. 18 annunciator wire.
3 boxes insulated staples.
1 electric or gasoline soldering iron.
3 rolls friction tape.
1 lb. solder.

After getting a start in this work so you are buying considerable of materials and parts, you can get discounts or wholesale prices from your dealer, or by sending to some mail order house, and in this manner make still more profit on your jobs.

Now, whether you choose to follow bell and alarm wiring or not, every bit of the knowledge of these circuits and devices that you have gained in this section will be of great help to you in any line of electrical work, and particularly if you should enter any of the other great fields of a similar nature, such as railway signal, telephone, or radio work.

COYNE
Electrical School
CHICAGO ~ ~ ILLINOIS

ESTABLISHED 1899

ELECTRIC SIGNALLING SYSTEMS

TELEPHONES

Section Three

TELEPHONES

The telephone industry today is one of the greatest branches or fields of electrical work, and is expanding at the rate of several hundred millions of dollars per year.

Tens of thousands of trained electrical men are kept constantly employed in the fascinating work of this field, and its continual rapid development creates new jobs for several thousand more yearly.

The modern telephone is a form of electrical signalling device of the most refined type. It has become one of the greatest factors in our present civilization and is an absolute necessity to modern business.

Important business transactions are carried on over the vast telephone network of this country every minute of the day and night, saving vast amounts of time and making distances seem very small.

Today a farmer can talk to his neighbor a few miles away, or call the nearest town for groceries, machinery repairs, or the doctor—all for a few cents cost.

A resident of any large city can call any individual one of the thousands or millions of people who may live in that town, or in any other town in the country.

In a few minutes a connection can be established from New York to Los Angeles, or from New Orleans to Duluth, and a business or social conversation can be carried on for a few dollars.

We can also talk to people across the ocean, through undersea cables, or by means of the combination telephone and radio connections now in common use.

86. GREAT FIELD FOR SPECIALISTS WITH ELECTRICAL TRAINING

To keep all this vast and marvelous system of telephones functioning perfectly requires thousands of well trained electrical men who are specialists in circuit tracing, trouble shooting, and care and adjustment of the relays and parts of these devices. Many more men are required to install the thousands of new telephones constantly being added to this vast system.

87. TELEPHONE KNOWLEDGE VALUABLE IN ANY LINE OF ELECTRICAL WORK

The telephone field is one in which you can use every principle that has been covered so far in this signal section, and in the sections which follow there will be much information applying to telephones in particular. And even though you may never specialize in or follow telephone work, you should at least have an understanding of the fundamental principles of telephone equipment. Many power plants, factories, shops and offices have their own private telephone systems, and in any line of electrical maintenance work you are likely to find good use for this knowledge.

88. PRINCIPLES OF OPERATION

The telephone is a device to transmit sounds and voice from one point to another. Telephones do not actually carry the sound itself, but instead reproduce it by means of electric current impulses.

In order to understand how this is done, we should first know something of the nature of sound. Most everyone knows that any sound is transmitted by means of waves in the air. These air waves may be set up by one's voice, clapping of hands, firing a gun, or anything that causes a disturbance of the air.

Different sounds have waves of different volume and frequency. A loud sound has waves of greater volume or energy, and a low or feeble sound has waves of less volume or energy. A high pitched sound has waves of high frequency, and a low note has waves of lower frequency.

These little puffs or waves of air strike our ear drums and cause them to vibrate and transmit impressions of various sounds to our nerves and brain, thus enabling us to hear them. Figs. 108 and 109 show several different forms of sound waves, represented by curves showing their volume and frequency.

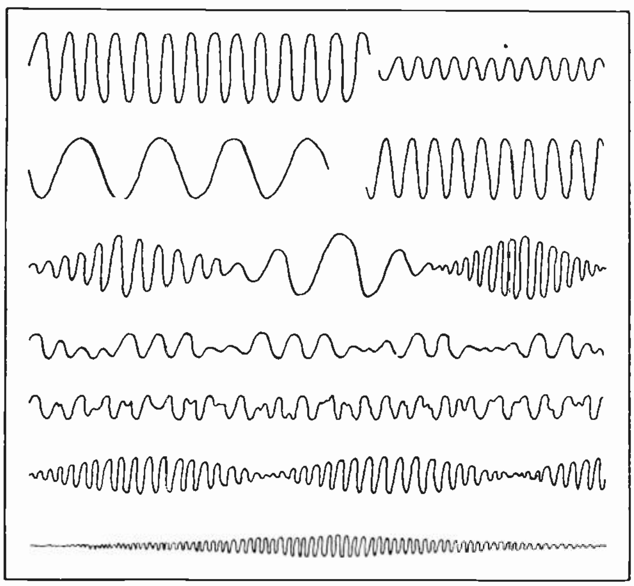

Fig. 108. This sketch shows a number of different forms of sound waves represented by curves. The upper line shows two groups of waves, both of about the same frequency, but the first group of considerably greater volume than the second. The second line shows two groups of about the same volume, but the first is of much lower frequency than the second. The third line shows waves of varying volume and varying frequency.

In order to be heard by the ordinary human ear, sound waves must be between 16 per second and 15,000 per second, in frequency. These are called **Audible** sounds. Many people cannot hear sounds of higher pitch or frequency than 8,000 to 9,000 waves per second, and it is only the highest of musical or whistling notes that reach a frequency of 10,000 or more per second.

Sound waves travel about 1,100 feet per second in air, and abount 4,700 feet per second in water.

Ordinary sounds can only be heard at distances from a few feet to a few hundred feet, and the loudest sounds only a few miles.

This is because the actual amount of energy in the sound waves is very small and is quickly lost in traveling through air.

Electricity travels at the rate of 186,000 miles per second, and can be transmitted over hundreds of miles of wire without much loss. So if we change sound wave energy into electrical impulses and then use these impulses to reproduce the sounds at a distance, we can greatly increase both the speed and the distance sounds can be transmitted.

This is exactly what the telephone does.

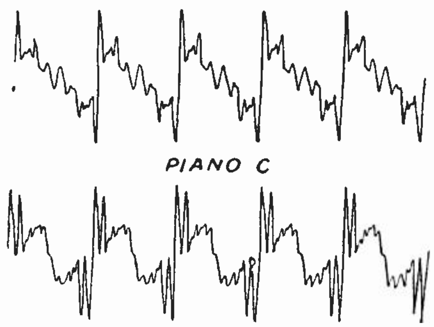

Fig. 109. These waves are typical of various musical notes, having the small variations in frequency and volume occurring at regular intervals, forming groups or large variations in the general note.

89. TRANSMITTING AND REPRODUCING SOUND WAVES ELECTRICALLY

In Fig. 110-A is shown a sketch of a simple form of telephone. Sound waves striking the **Transmitter** at the left, cause it to vary the amount of current flowing from the battery through the transmitter, and also through the **Receiver** at the right. These varying impulses of current through the receiver magnet vibrate a thin diaphragm or disk and set up new air waves with the same frequency and variations as those which operated the transmitter. Thus the original sound is reproduced quite faithfully.

This illustration of the telephone principle shows that the actual sound does not travel over the wires, but that the wires merely carry the electrical impulses.

Figs. 110-B and 110-C show the same circuit with different amounts of current flowing in each case, as they would be at the time different sound waves strike the transmitter.

This simple telephone would serve to transmit the sound only in one direction, but would not permit return conversation. For two-way conversation we can connect a transmitter and receiver at each end of the line, all in series with a battery, as shown in Fig. 111.

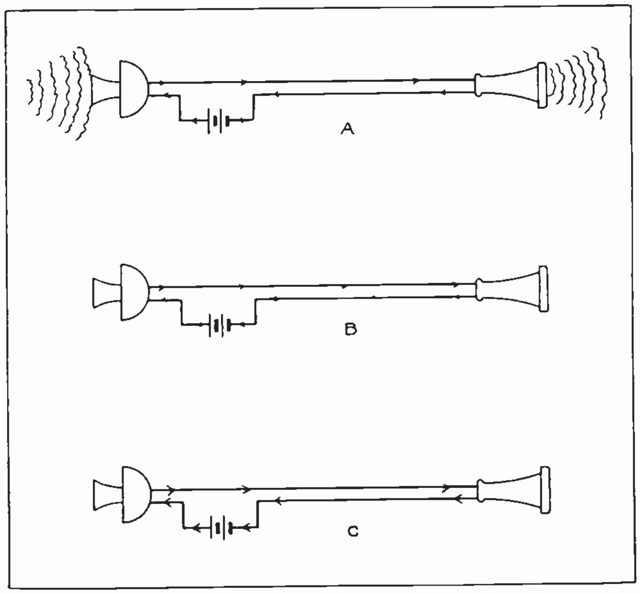

Fig. 110-A. Sound waves striking the transmitter are reproduced electrically by the magnets in the receiver.
B. When feeble waves strike the transmitter only small currents flow in the circuit.
C. When stronger waves strike it heavier currents flow.

With this circuit, when either transmitter is spoken to, both receivers are caused to operate, so this system can be used to carry on conversation both ways.

However, we still do not have any means to call the distant party to the telephone.

This can be arranged very easily, as in Fig. 112, by simply attaching a return call bell and push button system. In this circuit we have made use of one of the talking circuit wires, and a ground path for the bell circuit, but it still requires an extra wire for the signals. This wire can be eliminated by the use of a **Receiver Hook Switch,** to separate the talking and ringing circuits when the receiver is up or down.

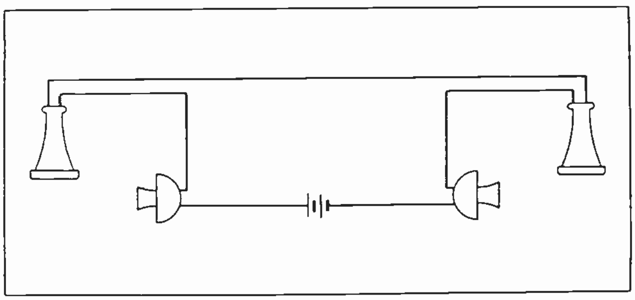

Fig. 111. Two transmitters and two receivers connected in series to form a simple two-way telephone circuit.

The circuit shown in Fig. 112 can be used for a very practical telephone for short distances, such as between a house and barn, or in a large shop or office building. But for longer distances we should also have the hook switch to save the extra wire, and an **Induction Coil** to increase the voltage for the long line. The bells should also be of a special high resistance type, so they will operate on less current and obtain further line economy.

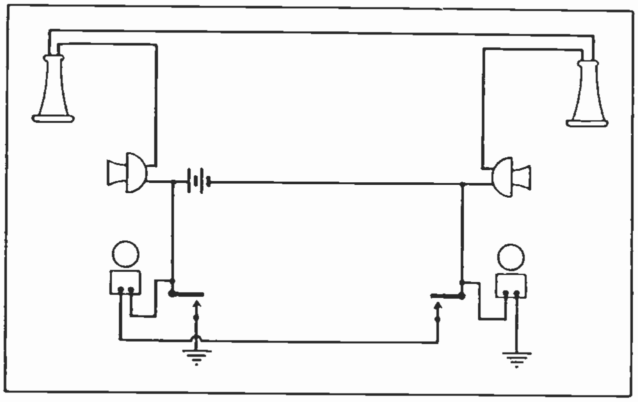

Fig. 112. **Simple telephone system for two-way conversations, and including bells and buttons for calling the parties to the telephone.**

90. IMPORTANT PARTS AND DEVICES

Now we have found that the more important parts of a telephone are the **Transmitter, Receiver, Bell, Hook Switch, Induction Coil,** and **Battery,** or source of current supply. Some types of telephones also require a special **Magneto** to operate the high resistance bells.

In order to more thoroughly understand the operation of various types of telephones, and also their care and repair, we should now find out more about each of these important parts mentioned.

Although there are many styles of telephones and various circuits and systems, they all use these same fundamental parts, and if you get a good general knowledge of them you will be able to understand almost any telephone installation you may encounter.

91. TRANSMITTER

The transmitter, as was mentioned before, acts as a valve to release from the battery, electric current impulses in synchronism with the sound waves which operate the transmitter. This is done by the use of a variable resistance in the form of carbon granules (particles) in a small cup-like container.

This cup has a loose cover or front end, which is attached to the thin disk or diaphragm directly in front of the mouthpiece.

The mouthpiece acts as a sort of funnel, to concentrate the sound waves on this disk. As the waves strike the disk, they cause it to vibrate slightly and this moves the loose end of the carbon container and compresses and releases the carbon grains or granules. See Fig. 113, which shows these parts in detail.

The transmitter circuit is arranged so the current from the battery must flow through the carbon granules from one end of the cup to the other. When the carbon particles are compressed tightly the contacts between them are better, their electrical resistance is lower, and they allow a strong current to flow. When they are released and their contacts loosened, the resistance increases and less current can flow.

So, as the various sounds strike the transmitter and cause the disk and button to vibrate rapidly, it controls or liberates from the battery corresponding impulses of current. Fig. 114 is a sketch showing the connections and electrical circuit through a transmitter.

Fig. 115 shows several different forms of electric current represented by curves. The straight lines are base or zero lines, and are considered as points of no current value. When the curve goes above the line it represents positive or current in one direction; and when it goes below it means negative or current in the opposite direction. Fig. 115-A shows a steady or continuous flow of direct

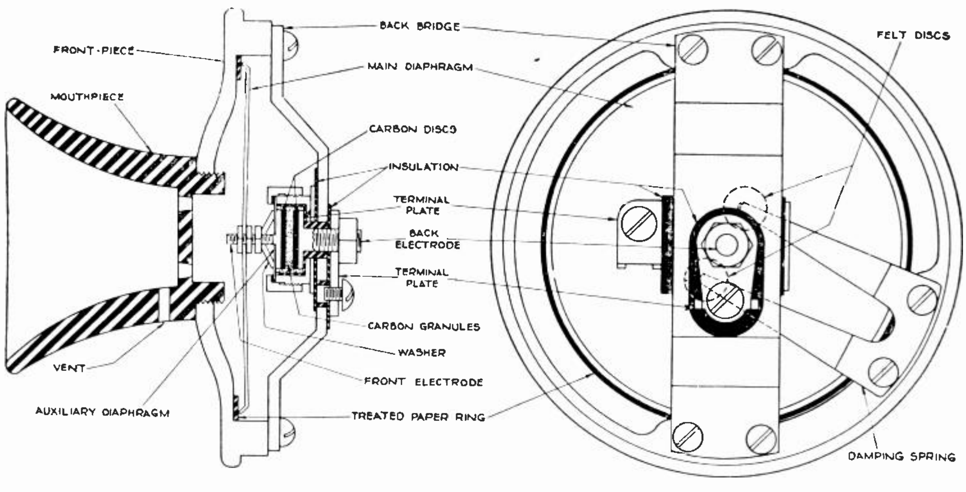

Fig. 113. **This diagram shows two different views of a telephone transmitter and its parts. Examine each very closely, and note the names of each part.**

current, such as the battery would ordinarily supply. Fig. 115-B shows pulsating direct current such as the transmitter would produce. The height of the curve above the line indicates the value of the various current impulses. While this current varies in amount, it is still flowing all in one direction.

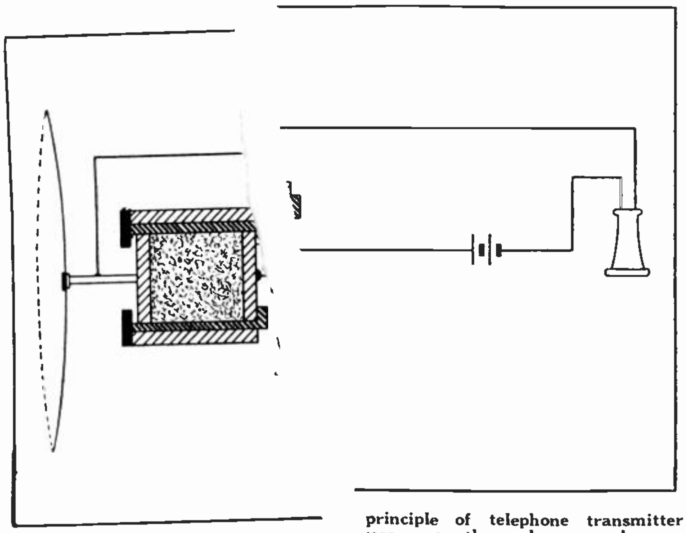

Fig. 114. Simple sketch showing principle of telephone transmitter button, and how the varying pressure on the carbon granules varies the resistance and current flow in the circuit.

Fig. 115-C shows ordinary alternating current, such as a magneto or A. C. generator would produce. This current continually varies in amount and regularly reverses in direction. Fig. 115-D shows alternating current of irregular frequency and varying volume, such as produced by a telephone induction coil, which will be explained a little later.

Fig. 116 shows another type of transmitter of slightly different construction, but similar in operating principle to the one in Fig. 113. This transmitter has the disk or diaphragm mounted in a soft rubber ring, to allow it free movement without rattling or chattering.

