TELEPHONY

INCLUDING

AUTOMATIC SWITCHING

SMITH

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TELEPHONY

INCLUDING

Automatic Switching

Telephonic Speech Transmission. The Telephone Exchange. Automatic Switching. Multi-Office and Large City Systems. Private Exchange. Testing and Adjustment.

BY

ARTHUR BESSEY SMITH

Electrical Engineer

ILLUSTRATED

TK 6162 S65

CHICAGO

FREDERICK J. DRAKE & CO.

PUBLISHERS

125341

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Printed in the U. S. A.



PREFACE

The widespread interest in the telephone and the usefulness of viewing the art from more than one standpoint are sufficient reasons for the appearance of this book.

The telephone world of these days is laying great stress on automatic switching. Like other industries, telephony has varied its point of emphasis from time to time. Once it was the achievement of speech transmission, then it was the manual switchboard. Once it was wires and cables, then it was the multi-office exchange.

The present interest in automatic switching is due to the period of economic refinement, which calls for more efficient ways of doing things.

This book may serve as an introduction to telephony, and the space given to automatic switching is roughly indicative of its importance just now. Not every item of telephony is covered, because there is not room for all of them. But it is believed that the reader will get an adequate idea of the present status of telephony, and we trust will be led to pursue with thoroughness the mastery of his part in this great and useful industry.

ARTHUR BESSEY SMITH.

Evanston, Illinois,
January, 1924.



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TELEPHONY

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AUTOMATIC SWITCHING

CHAPTER I

THE MAGNETO RECEIVER

The electric telephone has so completely won its way into the life of the world, that no eulogy of it is necessary. Since its invention by Dr. Alexander Graham Bell in 1876, it has been developed and improved with great rapidity. America in particular has shown her appreciation of this device, and today depends upon the telephone to a degree unknown in other countries. The desire to understand this means of communication is sufficient reason for writing and for reading this small book.

Sound.—Sound consists of vibrations in the air. In still air, these vibrations travel about 332 meters (1,090 feet) per second. Sound has three properties, pitch, loudness and quality. Pitch depends upon the number of vibrations per second. Loudness depends upon the amplitude of vibration of the air, on the to-and-fro motion of each patricle of air as it vibrates. Quality depends upon the combination of various simple tones which make up what is apparently but a single tone. Quality is sometimes called "timbre" or "tone color."

Articulate speech is judged by its ability to

convey ideas. Therefore it has but two properties, loudness and clearness. Loudness requires no definition. Clearness means the degree of ease with which the listener can understand the words which are spoken. It involves intricate combinations of many frequencies and amplitudes of vibrations, but the listener need not know what they are to judge the clearness. Speaking down into an empty cistern is an example of loudness with little clearness. The speech of a careful person at some distance in a quiet, open space is clear, though it may be weak.

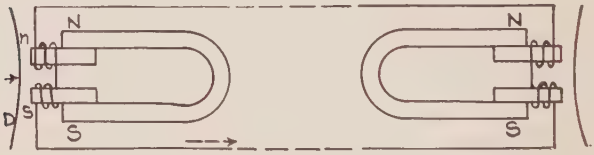


Figure 1.—Telephone Receiver Used as Transmitter and Receiver.

The Telephone Receiver.—The permanent magnet receiver, Figure 1, may be regarded as the basis of the electric telephone. It is possible to have a complete means of communication by connecting two of them by wires, using each receiver alternately as transmitter and as receiver. In fact, many an early private line was thus equipped, even if it did cause the user to move the receiver from mouth to ear many times during a conversation.

The permanent magnet receiver consists essentially of an iron diaphragm, *D*, in front of the two poles *n s*, of a permanent steel magnet, *N S*. The poles are made of soft iron. Each pole carries a winding of insulated copper wire. The two coils are connected in series so that current flowing in

the coils will either strengthen the magnetism in both poles or weaken it in both poles.

The magnetic flux caused by the steel magnet pulls the iron diaphragm and dishes it slightly.

When sound strikes the diaphragm, the latter moves in and out in accordance with the vibrations of the air. Each time it moves nearer to the poles, the magnetism becomes stronger. Each time the diaphragm recedes, the magnetism in the poles becomes weaker.

Whenever magnetism which passes through a coil becomes stronger or weaker, it causes a voltage to be set up in the coil. In the case which we are considering, the increase of magnetism caused by the approach of the diaphragm will cause a voltage to act and to drive current down in the receiver and to the right in the lower wire as indicated by the broken arrow. This current will pass through the other receiver, if the line is not broken or short circuited.

When the diaphragm recedes from the poles, the magnetism will weaken, thereby causing a voltage to exist, but in the opposite direction. This will drive current through the other receiver in the opposite direction. Thus the sound striking the diaphragm of one receiver produces an alternating current in the line and in both receivers. Thus the receiver which is being used as a transmitter is acting as a single phase, alternating current generator.

The passage of the alternating current through the receiver at the distant end of the line alternately strengthens and weakens the magnetic flux in the poles. This causes the pull on the diaphragm to vary. In the case being considered, the flow of current to the right in the lower wire will weaken the magnetism, so that the pull on the

diaphragm becomes weaker, and the spring force in the diaphragm will move it a little farther away from the pole tips. When the current reverses, it strengthens the magnetism, pulling the diaphragm

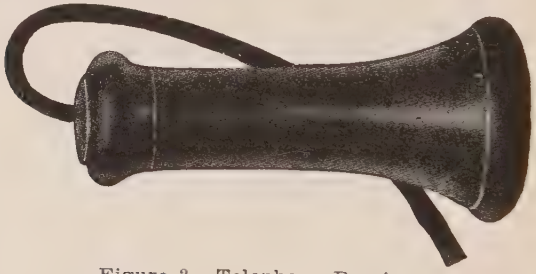


Figure 2.—Telephone Receiver.



Figure 3.—Receiver with Shell Removed.

nearer to the poles. Thus the second diaphragm is set into vibration, and its motions correspond to the motions of the first diaphragm.

With the receivers connected as shown, a sound wave which strikes the diaphragm of the receiver

at the left will cause it to move inward, and this will cause the other diaphragm to move outward and send the sound wave on into the air. But if the wires are reversed, it will not interfere with speech transmission, for the ear is able to interpret sound equally well in either case.

The external appearance of an average bi-polar permanent magnet receiver is shown in Figure 2.



Figure 4.—Disassembled Parts of Telephone Receiver.

When the shell is taken off by unscrewing the ear cap, the diaphragm may be removed and the magnetic assembly slipped out of the shell, as in Figure 3. A still further dissection is shown in Figure 4. The usual receiver has flat soft iron poles on which the wire is wound.

A brass cup serves as a frame on which the rest of the parts are mounted. The permanent

magnet is made of the best steel obtainable for the purpose, for it must retain magnetism for a long time. The soft iron poles and the permanent magnet are usually held together and onto the cup by means of a brass bolt which runs through their ends. However, there is one receiver which has the poles welded onto the permanent magnet, in which case the coils are wound on little spools and slipped over the poles after the magnet has been magnetized and the ends of the poles ground to a definite distance from the plane of the edge of the cup. This depth of grinding is from 0.30 mm (0.012 inch) to 0.38 mm (0.015 inch), depending on the maker. The first receivers were adjustable as to this air gap. But experience has shown that better results are obtained by fixing it at the best average value, and making the receiver non-adjustable.

The diaphragm is made of ferrotype metal, which is a fairly good grade of iron coated with black japan, lightly on one side and heavily on the other. The heavily coated side must always be put outward, so as to be next to the ear of the user, for the greater danger of rust comes from the outside.

The ear cap and shell have been made of hard rubber, resin compositions, and phenol fiber. Hard rubber looks well when new, but loses its good appearance, and is easily broken. Resin compositions vary greatly in appearance and strength, but the better ones are exceedingly hard. Phenol fiber seems to be the best of all, for it resists fracture better than the others and presents a good appearance through many years of service. It is marketed under several names, such as Bakelite, Redmanol, etc.

CHAPTER II

LOCAL BATTERY

The local battery telephone is a proper basis for an easy understanding of the telephone. For a long time it reigned supreme, and is still an ideal as to clear, loud, satisfactory transmission.

The simplest arrangement of this kind of a telephone, Figure 5, has a receiver, *R*, an induction coil, *P S*, a battery of electric cells, usually dry cells, and a transmitter. There is a local or

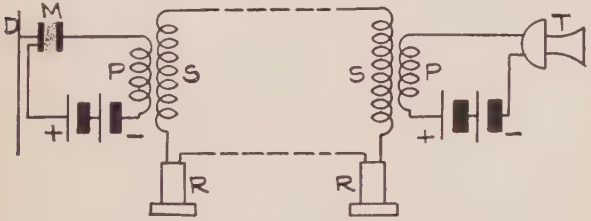


Figure 5.—Local Battery Telephone.

"primary" circuit containing the battery, and a line circuit containing the receivers.

The transmitter consists of a diaphragm, *D*, to which is attached a carbon electrode, usually a flat disc. Back of this is another disc electrode which is stationary. The space between the two is partly filled with granulated carbon. The circuit is connected to the two electrodes, so that the battery current will pass through the granular carbon.

The two electrodes and the granular carbon form the "microphone cell" *M*. It is a kind of rheostat. If the electrodes are pressed more closely together, the resistance of the cell is lowered. If the electrodes are moved farther apart, the resistance of the cell rises. This kind of action is caused by the diaphragm, when it is under the influence of sound. In this way the sound waves in air are able to make this rheostat vary in resistance.

The primary circuit contains the battery, the microphone cell of the transmitter, and the primary winding of the induction coil. As long as no sound strikes the diaphragm, the transmitter resistance is steady, and the battery current is constant in value. But when sound moves the diaphragm, the resistance of the cell rises and falls and the current falls and rises with the same characteristics. The transmitter in effect converts sound waves into electric waves of the same kind. The granular carbon transmitter of a simple form was invented in 1881 by Rev. Hunnings, an English clergyman.

The primary current during speaking is undulating. It rises and falls according to the voice, but never reaches zero. It may be regarded as direct and alternating current in one. Figure 6 may be used to illustrate the idea. Let us plot on cross section paper time to the right and current up and down. Direct current is represented by a horizontal line, parallel to the zero line. As time goes on it remains constant. Undulating current begins when the current begins to rise and fall. The dotted line shows what the direct current would have been if undulation had not started. Now, if the undulating part could be taken out and allowed to flow in a wire by itself, it would be true alternating current. It would flow first in one direction, then die away to zero and begin to

flow in the opposite direction. Hence we may say with truth that the undulating current in the primary circuit of a local battery telephone is capable of being analyzed into direct and alternating currents.

The induction coil (applied to the telephone in 1881 by Thomas A. Edison) consists of a straight iron core on which are two concentric windings. The primary winding is made of relatively few turns of heavy wire and has a resistance of 0.5 to one ohm. The secondary winding is made of relatively fine wire and more turns and has a

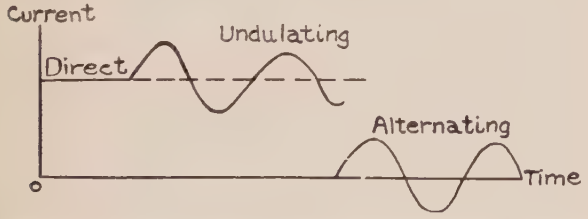


Figure 6.—Direct, Undulating and Alternating Currents.

resistance of 20 to 50 ohms. The core is soft iron, laminated. Norway iron wire was once considered best, but sheet silicon iron is now coming into use.

The induction coil is used to keep the transmitter in a local circuit of low resistance. In fact, in this circuit the transmitter is almost the only resistance. The battery is well under one ohm, in a new good cell practically negligible. The primary of the induction coil is not over one ohm. The connecting wires have a fraction of an ohm resistance. But the transmitter resistance will have about five to ten ohms, and sometimes more.

The induction coil also steps up the voltage of

the alternating component of the primary current, so that it is better able to traverse the line to the distant telephone. Notice carefully that it is not the battery voltage which is stepped up—it is that of the atlernating current only.

The primary current, before speech begins, magnetizes the core of the induction coil to a certain amount. When the sound acts on the transmitter, its rheostatic nature causes the primary current to rise and fall. Whenever it rises, the magnetism of the induction coil core becomes stronger. Whenever it falls, the magnetism of the core weakens. Thus the magnetism in the core of the induction coil undulates just as the primary current undulates.

The varying of the magnetism in the induction coil core causes an alternating voltage in the secondary winding. This alternating voltage drives an alternating current through both receivers and the line. The sound which enters the transmitter of one telephone instrument is reproduced with more or less fidelity in the receivers of both telephones.

In the sending telephone, the receiver is a handicap to sending speech. In the receiving telephone, the induction coil reduces the reception of speech. But both sending and receiving apparatus must be connected during conversation, because people can not be asked to operate switches. The frequent change in the direction of conversation forbids it. The best telephone instrument is that which has the best balance between sending and receiving, so that each function interferes as little as possible with the other.

"Side tone" is the sound which the speaker hears in his own receiver. It is evident that a person can hear his own voice in the telephone. Most people do not realize it. But if the receiver fails to work, they often complain that the telephone

sounds "dead." They notice the absence of something familiar—it is the side tone. This term is also applied to room noises which are heard in the telephone. Sometimes the room noises affect the transmitter so much as to render it difficult for the user to hear what the distant person is saying.

The amount of energy required for sound transmission is very small. It is probably the least of all the applications of power which man has made. So small is it, that if all the machinery in the world were made so perfect that it ran with absolutely no sound, the saving in power, the increased efficiency, would be entirely inappreciable. It is with this "microscopic" energy that telephony has to deal. It enters the telephone transmitter and controls electric force which, although much greater than that of the sound, is itself insignificant compared with the force of commercial electric light and power. At the receiving end, only a tiny fraction of that energy is delivered, yet the speech is intelligible.

THE TRANSMITTER

The transmitter is perhaps the least understood of all parts of the telephone instrument. The main diaphragm, upon which the sound acts, is fairly well understood. It was acoustically investigated by a number of physicists, and is still receiving a certain amount of attention. But the microphone cell, with its loose contacts of granular carbon particles with each other and on the carbon electrodes, does not readily yield to mathematical treatment, and requires in its design and manufacture the greatest care and precision.

The transmitter invented in 1881 by Hunnings used a carbon disc with a stationary electrode behind it, the space between being filled with granular

carbon. Since that time, it has been greatly improved in structure and operation. The granular carbon is now confined to a small cell, Figure 7, with a mica diaphragm closing the front. This makes it practically moisture proof. Moisture can not be allowed in the microphone cell, for it spoils the delicate action upon which the success of the transmitter depends.

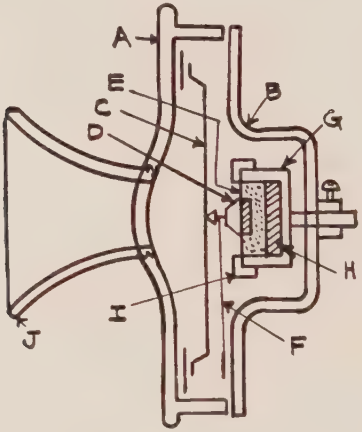


Figure 7.—Cross Section of Transmitter.

There are four arrangements of main diaphragm and cell which are now in any considerable use. A, The Western Electric type, with one auxiliary diaphragm, stationary cell. B, The split electrode cell. C, The two-diaphragm cell type, cell moving a little. D, The Kellogg type, with one auxiliary diaphragm, moving cell, integral with main diaphragm.

Each of the above types has its advantages

and its adovcates, but more follow type A than any other. Types C and D have for their object a greater microphonic action by a more violent shaking up of the granular carbon. The rear mica diaphragm of type C permits the walls of the cell to vibrate to a certain extent. The incorporation of the cell walls in the main diaphragm itself certainly seems to secure in type D the greatest possible shaking of carbon. Type B, the split electrode (Stromberg-Carlson), aims to vary the contact resistance at both anode and cathode and secure a longer path in granualr carbon.

Transmission of the voice must not only be loud, but clear. Anything which adds weight to the moving system hinders the transmitter from faithfully following all the little vibrations of sound. For this reason many transmitters which are loud, sound muffled, or hollow.

The type A transmitter is illustrated by the Western Electric structure in Figure 7. The front plate *A* is heavy, for it is the mounting plate for the other parts, and with the back bridge *B* forms the frame. This frame should not have appreciable vibration of its own—vibratory response to the voice should be confined to the main diaphragm *C* and the front electrode *D* with its auxiliary diaphragm *E*. The main diaphragm is made of aluminum, with a flanged edge which rests on an oiled cloth ring to cushion it a little. Two springs *F* press against an enlarged head on the front electrode stem and hold it firmly against the diaphragm. Hence the front electrode will partake of the motions of the diaphragm.

The microphone cell consists of a brass cup *G* with a back electrode *H*, a front electrode *D* mounted on a mica diaphragm *E* and the space nearly filled with granular carbon. The mica diaphragm is

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held on by a clamping ring *I*. The microphone cell is held by the bridge by means of a stem on the cup which passes through a hole in the bridge and is held by a set screw.

The mouthpiece *J* is screwed into the front plate and serves to guide the sound into the space between main diaphragm and front plate. It is made of hard rubber, resin composition, or phenol fiber, the last named being the most popular now. It is always provided with a vent in the form of slots

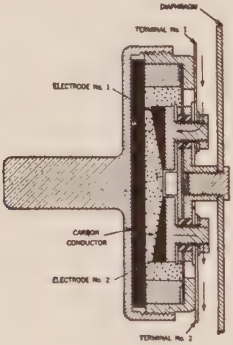


Figure 8.—Split Electrode Microphone Cell.

through the threads, or a little hole near the base. Various reasons are assigned for this venting. Years ago competitive salesmen used to suck on the mouthpiece of a rival transmitter and thereby pack it, reducing its transmitting ability. There is little reason for this safety now. There seems to be a little added clearness of transmission when a little vent is provided, and this is enough to continue its use.

The current is led into the microphone cell at two points, the back electrode through the mounting

stem, and the front electrode through the tension springs.

The electrodes are made of the purest carbon obtainable, carefully polished, and kept very clean. The granular carbon is likewise very carefully made and cleaned, screened to uniform size, and carefully measured as to the volume used in each cell.

The type B transmitter differs chiefly in that its front electrode is split into two parts, each of which

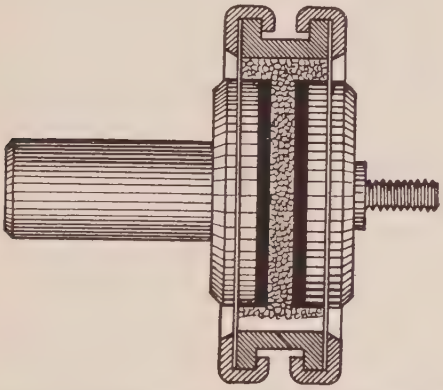


Figure 9.—Microphone Cell with Two Diaphragms.

is a terminal of the cell. Figure 8. Current arriving by terminal No. 1 goes into electrode No. 1, through part of the granular carbon to the back electrode, down through the electrode a little way, back again through more granular carbon to electrode No. 2 and terminal No. 2. The back electrode is an intermediate conductor. Some current leaks directly through the granular carbon, without traversing the back carbon plate.

The type C transmitter, Figure 9, has two mica

diaphragms, which permit the call wall to vibrate to a certain extent. The structure is very simple, and requires little explanation. The mounting stem is at the right, the threaded stem at the left passes through the main diaphragm. The mica diaphragms are held onto the ring-shaped cell body by clamping rings which are held on by bent-over lugs.

The type D transmitter, Figure 10, has its microphone cell in the body of the main diaphragm. The

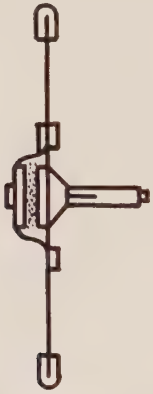


Figure 10.—Kellogg Transmitter Diaphragm and Cell.

cell is pressed out of the aluminum sheet. The front electrode is held into it by a stem and nut. The back electrode is mounted on the back stem, which is clamped into the back bridge. The mica diaphragm closes the annular opening around the back electrode, being held onto the diaphragm by means of an aluminum ring, riveted onto the main diaphragm. Current is led into the back electrode through the bridge, and into the front electrode

by means of a wire fastened to the aluminum diaphragm by one of the rivets.

The support of the edge of the main diaphragm is a matter of considerable importance. Formerly a soft rubber band was slipped over the edge of the disc. This made a soft pad which made the space air tight and prevented extra vibrations. But in time the rubber hardens and resists the vibrations of the diaphragm. Then it must be replaced. Now it is considered better to use a fairly hard ring and to obtain freedom of motion by bending the edge of the diaphragm over into a flange, as shown in Figure 7. The little flat edge which rests on the empire cloth ring may stick fast to the cloth, but even then it will not retard the motion of the diaphragm appreciably.