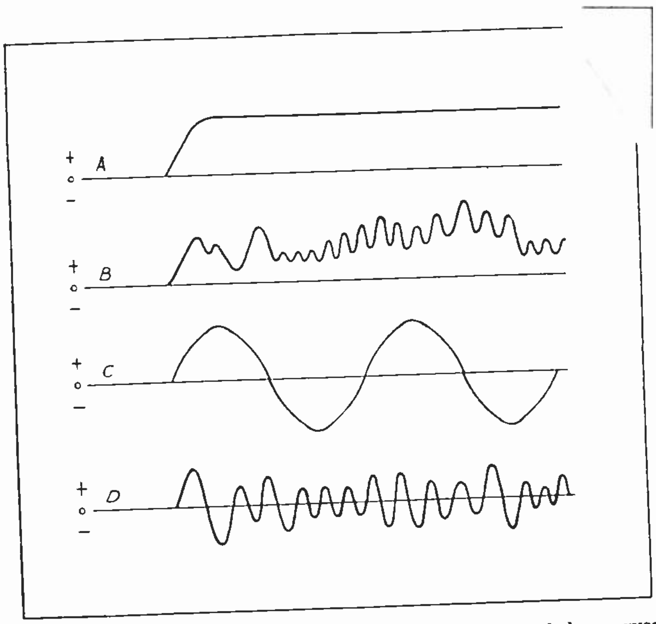

Fig. 115. Various kinds of electrical current represented by curves. Examine each curve very closely and compare with the explanations given.

Sometimes the carbon granules in a transmitter become packed or worn and need to be removed. In many transmitters the entire cup can be easily removed and exchanged. Loose terminals, broken connections, or dirt around the diaphragm also cause occasional trouble.

92. RECEIVER

The ordinary telephone receiver consists of a strong permanent magnet of horseshoe shape, a pair of electro-magnet coils at the ends of the permanent magnet poles, a thin disk or diaphragm, and the shell and cap in which these parts are enclosed.

See Fig. 117. The receiver at the left shows the parts named, while the one at the right shows a slightly different type which does not use the large permanent magnet, but just a strong electro-magnet instead.

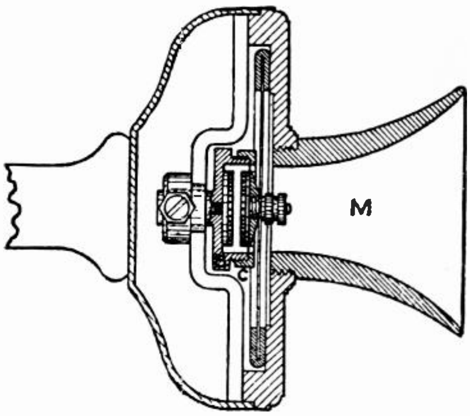

Fig. 116. Sectional view of a common type of telephone transmitter. The carbon cup is here shown empty or without any carbon granules in it.

The permanent magnet normally holds the iron disk attracted when the receiver is not in use. When "talking current," or current from the talking circuit, passes through the coils of the electro-magnets, its current variations strengthen and weaken the pull of the permanent magnet on the diaphragm, causing it to vibrate.

Telephones using induction coils have alternating current in the line and receiver circuits. This current reverses rapidly, and the reversals or alternations are of the same corresponding frequency and volume as the sound waves which caused them.

Some of these impulses were shown in Fig. 115-D. As these impulses pass through the receiver coils, they not only vary the magnetic strength of the coils, but also actually reverse their polarity. This causes the electro-magnets to strengthen the polarity and aid the pull of the permanent magnets on the diaphragm while the current flows in one

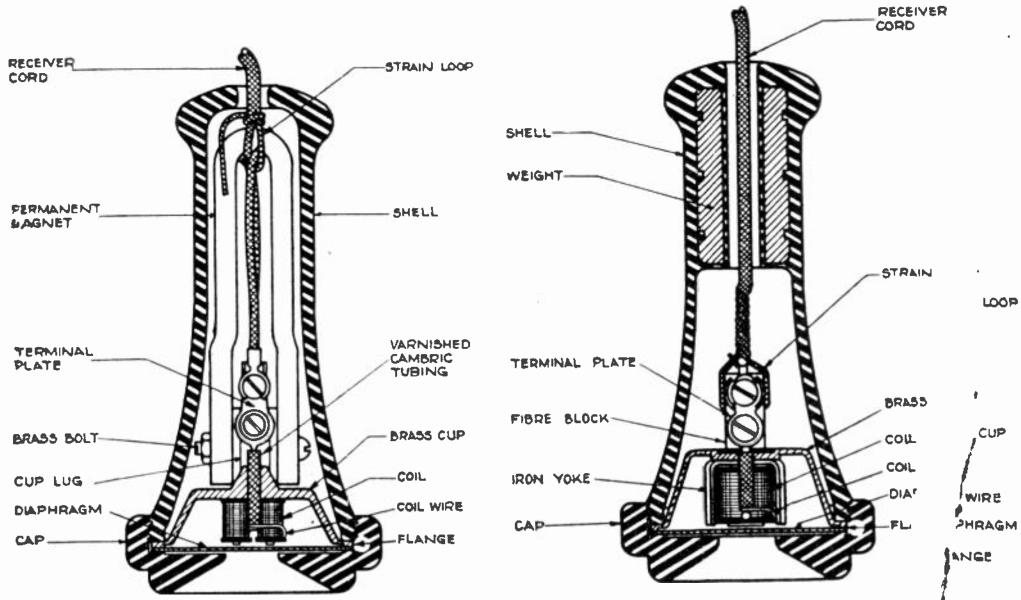

Fig. 117. Two sectional views showing the construction and parts of two types of telephone receivers. Examine all the parts carefully and note the names of each. The receiver on the right has a lead weight at the top of the shell to make it heavy enough to operate the hook switch, which will be explained later.

direction. But when it reverses, the magnetism of the coils opposes that of the permanent magnet and weakens it, thus making a considerable variation in pull on the diaphragm.

The coils of the receiver electro-magnets are usually wound with many turns of very fine wire, and if these coils are bruised or scratched it often breaks one or more turns of the wire and stops the operation of the receiver.

Some of the other more common receiver troubles are as follows: Loose end cap, allowing diaphragm to fall away from magnets; bent diaphragm, weak permanent magnet, loose cord connections, or broken receiver cord. The wires in these cords often become broken inside the insulation, from twisting and kinking, or from rough handling and dropping of receivers.

Testing with a dry cell, first at the cord tips, then at the receiver terminals, and listening for a click at the diaphragm as the circuit is made and broken, will easily disclose this trouble.

Another type of receiver, often called a "watch case" type, is shown in Fig. 118. These small receivers are used in head sets for telephone operators, and are very similar to those used by radio operators.

Their construction is much the same as the larger ones, except that they are much lighter in weight and have the permanent magnet in more of a circular shape.

93. HOOK SWITCH

The receiver is hung on a spring hook when not in use, and this hook operates a switch to disconnect the talking circuit and places the ringing circuit in readiness for the next call. This is called a **Hook Switch.**

By disconnecting the talking circuit, it saves wasting the battery cur rent when the 'phone is not in use. It also di sconnects the bell circuit when the 'phone is in use, and thus prevents the bell from being rung while parties are talking. Having this switch o perated by the receiver makes it automatic, as the party naturally removes and replaces the recei ver when starting and finishing the conversation

Fig. 119 sho ws a very simple type of hook switch. While the re ceiver is on the hook it is held down, and the en d of the hook lever presses against the center co ntact of the switch, keeping it held to the right a nd in contact with the spring "C." This closes the ringing circuit.

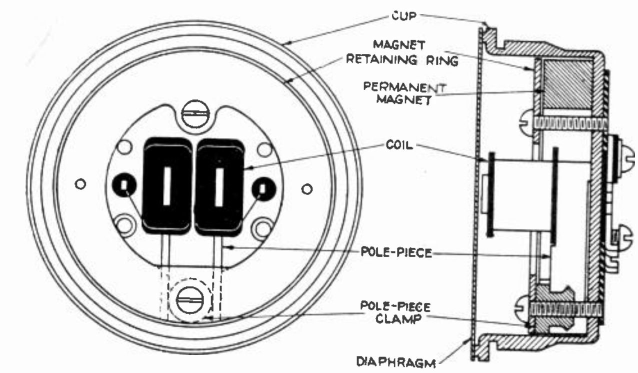

Fig. 118. Sectional view and front view of watch case receiver, such as used on telephone operators' head sets.

When the receiver is removed from the hook, the spring causes the hook to raise and the end of the hook lever to move to the left, allowing the center spring to make contact with "A" and close the talking circuit. It also opens the ringing circuit at the same time.

There are a number of different types of hook switches, but the principle of all of them is very similar and easy to understand.

If the contacts of a hook switch become burned or dirty, or if the contact springs become bent out of shape, it is likely to cause faulty operation of the talking and ringing circuits.

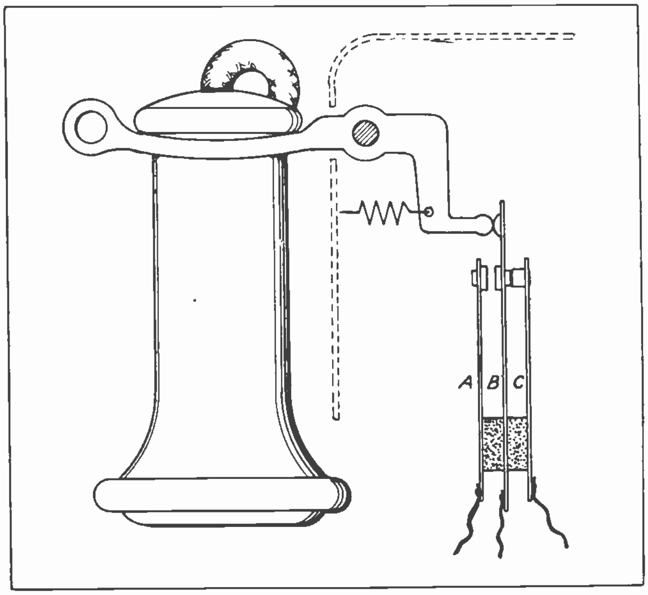

Fig. 119. Sketch showing the principle of a simple "receiver hook switch." Note what the operation of the spring contacts would be if the receiver was raised and lowered.

94. BATTERIES AND CURRENT SUPPLY

Telephones require, for the successful operation of their talking circuits, direct current supply of a very "smooth" or constant voltage value. This is because we do not want any variations in the current, except those made by the transmitter and sound waves.

In small private telephone systems and rural lines, dry cell batteries are often used, and in many cases each 'phone has its own battery.

Large telephone systems for city service use storage batteries or D. C. generators for talking current supply. Generators for this use have special windings and commutators for providing "smooth" D. C., as even the slight sparking and variations of voltage at the commutator of an ordinary power generator would produce a disturbing hum in the 'phone receivers.

Rural line telephones often use a hand-operated magneto to supply current to ring the bells, and some small exchanges do also. However, most exchanges use a generator to produce alternating current or pulsating direct current, for the operators to ring the various parties by merely closing a key switch.

95. INDUCTION COIL

As mentioned before, most telephones that are to be used on lines of any great length use an induction coil. The purpose of this device is to act like a transformer and increase the voltage of the impulses in the talking circuit, so they can be transmitted over long lines with less loss.

When a transformer "steps up" the voltage, it reduces the current in the same proportion, and the less current we have to send through the resistance of any line, the less loss we will have. By briefly recalling your study of Ohms Law and voltage drop principles, this should be quite easily understood.

Induction coils have a primary and secondary winding around a core of soft iron, and when the current impulses are sent through the primary, corresponding impulses of higher voltage are set up in the secondary by magnetic induction. Thus the name, "induction coil."

Fig. 120 shows a sketch of an induction coil. "C" and "C" show the ends of a core which is made of a bundle of soft iron wires. "H" and "H" are ends or "heads" to support the coil on the core. "P" and "P-1" are the terminals of the primary winding. "S" and "S-1" are those of the secondary winding.

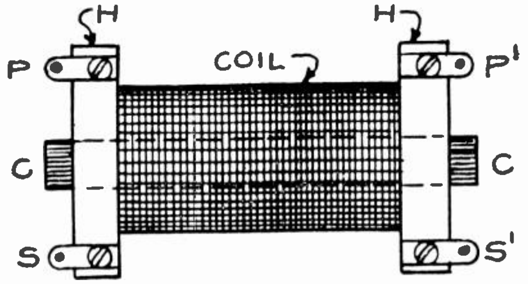

Fig. 120. This sketch shows the construction of the windings and core of a telephone induction coil.

The primary winding should be connected in the transmitter and battery circuit. The secondary winding connects to the receiver and line circuit. These connections will be shown a little later, in a diagram of a complete telephone circuit.

Fig. 121 shows a single, and also a double induction coil. Fig. 122 shows a sketch of the coils, core, and terminals of the induction coil as they are often shown in connection diagrams.

We recall from an earlier section on transformer principles, that transformers will not operate on ordinary direct current, but in the case of this telephone induction coil, the current from the battery is caused to pulsate or increase and decrease rapidly, by the action of the transmitter.

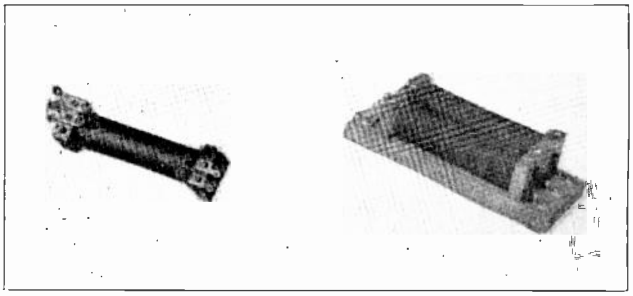

Fig. 121. On the left is shown a single induction coil with the terminal connections plainly visible. On the right is shown a pair of coils mounted on one base.

These variations in the talking current cause the flux of the primary coil to expand and contract, and induce the higher voltage impulses in the secondary.

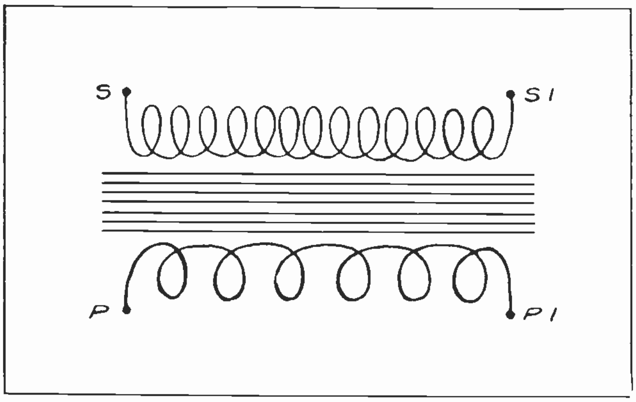

Fig. 122. The primary and secondary windings and core of an induction coil are often shown in the above manner in electrical diagrams.

96. TELEPHONE BELLS

While some telephones in small private systems use ordinary vibrating bells, the more common 'phones in general use in public systems use a **Polarized** bell, which operates on alternating current.

These bells have two electro-magnets and an armature, which is a permanent magnet; and two gongs instead of one, as in the case of the vibrating bell.

Fig. 122-B shows two views of this type of telephone bell.

In some cases, instead of the armature itself being a permanent magnet, a larger permanent magnet is mounted behind the bell coils and with one end close enough to the armature to maintain induced poles in it.

The coils of these bells are usually wound with many turns of very fine wire, and are designed to operate on very small amounts of current at rather high voltage, which makes them economical to operate on long lines.

The operating principle of the polarized bell can be easily understood by referring to Fig. 123. You will note that when current flows through the coils in one direction it sets up poles on the electro-magnets, which attract one end of the armature and repel the other, causing the hammer to strike the left gong as in Fig. 123-A.

Then, if we reverse the current as in "B," this reverses the poles of both electro-magnets, causing them to attract and repel opposite ends of the armature to what they did before. This makes the hammer strike the right-hand gong.

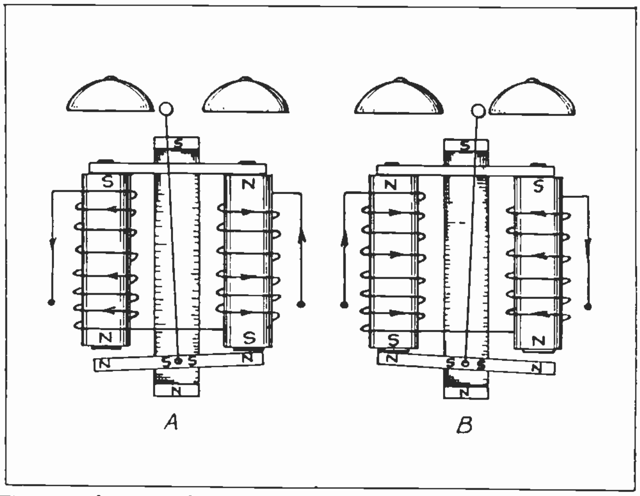

Fig. 123. These sketches show the electrical circuit of a polarized telephone bell. Note the polarity and position of the armature in "A," and again "B," after the current has been reversed.

Then, if we supply alternating current from a magneto or central generator, it will cause the coils to rapidly reverse and operate the hammer at the same frequency as that of the current supply.

Check carefully the polarity of the permanent magnet, the movable armature, and the electro-magnets in both bells in Fig. 123.