Tension springs were formerly placed at the edge of the diaphragm and part way in. Now the springs are usually made to press as near to the center as possible. Center damping is better because it reduces the possibility of the formation of nodes, and the vibration of the diaphragm in parts. It should vibrate as a whole.

The Induction Coil.—The telephone induction coil is one form of transformer. It operates on the same principles as are used in the power transformers which handle our lighting and power currents. But the conditions of use are different and its structure is also not the same.

The induction coil must handle weak currents of many frequencies and should treat them alike as much as possible. No one frequency may be unduly weakened, and no one frequency may be unduly strengthened. For this reason the magnetic circuit is not completely iron—part of it is air. Iron tends to make the speech loud, but not as clear as is desired, because there is a tendency to favor

some frequencies more than others. A coil made without iron, an air core, is most clear, but it is too weak. Hence there is a compromise in the use of a straight iron core, with the return magnetic circuit in the air.

If the iron in the core is solid, many eddy currents will exist in the iron. The same was found to be true in power transformers. It sapped the strength of the current, so that lamination was employed to reduce the circulation of current in the iron. But even with thin sheets of iron, about 0.35 to 0.5 mm (0.014 to 0.020 inch) thick, there are still some eddy currents left. It has been found that iron with about 3.5 to 4 per cent of silicon in it has a higher resistance to electrical current than good magnetic iron, and therefore has less eddy current. It also possesses higher permeability, therefore produces more magnetism. For these two reasons, silicon iron is now used in the best telephone induction coils.

The primary of a local battery induction coil is made of 300 or 400 turns of wire, 0.5 to one ohm with an inductance of 8 to 10 millihenries. The secondary may have from 1,500 to 2,500 turns, with 150 to 250 millihenries inductance. The transformation ratio is about 4 or 6 to one, that is, the secondary has about five times as many turns as the primary.

CHAPTER III

COMMON BATTERY

The use of local battery magneto telephones necessitates considerable maintenance work. To replace dry cells is the greatest part of it, but hand generators come in for their share of attention. For these reasons the operating of telephones by one battery located in the central office of the exchange has become the standard with

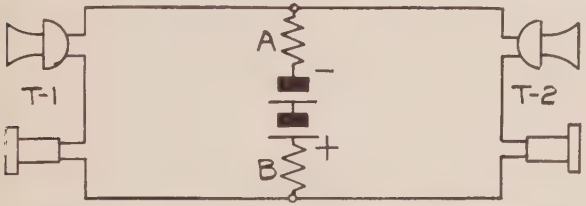


Figure 11.—Common Battery Bridged Resistance.

nearly all operating companies. It simplifies the substation apparatus, gives automatic signalling on manual boards, and easy control over the switches in automatic exchanges. Common battery working was proposed in 1890. During the period 1892-1899 it was being developed and applied, while by about 1900 it was considered to have arrived.

It is true that common battery causes the transmitter to work in a much higher resistance circuit, since it includes the subscriber line, which may

vary from five or ten ohms up to 500 or even 700 or 800 ohms. The longer the line, the weaker the sending of speech. But on the whole, it has proven to be the better way of working exchange lines, and by careful engineering and design, common battery has been made to talk remarkably well.

There are a number of ways by which common battery service may be rendered. The simplest is to connect two telephones in series with each other and the line and battery. This is done in some short private lines. But it is not feasible in pub-

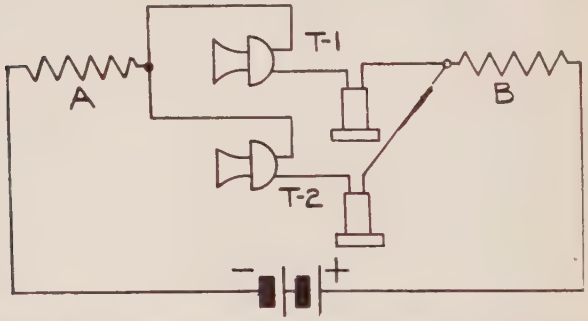


Figure 12.—Bridged Resistance Rearranged to Show Action.

lic exchanges. Those which follow show the development of the idea, though not in order of time.

The Bridged Resistance.—If across the two line wires between two telephone instruments, Figure 11, *T-1* and *T-2*, we bridge resistance and battery, we shall have a simple common battery system. Talking into the transmitter of either telephone will cause the current in its loop to undulate, and this will cause the current in the other loop to undulate also. The simple application of Ohm's law will show that whenever one transmitter lowers

its resistance, it will draw more current, and because of the bridged resistance, the other telephone will get less current. This may be more easily seen in Figure 12, where the same circuit has been thrown into the form of a divided circuit. *T-1* is in one branch and *T-2* is in the other, while the resistances *A* and *B* are in the common battery branch.

The Stone System.—This is made out of the above system by using inductive coils, or impedances, instead of resistances. Figure 13. They greatly increase the effect which one subscriber loop has

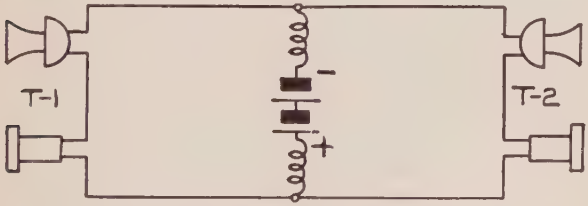


Figure 13.—Stone System of Common Battery.

over the other, because an inductive coil resists any change in the strength of current in it. In this it is like the flywheel of an engine, when the torque increases, the mass of the wheel prevents sudden increase of speed, and when the torque decreases, the wheel tends to keep the speed up.

The two subscriber loops are the intended path of alternating current, the conversation current. The battery current is supreme in the common branch, the inductive coils. There is a little of the alternating current in these coils, but if they are well made, it is negligible.

This circuit may be rearranged as in Figure 14 to show a little better the action. As far as the

flow of battery current is concerned, the two telephone instruments are in parallel. If they were of equal resistance, the current would divide equally. Usually the two telephones are not equal, so that one gets a little more direct current than the other. As long as the transmitters are quiet, the battery current is steady, unvarying in value.

When one transmitter rises in resistance, the current in that telephone falls. But the inductance of the two coils will resist this change, desiring to keep the current from falling. Hence the current in the other telephone will be increased. This in-

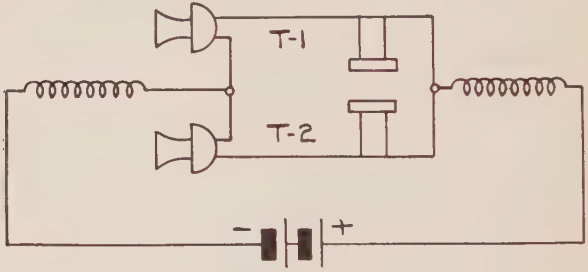


Figure 14.—Stone System Rearranged to Show Action.

crease is more than would occur if the coil were a plain resistance without inductance. When the same transmitter falls in resistance below its former steady resistance, the current in its telephone rises. But the inductance of the coils will resist this increase, and tend to keep the current constant. This deprives the other telephone of some of the current which it would otherwise get. In this way, the varying resistance of one transmitter causes the current in the other telephone to undulate in the same way.

The inductive coils give louder transmission than

plain resistance coils, but this result is due in part to the rapidity with which the transmitter changes resistance. If a transmitter increased resistance a certain amount, and then held that value indefinitely, the coils would momentarily increase the current in the other telephone, but it would soon sink to the slightly increased value which it would have if the coil were non-inductive.

The Stone system is used in some small private telephone systems, also in every reverting call on a party line.

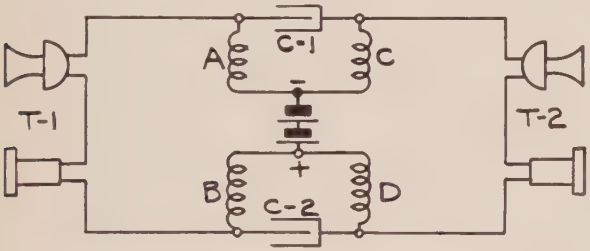


Figure 15.—Condenser-Impedence System of Common Battery.

Condenser-Impedance System.—The condenser-impedance system of common battery transmission, Figure 15, has two impedance coils for each subscriber line, and each telephone has its own separate circuit for the supply of direct current. The two lines are connected by means of condensers.

The two coils, *A* and *B*, are usually wound on one iron core, so as to secure greater magnetic effect and therefore more impedance to the alternating talking current. The coils, *C* and *D*, for the other telephone are on another core. In this way each telephone will get all the battery current which it can get in view of its resistance. A

short line can not rob a long line of current, as is the case in the Stone system.

As long as both transmitters are quiet, the current in both loops flows steadily, and there is no alternating current flow through the condensers. But if someone talks into the transmitter of *T-1*, the current in that loop will undulate. This produces an undulating voltage at the terminals of the condensers, *C-1* and *C-2*. Alternating current now flows through the two condensers and causes the battery current in the other loop to undulate. This

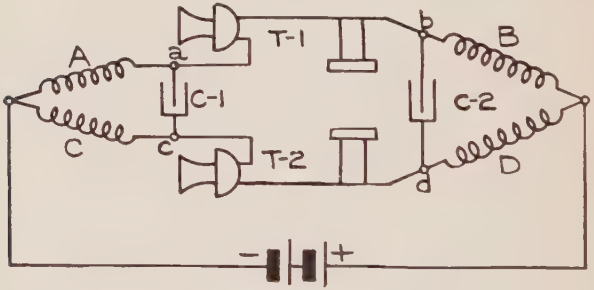


Figure 16.—Condenser-Impedence System Rearranged to Show Action.

affects the receiver of *T-2*, reproducing the speech.

A better understanding of the relationships and action can be obtained if we rearrange the circuit, as in Figure 16. Here it is seen that we have an extended Wheatstone bridge. Coils *A* and *C* are the proportional arms at one end, and coils *B* and *D* are the other two arms at the other end. The two telephones, with their lines, close the gap between the two ends. The two condensers take the places of galvanometers across the circuit.

If the two telephones and their lines were equal

to each other in resistance, there would be no difference of potential across the condensers, and they would not be charged. But the lines and telephones are seldom equal, hence the current in one telephone will be stronger than that in the other, and there will be a little charge on each condenser. But whether there is a charge or not, the condensers function the same.

The action of the impedance coils in this system is like their action in the Stone system, except that there is no "resistance shunting." The action is purely electrostatic induction through the condensers.

When one transmitter, *T-1,* lowers its resistance, the voltage from *a* to *b* is lowered. The magnetic inertia of the coils, *A* and *B,* resists any increase of current, so that this lowering of voltage is greater than would result from simple resistance action. The lowered voltage across *a-b* permits the condensers to discharge some electricity, which flows from *C-2,* past *b,* through *T-1, a, C-1, c* and telephone *T-2.*

When the same transmitter, *T-1,* increases its resistance, the voltage from *a* to *b* is raised. This would tend to reduce the current flow, but the magnetic inertia of the coils *A* and *B* resists any lowering of current, and continue to send as much current as ever. The excess, which *T-1* can not take, is forced through the condensers into telephone *T-2* in the direction *b, C-2, d, T-2, c, C-1,* to *a.* Thus a complete cycle of decrease and increase of resistance of the transmitter of *T-1* results in a complete cycle of alternating current in telephone *T-2.* In this way the mesh composed of the two telephones, their lines, and the two condensers is traversed by alternating current, which is the talking current. There is little alternating current

in the battery branch of the circuit, including the impedance coils.

Sometimes the condensers are transposed, as in Figure 17. This has been found to have the effect of reducing still more any noise which may come from the battery during the time that it is being charged. The two condensers form a by-pass for any such noisy current, and tend to shunt it from the telephones.

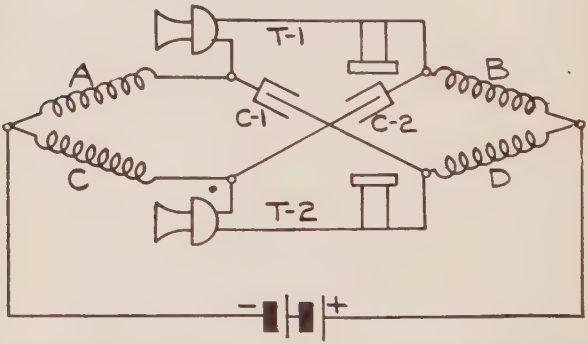


Figure 17.—Condenser-Impedence System with Transposed Condensers.

The Hayes System.—The Hayes system of common battery transmission (invented 1892, H. V. Hayes), Figure 18, uses a repeating coil to link the two subscriber lines together. The four windings, *A*, *B*, *C* and *D*, are on one iron core, so that all act as a transformer. Each telephone has its own separate battery current circuit, as in the condenser-impedance system. But there is a difference, that the battery is in the alternating current circuit. It must be a very quiet battery, in good condition and of low resistance, so that while being charged

the generation noise will not be heard. Usually a special "telephone" generator is used to charge the battery—a generator which produces very little undulation or "ripples" in its current. The condenser-impedance system can stand a much more noisy battery without disturbing conversation, because the battery is not in the path of the alternating talking current.

The operation of the Hayes system is very much like that of the local battery telephone with an in-

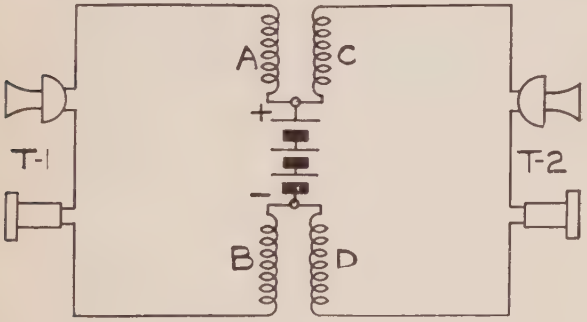


Figure 18.—Hayes System of Common Battery.

duction coil. The transmitter by varying its resistance causes the battery current to undulate. This undulating current makes the magnetism of the induction coil vary, which in turn causes an alternating voltage to exist in the coil windings which are in the other subscriber line. This induced voltage makes the direct current in that line rise and fall, and actuates the receiver in the receiving telephone.

The current in both loops is undulating, and may be resolved into direct current and alternating current. In the sending loop, the current undulates

by the rheostatic control of the transmitter. In the receiving loop, the alternating current is mixed with the direct current, resulting in undulating current.

COMMON BATTERY AND LOCAL BATTERY

Common battery is displacing local battery in all exchanges of appreciable size. Local battery still holds its own on rural lines in very many places. The latter gives louder, clearer transmission than the former, if its battery is new and strong. But common battery gives better average transmission, because the battery is of constant strength. The common battery telephone instrument is also simpler, as will appear in the description of telephone instruments.

CHAPTER IV

LOCAL BATTERY TELEPHONE INSTRUMENT

The simplest needs of a complete telephone outfit are to be found in a private line with a local battery, magneto telephone at each end. Figure 19. It connects two points so that A can talk to B over the telephone line. A study of the instruments and of the line will give the reader a good insight into the fundamentals of telephone communication.

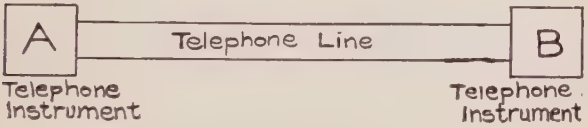


Figure 19.—Simplest Telephone System.

Each telephone instrument needs to have talking apparatus, signalling apparatus, and switching apparatus.

Short lines, often entirely within buildings, are quite easily rung with battery bells, in which case the arrangement of Figure 20 is suitable. The talking apparatus consists of the transmitter, receiver, induction coil and battery. The switch hook is the switching apparatus and the vibrating battery bell and the push button, *A* or *B*, are the signalling apparatus, using the same battery as the transmitter uses.

If *A* desires to call *B*, he presses the pushbutton *A*, which switches his own bell out of circuit and switches the battery into the ringing circuit composed of the ringing wire, *RL* and the line *L-2*, with the bell at telephone *B*. This rings the bell. To talk, both users take their receivers from the hook. In its normal position on the hook, the weight of the receiver keeps the lever down, so that the contacts are open. When removed from the hook, the lever rises, closing two circuits, the primary circuit (battery, transmitter and primary of induction coil) and the secondary circuit (receiver and secondary of induction coil). Battery current

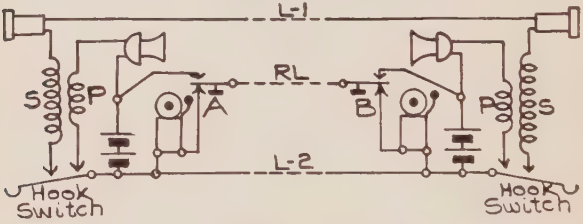


Figure 20.—Local Battery Private Telephone with Battery Bell Call.

now flows through the transmitter and the primary winding of the induction coil, so that speech into the transmitter will result in the production of an alternating talking current in the secondary winding and the main line, which includes both receivers. This gives the circuit condition, which was shown in simple form in Figure 5.

The principles of operation of the vibrating battery bell may be understood by reference to Figure 21. This bell consists of an electro-magnet fixed in a metal frame which is screwed to a wooden back. At one end the armature is fixed to the metal

frame by a flat spring, and on the other a small hammer is attached near the bell gong. The spring rests against an insulated stud with which electrical connection with the coil has been established. The current, in passing through the coils, attracts the

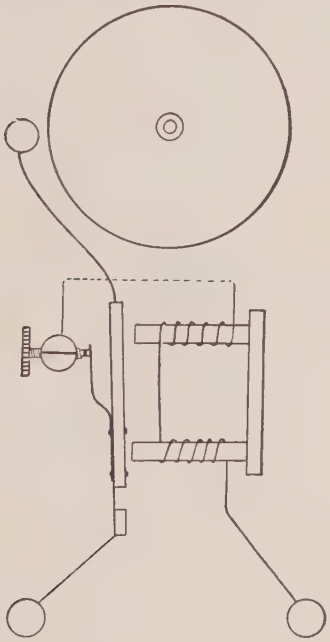


Figure 21.—Vibrating Battery Bell.

armature, and the hammer strikes the bell, but in doing so the spring is drawn away from the insulated stud, breaking the path of the current; the electro-magnet no longer attracts the armature, which is drawn back by the spring, when the cir-

cuit is again complete, and these same movements occur as long as the battery is connected.

These bells are usually wound to a resistance of 4 or 5 ohms, but may be wound to higher resistances if necessary. The higher the resistance, the greater the voltage necessary to ring the bell, and the worse the arcing at the contacts.

Local Battery.—Two kinds of electric batteries have been used for local battery telephones, dry cells and wet cells. The latter came first in the art, and the former had to make their place against great opposition. But dry cells have won their rights, and are justly used in great quantities to-

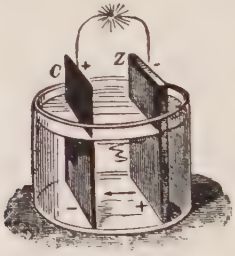


Figure 22.—Simple Galvanic Cell.

day. The dry cell is best adapted to intermittent work, such as in local battery telephones, which are not used for a total of more than a few minutes or a reasonably small fraction of an hour per day. Wet cells are as a rule better adapted to steady use, such as in the telephone set of a switchboard operator, under which service dry cells usually run down very soon. Hence we call dry cells "open circuit" battery, and the gravity cell a "closed circuit" battery. A few kinds of cells are described below.

The Primary Battery.—A simple cell, illustrated in Figure 22, shows the essential principle upon which all chemical batteries operate. A piece of zinc, *Z*, and a piece of carbon, *C*, are immersed in the proper solution or *electrolyte* and connected together with a wire which causes a current to flow from one to the other. The zinc is eaten up more or less rapidly. Zinc and carbon are the substances in common use; but others can be used.

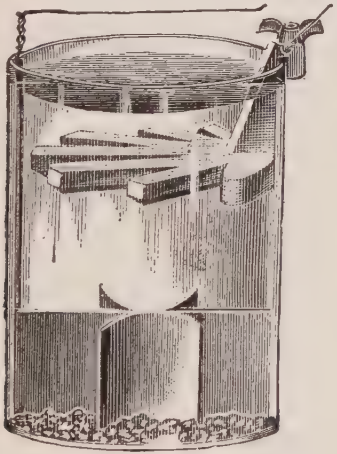


Figure 23.—Gravity Cell.

The current flows through the liquid from the zinc to the carbon and outside of the liquid from the carbon to the zinc. No current will flow unless the carbon and zinc are connected by a wire, though when disconnected the zinc is slowly eaten away.