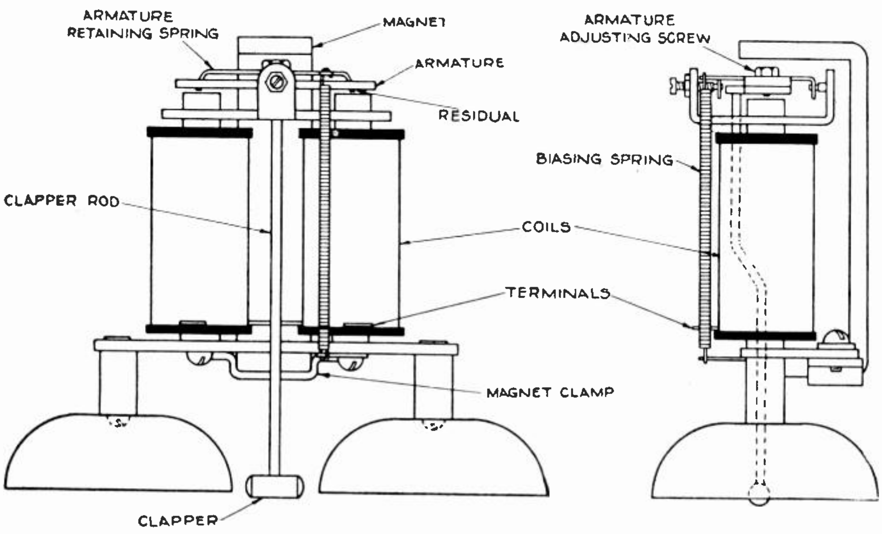

Fig. 122-B. Front and side views of a polarized telephone bell. Note the end of the permanent magnet, which is used to magnetize the armature by induction. Also note the biasing spring attached to one end of the armature.

97. BIASED POLARIZED BELLS FOR PULSATING D. C. OPERATION

Sometimes these polarized bells are equipped with a **Biasing** spring attached to their armature. This spring can be noted in Fig. 122-B. It enables the bell to be operated on pulsating direct current, which is sometimes used by the operators at central stations for ringing various parties on the line.

In such cases a rotary pulsating switch is used in the battery circuit to provide the interruptions in the current. The biasing spring normally holds the hammer against one of the gongs when the bell is idle. When current is sent through the coils in the proper direction, the electro-magnets will attract and repel the proper ends of the armature, to cause the hammer to strike the other gong.

When the current is interrupted, the spring draws the armature and hammer back again, striking the first gong once more. This will be repeated as long as the pulsating current flows. See Fig. 124. The pulsating wheel "W" has alternate sections of metal and insulation, so as it is rotated it rapidly makes and breaks the circuit of the battery and bell.

Fig. 125 shows a very good view of a telephone bell with the gongs removed.

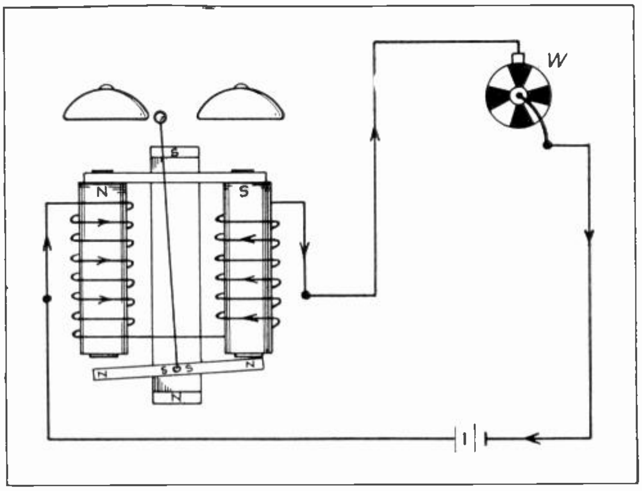

Fig. 124. This sketch shows how a "pulsator" or interruptor can be used to supply pulsating current from a battery and for the operation of telephone bells.

98. POLARIZED BELL WITH PERMANENT MAGNET ARMATURE

Another type of polarized bell used in some telephones, has both coils wound in the same direction and uses the permanent magnet for an armature. See Fig. 126.

In these bells the armature has unlike poles at each end, so in order for one of the electro-magnets to attract and the other to repel, they must have like poles. When alternating current is passed through this bell, the polarity of both electro-magnets changes at the same time. This causes attraction of first one end of the armature, and then the other.

Observe carefully the direction of current and polarities of the magnets in both bells "A" and "B" in this figure.

When telephone bells fail to operate, the trouble can usually be found in a loose connection, broken coil lead, weak permanent magnet, loose gongs, or magnet cores loose on keeper or frame.

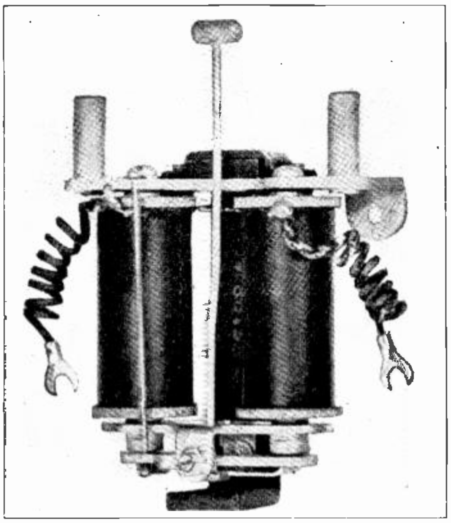

Fig. 125. Photograph of coils, armature, and hammer of a common telephone bell.

99. TELEPHONE MAGNETOS

As mentioned before, rural lines often use magnetos at each 'phone for the subscriber to ring any other party on that line, and also to call the central operator. These magnetos, when operated by the hand crank at normal speed, produce alternating current at fairly high voltage, usually from about 80 to 100 volts, and at a frequency of about 20 cycles.

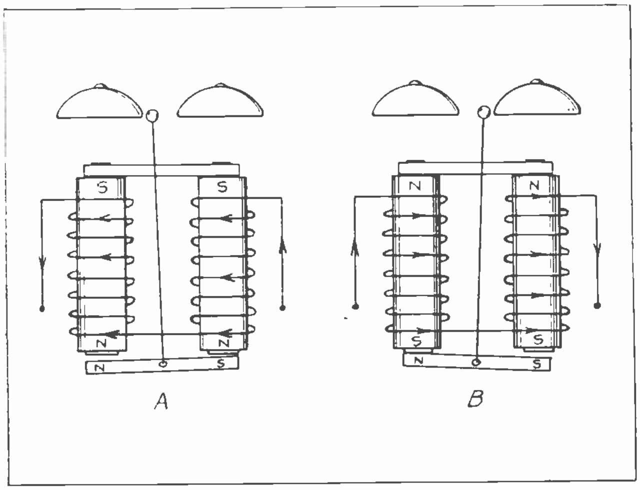

Fig. 126. This sketch shows the construction and windings of another type of polarized bell, which uses a permanent magnet for its armature. Note the polarity and position of armature at "A," and again at "B," after the current has been reversed.

Fig. 127 shows a sketch of a magneto of this type. The armature is usually of the shuttle type with just two large slots, in which are wound many turns of very fine wire. It is located in the base of the magneto between the poles of several large horseshoe magnets.

These supply the magnetic flux which is cut by the armature winding to generate the voltage. The armature is revolved quite rapidly by means of a large gear on the hand crank shaft, and small pinion on the armature shaft.

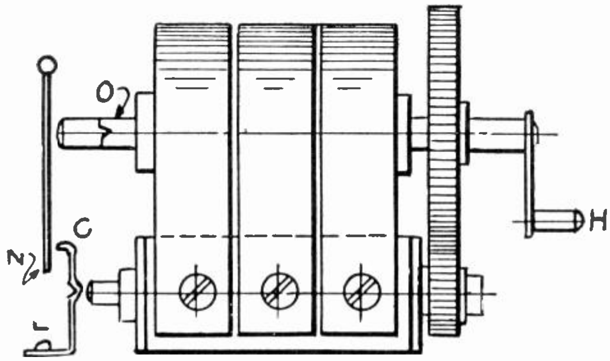

Fig. 127. Diagram of telephone magneto showing shaft extension which operates contact springs.

The crank shaft shown at "O" is equipped with a slotted extension and spring which pushes out against the contact spring "N" each time the crank is turned. This operates a sort of "shunt" switch.

When the magneto is idle this spring falls back, touching contact "C," and shunts out the magneto winding from the line circuit, so the talking current does not have to pass through this resistance.

When the crank is turned the shaft is forced out a small distance and opens these contacts, allowing the magneto current to flow to the line and bells. One end of the armature winding is usually grounded to the shaft, and the other end is insulated and carried out through the center of the shaft, which is hollow. This end or tip of the shaft is in contact with the small spring as the shaft rotates.

Fig. 128 shows two photos of telephone magnetos. The one at the right is equipped with a hand crank for use in a subscriber's telephone. The one at the left is equipped with an extension shaft such as used by central operators in some of the small exchanges.

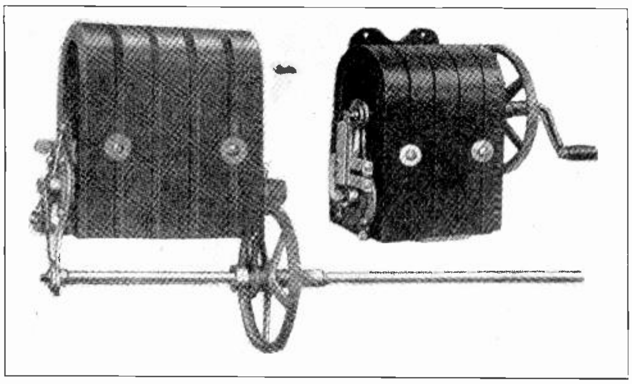

Fig. 128. These photos show two telephone magnetos. The one on the left for use in a small exchange, and the one on the right for a subscriber's telephone.

Some exchanges use a power-driven magneto, having it operated continuously by a small motor. In this case it is only necessary for the operator to close a key or switch to ring the party being called.

In Fig. 128 the spring contacts operated by the magneto shaft are quite clearly shown.

The permanent magnets in these magnetos often become weak after a certain age and need to be remagnetized or replaced. Sometimes a little oil and dirt collects on the contact springs, causing them to fail to make good connections; or they may become bent or worn so they do not make proper contact.

100. COMPLETE TELEPHONES AND CIRCUITS

Now that you understand the function and operation of the important parts of a telephone, let's see how they all work together in the complete 'phone.

Fig. 129 shows a common type of party line telephone used on rural lines and in small towns.

The view on the left shows the box closed, and the location of the receiver, transmitter, and bell gongs. On the right the box is opened up, showing the battery and magneto, hook switch in the upper left corner, and bell magnets on the door. The induction coil is not visible in this view.

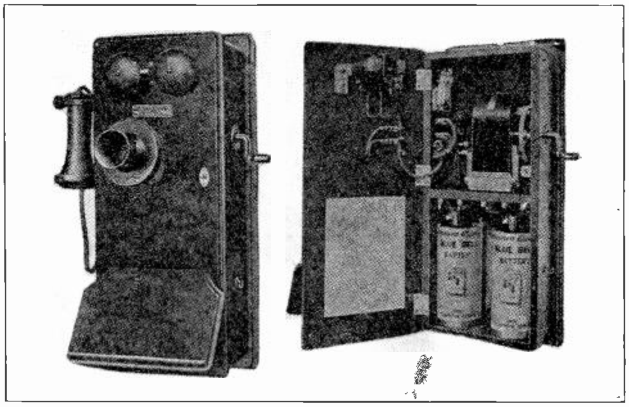

Fig. 129. Common type of party line telephone used on rural lines. This telephone is complete with its own batteries and magneto.

You will note that this 'phone is complete with all necessary parts, and has its own current supply for both the talking and ringing circuits.

Two or more telephones of this type can be connected in parallel on a line, and if desired can be operated without any central exchange or any other equipment.

Any party can ring any other party by a system of different calls, arranged in combination of short and long rings, similar to dots and dashes.

Party lines with a number of these 'phones can also be run to a central office, and from there they can be connected to any other line on the entire system. This is the purpose and function of a central office or telephone exchange. It is practical to have on one line only a certain limited number of 'phones, as otherwise the line would always be busy, and no other subscriber could use it while two parties were already talking over it. On rural lines the number of parties may be from ten to twenty per line. In cities, from two to four or six is more common.

When a subscriber on one line wishes to talk to someone on another line, he or she signals the central operator, who can, by means of switches and plugs, connect the **Calling Line** to the one called and then ring the party desired on the **Called Line.** The equipment and operation of exchanges is covered later.

Fig. 130 shows a complete diagram of the electrical circuit and connections of a telephone of the type shown in Fig. 129. Here we can see the relation of each part to the others and get a clearer idea of how they all operate together.

Trace out this circuit very carefully, until you are sure you clearly understand its entire operation.

The receiver is shown off the hook and the hook is raised, allowing the main contact spring to move to the left and close the two contacts on that side, completing the talking and line circuit. The large arrows show where the current flows from the local battery, through the transmitter, induction coil primary, hook switch contacts, and back to the battery.

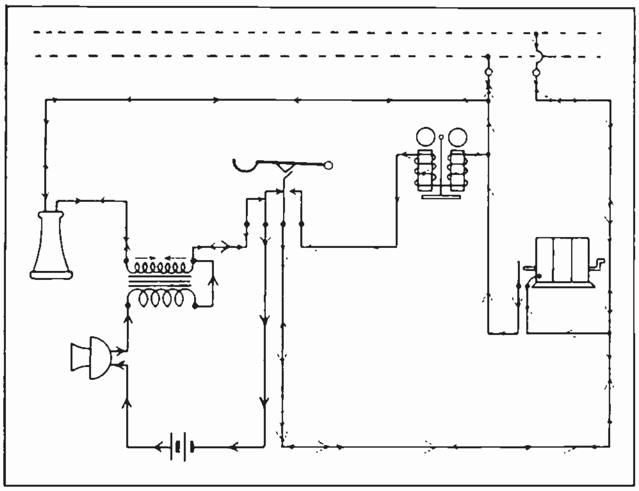

Fig. 130. Diagram showing connections and circuits of a telephone such as shown in Fig. 129.

When the party talks into the transmitter, this local current is caused to pulsate and sets up induced impulses of higher voltage but smaller current, in the secondary coil, receiver and line circuit. This is shown in the small arrows. You will remember that this current induced in the secondary coil and in the receiver circuit is alternating and rapidly reverses, so we show the arrows both ways. It also flows a short distance through one of the same wires with the battery current, but this does no harm.

The magneto is shown here in idle position, so its spring contact is open and keeps the magneto winding out of the ringing and line circuit at present. When the magneto is operated, the shaft pushes out and closes the circuit, and sends current through the bell and also out on the line to the other bells.

In order to ring anyone, the receiver must be on the hook, keeping the hook down and holding the main spring or line contact to the right and in contact with the spring on that side. The ringing current then flows as shown by the dotted arrows.

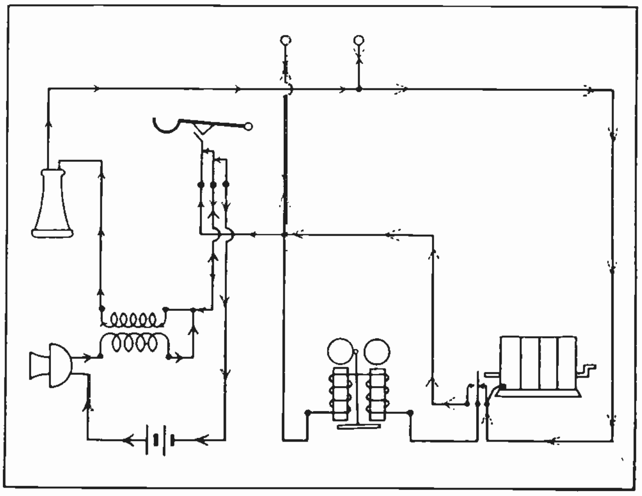

Fig. 131. Circuit diagram of another telephone using a different hook switch and set of magneto contacts. Trace the circuit and observe its operation very carefully.

Fig. 131 shows another telephone circuit, using a hook switch with only three spring contacts instead of four, and a magneto with three contacts instead of one or two. Compare this diagram carefully with Fig. 130. Here again the large arrows show the transmitter and local battery circuit; the small arrows, the receiver and line circuit; and the dotted arrows, the ringing circuit.

You will note that this hook switch does not make and break the ringing circuit as the one in Fig. 130 did. Here the ringing circuit is controlled by the magneto springs. When the magneto is idle, the long center spring presses to the right, keeping the bell connected to the line, ready to receive an incoming call. When the magneto crank is turned it forces the shaft outward and pushes the center spring to the left. This short-circuits the bell and makes a connection direct to the line to ring outside bells. In this type of 'phone the subscriber's own bell does not ring when his magneto is operated.

There are a number of different ways to arrange party line telephone circuits, hook switches, magneto contacts, etc.; but if you have a good understanding of these fundamental circuits and the operation and purpose of these important parts, you should have no difficulty understanding any 'phone circuit after tracing out its wiring or diagram.

101. CENTRAL ENERGY SYSTEMS AND 'PHONES

In large city telephone systems a central source of current supply is generally used for both the talking and ringing. In such systems the subscriber's 'phone does not need a battery or magneto.

The hook switch and circuit are so arranged that as soon as the receiver is removed from the hook, it closes a circuit and lights a small lamp on the exchange operator's switchboard.

The operator then plugs her 'phone onto this calling line and closes her key so the caller can give her the number desired. Then, if the called line is not busy, the operator connects the calling line to it and rings the party to be called.

A simple circuit for a telephone of this type is shown in Fig. 132. Keep in mind, when tracing this circuit, that the current supply comes in on the line from the exchange.

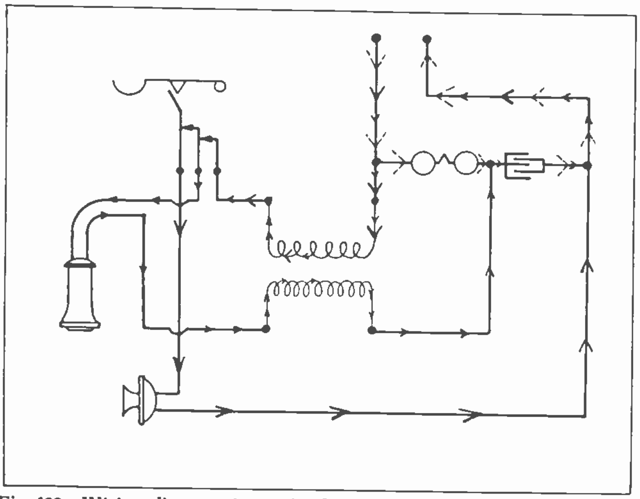

Fig. 132. Wiring diagram for a simple telephone to be used on a central energy system. This telephone gets all the energy from the line and central supply.

You will note that a condenser is used here to prevent the direct current for the transmitter circuit from passing through the bell or receiver circuits.

A condenser will pass or allow alternating current or pulsating direct current to flow through it, but blocks or stops ordinary direct current.

The "talking current," shown by the large arrows, comes in on the left line wire and passes through the induction coil primary, hook switch, transmitter, and back out on the right line wire. When the party is talking, the induced current in the secondary coil, shown by small arrows, flows out through the condenser and right line wire, to the receiver of the operator or called party; and back in the left line wire, through the primary coil, hook switch and subscriber's own receiver, and returns to the secondary coil. In tracing the receiver and line circuit, consider the secondary coil as the source of this energy.

A different symbol is used here for the bell, as it is simpler to draw in plans and easy to recognize once you are acquainted with it.

Fig. 133 shows a complete telephone of this type, for wall mounting. The bell, condenser and coil are mounted in the box, while the receiver is on the usual hook on the side, and the back of the transmitter can be seen in the front of the open cover.

Note the terminal blocks to which all connections are brought and numbered, making it easy to connect up or test the telephone.

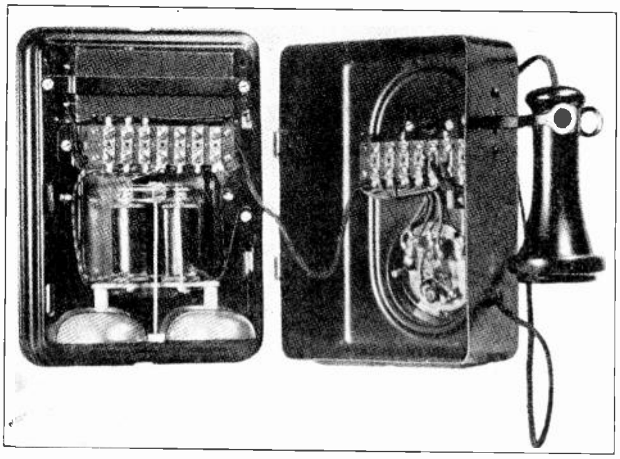

Fig. 133. Photograph of wall type telephone for central energy systems.

Fig. 134 shows another telephone of the central energy type, for use on a desk. This desk-type 'phone has the receiver and transmitter mounted on a separate stand for convenient use on the desk; while the bell, coil, and condenser are in a separate box to go on the side of the desk or under it.

The hook switch is inside the upright handle of the stand.

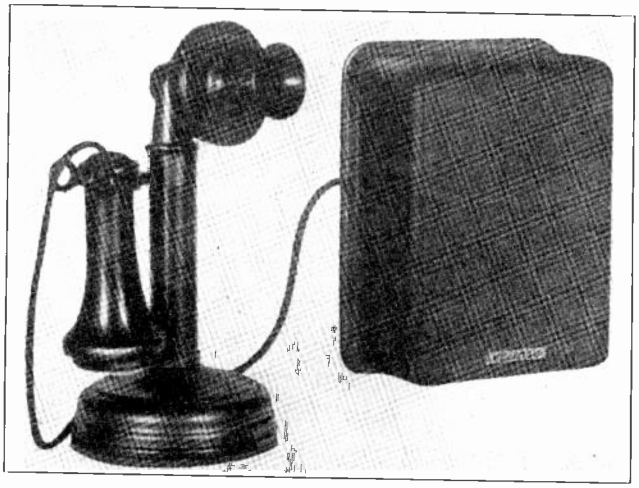

Fig. 134. Common desk type telephone with bell box to be mounted separately.

102. TELEPHONE EXCHANGES

As already mentioned, the telephone exchange serves to connect telephones of one line to those of other lines, and there are thousands of these central exchanges throughout this country, to handle the many millions of telephones in use.

The exchange in the small town handles the calls of the subscribers in the town, those of rural lines calling in to city 'phones, and those of one rural line calling through to another line, perhaps running out of town in the opposite direction. Thus this exchange serves the 'phones in that town and surrounding territory. Then it has its **Trunk Lines** connecting to exchanges of other cities, and can complete a circuit for one of its own subscribers, through the exchange of another town several hundred or even several thousand miles away.

This vast network requires many types of elaborate and complicated exchange circuits, which it is not our purpose to cover here, as they represent a very highly specialized type of work. They also require much more time than the ordinary electrician cares to spend on such circuits, unless he intends to specialize in telephone work. But, in order to give you a better understanding of the general operation of the exchange in connection with the 'phones we all use daily, and also to give you a good foundation to work from in case you should later specialize in such work, we will cover in the following material some of the fundamental parts and principles of exchanges.

Telephone exchanges are of two general types, namely, manual and automatic.

The general function of either type is to receive a signal from the calling subscriber, and get a connection and ring his party on any other line as quickly as possible.

With the manual exchange, the plugging, switching and ringing operations are performed by human operators, usually girls. With the automatic exchange these operations are performed by electrical and mechanical devices.

103. SWITCHBOARDS FOR MANUAL OPERATION

Fig. 135 shows a manual exchange or switchboard, for handling one hundred lines. These lines are brought up to **Jacks** on the upright front of the board.

On the flat, desk-like, part of the board is a set of **Plugs**, attached to **Cords** beneath, and also a set of **Key Switches.** Directly above each jack is a **Drop** similar to an annunciator drop.

When a subscriber on any line signals the operator, the little drop window or shutter for his line falls down, showing the operator that someone on that line is calling. There are two plugs in front of that line, one for talking and one for ringing.

The operator lifts the talking plug and inserts it in the line jack opening. Then, by pressing her key in one direction, she can answer the **Calling Party** and receive the number he wishes to call.

If the line of the party desired is not busy, the operator then lifts the other plug in line with the first one, and places it in the jack of the "called" line. Then, by pushing the key in the other direction, she can ring the party desired.

By pushing the key back to the listening position

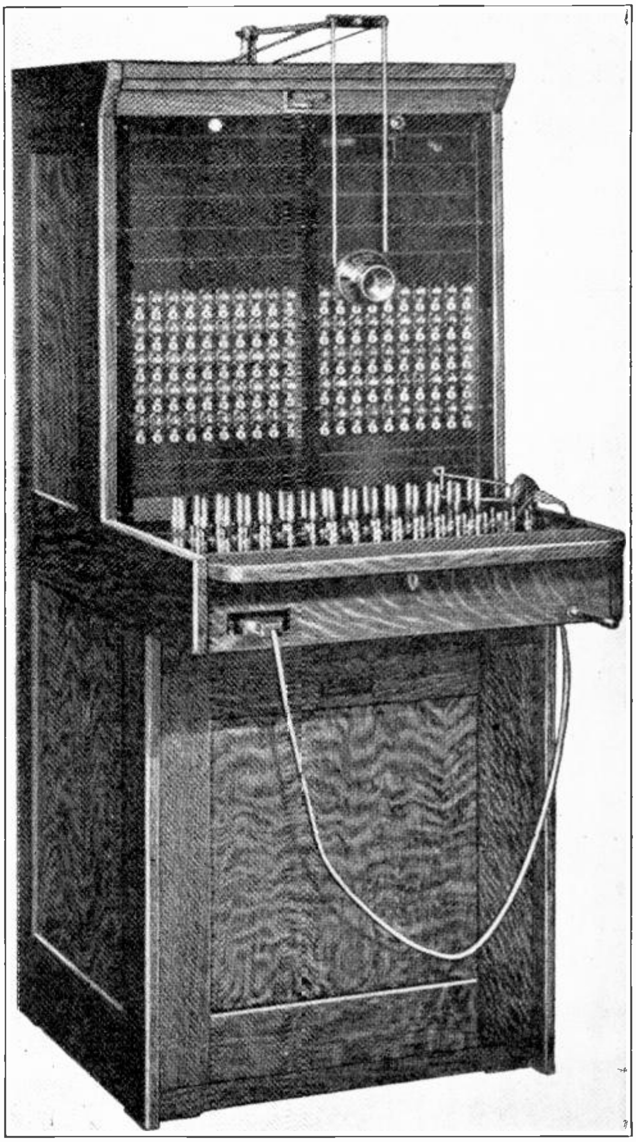

Fig. 135. A small exchange switchboard of the magneto type, showing plugs, jacks, and the operator's transmitter and receiver.

again, the operator can hear the party answer. When he does, she can release the key to vertical or neutral position. The parties then carry on their conversation through the wires in the cords.

The cords are equipped with very flexible wires, and have weights on little pulleys as shown in the left view in Fig. 136. At the right is shown a large view of the pulley and weight. These weights keep the cords straight and pull them down again each time the plugs are dropped to idle position.

The operator's head-set is shown lying on the keyboard in Fig. 135, and the transmitter is shown on an adjustable arm and cord in front of the board.

Fig. 137 shows a closer view of the keys, plugs, and jacks of a board of this type. The key switches are shown in the foreground, and directly behind these and indicated by the arrow is a row of small lamps to show the condition of the circuit to the operator. Behind the lamps are the plugs, and above are the plug jacks and drops.

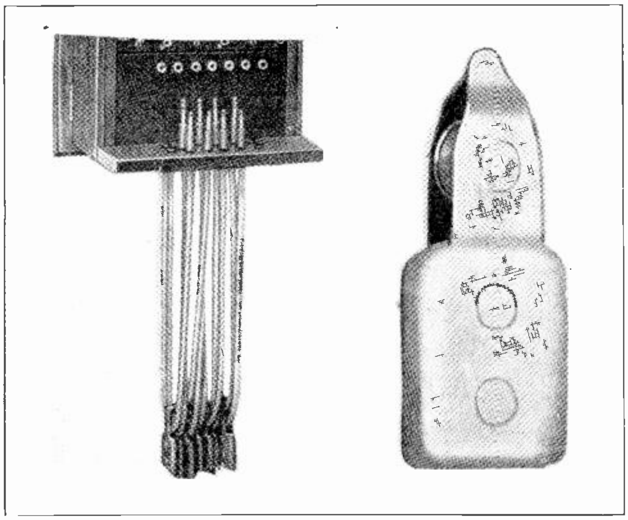

Fig. 136. The view on the left shows the manner in which the plug cords are held straight by the weighted pulleys. A larger view of one of these pulleys is shown on the right.

104. KEY SWITCHES

A very good view of two switchboard keys is shown in Fig. 138. The levers or key handles can be pushed in either direction, and their lower ends have rollers or cams that push and operate a set of spring contacts on either side, depending on which way they are pushed. Examine these switches and all their parts carefully.

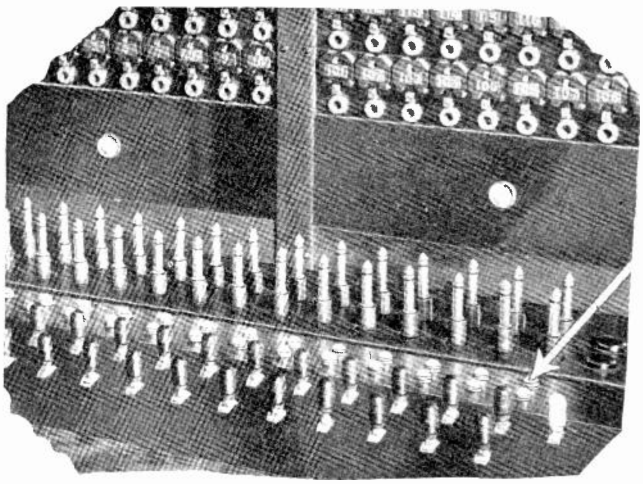

Fig. 137. This photo shows very clearly the arrangement of the operator's key switch, plugs, and jacks.

105. SWITCHBOARD LAMPS

Fig. 139 shows a special type of lamp used for switchboard signals, and also two of the glass caps or "bull's-eyes" that are used over the ends of the lamps.

These lamps are made very small in order to get them in the small spaces on the boards. The actual size is only about one-fourth that of the photo in this figure. The bulb is held in the two metal clips shown on the top and bottom, and these are separated at the base by a piece of hard insulation. The lamps are pushed into their sockets endwise, and these metal strips make the contacts to complete the lamp circuit. The forward end of the lamp is all that shows in the opening they are placed in.

The bull's-eyes are made in white and various other colors to indicate various circuit conditions.

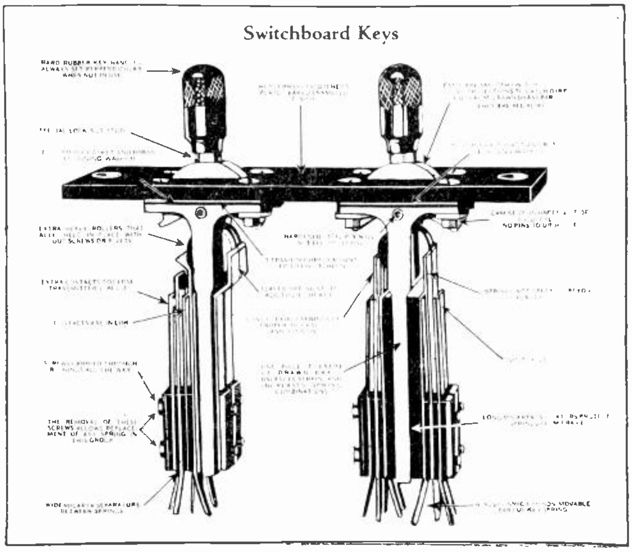

Fig. 138. Here we have an excellent view of two key switches, showing how the key levers and rollers operate the spring contacts, and open and close various circuits.

106. PLUGS

Fig. 140 shows a cord plug. These plugs can be made with two, three, or more separate metal elements for as many separate circuits through them. The plug tip at the extreme right end is part of a small metal rod which runs through the center of the plug to the left end, where the wires are attached. Around this is placed a tube of insulating material. Then another slightly larger, but shorter, metal sleeve is fitted over this. Still another tube of insulation, and a third metal element are often fitted over the first ones, and then an outer shell of insulation over the whole.

The several separate metal elements and ends of the black insulating sleeves can be seen in Fig. 140, which is an actual size view.

When these plugs are inserted in the jacks, the various jack springs make contact separately with each of the plug elements and circuits.

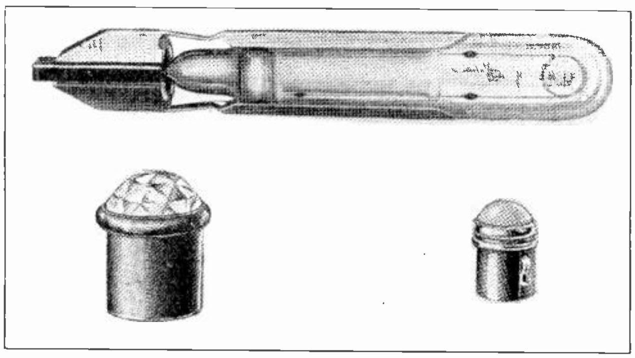

Fig. 139. The upper view shows one of the special telephone switchboard lamps, and below are shown two types of glass caps, or bull's-eyes used with such lamps.

107. JACKS AND DROPS

A complete jack, with the drop and drop magnet mounted above it, is shown in Fig. 141. This view clearly shows the jack thimble, contact springs, wire terminals, drop magnet, armature, and shutter. Examine the photo and printed description very carefully.

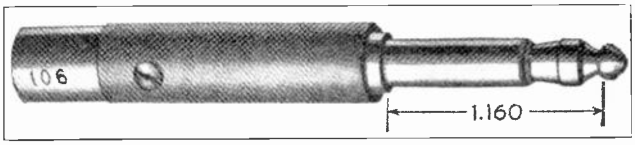

Fig. 140. Full-sized view of a switchboard plug showing how the several circuits are obtained through its tip and insulated sleeves.

Note that the armature to operate the drop is at the left end of the drop magnet, hinged at the top, and attached to a long lever arm which runs over the top of the magnet to the drop latch at the right end. This construction enables a very small movement of the armature to give a greater movement at the drop latch.

The plug would be inserted from the right in the thimble at the lower right-hand corner; and as it goes in, its tip and sleeve elements make contact with the spring shown. It forces some of the springs apart, opening certain circuits, and closes others from the springs to the cord wires.

Fig. 142 shows two diagrams of jack and drop circuits from opposite sides, one without the plug and one with the plug in.