The Gravity Cell.—A form of cell known as the "Gravity," "Crowfoot" or "Bluestone" battery is shown in Figure 23. This battery is used

to a great extent in telegraph service and also in telephone work where a small but constant current flowing all the time must be had.

Three sheets of copper fastened together at the middle constitute the positive electrode, and to this is attached an insulated wire. The zinc is in the form of a "crow foot," having a lug attached and adapted to hook over the rim and permit the device to hang in the glass jar. This battery is set up by first putting the copper in place in the bottom of the jar and filling in around the copper to a height almost sufficient to cover it, with sulphate of copper, called blue vitriol; and then filling the jar with water and setting the zinc in place, as shown in Figure 23. Sulphuric acid forms in this battery which attacks the zinc and forms zinc sulphate, a fluid which occupies the upper portion of the cell, being lighter than the solution of copper sulphate. The name "gravity cell" is given to this battery because of the fact that the two solutions are kept apart by gravity instead of by means of a porous pot, and the line of separation may easily be distinguished as the zinc sulphate is colorless while the copper sulphate is of a dark blue color. This "blue line," as it is called, should not be allowed to rise high enough to come in contact with the zinc, but should be kept about half-way between it and the copper. The blue line can always be lowered by short-circuiting the battery for a little while or by filling in with zinc sulphate from another battery or by siphoning off some of the blue fluid and filling in with water. Sometimes the reverse may occur and the blue line sinks down. Should it reach the upper parts of the copper, unless the difficulty can be remedied by dropping in more blue stone, some of the zinc sulphate should be siphoned out and clear

water supplied in its place. On account of their high internal resistance these batteries are not adapted to subscriber sets, but they give fair results on the operator's transmitter.

The Gordon Cell.—This cell, as illustrated in Figure 24, which gives an open view of the cell showing the parts assembled, consists of a perforated tin cylinder, the negative element, which is filled with black oxide of copper—a powerful depolarizing

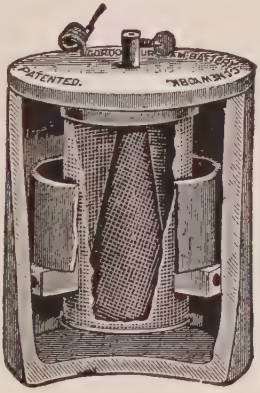


Figure 24.—Gordon Cell.

agent. To the lower portion of the cylinder, three porcelain cleats or lugs are attached by iron bolts, and the rolled zinc cylinder, forming the positive element, rests upon these lugs. Sodium hydrate (caustic soda) constitutes the electrolyte. Fastened to the zinc and extending through a porcelain bushing in the cover and forming the negative pole is a No. 12 B. & S. gauge insulated copper wire.

The positive pole is formed of a metal rod passing through a porcelain bushing in the center

of the lid. This rod supports the entire negative element to which it is fastened. A layer of oil is poured over the top of the solution to prevent evaporation after the cell is set up complete.

In comparison with most other cells, the electromotive force of this cell is low, being very close to 0.66 volt under working conditions. The internal resistance is about 0.04 ohm. The 6x8-inch cell has a capacity of 300 ampere-hours when discharged at a rate varying from one to six amperes. Larger sizes of cells are made, with capacities said to be as high as 1,000 ampere-hours.

The cell is adapted to open or closed-circuit work, particularly the latter, where for a long time a small current is required steadily. It has these advantages: Until entirely exhausted requires no attention. Throughout its life it maintains a constant electromotive force. At all ordinary temperatures it is non-freezing. It is free from local action. The zinc is amalgamated.

The Edison primary cell employs the same materials but the copper oxide is in plate form. The zinc is also a plate. It is easier to set up and is much used.

THE DRY CELL

The dry cell derives its name from the fact that the electrolyte is not in the form of a free liquid, but it is absorbed by some kind of porous material like blotting paper or saw dust, and evaporation is prevented by sealing the cell.

These cells are not strictly dry, for their very action depends on the presence of moisture. If they become really dry chemical action ceases, and with it their ability to generate a current.

Electrically and chemically the dry cells have been brought to such a high standard of efficiency

that their outputs are as great if not greater than any of the other types of the Leclanché batteries and their recuperative power is better. From the viewpoint of economy and convenience they are superior because of their low cost, and non-spillable and non-breakable features.

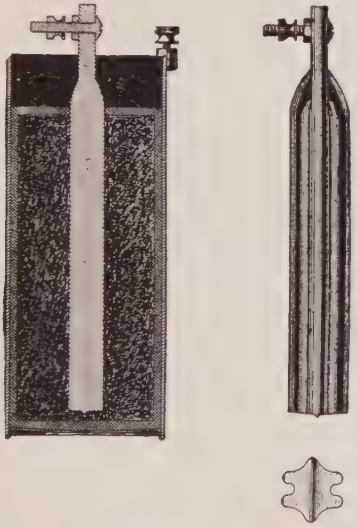


Figure 25.—Section of Dry Cell.

In Figure 25 is shown a dry cell. A zinc cup forms the outer casing so that it answers the purpose both of retaining chamber and positive electrode. Shown in detail at the right of Figure 25 is a carbon rod which forms the negative electrode, and which is held in the center of, but out of contact with, the cup, all the surrounding space being filled with a mixture of peroxide of manganese,

powdered carbon and some porous substance which will hold moisture. The whole is saturated with a solution of salammoniac.

The exact formulæ used by various manufacturers are not made public. A cylinder of several thicknesses of blotting-paper lining the inside walls of the zinc chamber will prevent the carbon and manganese from coming directly in contact with the zinc.

The zinc chamber is closed, after assembling, with a substance resembling sealing wax poured in while hot, and an outer casing of pasteboard put on. This outer casing has no other function than to insulate the zinc cup from surrounding objects. A binding post serving as the positive end of the cell, is provided at the end of the carbon plate which projects through the sealing material, and a rod extending upward from the casing of zinc carries a binding post which constitutes the negative pole.

Dry batteries may be temporarily renewed by drilling a few holes through the outside case and setting the batteries in a jar filled with a strong solution of salammoniac. This serves very well in an emergency case where it is necessary to get a telephone in working order quickly. In case no salammoniac is at hand, a strong solution of salt and water may be used. The holes should not be punched in such a manner that the zinc case is forced through the paper lining; they should be cut clean with a small drill.

The selection by exchanges of batteries having a high degree of electrical efficiency is of paramount importance and low first cost should not be considered as against a basis of practical commercial test.

In exchanges, therefore, where the poorer types

are used the extra expense is very heavy as such exchanges are compelled to pay for the labor and other expenses incident to four renewals, where by using the best types of cells only one renewal would be necessary.

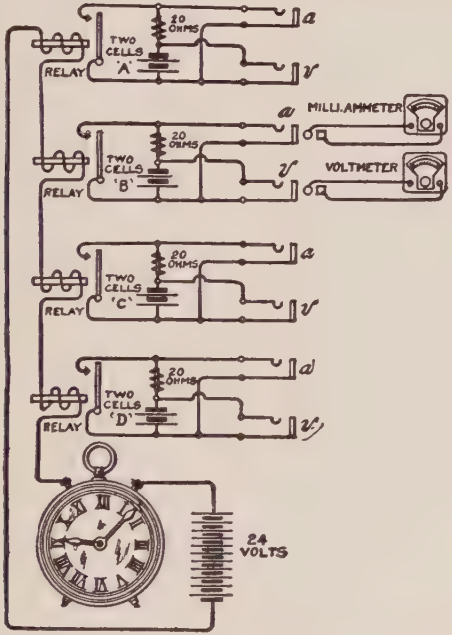


Figure 26.—Method of Testing Primary Batteries.

Battery tests are often made by short-circuiting the cell for a given period, or by permanently closing its circuit through a certain resistance and noting the time taken for a cell to completely discharge or to discharge until its voltage is reduced

to a certain amount. These methods lead to erroneous conclusions. These conditions are not those of practical telephony; cells designed for open-circuit work only being thus tested under the conditions of work that would be given to a closed-circuit cell.

A method of making comparative battery tests which may be made to closely approximate the actual conditions of service, is shown in the diagram, Figure 26. Any ordinary clock may be equipped with three contacts on its face, each adapted to be engaged once each hour by a wiping contact carried by the minute hand. Each of these contacts extends over an arc equal to that traversed by the minute hand in the time during which it is desired to have the battery on closed circuit, assuming it to be for five minutes. Thus for a period of five minutes, three times each hour the circuit will be closed, there being between each closure an intermediate open-circuit period of fifteen minutes. The winding of a number of relays, and a battery of 24 volts are placed in series in the circuit with the contacts of the clock. For each battery to be tested a relay is provided and when operated each relay closes its battery circuit through a resistance which equals the average resistance of the transmitter designed to be used in that battery.

In Figure 26 *a* and *v* represent two double-contact spring jacks connected with the circuit of each battery being tested. This facilitates the daily reading of the current and voltage. The connection of jack *a* includes both the coil and the battery being tested between its terminals, while the connection of jack *v* is across the terminals of the battery only, in order thus to make a direct reading of the voltage when the same kind of a plug in connection with a voltmeter is inserted.

Figure 27 illustrates in plotted form of curves the result of tests made with apparatus arranged as referred to above. Each battery, in these tests, was closed through its resistance three times an hour for a period of six minutes, all readings were taken for each battery at twenty-four hour intervals and while the batteries were delivering current through 20 ohms to the milliammeter. The voltage readings alone were considered a true indication of the con-

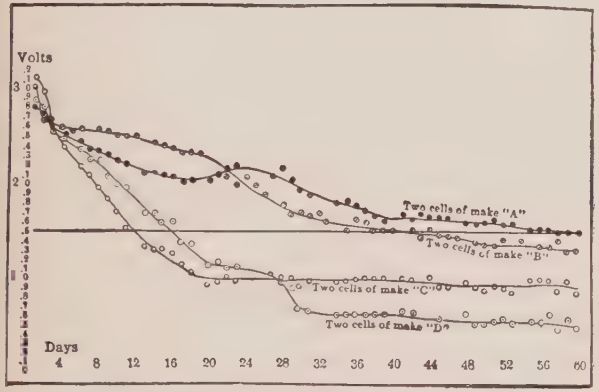


Figure 27.—Record of Dry Cell Test.

dition of the cell, inasmuch as at all times the current was shown to be substantially in proportion to the voltage. Therefore, for every day during the test these curves show the voltage of each battery. At a height indicating one and one-half volts a line is drawn across the curve sheet, as it was assumed that a battery of two cells was inefficient for service when it dropped below one and a half volts in potential; and the number of days required under the conditions of the test for each battery to drop

below this voltage is indicated by the point where the horizontal line is crossed by the curve. These curves show the duration of the several batteries before the drop as follows: *A*, sixty days; *B*, forty-four days; *C*, not quite twelve days; *D*, about 16 days. While the curve indications for *A* and *B* were both first-class, the showing for *B* is inferior to that of *A*. Both batteries *C* and *D* show poor results, although the showing of battery *D* is somewhat better than that of battery *C*.

In making these tests the conditions must be adjusted to meet the requirements of the exchange. Equality of resistance between the coil through which the discharge is made and the average of that of the transmitter and primary winding of the induction coil should be maintained. When desired the clock can be adjusted to close the circuit more frequently and for a smaller period of time. The actual average conditions of telephone service, however, may be more closely approached by opening the circuit of the clock at night, thereby giving a complete rest to all of the batteries, as this is the least busy time for the telephones.

Magneto Signalling.—Magneto signalling is better for all around telephone work, because it is better adapted to long lines, with their attendant resistance. Battery bells are therefore not used to any considerable extent. The magneto generator and bell do not require any battery, which is a great relief, and stay in adjustment over very long periods of time.

The principles of magneto signalling are shown in Figure 28. *G* is a permanent magnet; *a b* is a soft iron armature magnetized *S* at both ends by induction. The upper poles of the electro-magnet are both magnetized *N* when no current is passing, hence both ends of the armature are at-

tracted alike, and will remain against either pole. The electro-magnet poles are oppositely polarized when a current flows, and one end of the armature

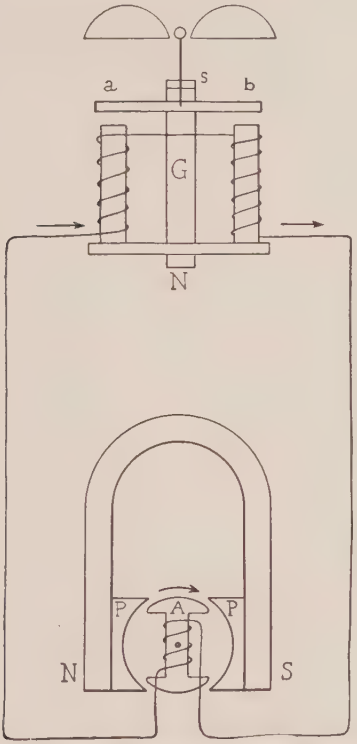


Figure 28.—Principle of Magneto and Polarized Bell.

will be attracted more strongly than the other. The current is reversed at the half revolution of the generator, thus reversing the poles of the electro-magnet, and the hammer is drawn to the other gong.

The rapid rotation of the generator armature causes a ringing like that of an ordinary alarm bell.

The generator consists of three or more strongly magnetized horseshoe magnets. The soft iron armature *A*, usually of the Siemens *H* pattern, is pivoted between the soft iron pole pieces *P P*. In the deep grooves on the sides the wire is wound. The pole pieces are cut to fit closely around the curved sides of the armature. In the position shown in the figure

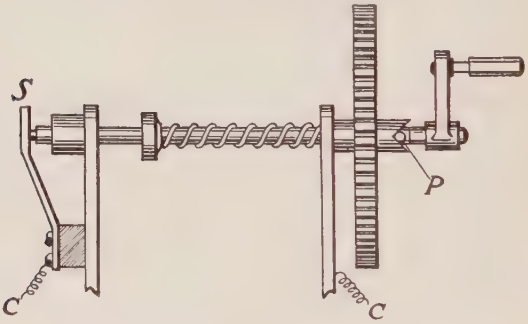


Figure 29.—Magneto Generator Shunt.

most of the lines of force pass from the *N* to the *S* pole through the curved sides of the armature. The number of lines of force cutting the coil constantly varies as the armature rotates, and currents are produced in the coil which flow to line, to which the coils are joined. The resistance of the armature is between 160 and 200 ohms. Various devices have been adopted to cut out the coils which should not be in the circuit of the incoming current, two of which are illustrated. In Figure 29, *cc* are the ends of the coils which are short-circuited by the spring *S* and the axle when the generator is at rest. When the handle is turned the pin *p* rides up

the V recess, drawing the axle away from S, breaking the circuit there and bringing the coil into circuit.

A simple illustration of magneto telephone is found in Figure 30. This shows a private line between two stations, each of which is a series telephone. The name comes from the arrangement of the bell and generator in series with each other. Normally the generator is short circuited, as was described above.

When one person desires to call the other, he turns the crank of his hand generator. The first

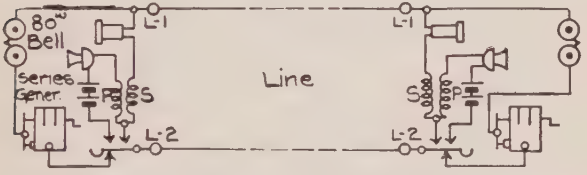


Figure 30.—Telephone Line with Series Magneto Telephones.

quarter turn takes the shunt off the armature coil. Then the rotation which follows causes the generation of alternating current, which passes through both bells and makes them ring. When the user stops turning the crank, the shunt is put back on the armature. The caller then takes his receiver from the hook.

When called party answers the call, he removes the receiver from the hook. In each removal of the receiver, the generator and bell were switched out of circuit, and the talking apparatus connected to the line. The receiver and secondary of induction coil are in the line, the transmitter, battery and primary of induction coil are in the local circuit, although this local circuit touches the line

circuit from the hook to the common terminal of the coil. During conversation the circuits are as was described in the simple sketch of Figure 5.

Notice a few points of interest about this series telephone. The apparatus and circuits of the telephone instrument proper are between the line binding posts, *L-1* and *L-2,* so that only the two line wires connect the two instruments. If we have one instrument alone, not connected to any line, turning the crank will not ring the bell. Also, if we speak into the transmitter with the hook lever up, we can not hear any "side-tone" in the receiver. But if we short circuit the line binding posts, we can ring the bell with the generator, and we can hear side tone if we speak with the hook up.

When the receiver is on the hook, all the talking apparatus is connected to one line. This makes it less likely to receive damage from lightning, than if, for example, the primary of the coil were connected to *L-1* and the secondary were connected to *L-2.* The hook switch is usually much better insulated than it is possible to insulate the induction coil, and can stand having its members across the line.

The bridging telephone, Figure 31, is used to a great extent on party lines, and is worth much study. The simplest form is here shown. The bell is wound to 1,600 ohms, although 1,000 ohms and 2,500 ohms are also in use. It is permanently bridged across the line. This does not interfere with speech, for it has from 40,000 ohms to 100,000 ohms impedance to talking current (depending upon the maker). Even to ringing current its impedance is high, something like 5,000 or 6,000 ohms, so that a number of them can be bridged on the same line and yet all may be rung successfully.

The hand generator is also connected across the line, but it has a cut-out switch which keeps the circuit open when the crank is at rest. Figure 32. The first quarter turn of the crank connects the armature coil across the line.

The talking circuit, Fig. 31, is the same as in a series telephone. Sometimes a condenser is inserted

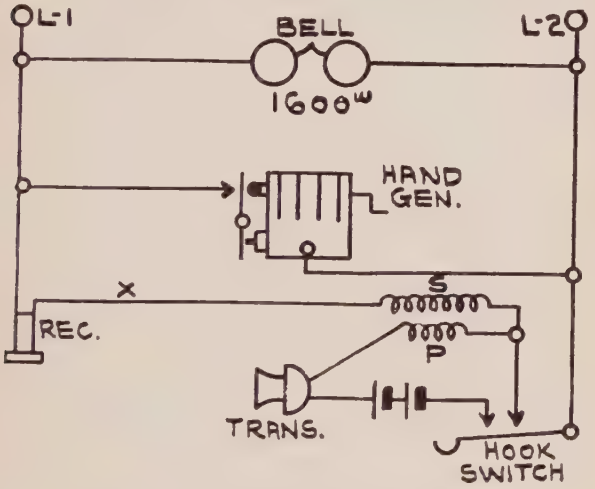


Figure 31.—Regular Bridging Telephone.

at *x* to make the talking circuit of higher impedance to ringing current, and to permit ringing on a line even if one or more receivers are off the hook.

Some interesting facts may be noticed. If the telephone is not connected to any line, the bell may be rung by turning the crank. But if the line binding posts are short circuited, turning the crank will not ring the bell, and the experimenter will notice that the crank turns hard, it has a "drag."

This is because the short circuit cuts out the bell, and permits a heavy current to flow.

If we take down the receiver and speak into the transmitter, we may perhaps hear a faint side tone, due to the current flowing from the induction coil secondary through the bell. But if the line binding posts be short circuited, the side tone will be as loud as it was in the series telephone.

Some bridging telephones are made in which the bell is wired to a bottom contact on the hookswitch.

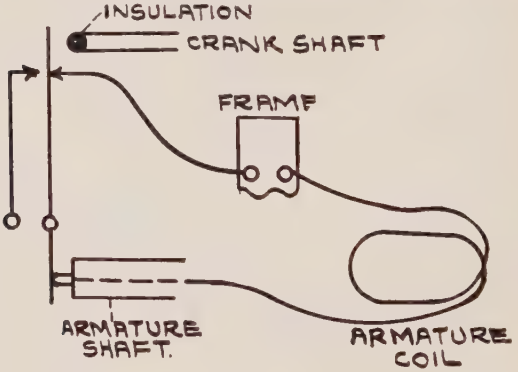


Figure 32.—Switch on Bridging Generator.

This cuts off the bell when the lever is up. This is an unnecessary device in most cases.

The Generator.—The generator of a magneto telephone is a much used and much abused machine. It must stand much or little use every day, involving sudden starts and stops. It can not be lubricated as good machines ought to be, and yet it must keep going in summer and winter without failing, for who can tell when the life of the farmer's child or wife may depend on its call for help?

Yet today it is one of our most dependable pieces of apparatus.

Generators are made with three, four and five magnets, referred to as "bars." Two-bar magnetos have been used, but their use was practically restricted to calling central on party lines having biased bell selective ringing. They were weak to avoid ringing the bells, yet permitting the subscriber to ring down the drop at central. There have been some 6-bar generators made, but it is doubtful if it pays to have them. Three-bar and 4-bar generators are used on series telephones, and 4-bar and 5-bar generators on bridging telephones.