In the upper diagram you will note that springs 3 and 4 are making contact, also springs 5 and 6. Springs 5 and 6 close a circuit from the line through the drop magnet.

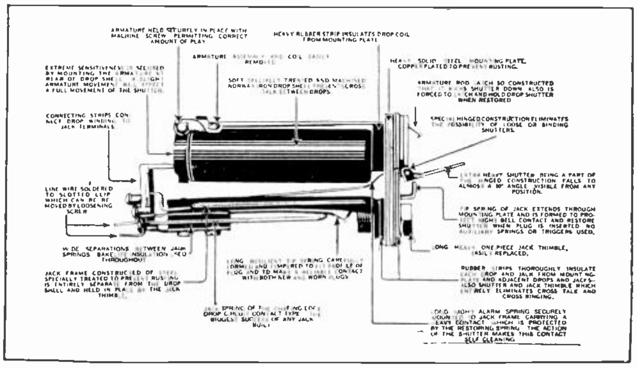

Fig. 141. This descriptive diagram shows the parts of a telephone jack and drop complete. Examine each part and its description very carefully.

In the lower view, showing the plug inserted, we find that springs 5 and 6 have been opened, breaking the circuit through the drop magnet, as it is not needed while the plug is in. Springs 3 and 4 are also opened. This is done by an insulating piece which is not shown here, but fastens 5 and 3 together mechanically, so the upward movement of 5 also forces 3 up. Springs 3 and 4 are not shown connected to any circuit in this illustration.

Referring again to the lower view, we find that the plug has a circuit to its tip and sleeve from spring 5 and thimble 7, thus making a circuit from the line to the cord wires.

108. SIMPLE SWITCHBOARD CONNECTIONS

A sectional view of part of a switchboard is shown in Fig 143. This shows the line connection to a simple jack and drop of the separated type; and also the plug, cord, and switch connections.

When an impulse comes in on the line, the drop magnet releases the shutter, the operator inserts one plug and closes her key to listening position. After receiving the number she inserts the other plug in the jack of the called line (not shown) and pushes key to ringing position, sending current from the board magneto to ring the called party. When this party answers, the talking current from the two lines flows through the jacks, plugs, cords, and key switch. When the conversation is finished, the plugs are pulled and dropped to their present positions in the diagram, the drop reset, and the key restored to normal position.

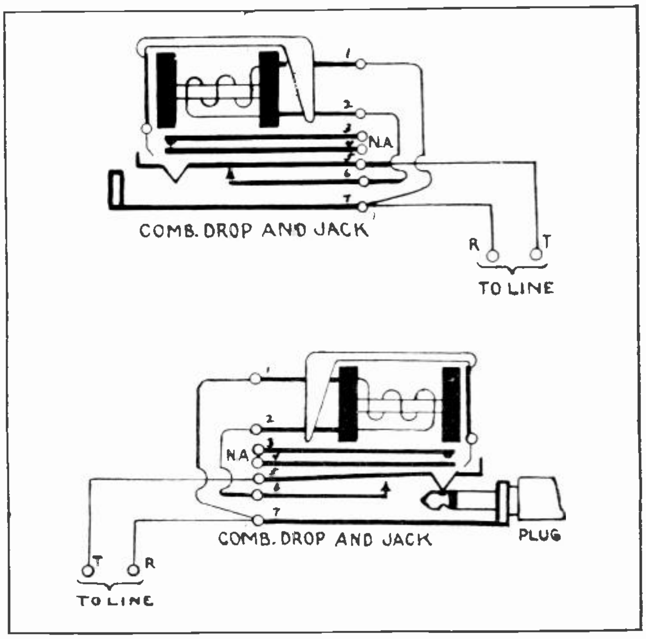

Fig. 142. The upper sketch shows the electrical connections and position of contact springs without the plug inserted. Below are shown the electrical circuit and position of springs with the plug in the jack.

Fig. 144 shows a switchboard with some of the cords in place in the jacks for conversations between various lines.

Many large switchboards use only the signal lamps to indicate an incoming call, and do not use the magnetic drops.

Fig. 145 shows two views of the inside and back of a manual switchboard. In the left view you can see the drop magnets in the upper section, a group of relays in the center, and the induction coils and part of the terminals below. At the extreme right of this view are shown the wires grouped or cabled along the side of the cabinet.

In the right-hand view the relay panel or "gate" is opened, showing the jacks and cords.

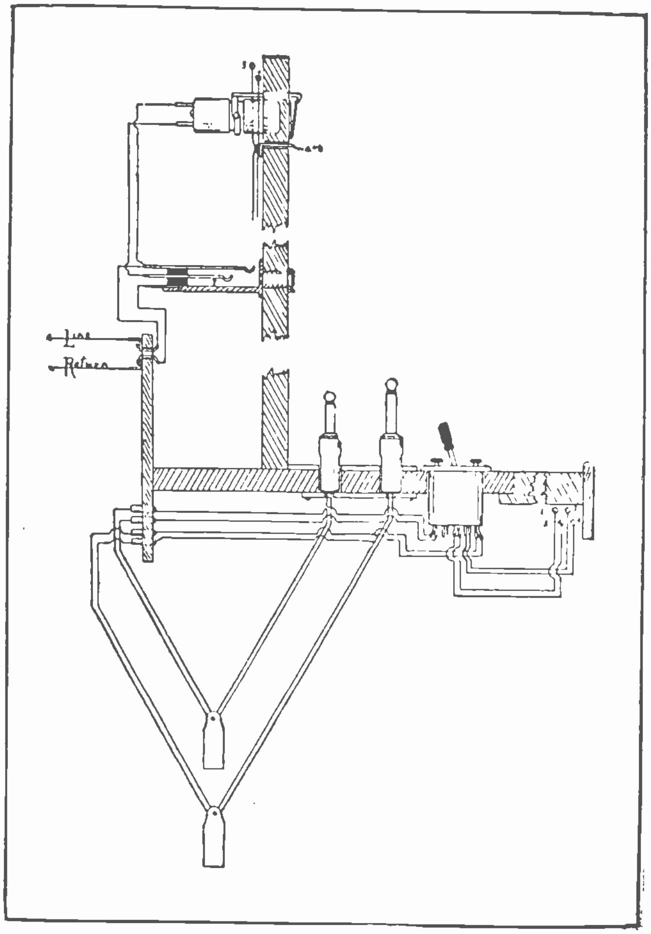

Fig. 143. This simple sketch shows the general operating principle of a manual switchboard.

Fig. 146 shows a small desk type switchboard for mounting on a table or desk in private offices, where an operator is to be able to call various people in the building.

Telephone wiring requires men who are expert in reading plans and making careful and accurate connections of the thousands of wires and devices used on the switchboards.

109. TELEPHONE RELAYS

The top photo in Fig. 147 shows a telephone relay. Its armature is at the right-hand end of the magnet, and is bent and hinged to the corner of the magnet frame. When the magnet attracts the lower end of the armature to the left, its upper horizontal portion moves upward at its left end, pushing the center contact springs upward. This causes them to break circuits with the lower contacts and make circuits with the upper ones. So you see that while these relays are constructed differently and are much smaller and more compact than the pony relays used in alarm and telegraph systems, still their operation and principles are much the same.

110. CABLES AND TERMINALS

The center photo in Fig. 147 shows a piece of lead-covered telephone cable with many paper-covered wires inside it, and covering of extra insulation between them and the lead sheath. Cables of this kind are very necessary to carry the vast numbers of wires in telephone systems.

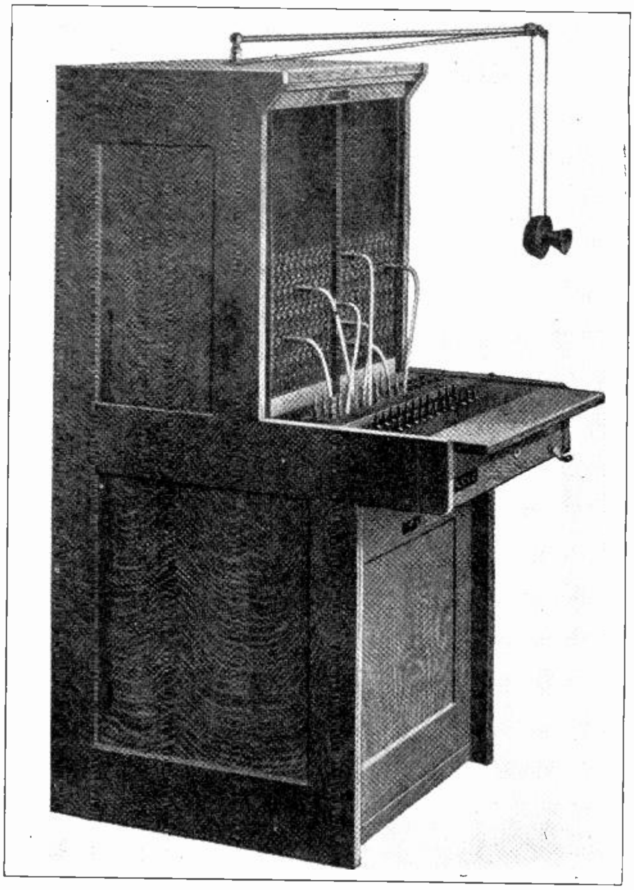

Fig. 144. Side view of a magneto type switchboard with some of the plugs in place in the various line jacks.

The lower view in the same figure shows a terminal block to which a number of wires can be neatly and conveniently connected. The wires from a cable can be soldered to the lower ends of the terminal strips, and the switchboard wires connected to the other ends by means of the small screws shown.

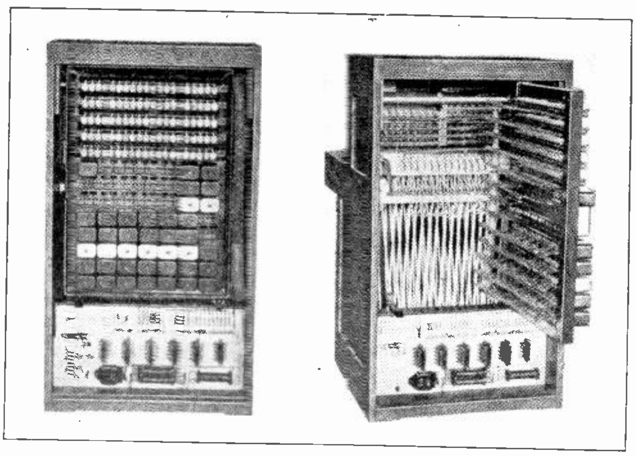

Fig. 145. These two views of the rear of a switchboard show the relays, drops, and cords very clearly. Note the neat and compact arrangement of all parts and wires.

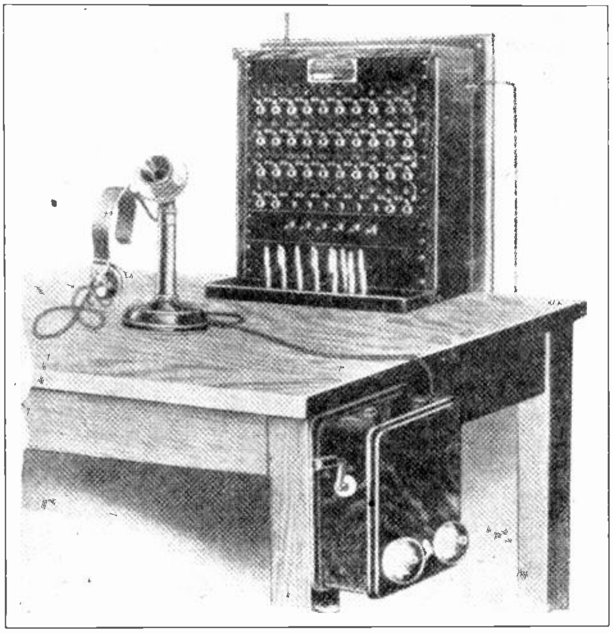

Fig. 146. Small desk type telephone exchange.

These terminal blocks greatly simplify the wiring and testing of telephone and switchboard circuits.

In wiring telephone switchboards, ground connections are also used to simplify much of the wiring. Metal strips and plates are used for common ground connections to the battery negative terminal. This eliminates a number of unnecessary wires.

Some exchanges also use a ground connection to earth for ringing their subscribers.

Fig. 147-D is a complete wiring diagram of a simple manual exchange showing just two subscribers' 'phones connected through the exchange. The different circuits are marked with different kinds of arrows and symbols.

Trace out carefully, one at a time, the transmitter and receiver circuits of the calling subscriber's

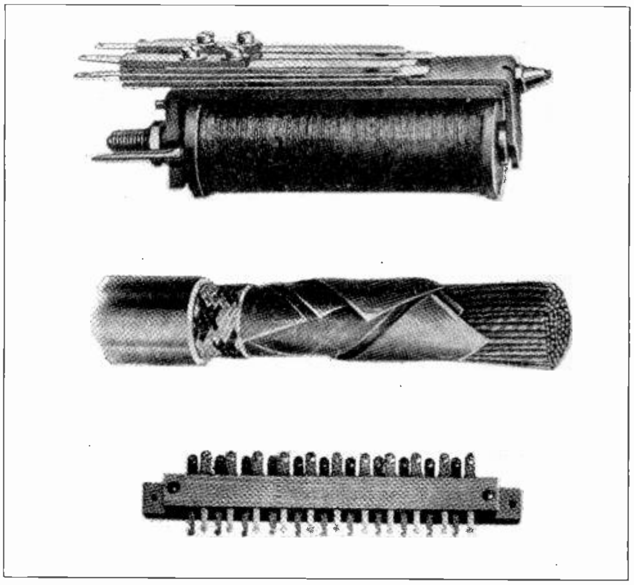

Fig. 147. The upper view shows a telephone relay. In the center is shown a section of telephone cable. Below is a group of terminal springs in a terminal block.

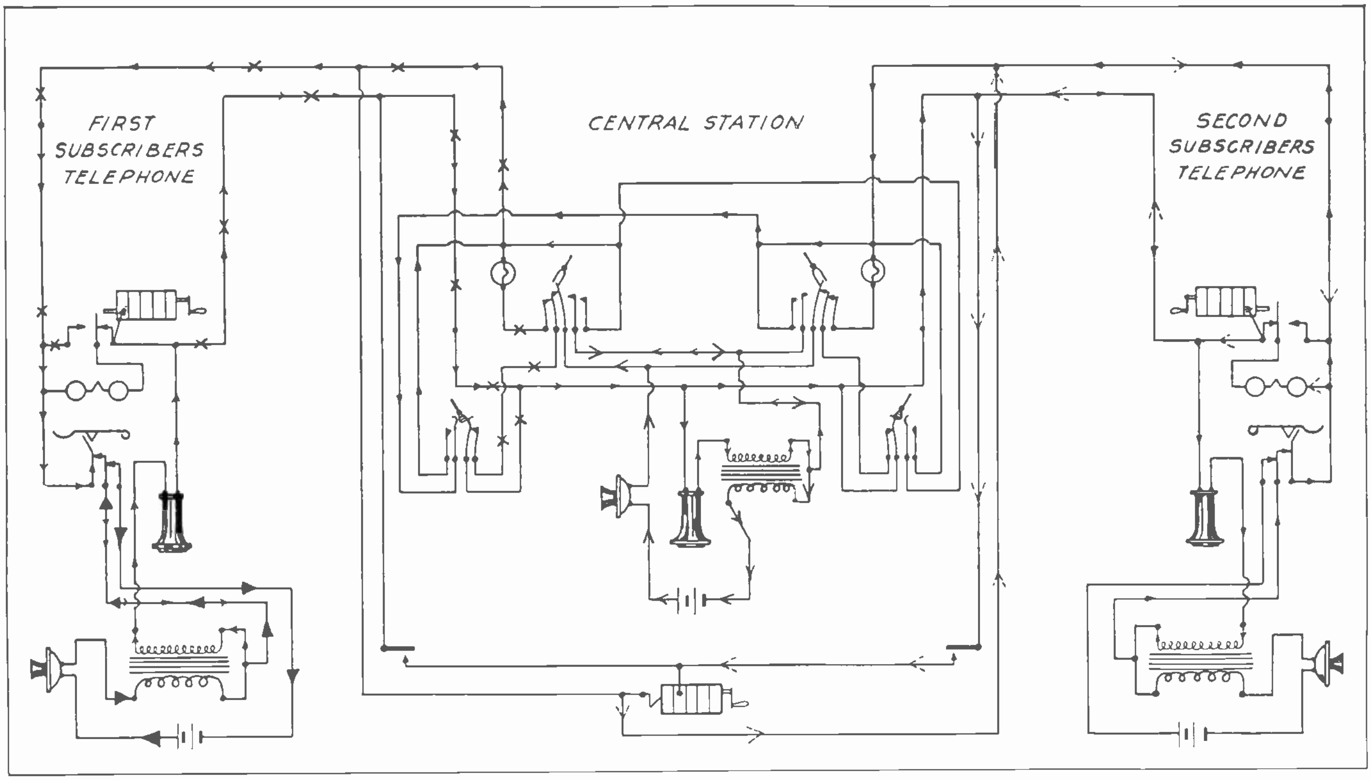

Fig. 147-D. Complete diagram of a simple telephone exchange with two subscribers' telephones connected. This will enable you to trace the talking and ringing circuits which are marked with different forms of arrows and symbols. Carefully tracing this diagram will help you to understand telephone exchange principles more fully.

'phone at the left, and through the exchange to the called subscriber's 'phone at the right. Also trace the operator's magneto and calling circuit to the called 'phone; and the operator's talking circuit. Note the positions the various keys must be in to get the different circuits closed, and in order to trace some of the circuits it will be necessary for you to imagine certain switches are closed to the opposite positions.

There are many other types of exchange circuits, and this simple one shown here is more typical of an army field telephone exchange, but is chosen because of its simplicity and just to give you a good idea of their general nature.

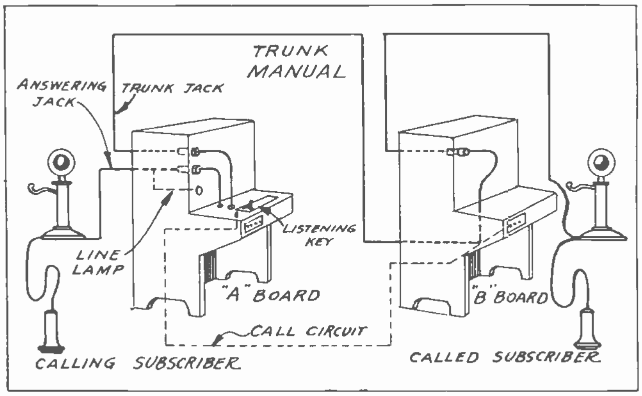

Fig. 147-E. Simple "one-line" diagram showing a telephone circuit through two exchanges and a trunk line.

Fig. 147-E is a simplified diagram showing how a call from one subscriber is routed through his local exchange over a trunk line to the distant exchange, and from there to the called subscriber.

This sketch is what is known as a one-line diagram, using only one line to trace the pairs of line wires actually used.

Fig. 147-F shows a photo of a large manual exchange switchboard in operation, and Fig. 147-G shows the rear of such board. Note the very neat and systematic arrangement of all parts and wires, which greatly simplifies the wiring and testing of such switchboards.

Fig. 147-F. This photograph shows a section of a large manual telephone exchange. Each operator controls a section of the board with its respective plugs and jacks.

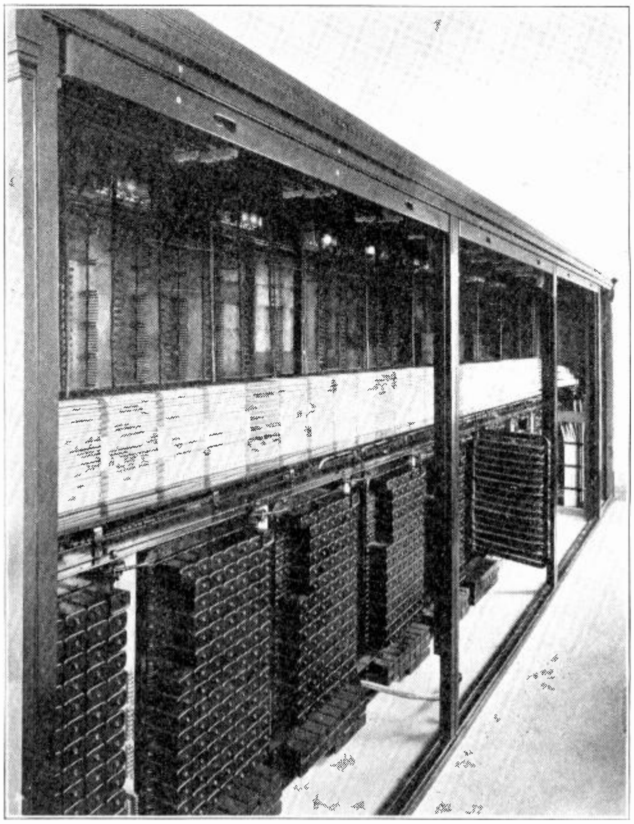

Fig. 147-G. Rear view of a central exchange switchboard of the type shown in Fig. 147-F. Note the very neat and compact manner in which all parts and wires are arranged to simplify connections and testing of such exchange units.

In apartment houses and offices, small telephone installations called inter-communicating systems are often used.

Any party of the group can call any other party by means of proper push buttons. There are separate push buttons and call circuits for each 'phone.

These systems are very useful and practical where the lines are not long and where the system is not large enough to pay to keep an operator.

Fig. 147-H shows the wiring diagram for three such 'phones. Trace out the talking and ringing circuits, and the operation of the system will be clearly understood. A, B, and C are groups of push buttons for calling the different 'phones. The numbers on each button contact indicate which 'phone it will call.

Fig. 147-I shows a photo diagram of five different styles of 'phones which can be obtained for such inter-communicating service.

Fig. 147-J shows two types of inter-communicating 'phones, one with the push buttons on a desk block, and the other having them on its base.

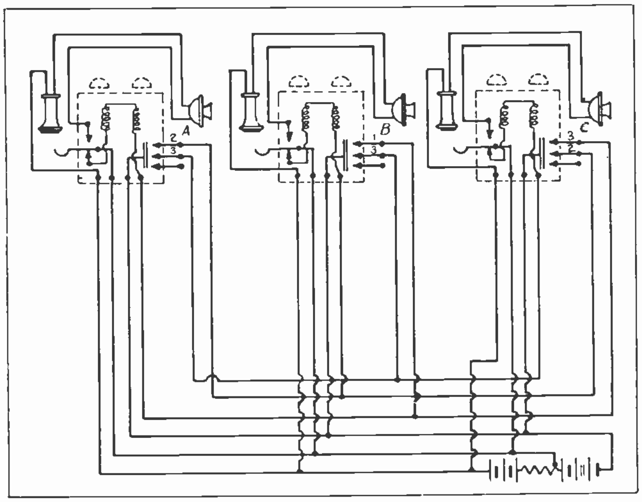

Fig. 147-H. Wiring diagram of three telephones on an inter-communicating system.

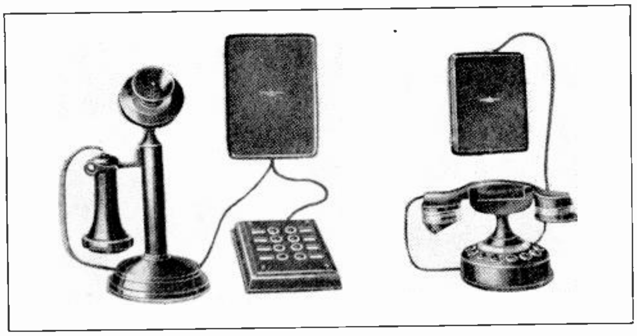

Fig. 147-J. Two types of inter-communicating telephones. The one on the right has the call buttons on the base of its stand.

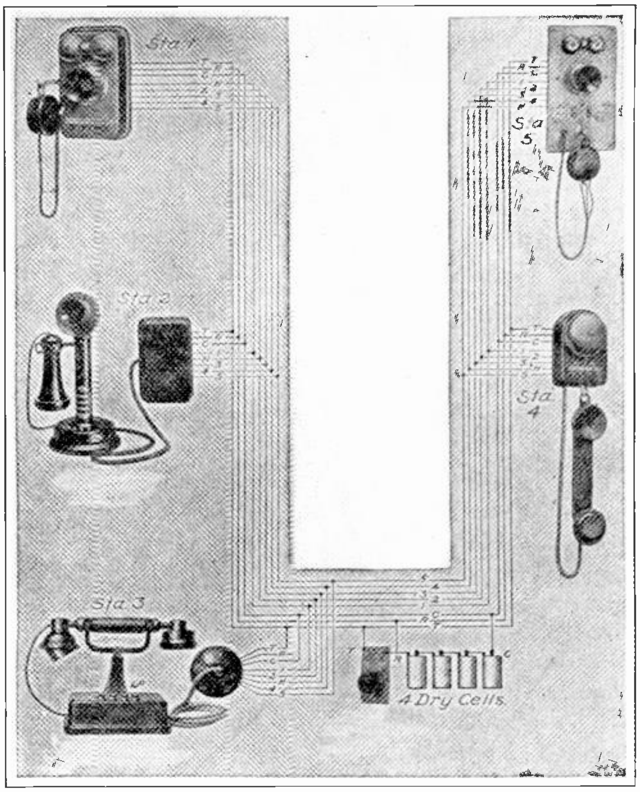

Fig. 147-I. Photo diagram of several types of inter-communicating telephones, showing their connections and batteries, and ringing and talking wires. Such telephone systems are commonly used to communicate with various offices in one building. No exchange or operator is needed, as each party is called by one of a number of push buttons.

AUTOMATIC TELEPHONES

Automatic exchanges do all switching, ringing, and signalling by means of electrical and mechanical devices, and eliminate the human operators. This not only saves the cost of labor of numerous employees, but accomplishes faster and more accurate operation. It provides much more complete privacy for telephone conversations, and, because it is purely electrical and mechanical, it doesn't make the errors caused by possible sleepiness or thoughtlessness of human operators.

The automatic telephone exchange is undoubtedly one of the greatest triumphs of telephone engineering, and they are rapidly replacing many of the largest manual exchanges in this country.

There are several different types of automatic telephone equipment, and most of them are still undergoing rapid changes in the processes of development and perfection. One of the most successful systems is called the "Strowger System", after the name of the man who developed it.

Complete automatic exchange circuits are very complicated, and would require a great deal more time and study than most students would care to spend on the subject, unless they were preparing to specialize in this work. The fundamental principles of this equipment, however, can be quite simply explained.

The following paragraphs are intended to give you a general understanding of them.

110. SIMPLE OPERATING PRINCIPLE

The Strowger System uses what is known as the "step by step" equipment. When the subscriber wishes to call a certain party, he dials the desired number with the dial on his own telephone. This dial in its rotation sends a number of impulses to magnets and relays at the exchange, causing them to move a selector element which picks out the desired line. Other parts of the mechanism then test the line to determine whether it is busy or not, and if it is clear an automatic switch starts ringing the called party.

111. DIALS, CONSTRUCTION, AND OPERATION.

The principle difference between a subscriber's 'phone to be used on an automatic exchange and those for manual systems is the dial. The transmitter, receiver, and other parts remaining fundamentally the same.

Fig. 148 shows an ordinary desk telephone, equipped with a dial for automatic operation. You will note that this dial has ten holes or finger openings, around the outer edge of the rotating part.

When this finger plate rests in the normal position, there is a number on a white stationary disk directly under each of these openings. Starting at the one on the right hand side, and reading counterclockwise, these numbers are 1, 2, 3, 4, 5, 6, 7, 8, 9 and 0.

When the subscriber wishes to dial or call party No. 246, he places his finger in the opening over No. 2, and pulls the dial around to the right until his finger strikes the **Stop Hook** shown at the bottom of the dial, and then releases it. He then places his finger in the opening over No. 4, and again pulls the dial around to the right until his finger is stopped by the hook. Once more the dial is released, and allowed to return to normal position. Then No. 6 is dialed in the same manner.

Each time the dial is rotated clockwise it catches and winds a helical spring inside the case, and a pawl secured to the rotating plate slides over the teeth of the ratchet on a combined ratchet and gear wheel. When the finger plate is released the spring causes it to return to normal position, and the pawl in this backward movement engages the ratchet and gear wheel, turning them back with it at a definite speed, a certain exact distance for each number dialed.

Fig. 148. Desk telephone equipped with dial for use on automatic exchange systems.

112. IMPULSE SPRINGS.

The rotating of this main gear drives a smaller gear or pinion at higher speed, and this pinion rotates an **Impulse Cam,** which rapidly opens and closes a set of contacts or **Impulse Springs.** By means of a worm wheel the pinion also rotates a small speed governor, which causes the gear and dial to turn at a definite speed. This, of course, is necessary to make the impulse springs open and close at regular intervals.

Fig. 149 is a sketch showing the various parts we have just mentioned. Examine this sketch closely, and observe how the main gear drives the pinion, impulse cam, and governor. In the lower right hand corner of the sketch another view of the cam and impulse springs is shown. The arrows indicate their position with respect to the other parts. This view of the governor shows quite clearly how it operates.

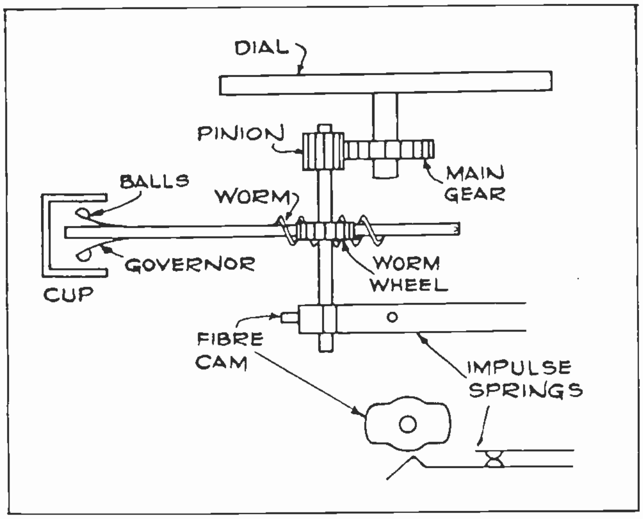

Fig. 149. This sketch shows the mechanism and operating principles of the dial and impulse springs.

If the governor shaft attempts to rotate too fast the small governor balls fly outward on their springs, due to centrifugal force, and rub the inside of the cup, thus retarding the speed of the mechanism.

Fig. 150 shows another view of this same mechanism, in which some parts can be seen a little more clearly than in Fig. 149.

Fig. 151 shows a photo of the complete dial mechanism. In this view you can get an excellent idea of the arrangement of the parts. In addition to the impulse springs at the left of the cam, you will also note an extra set of spring contacts called **"Shunt Springs".** These are used to temporarily short circuit the other parts of the telephone, during ringing operation. This is necessary because it would be difficult to send the ringing impulses through the resistance of these other parts.

These springs are operated by a small additional cam as soon as the dial is turned from the "off-normal" position. But they are opened as soon as

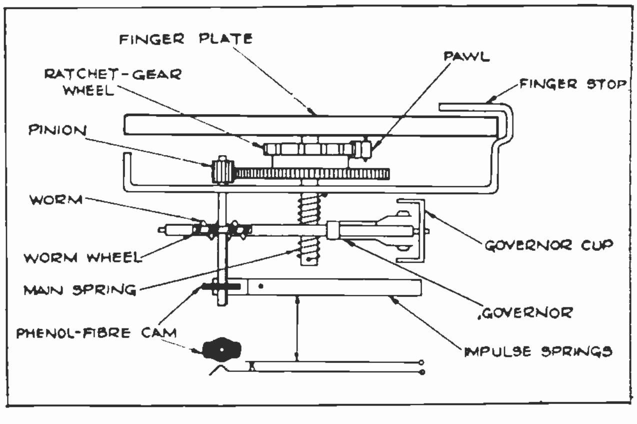

Fig. 150. Another view showing some parts of the dial mechanism more clearly.

the dial returns to normal. In addition to cutting out the resistance of the other telephone parts, these springs also prevent the clicking that would otherwise occur in the receiver during the operation of the dial.

The impulse cam revolves one-half revolution for each movement of one number on the dial, and as the cam has two projections it opens the impulse springs twice in each revolution. Thus, when we dial the number 8, the cam makes four revolutions, and opens the spring eight times. The dial is so set with a certain distance from the number 1 to the finger hook, that an extra one-half revolution is made each time any number is dialed. This will be explained later.

Fig. 152 shows a better view of the top of the dial, and its numbers.

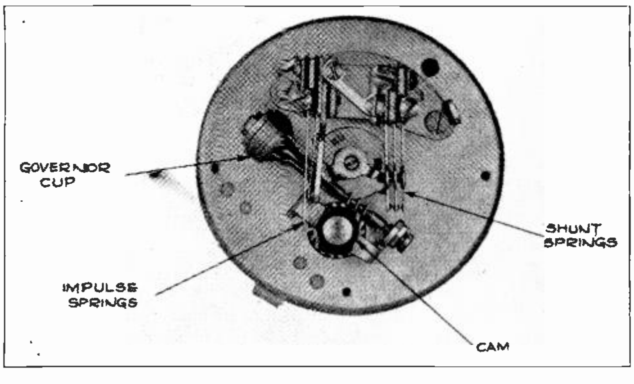

Fig. 151. This photograph shows an excellent view of the impulse springs and cam, shunt springs, and governor of a dial.

113. LINE BANKS AND "WIPER" CONTACTS.

The various groups of impulses, sent into the exchange by dialing different numbers, cause certain relays to energize as each impulse passes through them. These relays and magnets, as before stated, perform the switching and ringing operations.

In order to enable you to understand this equipment and these circuits more easily, let us first examine the arrangement of the various line terminals at the exchange.

For an exchange to handle 100 lines, the terminals of the lines would be arranged in a **Bank of Connectors** as shown in Fig. 153.

Fig. 152. Front view of dial, showing finger plate, holes, numbers and finger stop.

In order to eliminate unnecessary wires and simplify this figure only two telephones, Nos. 14 and 33, are shown connected to the bank at present. At first glance the arrangement of the line numbers in this connector bank may seem peculiar, but suppose some automatic device was to move the **Wipers** of the calling telephone step by step, up into this bank and select a certain line, say No. 14.

One step upward would bring the wipers in line with the lower row of connectors. Then four steps to the right would bring them in contact with No. 14. Dialing the numbers 1 and 4 would have accomplished this.