The series generator needs to generate a fairly high voltage, if it is to be used on a line which has several bells in series. But in these days, the series line has practically died out. Series telephones are now used on small exchanges because they are cheaper than bridging instruments.

The bridging generator needs to generate a fair voltage (80 or 90 volts) and must have low armature resistance and plenty of magnetism to maintain a good voltage when delivering a heavy current, as when ringing many bells in parallel.

One thing that largely determines the efficiency of a generator is the distance from the armature to the field poles. The air gap between these parts should be as small as possible, and should be uniform the entire length of the machine. To insure this the poles may be cast in soft iron and then milled on their concave surfaces so that each and every one will be exactly the same shape. See Figure 33. These poles being fastened to brass heads by four machine screws and four dowel pins, there is no chance of their working loose. An approved type of generator much in use has its

armature placed between the poles and it revolves on a shaft extending through the brass heads. At one end this shaft supports a pinion which engages the large gear wheel to which the crank is attached. At the other end the shaft is insulated from

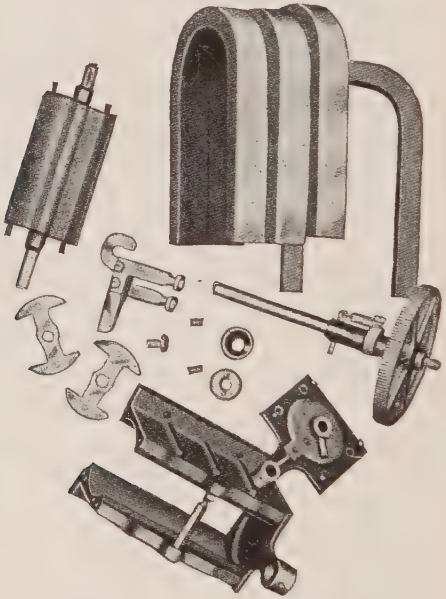


Figure 33.—Generator Parts.

the brass head and then passes through the head to come into contact with the armature spring of the shunt. The fact that the armature shaft is supported between the same two heads that hold the poles allows no variation in the distance between these parts.

Figure 34 shows an armature of a four-bar generator. It is composed of laminations or segments placed side by side so as to form a single unit. These segments are punched out of soft sheet steel, and are so uniform in size that a smooth surface

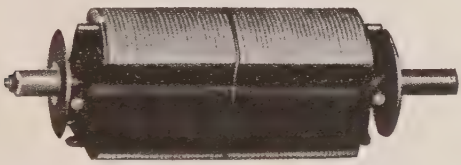


Figure 34.—Generator Armature.

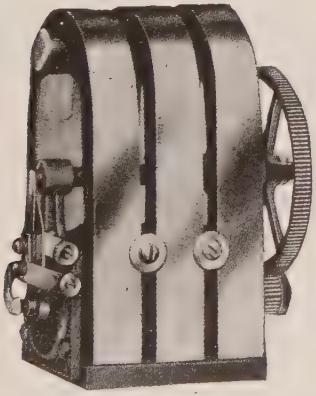


Figure 35.—Three Bar Generator.

is presented when they are assembled. The object of the laminated armature is to eliminate eddy currents which would reduce the efficiency of the whole generator. However, this loss is by many manufacturers considered allowable, and excellent generators are made with solid armature cores.

The running gear is made up of a steel pinion and a brass gear wheel. These two different metals work together with little friction.

The shunts of both the series and bridging generators are very simple. One form of series instrument has two springs. Normally the armature is shunted out of the circuit by the two springs being in contact. The turning of the crank forces the crank shaft out against the longer spring, thus breaking the short circuit.

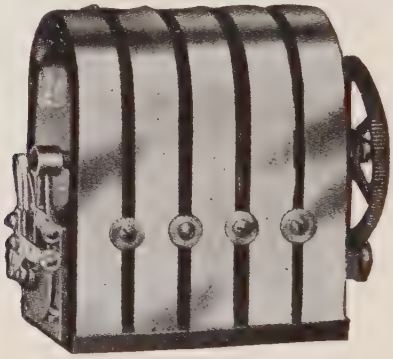


Figure 36.—Five Bar Generator.

The bridging shunt, Figure 32, consists of three springs arranged so that the armature is short circuited when the instrument is not in use. The turning of the crank breaks the short circuit and bridges the instrument across the line.

Short circuiting the armature practically eliminates lightning trouble, as it is almost impossible for lightning to burn out a generator.

Figures 35 and 36, which show the three and five magnet generators complete, and Figure 33, which shows a four magnet generator dissected.

The Ringer.—A type of ringer is shown in Figure 37. In Figure 38 the armature and its relation to

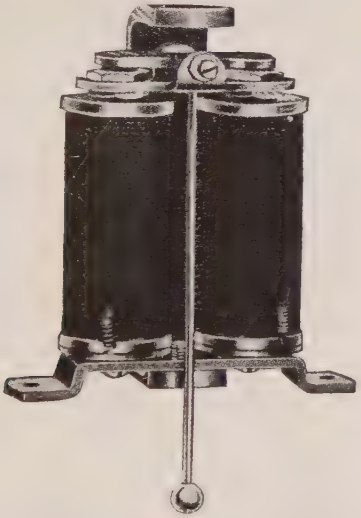


Figure 37.—Ringer of Telephone Bell.

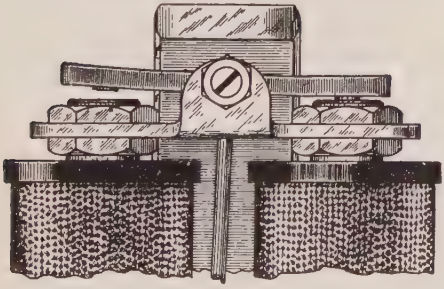


Figure 38.—Relation of Armature and Cores.

the cores is shown and Figure 39 shows the bell. The cores of the coils extend beyond the heads

and are threaded on the ends. On each core are two lock nuts between which rests a yoke supporting

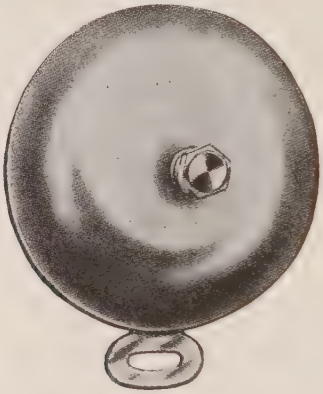


Figure 39.—Gong of Bell.

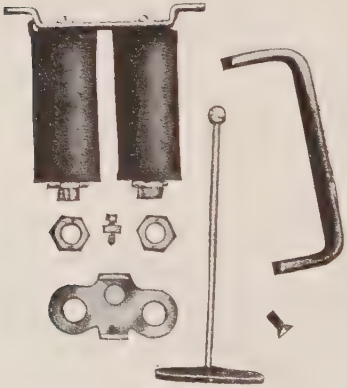


Figure 40.—Ringer Movement Disassembled.

the armature. If the lock nuts on one core are turned in one direction, that end of the yoke is brought closer to the coil, and if turned in the

opposite direction, that end of the yoke is carried away from the coil. As the yoke supports the armature, any change in the position of the yoke causes a like change in the position of the armature.

The armature is pivoted in the middle between two lugs on the yoke. On one side is a pivot point, while on the other is a screw which affords a support as well as a means of adjustment. This screw is fitted with a lock nut so there can be no chance of its working loose. With a pivot point on one side and a sharp pointed screw on the other, there need be no pressure against the armature to hold it firmly. Figure 40 shows the screw, lock nut and pivot point ready to mount in the yoke. To the armature is riveted a striker rod of brass with a brass striker ball at the end.

Referring to Figure 38 it will be seen that the ends of the armature are formed so that they lie parallel to the ends of the cores.

Brass studs inserted in the armature keep it from coming into direct contact with the cores. These studs project but a few thousandths of an inch (or hundredths of a millimeter).

The heads of the cores are made of heavy fiber, and are securely fastened to the cores. The coils are wound with enamel-covered copper magnet wire.

The winding of the coil terminates in a lug and therefore there is no wire connection brought out of the coil. The fine wire terminals on ringer coils have caused a great deal of trouble in the past.

The magnet is made of magnet steel and is firmly fastened to the ringer mounting by a machine screw.

The Hookswitch.—The hookswitch has received considerable attention and greatly improved in the past twenty years. The old ones were fastened to

the bell or telephone box at two or three places. Expansion and contraction of the wood put them out of adjustment. The lever stuck out of the side of the box, making it hard to pack for shipment. Now they are made in one unit, so that they stay in adjustment. The lever is removable during shipment, permitting a smaller box.

A hookswitch of recent type is shown in Figure 41. The long lever actuated by a coil spring of phosphor-bronze wire mounted in the base controls the action of the contact springs.

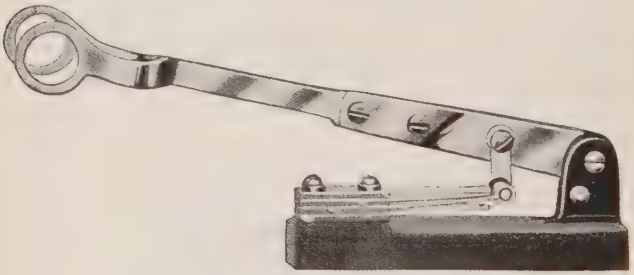


Figure 41.—Telephone Hook Switch.

The lever is made in two pieces so it is possible to remove the hook from the telephone cabinet without disturbing the contact springs or altering the adjustment in any way. A slot in the lower half of the lever accommodates the other portion, and the two pieces are securely fastened together by machine screws.

The contact points are pure platinum rivets, which pass through the springs, and are riveted on both sides. Silver contacts are also used with perfect success. Hard rubber bushings and separators insulate the springs and mounting screws from each other and from the iron mounting. The

master or line spring attached to the lever by a stirrup is also insulated by a hard rubber bushing. There are no electrical connections between the contact springs and the lever or mounting, thus precluding any chance of a subscriber receiving a shock from touching the hook.

Each spring has a clip for connecting the wires conveniently. These clips extend forward so as to bring the connectors into plain view. The base

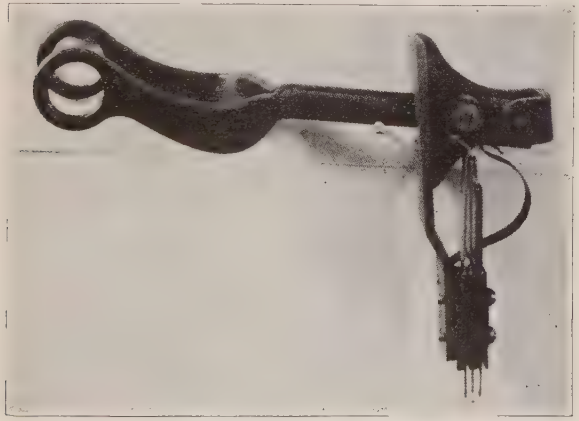


Figure 42.—Hookswitch for Wall of Box.

or mounting is cast of iron and is fastened by two screws put in from beneath to the shelf of the telephone.

Another type of hookswitch, Figure 42, is made to mount on the side of the telephone box. The lever is removable. The end of the lever is made round so that if the subscriber places the receiver momentarily on it, large end down, it will not injure the diaphragm. The holes in the ends of the prongs

are to take the receiver cord. Double the cord, push it through the holes, and the telephone may be carried and installed without danger of the receiver falling out and being damaged.

Receiver Cord.—A receiver cord is made up of two separate conductors, each one being composed of strips of copper tinsel or fine wires which are spirally wound around a thread so as to render it flexible. The two conductors are run along together in one sheath and are insulated from each other, as each one is covered with cotton or silk

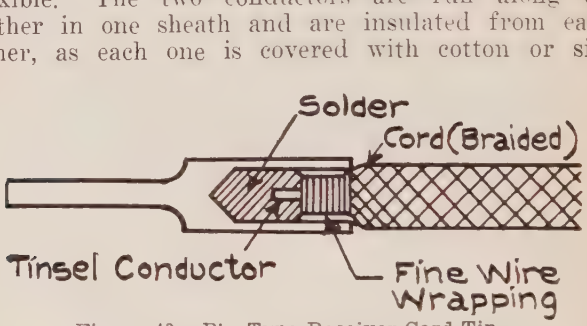


Figure 43.—Pin Type Receiver Cord Tip.

wrap and braid. The sheath or covering for the two conductors consists of one or more layers of braided cotton or silk. A metal tip forms the terminal of each conductor. One end of each of the two conductors is fastened to the binding posts of the telephone and the other two ends are fastened to the receiver, forming a loop by which the current reaches the receiver.

Cord tips are of two kinds, the pin type and the spade type. The former is illustrated in Figure 43. It consists of a solid rod of brass, one end turned down to the size of a wire, the other end drilled out large enough to take the cord. The whole is nickel plated. The braid on the cord is cut away for a short distance, the end of the braid

bound down with fine wire to keep it from fraying, and the end thus prepared thrust into the hollow end of the tip. There it is soldered, as may be seen by the shaded region inside the tip.

The spade tip is shown in Figure 44. It is made of sheet metal, punched and formed into the shape indicated. Two lugs are bent over the prepared end of the cord and the whole soldered together.

The pin tip is very useful if the binding post has a hole in it. But the spade tip finds much wider application, for it is easily held under any good round head or fillister head screw. It does not

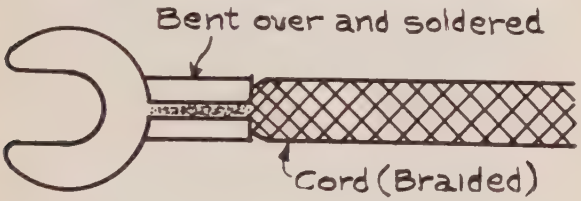


Figure 44.—Spade Type Receiver Cord Tip.

look quite as neat as the pin tip, but is cheaper and gives perfect connections.

Cabinets and Boxes.—The telephone apparatus of one instrument is housed in a variety of ways. We may divide them into wall telephones and desk telephones. The former are designed to be attached to a wall, the latter are especially adapted for tables and desks. At the present time the wall sets are chiefly of the compact type and the residence or hotel type. The older types, having the battery box separate from the bell box, and frequently the transmitter separate from both, are now made seldom if at all. The desk telephone set is almost universally of the "stand" type, but

there are indications that the combination hand microphone set may come into considerable use in America. The last named is used very much in Europe, but has not found favor with American telephone operating companies because the maintenance is higher.

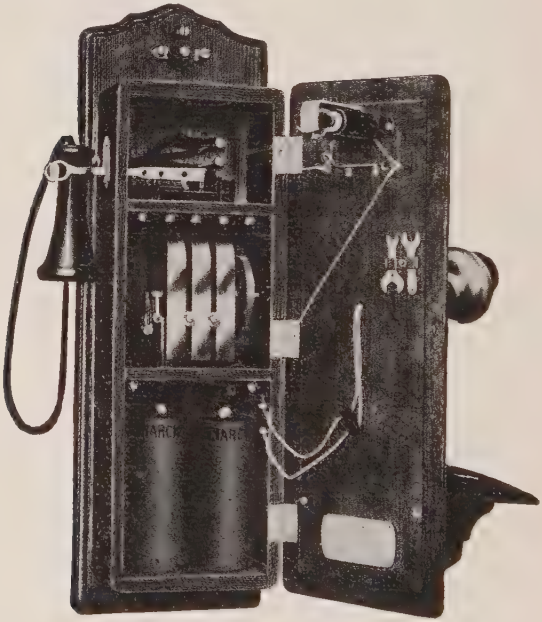


Figure 45.—Compact Telephone.

COMPACT TYPE TELEPHONES

The compact type of telephone is used to a greater extent than all other types of magneto telephones combined. The apparatus is easy of access. it is neat in appearance; its wiring is simple. As

all the apparatus is enclosed in a single cabinet, it utilizes a comparatively small amount of space, as the name implies, and is easy to handle and install.



Figure 46.—Compact Telephone (Bridging) Closed.

Compact Type Series Telephones.—A series telephone of the compact type is shown in Figure 45. It is equipped with a 3-bar generator and 80-ohm ringer. Some exchanges prefer to use 250-ohm or

even 500-ohm ringers, but 80-ohm ringers are extensively and satisfactorily used for all classes of individual lines. The bridging telephone has replaced the series set for practically all party line work.



Figure 47.—Compact Telephone (Bridging) Opened.

A compact type bridging telephone is shown in Figure 46. It is somewhat wider than the series telephone, because the hand generator has five bars or magnets and therefore occupies more space. The

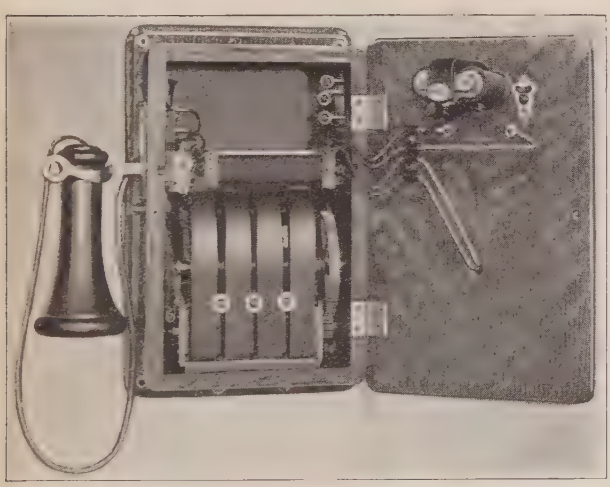




Figure 18.—Residence Type Magneto Wall Telephone.

transmitter is on a short arm near the center of the door, pivoted to permit considerable vertical adjustment. The writing desk is much steeper than was formerly the custom. A small hook at the right is provided to hold the directory. The same telephone, opened, is shown in Figure 47. There are no shelves. The hookswitch is mounted on the left wall, the generator on the back wall, and the bell, induction coil and condenser on the door. The wires are all cabled. No circuits are carried through the door hinges, as was done in older types, illustrated by Figure 45, which practice no longer obtains.

Residence or Hotel Type Telephone.—A residence or hotel type magneto telephone is shown in Figure 48. The arrangements are clearly visible, except that the battery of two or three dry cells must be located somewhere else. They are put in a nearby closet, in the cellar or basement just under the telephone, or in a battery box on the wall. The transmitter arm is usually shorter than that found on the compact type wall telephone, being reduced to a mere pivot on the back of the shell. The lightning arrester consists of a carbon block on the right upper portion of the box.

Desk Telephone.—A desk telephone, magneto, is shown in Figure 49. The stand consists of a base and a tube which rises vertically from the base. The transmitter is pivoted to the top of the tube or post. A few stands are now made with the transmitter neck solid, a very great improvement over the useless and expensive pivot. The hookswitch is in the tube or down in the base, and is operated by the lever which is seen at the left of the transmitter. In the base are terminals to which are attached the cords and wire conductors.

The bell box contains the bell, hand generator,

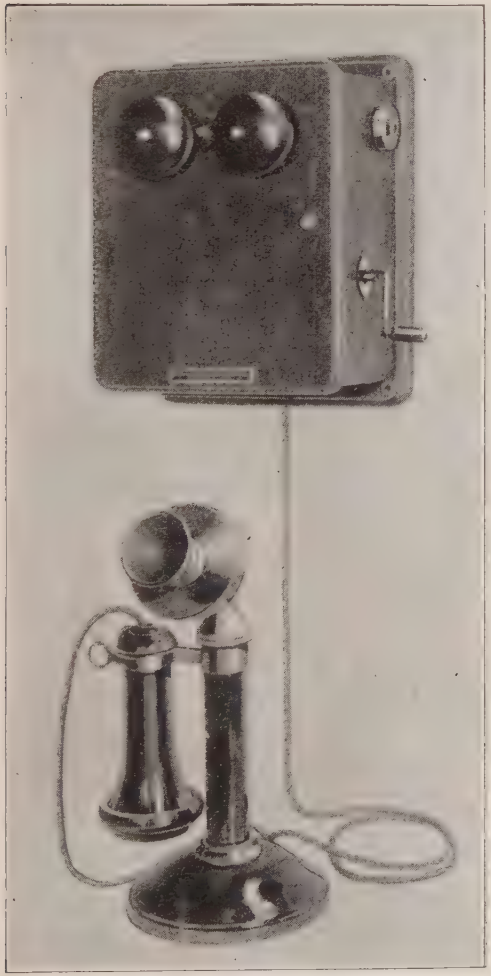


Figure 49.—Magneto Desk Set.

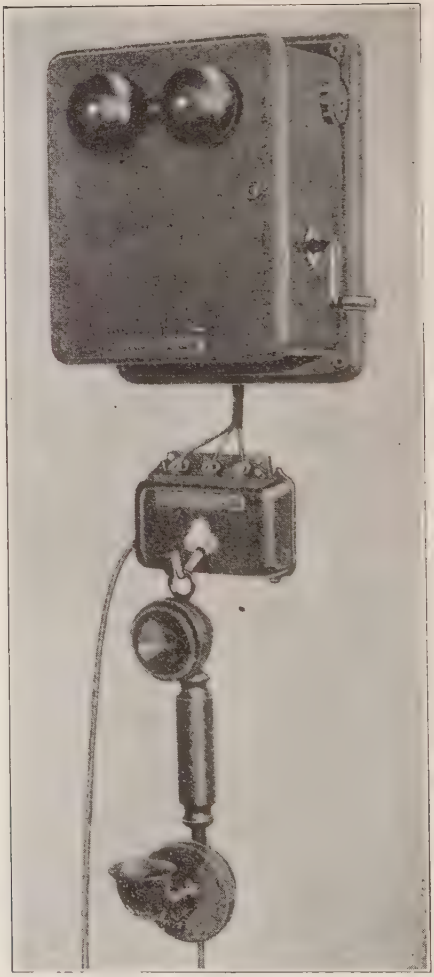


Figure 50.—Hand Microphone Set (LB).

lightning arrester and induction coil. A flexible cord connects the stand to the box. The battery must be located elsewhere. There have been stands made in which the induction coil was in the base, but the space is rather small and such a telephone does not talk as well as those whose induction coil is in the bell box.

Hand Microphone Telephone.—The hand microphone telephone set, Figure 50, sometimes referred to as a "combination" set, differs from the desk stand type in that the transmitter and receiver are made into a unit which is held in the hand. The hookswitch is mounted in a little box, which serves also as a meeting place for the cords which unite the bell box, switch box, and hand piece. Some attempt was made to put the hook switch in the microphone-receiver piece. It was operated by a pushbutton or a hand grip, which must be pressed all the time that a conversation was in progress. Another one was made with the hookswitch attached to an eye in the end of the handpiece. When hung on a dead hook, the weight of the piece operated the switch. The hand grip and pushbutton types have proved unsatisfactory, because the slightest relaxing of the attention of the user caused the hand to let go, and signal the operator (manual exchange) or release the connection (automatic exchange). It is perhaps not yet settled which of the other two is best. Time and use will tell.

VARIATIONS IN MAGNETO TELEPHONE CIRCUITS

From the series and bridging circuits given above, there are a number of interesting variations, caused by different services rendered and by different ideas of designers.

Series Telephone Circuit (Shunting Type).—The series telephone circuit, Figure 51, is arranged to remove the part not desired by short circuiting it.

The talking part and the ringing part are wired in series between the line binding posts, *L-1* and *L-2*. When the hook switch is down, the receiver and secondary winding of induction coil are shunted out. When the lever is up, the shunt is removed from the receiver and coil and put around the bell

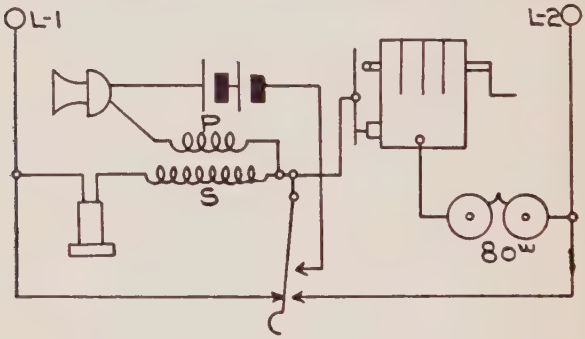


Figure 51.—Series Shunting Type Telephone.

and generator. The generator itself has the usual automatic shunt which cuts it out when the crank is at rest. The rising of the hook lever also connects the primary circuit, transmitter, battery and primary winding of induction coil. This circuit has the advantage of keeping the receiver and induction coil shortcircuited when not in use, thereby making them less likely to be burned out by lightning.

Bridging Telephone with Series Shunting.—In this circuit, Figure 52, the shunting device of the series telephone is used to protect the receiver and induction coil of the bridging telephone. During conversation, the bridging bell is shunted out of circuit. The generator is left directly across the

line, but is cut off (opened) when the crank is at rest, protected by being shortcircuited by its own spring.

Silent Ringing Telephone.—Some makers have thought that it is an advantage to have the bell of the station which is calling remain silent while the generator is being turned. The bell is removed

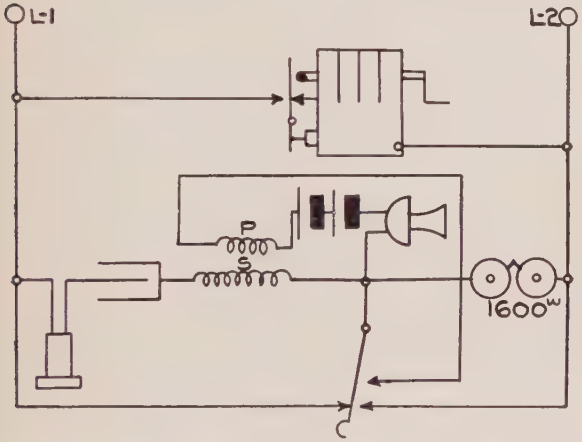


Figure 52.—Bridging Telephone with Series Shunting Hookswitch.

from circuit in two ways, by opening and by shunting. The latter is shown in Figure 53. When the crank of the generator is turned, the main shaft moves to the left, moving a spring which takes the short circuit off the generator and puts it on the bell. The other arrangement, Figure 54, has a similar spring on the generator, which switches the *L-1* binding post wire from the bell to the generator.

Harmonic Ringing Telephone.—Though harmonic

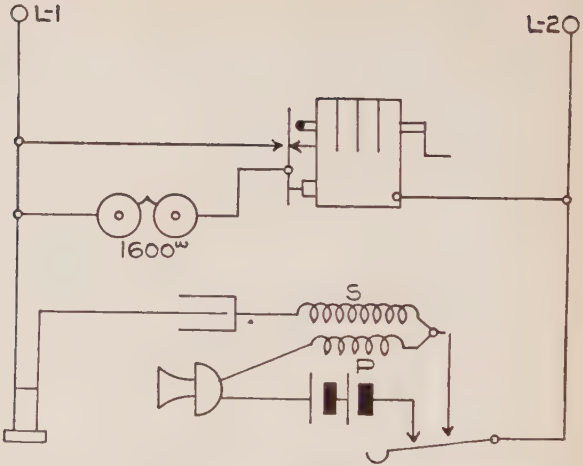


Figure 53.—Silent Ringing Bridging Telephone, Bell Shunted Out.

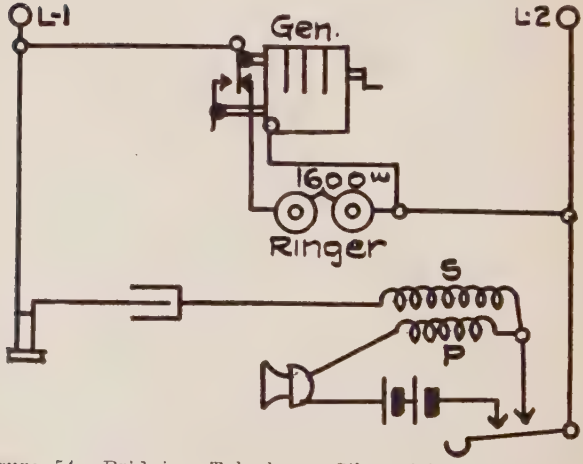


Figure 54.—Bridging Telephone, Silent Ring, Bell Opened.

ringing will be treated more fully elsewhere, it is in place to show here what changes are necessary to adapt a magneto telephone to this kind of signalling, Figure 55. The bell must have a condenser in series with it, for this lowers the impedance of that branch of the circuit, permits more ringing current to flow, and makes the bell ring more strongly. The generator is of the direct cur-

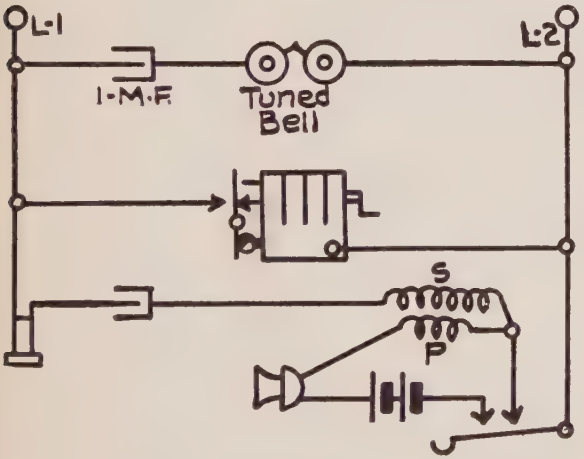


Figure 55.—Harmonic Telephone (LB) D. C. Generator.

rent type, so as not to ring the bells. It has its armature equipped with a commutator, which permits the generated current to flow out in only one direction.

Local Battery Talk, Common Battery Signal.—There are some common battery exchanges which have a few subscriber lines which are so long that the transmitter does not get enough current to

send well. In this case, the circuit of Figure 56 is sometimes used. The bell has a condenser in series with it to keep the battery current out of it. If this were not done, the resulting flow of current would signal the operator permanently, which is a case of trouble. But the ringing current goes through the condenser readily enough and rings the bell. When in use, battery current will be flowing through the receiver. This will weaken the receiver if it flows in such a direction as to weaken the magnetism. It will make the receiver work better if the line current aids the magnet. Hence it

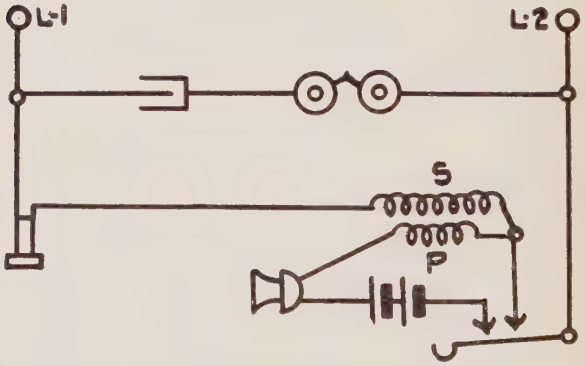


Figure 56.—Local Battery Telephone for Common Battery Signalling.

is necessary to "pole" the receiver, that is, to connect it so as to have the current aid the magnet in the receiver. Some automatic systems reverse the current in the calling line when the called subscriber answers. In this case poling is not effective, for part of the time the current flows one way and part of the time in the other direction.

But on a very long line the weak battery current may not weaken the reception very much and if

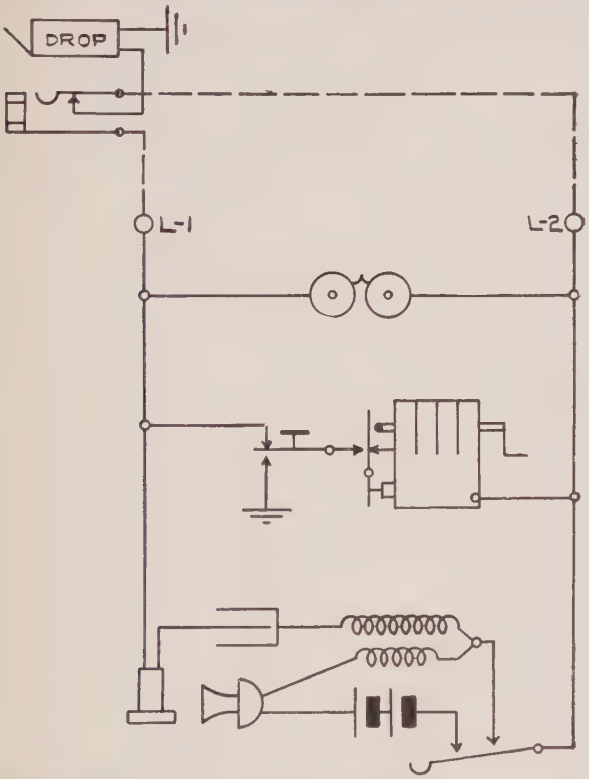


Figure 57.—Magneto Telephone, Non-Interfering Ring.

the transmission requirements are low, it may be permitted.

Non-Interferring Ring.—Sometimes it is desired to arrange it so that when a subscriber on a party

line rings the central office, it will not ring any other bells on the line. This is secured by the arrangement of Figure 57. A push button is inserted between the generator and the *L-1* binding post. When pressed, this button switches that end of the generator to ground. In the central office, the line drop is connected from an inside contact

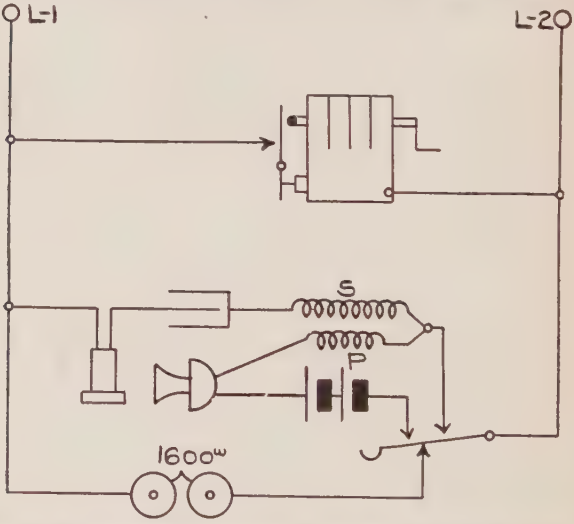


Figure 58.—Bridging Telephone with Bell Cut Off at Hook.

of the jack to ground. Hence, the operation of the generator with the button pressed will send current along line 2 through the drop to earth, without ringing any bells on the line.

Bell Cut Off at Hook.—At one time it was very much the habit with Independent makers to carry the bell circuit through the switch, as in Figure 58. This cut the bell off the line at each telephone

which is talking. But the impedance of the bell to talking current is so high that the presence of the bell does no harm.

Desk Telephone Circuits.—Almost any kind of circuit can be built into a wall telephone with ease and cheapness. In a desk set it is not as easy, because of the conductors required in the flexible cord which must connect the stand to the bell box. This cord is a fairly expensive part. It wears out and from time to time must be replaced. The cost of this comes out of the telephone company.

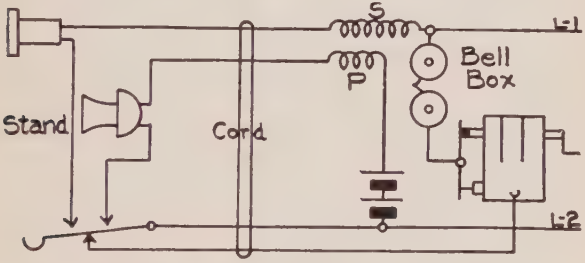


Figure 59.—Desk Set Circuit, Series (Opening).

Hence there is a just desire to keep down the number of conductors in the cord. This is done by skillful arrangement of the circuit, though in some cases a maker has put the induction coil in the base of the stand to retain some feature of circuit and yet not have many conductors.

Series Desk Sets.—A commonly used circuit is shown in Figure 59. It switches the ringing and talking parts in and out by opening each. Thus, line 2 (*L-2*) leads directly to the lever of the hook-switch. With the hook down, the path leads through the generator and bell to *L-1*. But when the hook is up, the bell circuit is opened, and the receiver

and coil circuit closed. The induction coil is in the bell box, where the battery is attached. It requires four conductors in the cord. Notice that the primary and secondary windings of the induction coil are on opposite sides of the line.

Another circuit is shown in Figure 60. It is of the series shunting type, because it removes the talking or the ringing part of the apparatus by shunting it. If the hook lever were in the middle, the receiver, secondary of induction coil, generator and bell would be in series across the line. When

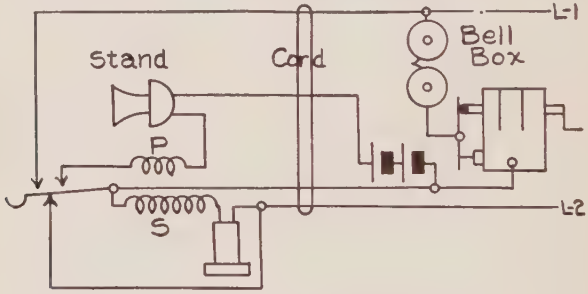


Figure 60.—Desk Set Circuit, Series (Shunting).

the hook is down, the receiver and coil are short-circuited out. When the hook is up, the shunt is switched from the receiver and coil to the generator and bell. At the same time, the primary circuit is connected at the other upper contact. To secure this circuit with four conductors, the maker put the coil in the base of the stand, a practice which is not considered good with present designs of coils. But this series shunting plan does keep both windings of the coil on the same side of the line. This, together with the short circuiting of the re-

ceiver and secondary, reduces the likelihood of injury by lightning.

If the induction coil were placed in the bell box, the series shunting circuit would be arranged as in Figure 61. This takes five conductors in the cord. Notice the same series arrangement, with the shunting of the receiver when the hook is down,

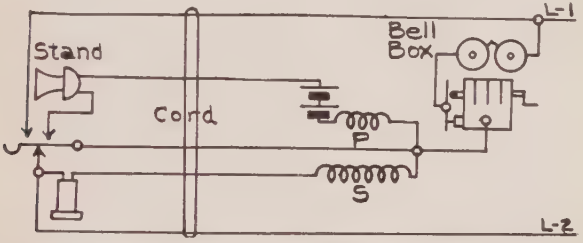


Figure 61.—Desk Set Circuit, Series (Shunting).

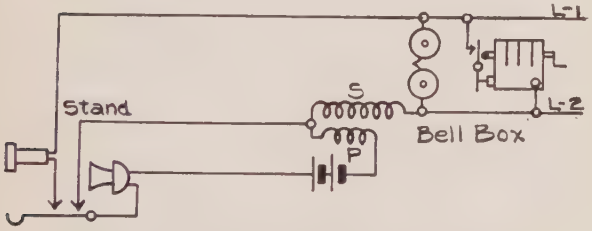


Figure 62.—Desk Set Circuit, Bridging.

and the shunting of the bell when the hook is up. This enables the primary and secondary to be tied together. As far as the writer knows, this circuit arrangement is not used.

Bridging Desk Sets.—A very simple bridging desk circuit with only three conductors in the cord is shown in Figure 62. The bell is left across the line all the time. The generator is cut in by the

turning of the crank as usual. There are three conductors to the stand, one for the receiver, one for the transmitter, and one common to both. Both windings of the induction coil are on the same side of the line. There is no bottom contact on the switch. It has been used for many years and seems to be satisfactory.

The shunting principle has been applied to the bridging as in Figure 63. The generator is not in the series circuit. It is bridged across the line and cuts itself in and out as usual. But the re-

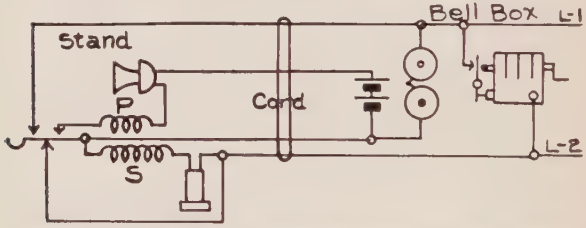


Figure 63.—Desk Set Circuit. Bridging (Shunting).

ceiver, secondary of induction coil, and bell are in series. When the hook is down, the receiver and coil are shunted. When the hook is up, it is the bell which is shunted. There are four conductors in the cord, because the induction coil is in the base of the stand. If the coil were in the bell box, it would take five conductors, as described above.

SCHEMATIC CIRCUITS AND WIRING DIAGRAMS

The circuits which have been shown were arranged with a view to making it easy for the reader or the telephone man to understand what is in the telephone, how the parts are related to each other, and how they are intended to work. Some

people call them "theoretical" diagrams. But they are not theoretical, they are practical, very much so. They show clearly the relationships which every telephone man ought to know.

But for the purpose of wiring a telephone, or of quickly locating any point in the apparatus, a

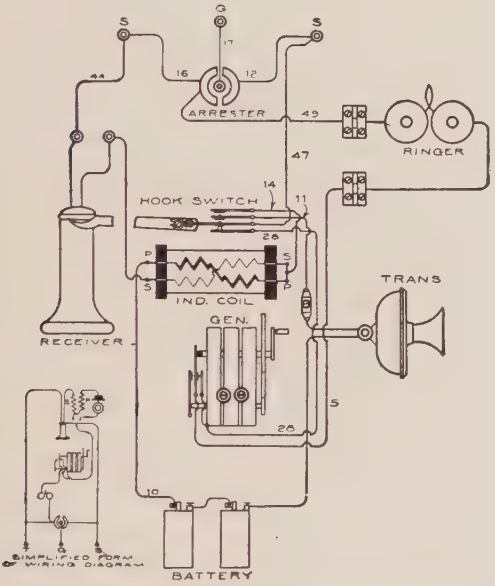


Figure 64.—Wiring Diagram for Series Instrument.