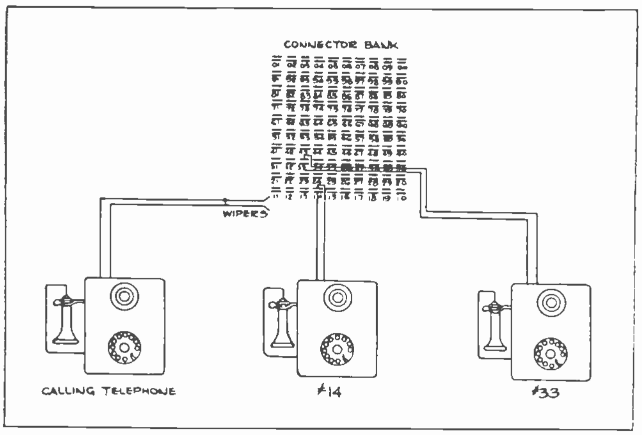

Fig. 153. Simple sketch showing the arrangement and principle of the connector bank of an automatic exchange.

Then suppose we dial the number 33. The first three impulses sent in by the dial would cause the switching magnet to lift the wiper three steps, bringing it in line with the third row of contacts from the bottom. The next three impulses received would cause the wipers to make three steps to the right, and engage line No. 33.

So we find that these numbers are arranged as they are, for convenience and simplicity in the operation of the mechanical selector.

This figure gives us some idea of the arrangement of the various lines and the connector bank at the exchange.

114. WIPER SHAFT AND SELECTOR MECHANISM.

Fig. 154 shows a sketch of the wipers attached to the shaft which raises and rotates them step by step. It also shows the **Vertical Magnets**—V. M., and the **Rotary Magnets**—R. M., which lift and rotate the shaft step by step.

By means of a special relay in the exchange circuit the first impulses which are sent in by the dial come to the lifting magnets, and the next group of impulses are switched to the rotary magnets.

Fig. 155 shows photos of both sides of one of these selector units.

Figs. 154 and 155 should be referred to while tracing out the circuit diagram in 156.

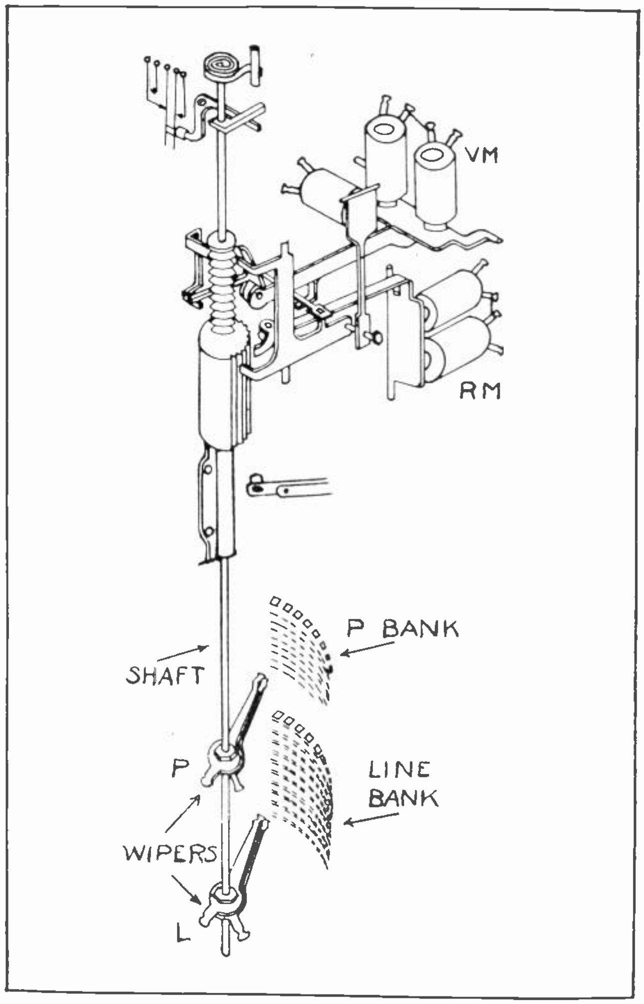

Fig. 154. This diagram shows the arrangement of the selector mechanism with its vertical magnets, rotary magnets, wipers, and wiper shaft.

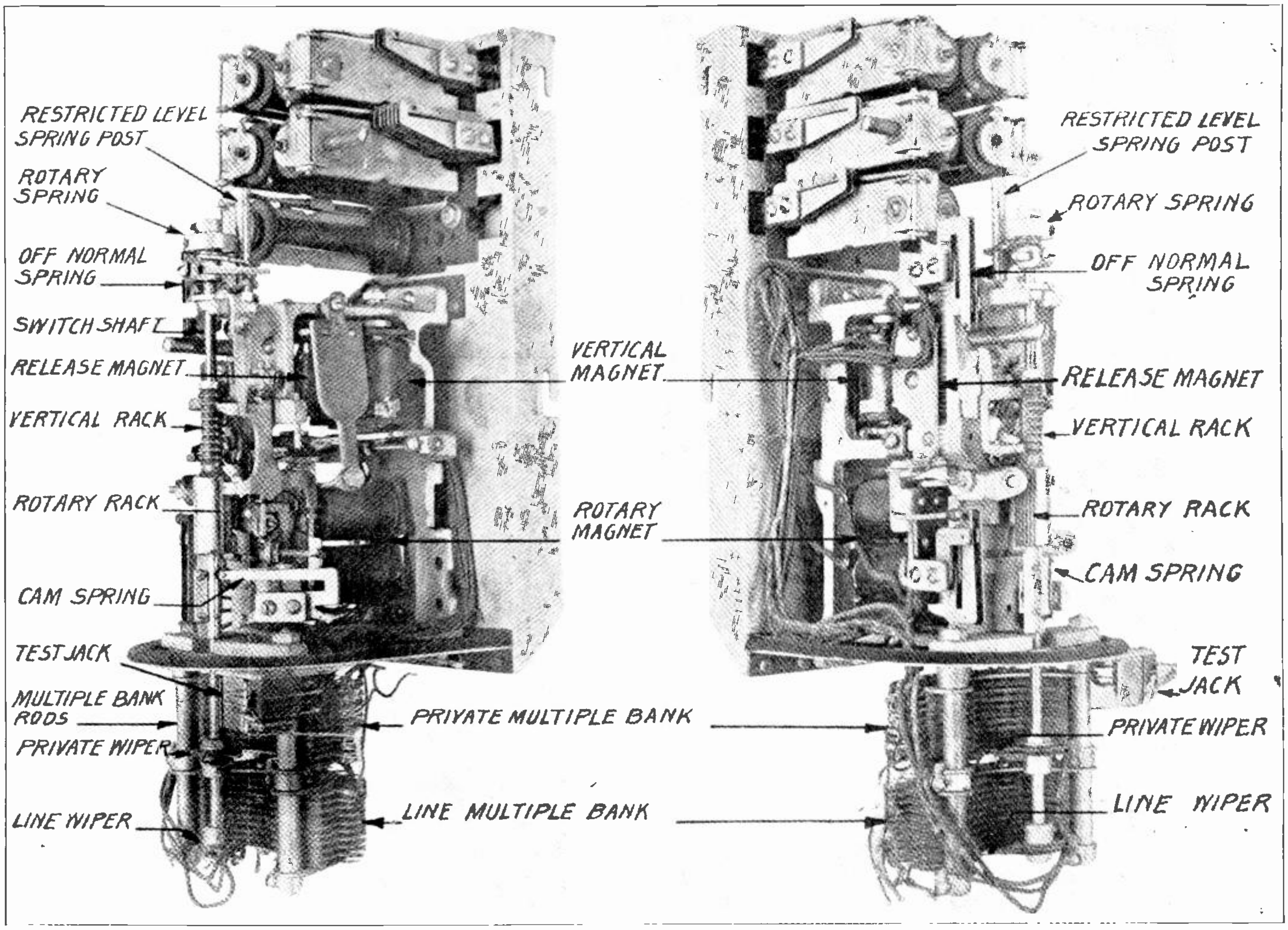

Fig. 155. Two photographs showing front and opposite sides of a complete selector unit. Note the relays above; vertical and rotary magnets, wiper shaft and rack in the center; and the connector banks below.

At the top of each unit in Fig. 155 are the relays which perform different switching operations in the exchange circuit. Underneath these are the vertical magnets or lifting magnets, and below are the rotary magnets.

On the shaft are two sets of notches called the **Vertical Rack** and **Rotary Rack** respectively. These are engaged by the hooks which are operated by the lifting and rotary magnets.

After the selector has completed a connection to a certain line, and the conversation is finished, then, when the subscriber hangs up his receiver, it closes a circuit to the **Release Magnet**, which trips the locking mechanism, allowing the wipers and shaft to return to normal position by the action of a spring and gravity.

115. SIMPLIFIED CIRCUIT OF IMPORTANT PARTS.

In Fig. 156 is shown quite a complete diagram of the more important circuits of the automatic exchange.

It is not at all necessary for every student to trace and understand this diagram at present, but it provides excellent circuit tracing practice, and if you are sufficiently interested in the principles of automatic telephones, or should later decide to prepare to specialize in this field, this simplified circuit should be of great help to you in obtaining an understanding of the most important parts.

In order to trace a circuit of this kind, it is necessary to do it step by step, and very carefully. If this method is followed, it will be found very interesting, and not nearly as difficult as it first appears.

This diagram shows a complete connection between a calling telephone, the automatic exchange, and the called telephone. Each circuit is traced with different types of arrows to make it easier to follow them.

The equipment in the calling phone consists of an ordinary transmitter, receiver, bell, condenser, and switch hook; and in addition to these, the impulse springs, and shunt springs used with the dial telephone.

As soon as the receiver is lifted from the hook, the hook switch will close the circuit, shown by the small solid arrows, from the positive terminal of battery No. 2, through the top winding of relay "L". Then through the shunt switch, impulse

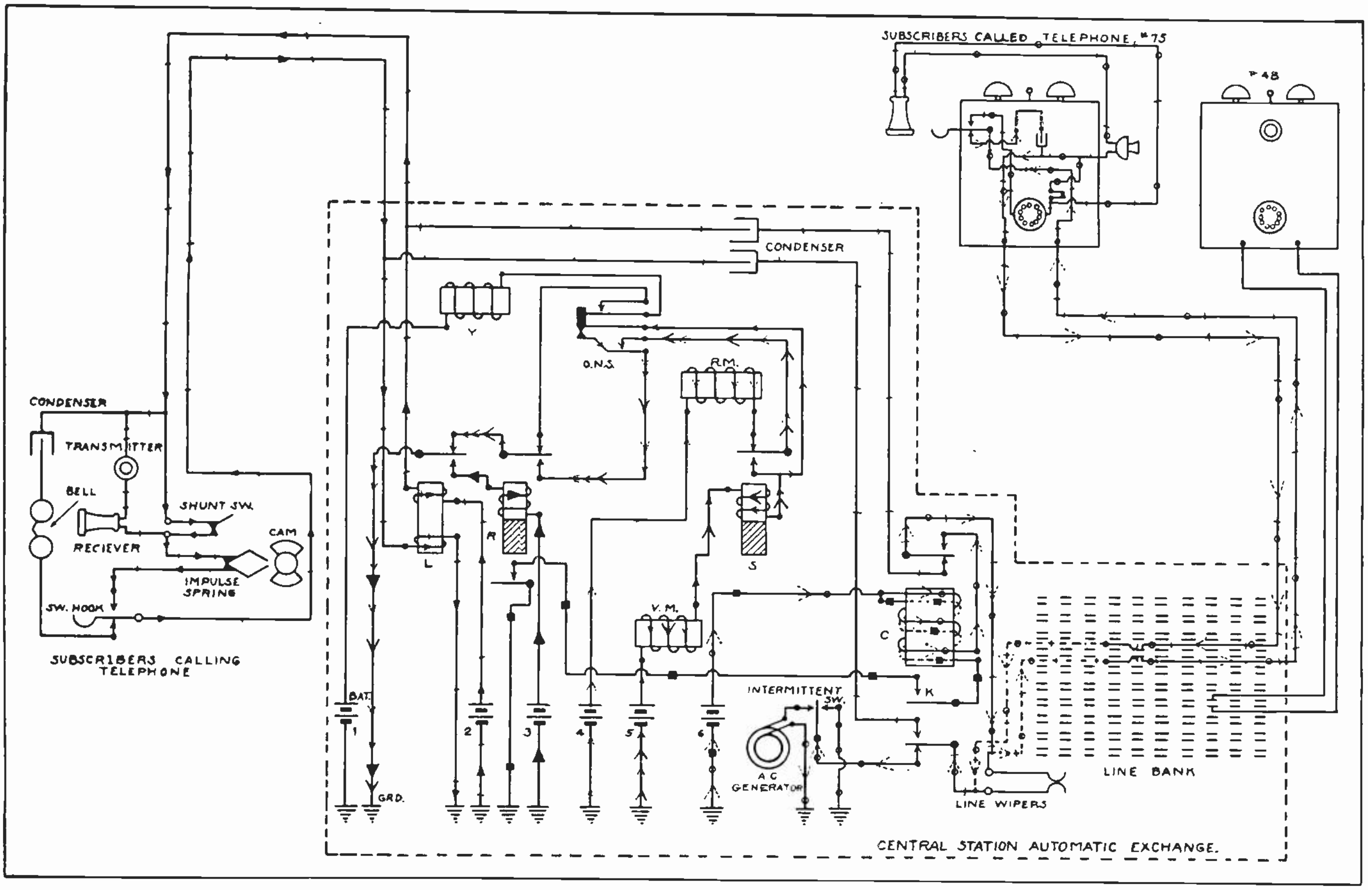

Fig. 156. Complete simplified diagram showing the wiring and operating principle of the fundamental parts of an automatic telephone exchange. Trace this circuit very carefully with the complete instructions given in these pages.

springs, and top contact of the hook switch at caller's 'phone, back through the lower winding of relay "L", and to ground.

You will note that the ground connections in this circuit are returned to negative of the batteries, so when starting to trace a circuit from any battery, as soon as this circuit is completed back to ground, you will know it has returned to negative of the battery.

To simplify this circuit a number of separate batteries are shown.

These current impulses in the circuit we have just traced, will cause relay "L" to become energized and attract its armature. When this armature is pulled down it closes a circuit shown by the large solid arrows from the positive of battery No. 3, through the coil of relay "R", "make" contact of relay "L", and to ground, which completes this circuit.

The term "make contact" is used here, meaning the contacts made when the relay is energized and the armature attracted. The term "break contact" when used, means the contacts that are closed when the relay is de-energized. In other words, the contacts made when the armature is attracted are referred to as "make contacts". Those made when the armature is released are called "break contacts".

When the circuit just traced through relay "R" is completed this relay becomes energized and attracts its armature. So we find that both relays "L" and "R" became energized merely by the subscriber removing his receiver from the hook.

Now, assume that he dials the figure 1. When the dial is released, and as it returns to normal, the cam is rotated one-half turn, and opens the impulse spring once. This momentarily opens the circuit of the line relay "L", which is de-energized for an instant, and its contacts open the circuit of release relay "R".

However, relay "R" remains energized through this short period even though its circuit was momentarily opened. This is because it is a **Slow Acting** relay, and does not release its armature the instant the current is interrupted, but holds it for about a second afterward. This will be explained later.

If the calling subscriber now dials the number 7, opening the impulse springs seven times, the circuit of relay "L" will be broken each time, and allow its armature to release momentarily seven times. Each time it releases, the circuit of relay "R" is broken for an instant, but relay "R" acts too slowly to de-energize and release its armature during these periods, so it remains closed throughout the seven short interruptions of its circuit. But something else did happen.

Keeping in mind that the armature of relay "R" is now attracted to the "make contact", we find that the first time the armature of relay "L" was released it closed a circuit shown by the small open arrows from the positive of battery No. 5 through the vertical magnet, V.M., through relay "S", "break contact" of O.N.S., "make contact" of relay "R", "break contact" of relay "L", and to ground.

The letters "O. N. S." stand for **Off Normal Switch,** which will be explained later.

This circuit we have just traced energizes both the vertical magnet and relay "S". Relay "S", being another slow acting relay, will retain its armature in an attracted position during current interruptions of a fraction of a second.

The second time the armature of relay "L" was released it allowed current to flow, as shown by the large open arrows, from positive of battery No. 5 through vertical magnet and relay "S" again, then through the "make contact" of relay "S," "make contact" of the off normal switch, "make contact" of Relay "R," "break contact" of relay "L," and to ground.

The off normal switch is operated by the line wiper shaft as soon as it moves from off normal position. So as soon as the dialing operation is started, the first movement of this shaft closes certain contacts and circuits, but when the shaft is dropped and allowed to fall back to normal, it again opens these circuits.

Shortly after the last impulse of current has passed through the relay "S" it will de-energize and cannot again become energized, because the circuit has been opened at the off normal springs. Each of the seven impulses passing through the vertical magnet causes it to raise the wiper shaft one step, so the line wiper will now rest in line with the seventh row of line bank contacts.

Now we are ready for the subscriber to dial the second number. Let's assume that he dials No. 5. This again rapidly opens the line circuit five times, causing the line relay "L" to release momentarily the same number of times. Each time relay "L" is de-energized, now since the off normal switch is opened, a circuit can be traced as shown by the small dotted arrows from the positive of battery No. 4, through the rotary magnet R. M., break springs of relay "S," "make contact" of off normal springs, "make contact" of relay "R," "break contact" of relay "L," and to ground.