"wiring diagram" is made. A wiring diagram is usually furnished by the maker of telephone apparatus, as well as some kind of simplified circuit. Sample wiring diagrams are shown in Figures 64 and 65. They are for a series and a bridging wall

set, respectively. They also illustrate the little simplified diagram which is often put in the corner of the wiring diagram. The latter has the pieces of apparatus located about as they are in the actual telephone, with the terminals relatively placed.

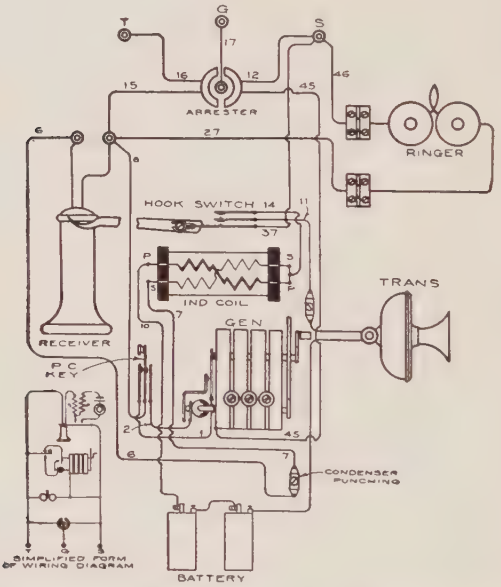


Figure 65.—Wiring Diagram for Bridging Instrument.

Every telephone man should train himself to locate on the telephone every point which is on the wiring diagram and also on the simplified circuit. He should also train himself on the reverse process —locating on the circuit every point of the actual apparatus. It is the best way to become familiar

with the apparatus, to be at home with it so that repairs can be easily and quickly made. No one else can do it for you—you must teach yourself. When a man knows both the circuits and the apparatus and how they work, he will soon master the art of telephone operation and maintenance.

CHAPTER V

THE PRIVATE LINE

A private line is one which connects two telephone stations which serve one interest and have no outside connections. Thus, such a line connects the doctor's office and residence, or two residences, or two rooms in a large building. If the line is entirely inside a building it is called an interior line. If it runs even partly outdoors it is called an outside line.

The private line is very useful in some cases. It was the first telephone system used. First two stations were used. Then three or more stations were put on one line. Each station had a different code or ring. One ring meant one station, two rings another, perhaps a long ring followed by a short ring called still another. Many businesses and private individuals still have private lines. For instance, a power company may have a line from the dam to the power house, if they are separated some distance. An electric power transmission company usually has a line paralleling its transmission line, with a telephone at each power house or substation.

When there are only two stations on the line, the series telephone serves very well. Since it is cheaper than the bridging instrument, it is usually employed. Series lines have even been used with three or four instruments on them, but in general the bridging telephone is preferred in such cases.

All telephone lines are either metallic or earth return (grounded). The former are better than the latter, but the latter are much used because they are cheaper. The grounded line is subject to noises from several sources, but the metallic line, when properly transposed, is very quiet.

The two-station private line, Figure 66, is metallic. Two wires are carried from one telephone to the other, carefully insulated all the way. The line in Figure 67 is grounded. There is only one

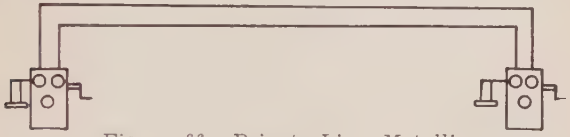


Figure 66.—Private Line, Metallic.



Figure 67.—Private Line, Grounded or Earth Return.

line wire. The other binding post on each telephone is connected to the ground. The electricity travels one way on the line wire and returns through the earth. The connection to the ground is usually made by clamping the wire to a water pipe. If no such pipe is available, a galvanized iron pump rod, six to nine feet long, is driven into the ground. The wire from the telephone is soldered to the top of the rod. In any case, the rod must reach permanently moist earth, in order that a good connection may be had.

Series Private Line.—The series private line may be illustrated by three stations, Figure 68. Two line wires are carried along from the first station to the last. It is connected to the terminal stations *A* and *C* just as if there were no other telephones on the line. Intermediate stations, like *B*, are inserted into one of the two wires. Cut one wire and connect the two ends thus made to the two line binding posts of the telephone.

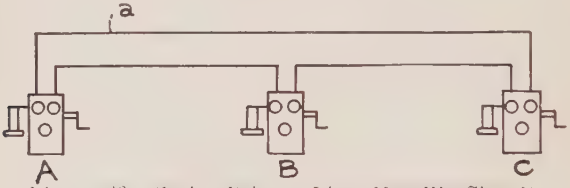


Figure 68.—Series Private Line, Metallic Circuit.

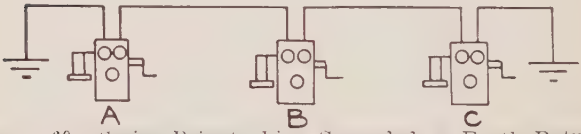


Figure 69.—Series Private Line Grounded or Earth Return.

The series private line of Figure 69 is grounded. Only one line wire is run between the stations. The intermediate stations are connected as above described, except that now there is no choice of lines to cut.

Line Troubles.—It is well to consider the effects of a few troubles. Such consideration helps a person to understand the principles involved, and makes it easier to reason out the probable cause of failure when a line ceases to work properly.

In any of the four diagrams, Figures 66 to 69, a

break in the line wire at any point will put the line out of service. It may be along the line, or it may be at the ground connection. The writer has known of such a break caused by the drying up of a very short ground rod. The ground became so dry and baked with the summer heat that the line would neither ring nor talk. Pouring a pailful of water down a hole beside the rod restored connection, but it was permanently remedied by using a long rod.

If the line between two of the stations in Figure 68 is very long and there is a break in one side of it as at *a*, telephones *B* and *C* may be able to hear each other but not loudly. But they can not ring each other. The reason why they can hear each other a little is that the two line wires from *B* toward *A* form a small condenser, and *B* and *C* will be talking through that small condenser. But it is too small a condenser to let much ringing current through, because the ringing current is of such low frequency.

If the line between two stations on a metallic circuit breaks, and both ends fall onto the wet ground, conversation and ringing frequently proceed fairly well, but it may be noisy.

If there is a heavy leak between the two line wires of the two-station metallic circuit of Figure 66, ringing will be more difficult and talking will be fainter. If the leak gets very bad, amounting to only a few ohms or practically zero, neither station can ring or talk to the other. Being equipped with series telephones, each user will hear his bell ring strongly, and the crank of the generator will turn hard. This is because he is ringing on a circuit of low resistance. Also, when each user attempts to talk, he will hear a strong "side tone" which is the sound of his own voice in his own

receiver. The line is said to be "short circuited."

A short circuit on a metallic line with several stations, as in Figure 68, will isolate the stations on either side of the short circuit. A short circuit between *A* and *B* will permit *B* and *C* to use the line, but they can not get *A*. If there were other stations beyond *A* to the left in the figure, they would be able to use their portion of the line but separated from the *B* and *C* end.

The grounding of a metallic circuit line has no bad effect if there is no foreign electricity to cause noise. Small country towns where there are no trolley lines nor power circuits will have no trouble, though the line will be more noisy in a thunder storm.

The grounding of an earth return line will do for it what a short circuit will do for the metallic series line. In the two station line of Figure 67 it will stop traffic. In the three-station line of Fig. 68 it will isolate part of the line from the other part.

Grounds and leaks have effect in proportion to their conductance. If the resistance of the leak is high (5,000 ohms, or so), it may be little noticed. If it gets low (1,000 or 500 ohms), it will make it hard to use the line. If it gets as low as 100 ohms, 50 ohms, or 25 ohms and lower, the line will usually be inoperative. In most cases ringing stops before talking fails.

Sometimes a break in the circuit may be partial, not total. In such a case, it often happens that if the user rings, the ringing current will break down the resistance of the fault, and for a time thereafter conversation may take place. But after a while the bad point opens again, and talking stops. This kind of trouble happens most at dry ground rods and poorly made splices in the line.

The conditions of talking on a series line are shown in Figure 70. The path of the high frequency talking current is through the receivers and induction coil secondaries in the two telephones which are being used, and through the bells of the other stations. The impedance of the line wires may not be much, but that of the bells is considerable. The resistance of the copper wire of each

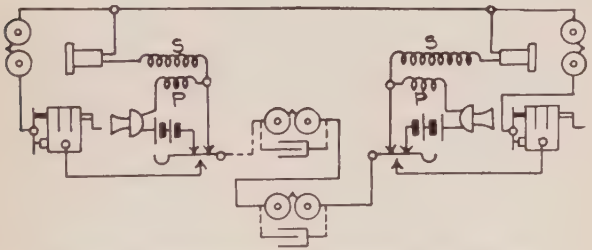


Figure 70.—Series Line. Talking Conditions.

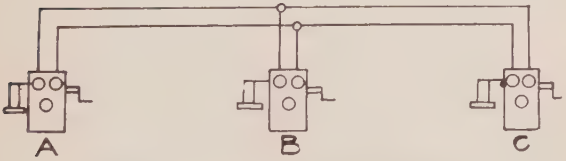


Figure 71.—Bridging Metallic Line.

bell is about 80 to 125 ohms. The total impedance to talking current is several thousand ohms. This weakens the conversation. It can be strengthened by shunting each bell with a condenser, half microfarad capacitance. This permits the talking current to pass around the bell and yet does not interfere with ringing.

Bridging Party Line.—For several stations, the bridging line is the best. The reasons will appear

during the discussion. The metallic line is arranged as in Figure 71. Two wires are run from end to end, and each telephone connected across the circuit. That is, one line binding post is tied to one line wire and the other binding post to the other line wire. The earth return line, Figure 72, is equally easy to connect. Connect each telephone from the line to ground.

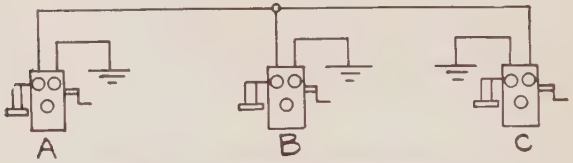


Figure 72.—Bridging Grounded Line.

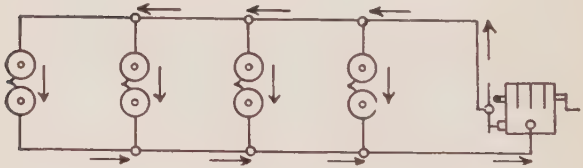


Figure 73.—Ringing Conditions on Bridging Line.

The conditions during ringing are shown in Figure 73. The current from the generator passes through one line wire and divides at each telephone, part of the current passing through each bell. This makes the current in the generator the strongest, and the current through the most distant bell the weakest in the circuit. For this reason, each bell has high resistance and high reactance and impedance. One thousand to 1,600 ohms are used, though some have been made with as high as 2,500 ohms and even 3,400 ohms. The current is alter-

nating, so the arrows show the flow of current at only one moment.

The talking conditions are shown in Figure 74. Each bell remains as a leak across the line, but its impedance to talking current is very high, so that the loss is almost inappreciable. It is not uncommon to have a bell whose talking current impedance is 50,000 to 100,000 ohms.

When there are several stations on one line, it frequently happens that when a person wants to ring, someone may be idly listening. His receiver and induction coil secondary form a serious leak, because they have relatively low impedance. To

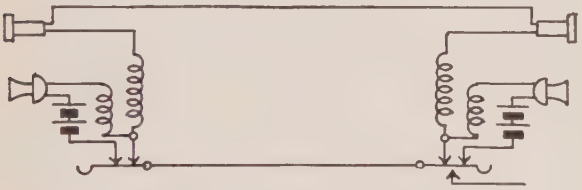


Figure 74.—Bridging Line, Talking Conditions.

avoid this trouble, it has become customary to insert a half microfarad condenser in the receiver circuit. This condenser has high impedance to ringing current (low frequency) and much smaller impedance to talking current (high frequency).

Figure 75 shows the ringing conditions on a bridging line, with stations listening. If it were not for the condensers in series with the receivers, each receiver off the hook would cause a leak of about 200 ohms to the ringing current at 16 or 17 cycles per second. But the insertion of the half microfarad condenser raises the impedance to about 20,000 ohms to the ringing current. To the talk-

ing current at an average of 800 cycles per second. this 0.5 M. F. condenser has only about 400 ohms reactance, which is very little account to the telephone. If a one M. F. condenser be used. its impedance to ringing current is about 10,000 ohms and to talking current 200 ohms.

Line Troubles, Bridging Line.—A leak to earth on a bridging metallic line will not interfere with operation if the line is free from induction, such as parallel power lines, trolley lines, etc. But since these are very common in many parts of the country

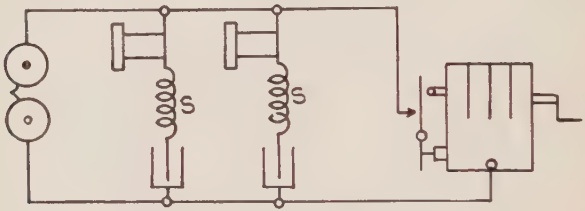


Figure 75.—Party Line Ringing Conditions with Stations Listening.

today (1923), noise must be expected if one side of the line gets grounded.

The earth return bridging line will be as noisy as the accidentally grounded metallic line, and perhaps more so. But if the earth return line becomes grounded, it will put the line out of service. Sometimes, if the earth return line is very long, eight, ten, or twelve miles, there may be a dead ground at one end, and the stations at the far end, away from the fault, will be able to ring and talk to each other. The resistance of the line wires permits this. But ringing and talking will be increasingly difficult as you approach the fault.

A leak across the two wires of a metallic bridg-

ing line acts like the ground just described. If it is of high resistance, it may not be noticed. If it is lower, it may make ringing difficult. If it is very low, and the line is short, it will stop all use of the line. But if the line is long, and the dead short circuit is at one end, the resistance of the line wires between the fault and the telephones at the far end may be great enough to permit them to ring each other fairly well, and talk satisfactorily.

A break in the line will isolate the telephones on either side. This is equally true for metallic and earth return lines. But if both ends of the broken line fall on wet earth, the earth return line may

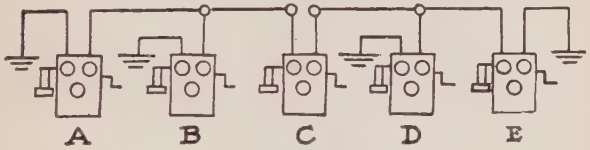


Figure 76.—Earth Return Bridging Line with Wrongly Connected Instrument.

be thrown entirely out of service, while the metallic line may continue to operate, though noisy.

A case of trouble was once brought onto an earth return bridging line by a person who connected a telephone as at *C* in Figure 76. The person was an old telegraph man, who was accustomed to putting everything in series. Also, the directions which came with the telephone directed both binding posts to be connected to line wires for metallic circuit, which was advised as better than grounded circuit. The other telephones, *A*, *B*, *D* and *E*, had been in good service for some time, when telephone *C* was added as indicated. At once the line acted queerly. Station *C* could call anyone else on the line with ease, and could talk though not as loudly as might be

desired. But stations *A* and *B* could not call *D* and *E*, though they could call each other as well as usual. In reality there were about five or six telephones on either side of the added station *C*. When by chance a station like *A* found another station like *D* on the line, they could barely hear each other. The reason was that the high impedance of the bridging bell at *C* almost cut the line in two. But when *C* himself had the receiver off the hook, the bell was either cut out or shunted by the low resistance receiver and induction coil.

LIGHTNING PROTECTORS

For the low voltages which are employed in telephony and telegraphy the silk, cotton and enamel insulation of the wire used in coils is sufficient, but there is no ordinary covering capable of resisting the enormous electro-motive force of lightning. Therefore lightning protectors or arresters, which are connected between the line and earth, are employed. These protectors or arresters act on the principle that the impedance of coils to lightning discharges is so great that the discharge sparks jump across the air-gaps between the carbons, and save the apparatus from destruction. In locations where lightning storms are very severe the lightning rods and earth wires should be as straight as possible and angles should be avoided as a flash, in preference to turning a right angle in an earth wire, will occasionally leap across a great space.

The disc arrester, Figure 77, has come into wide use on compact type telephones. It is mounted on the right side of the box near the top. A heavy insulating mounting piece supports two metal line plates, each of which has a terminal sticking through the wall into the box. The ground post extends through the center of the arrester, insulated

from both line plates. A carbon disc is held on the ground post by a nut, but is separated from the line plates by a mica disc. Turning the carbon disc usually clears it of particles which have lodged so as to ground the line.

The usual difficulty found with arresters is that if the air gap between the line plate and the ground plate is small enough to protect the telephone, it

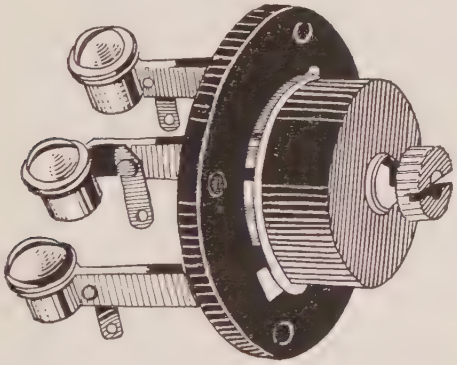


Figure 77.—Disc Lightning Arrester.

is very easily clogged by small particles loosened by lightning discharges. If the gap is large enough to prevent this undesired grounding, the lightning will very often prefer to go through the telephone and burn out coils. The former adjustment is preferable, trusting to the subscriber or repair man to turn the disc and clear the line.

Lightning may affect a telephone line in two ways, a direct stroke and an induced flow of cur-

rent. From the former there is no real protection. The writer has known a direct stroke to splinter several poles from top to bottom and burn up two or three spans of No. 12 B. W. G. iron wire. When a charge of electricity like this strikes a telephone line, we can only hope that no person is using a nearby telephone instrument, or even standing near it. The induced flow of current is more mild, and good protectors can handle it with safety. In this case, the flow of current in the telephone line is merely induced there by a lightning discharge between two clouds or between a cloud and earth.

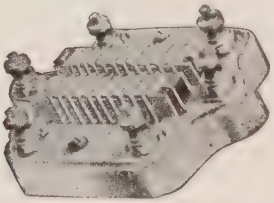


Figure 78.—Multi-discharge Lightning Arrester.

The multi-discharge arrester, Figure 78, is a combined air gap arrester and inductance. The line conductor is coiled around a carbon pencil (square) but insulated from it by mica strips. The gaps occur at the corners. Ringing and talking current pass through the coil with ease, for its inductance is very small. But lightning is a very high frequency oscillation, or at least has a very steep wave front, so that a very small inductance offers high impedance. For this reason, the lightning often prefers to jump to earth rather than to pass on into the telephone. This same principle is also used in power transmission circuits.

In addition to lightning, there is often danger

from high tension power lines. A cross with a 500 or 600 volt trolley line will burn out a telephone in an instant. Higher voltages are still more dangerous. A suitable fuse must be installed in series with the line, Figure 79, so that if such a cross does occur, the fuse will melt and open the line. The action is as follows. When the strong current gets onto the telephone wire, it is usually seeking ground.

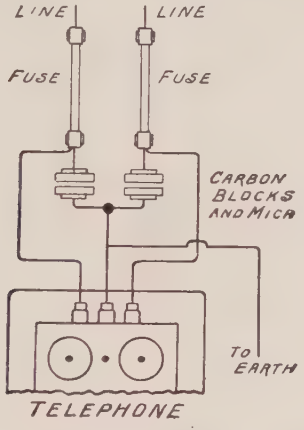


Figure 79.—Protector Installed at Telephone.

It easily jumps over the small air gap in the lightning arrester and flows to earth. The resulting flow of strong current blows the fuse, which opens the line. If the gap broke down promptly, and the fuse blew instantly, the telephone apparatus will not be harmed.

Whenever a telephone is found to be out of order, proceed with care. Do not hastily touch the line end of the fuses. It may be that there is a high tension cross still on the line, with the fuse open.

Ground a piece of wire, carefully touch the line end of the fuses, and observe if it sparks or flashes. Govern yourself accordingly.

The ground wire for a lightning arrester should be very carefully installed. Run it as straight as possible, good strong wire which will not break easily. Protect it as much as you can, or at least do not run it in places where it will be needlessly exposed to danger of breakage. The earth connection itself should be thorough. Permanently moist earth is necessary. The arrester ground is the most likely to be neglected, because it is not part of the talking or ringing circuit, and will not be missed in daily use. But it must be maintained if protection is to be had.

All telephone instruments are made for metallic circuit use, with two line binding posts and a ground post, each connected into the arrester. In installing a telephone on an earth return line, connect one line post to the ground post and ground them. Use the other line post for the single line wire. This gives the best protection.

CHAPTER VI

THE TELEPHONE EXCHANGE

The telephone exchange is used because the private or single line was not adequate to the needs of the people. General communication is necessary. People need to be able to talk rather freely from any place to any other place. This the single line could not do. So instead of having separate lines, each carrying from ten to twenty telephones, we have the central exchange, many telephones, each on one line which reaches a central point where it may be connected to any other line and its telephone. This is a general definition of an exchange.

The exchange includes a number of interesting things. There is the switchboard itself—the means by which any line is connected to any other line. There is the building which shelters the switchboard with its accessory apparatus and those who care for it. The lines which radiate to the telephones constitute the wire plant, including all the poles, cables, ducts, etc. which house the wires. There are also the installed telephone instruments, which are termed "subscriber stations" often abbreviated "substation." This chapter will direct your attention to the switchboard.

Exchanges and switchboards may be classified in a number of ways. Public exchanges are those which serve the general public. Private exchanges are those which serve only one industry or business concern each. Thus some power companies and some oil companies have their own private ex-

changes, not connected to any outside telephone system. Then there is the private branch exchange, which is a cross between the two. It is an extension of the single subscriber line to connect with several telephones, all in one business house. If the traffic gets too heavy, more than one subscriber line is used, but all are reached by the same call number. Each telephone is called an "extension" telephone. Local service between extension telephones is given.

Exchanges and switchboards differ according to the method of operation, manual or automatic. A manual exchange is one whose switchboard is operated by people, usually girls, who make and disconnect the circuits between subscribers. An automatic exchange has remote control switches, which connect the subscriber lines together at the will of the subscribers. Each subscriber can control switches by means of a calling device on his telephone. Then there is a cross between manual and automatic in the semi-automatic. This kind of exchange or switchboard has a complete automatic switchboard in the central office, but only ordinary manual telephones for the subscribers to use. Between each subscriber line and the automatic switchboard is an operator. She receives the call as in a manual office and controls the automatic switches to complete the connection.

Exchanges are also classed as single office and multi-office. The former has but one office, consisting of a building which houses the switchboard and its accessory equipment. Larger exchanges can not house all the switchboard in one building to good advantage. The subscriber lines become too long and expensive. So there are a number of separate offices, each having its own switchboard, but connected to each other by trunk lines.

Connections from the subscribers to distant cities are made over toll lines. In small boards, the toll lines are on the subscriber board, and are treated very much like subscriber lines. But in large exchanges there is a separate toll board, with trunk lines connecting the local switchboards to it.

Exchanges are also separated into local battery and common battery accordingly as they use these means of voice transmission. The former usually carries with it the idea of magneto signalling. But there have been boards made which were a cross between the two, in that the signalling was by common battery and the talking by local battery.

The magneto or local battery switchboard is the oldest and most easily understood, and will be described first.

CHAPTER VII

THE MAGNETO SWITCHBOARD

Several classes of circuits enter into the make-up of a switchboard. First, the line circuits, one of which is provided for the line of each subscriber entering the exchange. Second, the night alarm circuit, one only being provided for the entire switchboard. Third, the code alarm circuit. Fourth, the cord circuits, the number of which depends

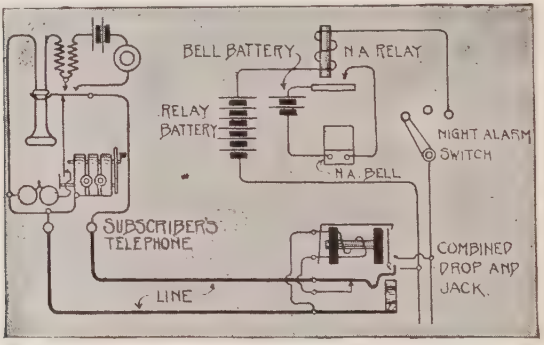


Figure 80.—Simple Magneto Line Circuit.

upon the number of line circuits and the greatest number of connections likely to be called for at any one time. Fifth, the operator's circuits, one of which must be provided for each operator. Sixth, the generator circuits, one of which is installed for each operator.

In Figure 80 the circuit of the subscriber's in-

strument, the line circuit and the night alarm circuit are shown. The only apparatus in the line circuit proper is a combined drop and jack, to the terminals of which the subscriber's line is led. The path for ringing current may be readily traced through the jack and the winding of the drop. In plugging in to answer a call a contact is broken in the jack which cuts the drop winding out of the talking circuit.

Whenever the operator is not sitting directly in front of the board, as is usually the case at night, the night alarm switch should be left closed. Then when a call comes in which might not otherwise be noticed, the night alarm bell will ring until the shutter is restored. The night alarm circuit operates as follows: In falling, the shutter closes a circuit through the relay battery and the night alarm relay. This relay in turn closes a local circuit containing the night alarm bell and two dry cells, causing the bell to ring. The night alarm contacts closed by the shutter in falling are described under the subject of "Combined Drops and Jacks." The relay in the night alarm circuit is quite sensitive and will operate on a very small amount of current, thus insuring a positive closing of the local circuit containing the bell. This latter circuit is independent of the night alarm contacts of the drop, and throws on the bell a steady current which is essential in order to get a satisfactory ring from any direct current bell. The current necessary to operate the relay is so small that it will not burn the night alarm contacts and leaves them bright and clean at all times. The combination gives a very effective and reliable night alarm.

Cord and Operator's Circuit.—A regular cord circuit and the operator's circuit are shown in Figure 81. Connected in the cord circuit are a

listening key *B*, a ringing key *A*, and a ringback key *C*. A disconnect signal, known as a clearing-out drop, is bridged across the two sides of the circuit. This drop has a very high impedance and does not shunt the voice currents to any appreciable extent, while it is readily thrown by the generator current in ringing off. In practice it is better to bridge in a clearing-out drop than to insert one in series on either side of the line, as the cord circuit is perfectly balanced and therefore quiet. Both sides of the talking circuit may readily be traced

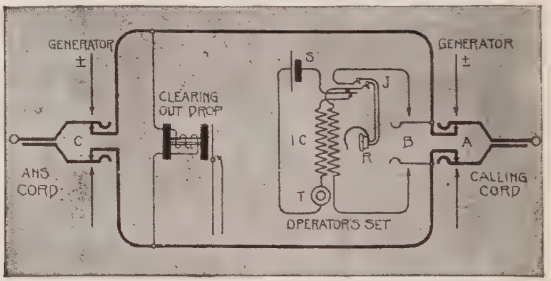


Figure 81.—Simple Magneto Cord Circuit.

from the answering plug to the calling plug, the platinum contacts of the keys *C* and *A* being the only apparatus through which the voice currents pass. By means of the ringing keys *C* and *A* the operator may ring out on either cord at will. Each ringing key, when operated, opens the cord circuit so that no generator current passes back to ring the operator in the ear.

The operator's telephone set consists of a head telephone *R*, a cut in jack *J*, an induction coil *I C*, a transmitter *T*, and a battery *S*. The operation of this circuit is similar to that of an ordinary

subscriber's telephone set. The induction coil is of a special type designed to meet the needs of the operator. A listening-in key B is wired in connection with each cord circuit in such a manner as to enable the operator to cut her telephone set into the particular cord circuit she happens to be using.

What is known as the Bell type switchboard differs from other boards in that the line drops

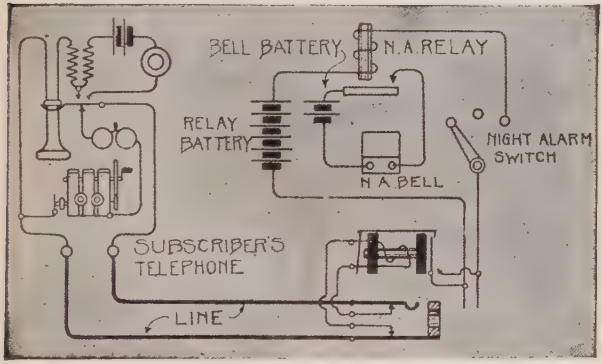


Figure 82.—Line Circuit. Small Magneto Switchboard.

are *manual restoring* instead of *self-restoring.* This, of course, slows down the speed of operation, but the board can be used with satisfaction where extreme rapidity is not required. The operator's circuit, the cord, night alarm and generator circuits and the pieces of apparatus entering into them, are all exactly the same as those used in the Express boards. The line circuit is shown in Figure 82. The line jacks are located in one bank directly under the drops.

Metallic and Earth Return Lines.—There are two principal types of line circuits: first, where only one wire connects the subscriber's telephone to the exchange, the return circuit being a common conductor, and the second, where two line wires are used, making what is called a metallic circuit. The common return of the first may be either the earth, when the sytsem is called "grounded," or it may be a common wire, when the system is known as a "common return." Figure 83 shows two grounded lines connected through the switch-

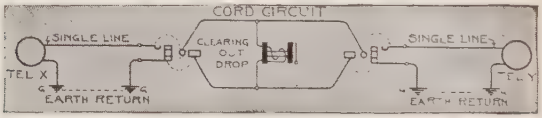


Figure 83.—Magneto Switchboard Connection, Earth Return.

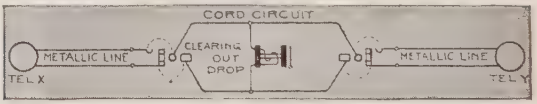


Figure 84.—Magneto Switchboard Connection, Metallic Circuit.

ing device of the switchboard called a cord circuit. Figure 84 shows two metallic lines similarly connected. A properly constructed metallic line circuit is the only construction which will assure the most efficient results, and should always be used when possible.

If metallic circuits are used throughout the system, the switchboard cable should be connected by pairs straight through the distributing frame to meet the open line wires of the subscribers' circuits at the pole terminal box.

If the system is grounded or common return

there will be of necessity some cross-talk. But in order to reduce the cross-talk as much as possible, all lines should be carried metallic through the twisted pairs of the cable to the terminal box where the open line wire construction commences. At this point connect all of the sleeve or colored wires to a common conductor not less than a No. 8 B. and S. Gauge, as shown in Figure 85, and run to a good ground or to the common return

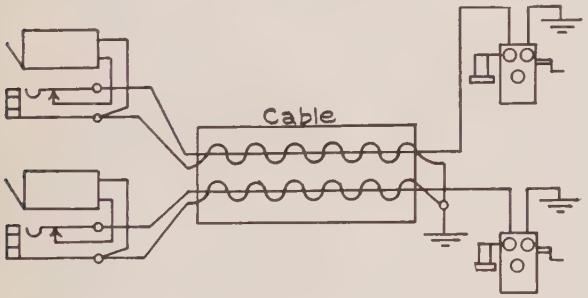


Figure 85.—Carrying Lines Metallic Through the Cable.

wire of the system. This will give a metallic twisted pair circuit for each line to the open wire construction.

If the wires are connected to the common conductor at the distributing frame or arrester strip, and each conductor of the outside cable used as a line wire, the cross-talk would be greatly increased. This is due to the fact that the cable conductors would then be in the condition of parallel line wires without transposition and the electrical induction from any one of them carrying voice currents would affect the remainder in the same cable, and thus bad cross-talk would result. This induc-

tion cannot exist between lines made up of twisted pair circuits.

Care must be exercised in connecting sleeve wires to the ground or common return as any reversal of these conductors will produce trouble when a circuit thus transposed is connected through the switchboard cord circuit to a properly grounded line. A short circuit will be established from the tip side of the wrongly grounded line, through the common return to the sleeve of the connected line, as shown in Figure 86. On account of this low resistance path across the line no conversation

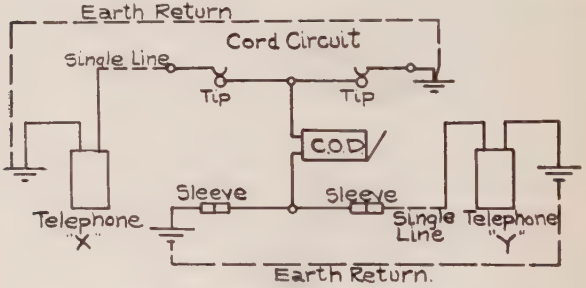


Figure 86.—Effect of Reversed Line.

can take place between the connected subscribers, neither can they ring down the clearing-out drop for disconnection. The lines will of course remain tied up until the operator discovers the trouble.

Parts of Magneto Switchboards.—Before going more fully into the circuits of magneto switchboards, it is well to take a look at some of the parts which go to make up the board and which are used in the circuits. There are a number of manufacturers of this kind of apparatus. It is not practical to show illustrations of all the types made. We shall select a few varieties to illus-

trate structures which are in common use and from these all the essential principles of switchboards can be learned.

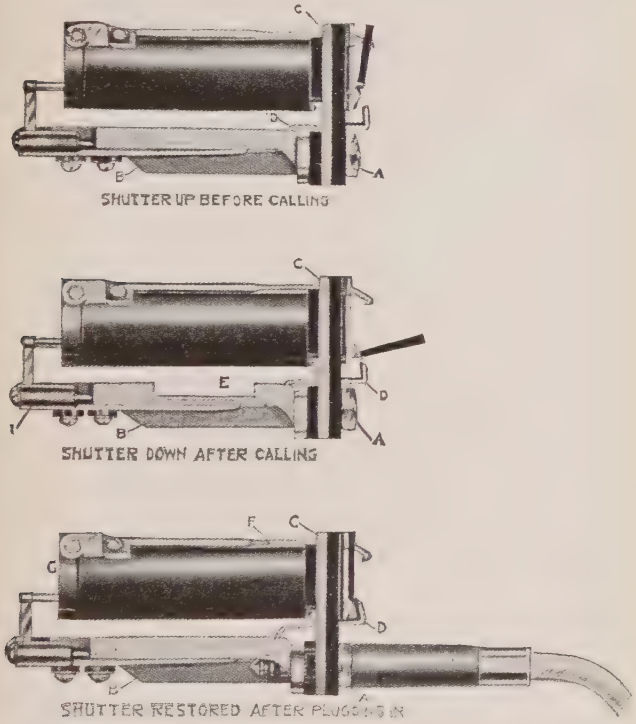


Figure 87.—Combined Drop and Jack, Self Restoring (Kellogg)

COMBINED DROPS AND JACKS

The line signal and its accompanying jack are, on account of the exacting requirements and duplication, the most important pieces of apparatus

in small switchboard construction. The combined drop and jack which is used in all Express type switchboards is made up of a sensitive tubular drop mounted together with a spring-jack on the same strip. Figure 87 illustrates in three views the operation of this piece of apparatus. The first view shows the normal condition with the drop shutter up and ready to receive a call, the second view with the shutter down after a call has been received, and the third view with the shutter restored by the act of plugging into the jack. The restoring mechanism is clearly shown in this last view. The line or tip spring of the jack is elongated sufficiently to project through an opening in the mounting strip and by its rise, due to the insertion of the plug, restores the drop shutter and holds it in this position as long as the connection is up. The upward movement of the tip spring also opens contact with the short or local jack spring, and thereby cuts the drop winding out of circuit.

The means for mechanically restoring the shutter in this mechanism is very simple. No additional parts are required for accomplishing the complete restoration of the shutter, and for holding it in its locked position during the connection.

The Drop.—Figure 88 shows the parts of one complete drop mechanism. It is of the tubular or iron-clad type. The armature and core are of the same quality of iron. The winding is insulated from all metal parts of the drop. The armature is supported on trunnion screws through the agency of a one-piece, formed, metal bridge, thereby insuring extreme sensitiveness. Figures 87 and 89 show the peculiar shape of the shutter hook and the opening of the shutter itself, through which this hook passes when the same is restored. This

construction overcomes any tendency of the armature to freeze to the shell or core, as the drop

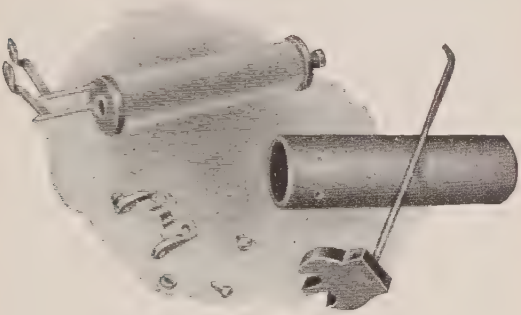


Figure 88.—Drop Disassembled.

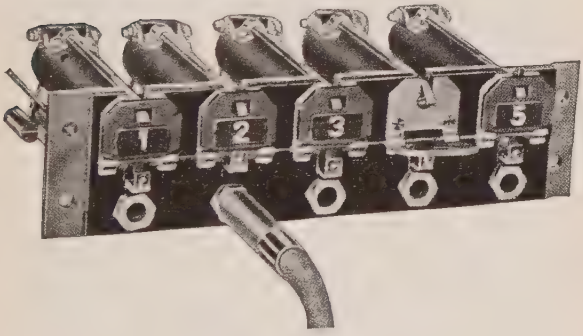


Figure 89.—Strip of Drops.

forces the hook lever down so that its catch will always engage and retain the shutter.

Each complete drop tube is insulated from the mounting strip and from the other tubes. This individual insulation is the most effective way to

avoid chances of burning out the drop winding, and to prevent crossing up the lines through the windings.

The tubular part of the drop, including the winding, can be removed from the mounting independently of the jack if so desired without unsoldering any connections, the only tool required being a small screwdriver. This is a great convenience if the drop happens to burn out by lightning or other cause, which will sometimes happen, even with the best protection.

The Jack.—Each jack consists of a rigid brass

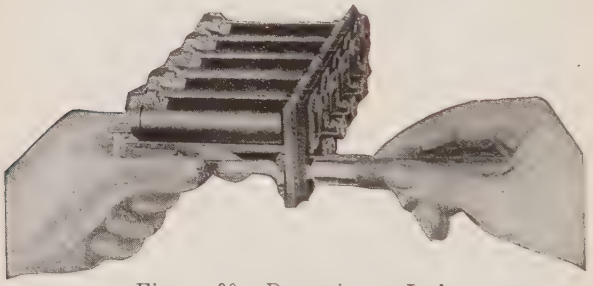


Figure 90.—Removing a Jack.

frame on which the German silver tip and local contact springs are fastened with hard rubber separators for insulation. The sleeve connection is in the form of tubular screw with a hexagonal head. This sleeve passes through the mounting strip, and with the help of two steady pins located in the jack frame, holds the whole firmly in position. Like the drops, each jack is thoroughly insulated from the mounting by hard rubber. Figure 90 shows the method of removing a complete jack without disturbing the drop by simply unscrewing the hexagonal sleeve previously mentioned.

Small connecting clips are soldered to the switchboard cable and attached to the terminals at the rear of the jack by machine screws, constituting a drop and jack which can be removed from the switchboard without the use of a soldering iron.

These drops and jacks are assembled on a laminate mounting made up of a rigid piece of sheet brass, faced and backed with thick strips of hard rubber for insulating purposes. The standard mounting is for five drops and jacks per strip, as shown in Figure 89.

The drop shutters are attached to the front of this mounting, and are provided with removable metallic number plates, allowing the drop numbers to be readily changed.

Night Alarm Contacts.—Each drop is so constructed as to operate a positive night alarm contact when the shutter is down and in its calling position. This contact is made by a lip on the lower portion of the shutter, forcing a gold-plated spring into metallic connection with a gold-plated rod. These springs are fastened to the metal frame of the mounting strip, while the rod extends across the face of the mounting, and is held in the rubber and normally insulated from all metallic parts. This obviates establishing the night alarm connection through the hinge of the drop, a method which has not proven entirely satisfactory.