These impulses in this circuit will cause the rotary magnet to become energized each time and rotate the wiper shaft, carrying the wipers five steps to the right. This brings them in contact with No. 75 of the line bank, as indicated in the diagram.

The dotted lines from the normal position of the line wipers show the upward movement of the shaft caused by the vertical magnet, and the rotating movement to the right caused by the rotary magnet; and they show the circuit which will now be completed to the called subscriber's telephone.

As soon as the line wipers are in contact with No. 75 in the bank a circuit is completed through the bell of the called telephone. This circuit can be traced (backwards) by the large dotted arrows from the top brush of the generator, through **Intermittent Ringing Switch,** "break contacts" of relay "C", lower switch spring and lower contact No. 75 on the bank, "make contact" of hook switch, bell and condenser, then back to the upper contact in the bank and upper wiper spring, on through the top "break contact" of relay "C", low resistance winding of relay "C", through battery No. 6, to ground.

This is a long circuit to trace and should be gone over again until you have it well in mind.

You will note that relay "C" has two windings, one of low resistance and the other a high resistance coil of many more turns. The low resistance coil is to receive a heavy current impulse to first attract the relay armature, then the high resistance locking coil will hold the armature attracted with less current.

The current from the generator is A. C. and will not energize the coil of relay "C." The intermittent switch at the generator keeps making and breaking the circuit at regular intervals, so the called subscriber's bell rings for short, repeated periods and not continuously.

This flow of alternating current through battery No. 6 to ground does no particular harm to the battery. We will remember from an earlier article that the alternating current will pass through the condenser at the bell, but this same condenser will not allow direct current to pass. As soon as the called subscriber lifts his receiver off the hook a flow of direct current from battery No. 6, and traced by the round dots, passes over the same circuit we have just traced to the bell, except that the bell is now cut out by the hook switch, and the transmitter is placed across the line.

Trace this carefully by following the round dots. This flow of direct current will now energize the low resistance winding of relay "C," closing contact "K," which acts quickly before any of the other contacts of this relay can move, thus closing a lock circuit in which current flows from the positive of battery No. 6 through the high resistance winding of "C," lower "make contact" of relay "C," "make contact" of relay "R," and to ground. This circuit is traced by the square dots.

With relay "C" fully operated, the talking circuit is now complete through both telephones. This circuit can be traced by the short dashes across the line.

Now, when the calling subscriber hangs up his receiver and breaks the circuit through the line relay "L," it in turn releases and breaks the circuit through relay "R," which, after an instant of delay because of its slow action, releases its upper armature and makes the circuit from battery No. 1 through the release magnet "Y," "make contact" of off normal spring, "break contact" of relay "R," "break contact" of relay "L," and to ground.

This circuit will energize the release magnet "Y," which trips the wiper shaft, allowing it to fall back to normal position. This action interrupts the circuit of release magnet "Y," because the dropping of the wiper shaft opens the "make contact" of the off normal spring.

When relay "R" was de-energized it also opened the high resistance locking circuit of relay "C," allowing its contact to move back to normal position.

Telephone No. 48 merely shows where another telephone of this number would be connected in the back. It is not expected that you will perfectly understand all of this diagram the first time you trace it through, as it is rather complicated and one which requires even an experienced man some time to absorb. But if you are interested enough in this branch of work to trace each step of the operation through this circuit several times it will not only be excellent practice, but will give you a good understanding of the fundamental principle and more important parts of this type of automatic telephone.

There are a number of other auxiliary relays and contacts used with this equipment in larger exchanges where it is necessary to have a number of line banks from which to select.

There is also an added mechanism which automatically tests out any line before completing the calling circuit. If that particular line is busy at that instant, this relay will close a circuit which gives an intermittent buzzing note to the calling subscriber, indicating that the line he desires is busy.

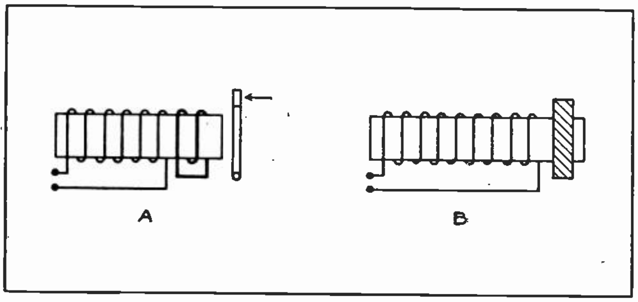

Fig. 157. Two types of slow acting relays. The one on the left has a short-circuited coil of a few turns, and the one on the right has a large copper ring around the end of the core.

116. SLOW ACTING RELAYS

The slow acting relays used with these automatic telephones are very interesting devices. In addition to the regular winding on the core there is also a heavy ring of solid copper placed around the core end. Or, in some cases, just a short-circuited winding of a few turns. This copper sleeve, as it is called, acts as a single turn secondary winding.

When the current is interrupted in the main coil of the relay its collapsing flux induces a rather heavy current in this copper ring. The extremely low resistance of this ring circuit allows the current flow to continue with infinitely small voltage, and as long as there is any flux left from the decreasing current, both in the main coil and in the ring itself.

This persisting flow of current in the ring develops enough magnetism in the core to cause it to retain its armature a little longer. Thus we get the terms "slow acting" relay.

By changing the size of these copper rings, or the number of turns when a shorted coil is used, we can vary the amount of time the relay will delay its action from a very small fraction of a second to one or more seconds.

Fig. 157 shows two sketches of relays of this type. The one at "A" uses a short-circuited coil. The one at "B" uses a copper ring.

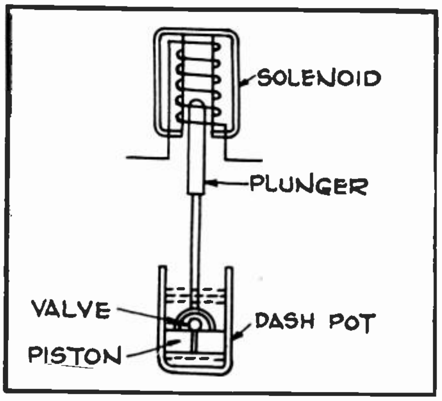

Fig. 158. This sketch shows the use of a dash-pot to slow the action of solenoids and electro-magnets.

Some relays have what is called a "dash-pot" attached to their armature to slow its action. These dash-pots may consist of a plunger in a cylinder filled with oil or air which only allows the plunger to move rather slowly as the oil or air escapes past the edges or through the small opening in the plunger.

Fig. 158 shows a relay equipped with such a dash-pot.

Various selective circuits can be arranged in automatic telephone systems by the use of condensers and choke coils of different sizes.

A condenser placed in the circuit of certain relays will only allow alternating current to pass through and stops all flow of direct current. A choke coil, however, will allow direct current to pass rather freely, but quite effectively blocks the flow of alternating current.

Many of the telephones being installed nowadays for use with manual exchanges are also equipped with a place to mount the dial, because in many localities it is expected that the automatic exchange will replace the manual in a short time.

Fig. 159 shows a very convenient, modern type of desk telephone. With this telephone the receiver and transmitter are both mounted on one handle, so the subscriber doesn't have to move a transmitter stand close to his mouth to carry on a conversation. This receiver and transmitter, when not in use, are laid in a "cradle" which has a small strip in the bottom that is attached to a spring in the stand. This operates a hook switch each time the receiver is removed from or replaced in the "cradle."

Fig. 159. Modern desk type telephone equipped with dial for automatic operation.

Fig. 160 shows a room in an automatic telephone exchange. At the right can be seen a long bank of selectors with white covers over their mechanisms.

Fig. 161 shows a view in another exchange with a switchboard at the left, selector banks in the rear, and a motor generator for supplying the talking and ringing current at the right.

117. TELEPHONE LINES

The operation of the millions of telephones in this country today requires a vast network of telephone lines. These lines can be divided into two general classes—the small individual or party lines which connect one telephone or a small group of telephones to the central exchange, and main lines, or **Trunk** lines, as they are called, which connect from one exchange to another.

The individual or party lines, of course, are only in use when the subscribers whose telephones are on them are talking.

The trunk lines, however, carry the main business between exchanges and large towns, and are kept busy the greater portion of the time. These trunk lines might be called the arteries of the telephone system and are fed by the smaller branch lines from each exchange.

118. GROUND CIRCUITS. CABLES

Some telephone lines are made up of two insulated wires for each circuit and known as metallic circuits. Other lines use one insulated wire on the poles, and the other side of the circuit is completed through earth by carefully made ground connections. Some lines which use a two-wire or metallic talking circuit use a ground circuit for ringing.

Telephone line wires are usually bare and without any insulation except the small glass insulators which support them on the poles. Under normal conditions this is sufficient insulation, because they do not operate at high voltages. Many telephone lines use galvanized steel wire and some use copper wires. Most all of us have seen trunk lines following highways or railroads from one town to another and with their hundreds of wires on numerous cross arms on the poles. This type of line is being replaced in many localities by the more compact telephone cables.

The large masses of open wires on the older lines offer a great deal of wind resistance and accumulate enormous loads of sleet at certain times of the year. This has a tendency to break down poles and disable the lines, making them very costly to keep in repair. Where cables are used, one lead sheath about 2 to 3 inches in diameter may carry from 500 to 1,200 pairs of small wires. These individual wires are all insulated from each other with proper wrappings and the entire cable insulated from the lead with an additional wrapping. Such cables are very heavy and not strong enough to support their own weight between long spans. Therefore, they are usually supported by what is called a **"Messenger"** cable made of stranded steel wires, and to which the lead cable is attached at frequent intervals by means of hooks or wire supports.

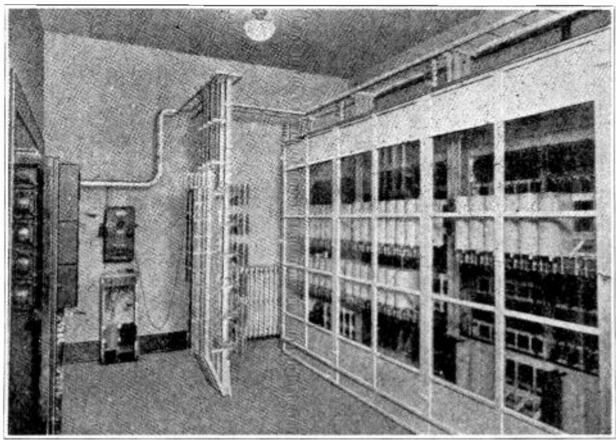

Fig. 160. This photograph shows a view of the selector units in an automatic telephone exchange.

The lead sheath protects the wires from moisture and injury, and cables of this type can be run underground in cities, as well as overhead on poles across the country. In connecting or repairing such cables the small wires are spliced separately, soldered, and carefully reinsulated with sleeves of paper or other insulation over the splice. The numerous splices are often staggered or made a few inches apart to prevent too large a bulge in the cable at the joints.

When the wires are all spliced, a large lead sleeve, which has been previously slipped over the cable, is then slid over the splice and sealed in place with hot lead, similar to a "wiped" joint in lead piping.

The entire splice is then dried out by pouring hot parafin through it and finally filled with parafin or other insulating compound, and the small filler hole in the lead sleeve is then sealed tightly.

All moisture must be kept from the inside of such cables and splices.

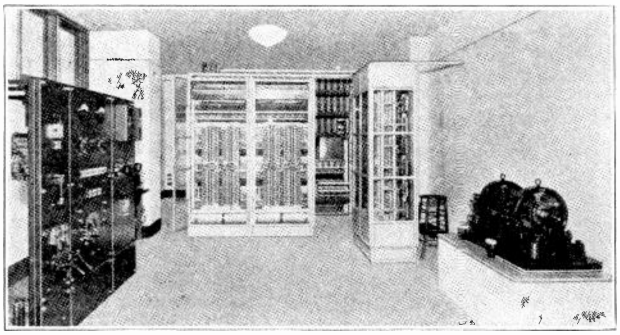

Fig. 161. Here we have another view of an automatic exchange showing the switching units in the background, power switchboard on the left, and motor generator on the right.

119. LIGHTNING PROTECTION AND TRANSPOSITION

Where open wire lines are used, it is customary to run lightning ground wires from the top of certain poles along the line down to an earth ground at the bottom of the pole. These wires serve as small lightning rods to drain severe static charges and lightning from the telephone line. Small lightning arresters are often used at the 'phones on rural party lines to ground any lightning charges and prevent damage to telephones and property.

Where telephone lines run parallel to power lines they often pick up, by magnetic induction, an interfering hum. To avoid this, the pairs of wires should occasionally be crossed into opposite positions on the poles or cross arms, so that one wire will not be closest to the transmission line throughout its entire length.

This crossing of wires to prevent induced interference is known as transposition. Sometimes it is also done to avoid "cross-talk" or induction from other telephone wires.

Transposing the wires frequently and evenly will balance out most of this induction. Telephone lines should never be left close enough to high voltage power lines so that there would be danger of them coming in contact with each other, for in case they did people using the telephone lines might be injured.

Satisfactory telephone operation depends to quite an extent on proper line construction. Therefore, all telephone lines should be made with the proper materials and the wires properly spliced with low resistance joints, ground connections kept in good condition, etc.

120. PHANTOM CIRCUITS

Considerable economy and saving of wire can be effected in telephone line construction by the use of what are known as **"Phantom"** circuits. By this method one additional circuit can be obtained for each pair of lines already in existence. This can be done without the addition of any other wires, merely by using two existing lines, one to form each side of the new line or phantom circuit.

By the use of proper induction coils, or **Repeater Coils,** as they are called, a conversation can be carried on over this phantom line without interfering with either of the two actual lines. A repeater coil is simply a transformer with primary and secondary windings of an equal number of turns.

Fig. 162 shows the manner in which a phantom circuit is obtained from two metallic circuits. Lines No. 1 and 2 are ordinary metallic lines or physical circuits using repeater coils to transfer the current impulses from the transmitter circuits to the lines. Line No. 3 is a phantom circuit obtained by connection of its coil to the exact center of each of the others on lines 1 and 2. With this connection the current in line 3 can divide equally through each of the other lines or pairs of wires and, therefore, does not interfere with their talking currents at all.

With four metallic circuits we can obtain two phantom circuits directly, and then a third phantom circuit between the first two, so we find that where a considerable number of trunk lines are run from point to point a large number of phantom circuits can be arranged to use the same lines.

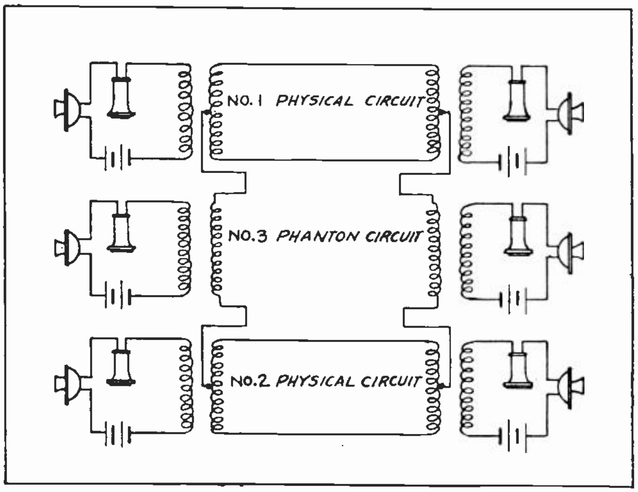

Fig. 162. Elementary sketch showing how a phantom circuit is obtained from two metallic or physical circuits.

This practice is also followed in telegraph work.

Telephone lines, if used on trunk circuits and special radio station wires, are constructed with a carefully determined amount of resistance. Special resistance and impedance coils are placed in the circuit of such lines to make them most efficient in the handling of certain frequencies set up by voices or musical notes. This principle will be more fully explained in a later section on radio.

Operators of radio broadcasting stations frequently lease wires from the telephone companies to use in picking up and transmitting certain news or entertainment features at quite a distance from a broadcasting station. Telephone systems are becoming more and more linked up with radio stations, not only for amusement programs, but for the trans-oceanic and commercial conversations as well.

121. TELEPHONE TROUBLES

Faults and troubles arising in telephones or telephone exchanges can usually be located by the same general methods of systematic testing that have been covered in connection with other signal circuits. A diagram of the wiring and connections is always of the greatest help in testing any telephone circuit.

Some of the more common telephone troubles which occur in the separate parts, such as transmitter, receiver, hook switch, etc., have already been mentioned. Other likely places to look for faults are at the spring contacts of key switches and relays, which may have become burned, dirty, or bent out of shape; wire terminals, which may have become corroded or loose on the binding screws; weak batteries, weak magneto magnets, weak receiver magnets, etc.

Telephone circuits and devices can often be tested very conveniently with a telephone receiver, as well as with test lamps and buzzers. The receiver can be used to determine if the talking current is coming through to certain circuits, and also to determine whether high resistance circuits are completed or not, by the clicks which should be heard in the receiver when its terminals are touched to any line circuit.

Careful application of your knowledge of the principles of fundamental telephone parts and circuits and methods of systematic trouble shooting should enable you to locate most any of the ordinary troubles in telephone equipment.

Don't forget that a thorough understanding of the material covered in this section on telephones will be of great help to you in any line of electrical work, and particularly in radio, if you should follow this branch at any time.