A very different appearing line drop is illustrated in Figure 91, which shows a portion of the front of a switchboard, with one of the drops operated. The drop proper is backed with an aluminum piece which makes the fallen shutter much more visible. Figure 92 shows a strip of these combined drops and jacks. The springs of the right hand jack can be seen at the right of the picture. At the upper left hand corner of

each drop is a contact which operates when the armature of the electromagnet is being vibrated

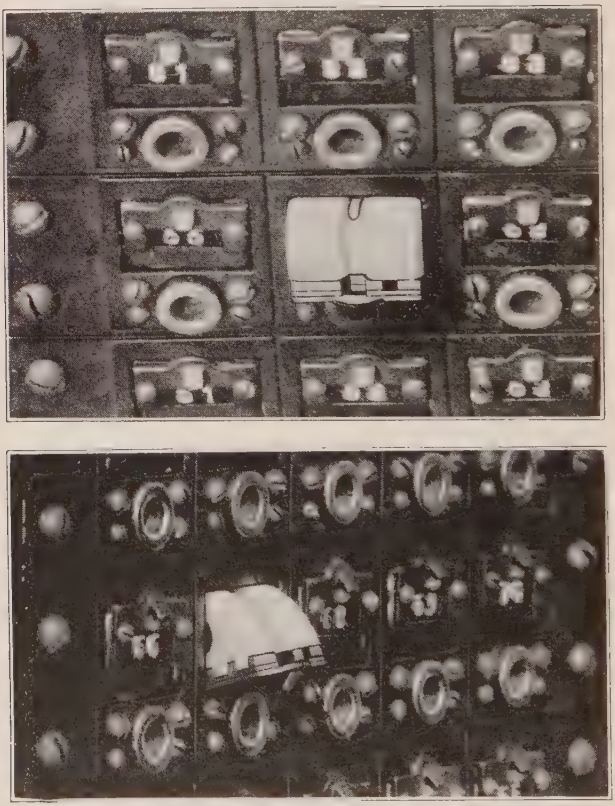


Figure 91.—Stromberg-Carlson Magneto Drop.

by ringing current. It is called the "code alarm contact" because it repeats to a bell or buzzer the code signals being rung on a rural line, so that

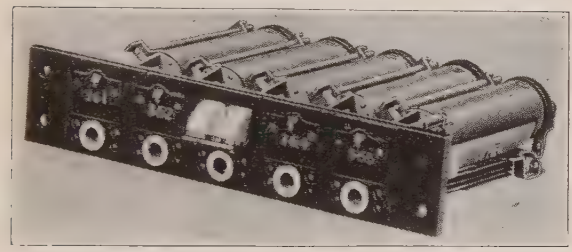


Figure 92.—Stromberg-Carlson Drop and Jack (Front).

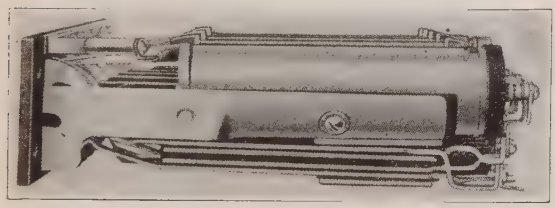


Figure 93.—Stromberg-Carlson Drop and Jack (Side).

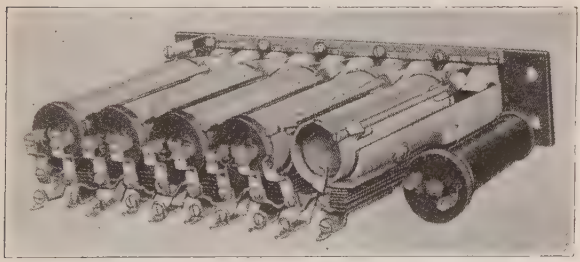


Figure 94.—Stromberg-Carlson Drop and Jack (Rear).

the operator need not answer unless the call is for the central office. This is a contact in addition to the regular night alarm contact, which produces a continuous alarm. Figure 93 is a side view of the strip giving more details of the jack springs and of the support for the electromagnet. Figure 94 is a rear view of the strip of jacks, with one coil removed. The latter is accomplished by loosening screws without unsoldering anything. The long rod at the upper side of the tubular magnet is the adjusting screw for the code alarm contact.

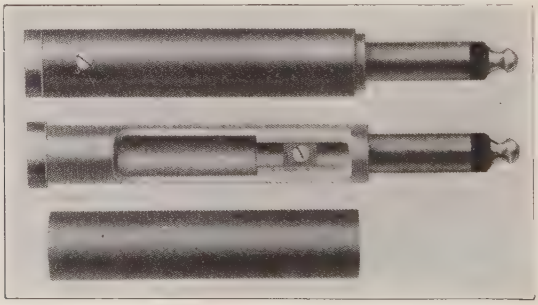


Figure 95.—Stromberg-Carlson Plug.

Figure 95 shows the type of plug which goes with this jack. It has only two conductors, tip and sleeve, because no more are necessary on a magneto board of this size.

Still another kind of drop and jack are shown in Figure 96. This shows more clearly than previous illustrations just how the insertion of the plug into the jack restores the shutter. Both tip and sleeve of the plug make contact with springs in the jack. It is the sleeve spring in the jack which, when the plug is inserted, presses upward a long

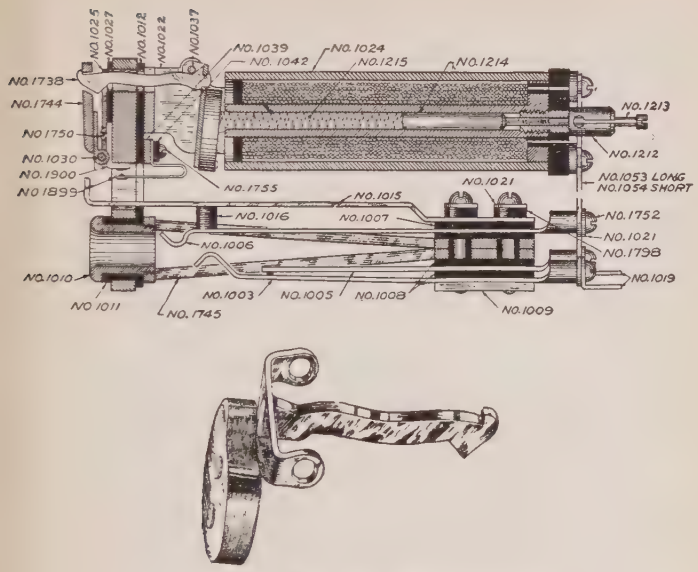


Figure 96.—Monarch Drop and Jack.

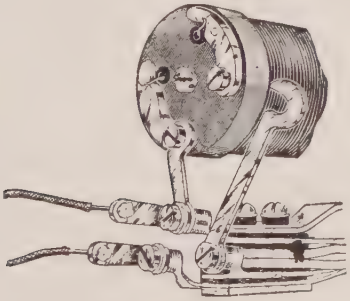


Figure 97.—Removing Coil from Monarch Drop.

spring whose front end projects forward and lifts the shutter.

The armature of the electromagnet is held normal by a coiled spring inside the core of the magnet. A screw at the rear permits this spring to be closely adjusted. The coil is removed, as shown in Figure 97, by loosening the links which lead the current into the coil. The rear end of the jack is just below the coil, and the line wires lead off to the left.

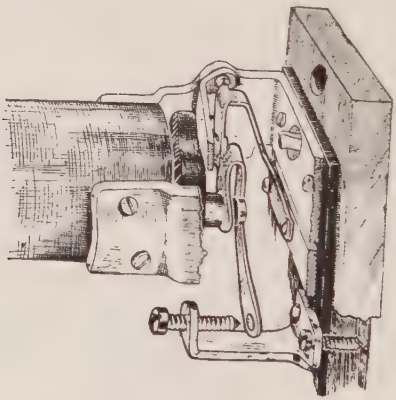


Figure 98.—Code Contact on Monarch Drop.

The code signal is supplied by a slightly different drop, shown in Figure 98. The code ringing contact is clearly visible at the bottom of the cut.

COMBINED RINGERS AND JACKS

The various parties on a bridging line usually employ a code of known signals, consisting of either short or long rings, for calling each other. When these lines are connected to the ordinary switchboard drop, the operator depends on the noise

made by the vibration of the drop and armature to determine whether the exchange is desired or the drop has a code alarm contact which repeats the signals on a bell or buzzer.

A combined ringer, drop and jack is sometimes used. Figure 99. It consists of a long core ringer

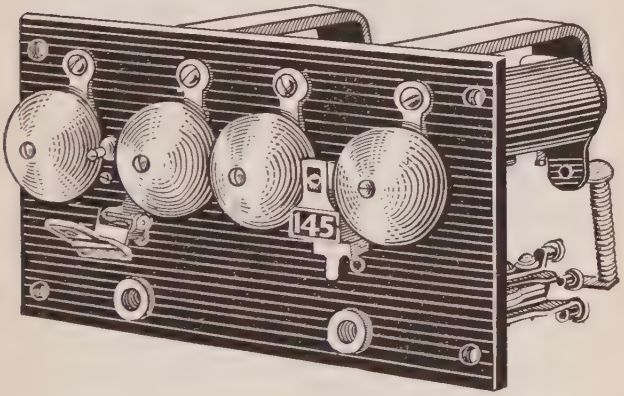


Figure 99.—Combined Ringers, Drops and Jacks

with double gongs and a latch drop indicator, the latter designed to indicate the line signaling. This drop is provided with night alarm contacts which can be wired to the regular night bell circuit. The jack mounted in connection with each ringer is of the same construction as that used on a combined drop and jack, but is not provided with the self-restoring feature. The local contact spring in the jack is opened when a plug is inserted, thus cutting the ringer coils out of the line circuit.

Two combined ringers, drops and jacks mount side by side on a mounting strip and occupy the space of two strips of the combined drops and jacks.

CORD CIRCUIT APPARATUS

Clearing-out Drops.—These are of the same design as line drops (see Figure 100) and are fitted with the same sort of night alarm contacts, but are not associated with jacks. Many drops are wound to 500 ohms resistance and present a high



Figure 100.—Clearing-Out Drops (Kellogg).



Figure 101.—Plug and Cord (Kellogg).

impedance to voice currents and have no appreciable effect in cutting them down. Various arrangements of clearing-out drops will be shown in the discussion of cord circuits.

Plugs.—Figure 101 shows in principle a design of plug used in some types of magneto switchboards.

The tip contact of the plug is of brass, reinforced by a steel rod running back through the sleeve contact which is also of brass. The two are insulated by a bushing of hard rubber. The heel

of the plug is threaded to receive the cord. The tip terminal of the cord is fastened by means of a machine screw to the butt end of the steel reinforcing rod. A tough red fiber sleeve incloses the cord connections.

Another make of plug is shown in Figure 102. The structure is somewhat like the preceding example and the cord is fastened in the same way. The sleeve conductor is turned back and held by pressure between the cord and the threads in the

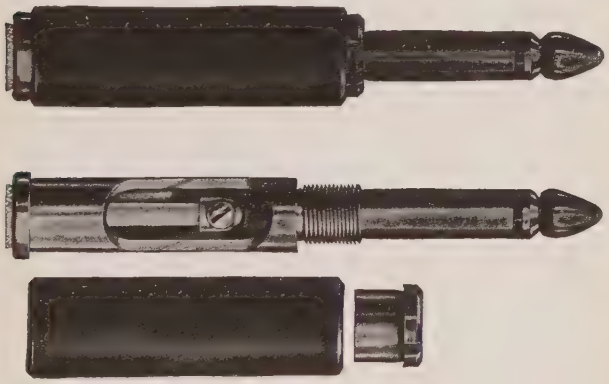


Figure 102.—Monarch Plug.

tube. The protecting jacket or sleeve of fiber tubing is held on in a novel manner. There is a collar on the cord end of the plug and the cover is slipped on from the tip end. A brass ferrule screws on from this same end and holds the cover in place. The ferrule runs up solidly against the metal shoulder on the plug and does not clamp the sleeve tightly. It leaves it loose so that it turns easily on the plug. There is a tendency for

the operator to twist the plug while inserting it in the jack. The loose cover prevents this turning.

Switchboard Cords.—A switchboard cord seems to be a very simple thing, but experience has shown that a satisfactory cord is one of the most difficult things to manufacture. Cord maintenance is one of the very heavy expenses in switchboard operation. Of necessity the operators can not handle the cords gently, the work must be done quickly, expecially during the most busy hour of the day.

The basis of the best cord is tinsel. This is a very small copper conductor, usually made out of a very fine wire, flattened into a ribbon. It is then spiralled around a thread. This is the unit out of which cords are built. One type of cord, Figure 103, contains two conductors, and is built up in a manner similar to a manilla rope, which insures maximum wearing qualities. The several tinsel strands, composing each conductor, are first twisted together, served with two layers of Tussah silk, treated with a special moisture-proof compound, and then covered with a braided sheath. Two conductors, together with dummy and filler threads, are finally twisted as a rope and covered with a heavy and closely woven glazed outer braid.

Another type of cord is made up as follows. Each conductor consists of twenty-one strands of fine copper tinsel loosely fastened together. The tip conductor is covered with an insulation of Tussah silk outside of which is a cotton covering and over both of these coverings a braided linen covering completes the insulation. The outer or sleeve conductor rests against the inside of the spiral spring which is coiled around the outside insulation of the tip conductor. Outside of this is a heavy cotton braid which is given a glaze or polish, which protects it from moisture, improves its

wearing qualities and allows it to run easily through sockets and pulleys.

Tinsel cord is preferred because its low resist-



Figure 103.—Switchboard Cord (Tinsel).

ance permits the conversation current to pass through with little loss. But it is not a very durable cord. Steel cord has been used to quite an

extent, although its transmission loss is appreciable. Some companies use it on local connections, but have tinsel cord for all toll connections. Steel cord does last very much longer, and gives a very



Figure 104.—Steel Cord Construction. Outer Layer—Linen Braid. Second Layer—Cotton Braid. Third—Steel Wire. Fourth—Linen Braid. Fifth—Silk Braid. Sixth—Linen Braid. Seventh—Steel Wire. Eighth—Linen Braid with Three Tinsel Strands. Inner—Twine.

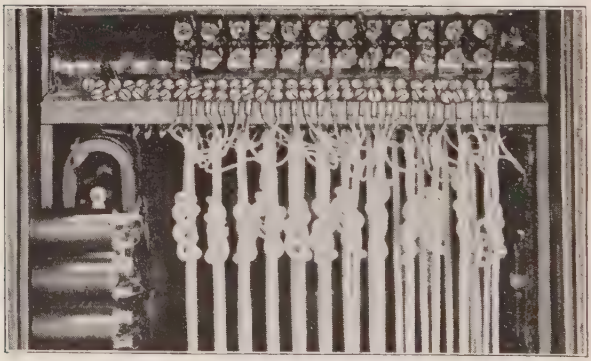


Figure 105.—Cord Terminals.

definite break when it does wear out. Tinsel cord often breaks a strand at a time and is noisy if disturbed.

One type of steel cord is shown in Figure 104. A little tinsel has been added, in an attempt to

reduce the transmission loss. Another maker wrapped fine copper wire around each steel wire throughout the entire length of the cord. But in both cases, the resistance of the cord is considerably higher than tinsel cord.

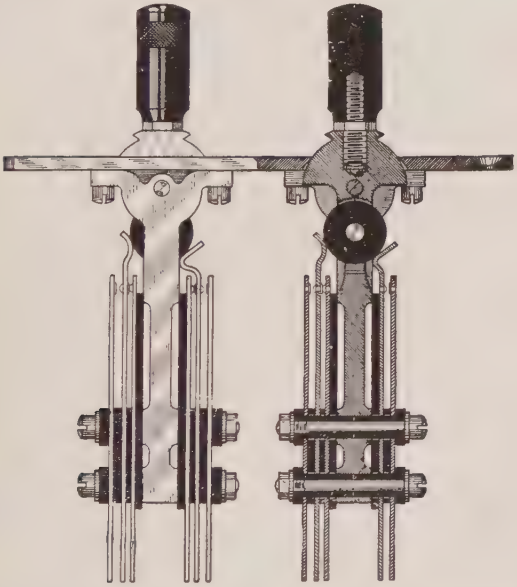


Figure 106.—Ringing and Listening Key (Monarch).

A very usual manner of fastening the ends of the cord to the switchboard is shown in Figure 105. The circuits in the board are brought to metal lugs, each of which carries a binding screw. The ends of the cord are equipped with spade terminals, which are held by the binding screws. The replacement of a cord and plug is the work of but a few moments.

Operator's Keys.—Operator's keys have been made in a variety of ways. The old keys used years ago were rather large, occupying more space than was necessary, although their springs were very accessible. But the progress has been toward more compact keys, secured by placing the springs vertically parallel to each other, as in Figure 106, which shows a Monarch key. The listening springs are on one side of the frame while the ringing springs are on the other side. The lever is pivoted in the frame at the top, with its insulating handle above the mounting plate and the plunger or roller between the ends of the springs. The listening side has the plunger spring bent so as to lock the lever in the operated position. But the plunger spring on the ringing side is more nearly straight, so as to be non-locking. The Monarch frame and the lever are both made of strips of metal formed and drawn through dies into the proper shape then cut off to the thickness required for each key.

The Kellogg key frame is bent into an L-shape out of a single piece of heavy metal, and is considered to be practically as solid as the Monarch construction.

The Stromberg-Carlson key, Figure 107, illustrate another type of construction, which is well adapted to compact work, and for cases in which many keys must be placed in one unit. The unit shown has the usual listening and ringing key, a ring-back key (push button form) and two clearing out signals. The latter are mechanically restored by the listening key. The bending of the two plunger springs by which the listening side is made locking and the ringing side non-locking is clearly visible.

The operators apparatus may be of the breast-plate form, or the transmitter may hang from the

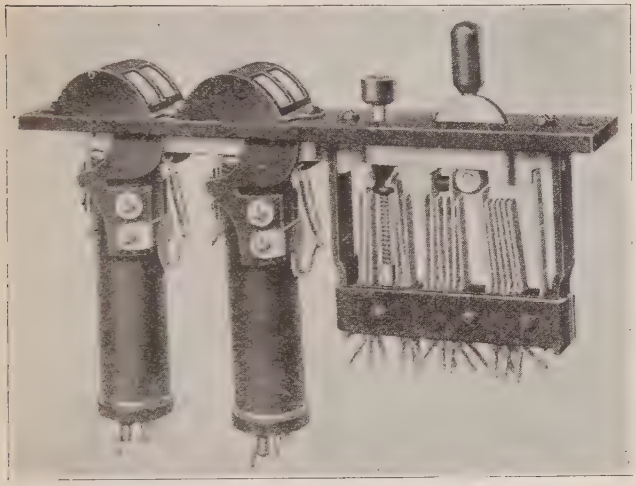


Figure 107.—Keys and Clearing-Out Signals (Stromberg-Carlson).

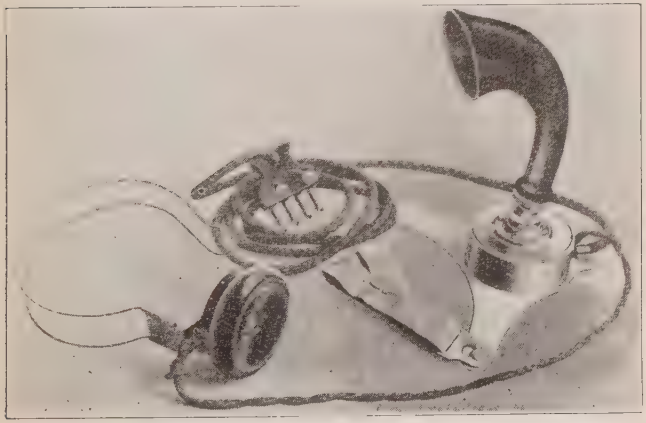


Figure 108.—Operator's Set with Breast Plate Transmitter.

top of the board. The latter is the older type, but is now used chiefly for small boards. The former, Figure 108, consists of a head receiver (watch-case receiver and head band) a transmitter mounted on a plate with a ribbon or cloth strap to go around the neck to support it, a plug to fit into the jack in the board at the operator's position, and cords connecting the three pieces mentioned. The mouthpiece is in the form of a long curved horn, not best for transmission, but the best under the circumstances. Plugs are made in various forms, intended to prevent insertion in the jack in any way but the right way, or so that any position will work. The one illustrated has the receiver on the two outside pins and the transmitter on the two inside pins. Reversal makes no difference.

The smaller boards have the hanging transmitter of Figure 109. The long arm carries the conducting cords up, over and down, and is adjustable forward and back. The transmitter may be raised and lowered, the weights taking up the slack cord.

The complete switchboard of 100 lines, Figure 110, has been brought to a very neat appearance. The combined drops and jacks, usually self-restoring, fill the back of the board. The board shown is partly equipped. The cords are likewise partly equipped. Early boards were made with the single drop as the unit, but now it is the better practice to make them in strips of five or ten. They can be cheaper and may be better mounted thus.

The back of the board, Figure 111, is covered by a panel which may be lifted out, exposing the wiring and such apparatus as hand generator bells and buzzers, cord terminals, dry cells, etc. There is also a terminal board for cord and operator's equipment Formerly there was also the subscriber

line terminal assembly in the back of the board but now the lines are cabled from the drops and jacks directly to the main distributing frame.

The circuits, Figure 112, of a small magneto switchboard are almost self-explanatory. The line

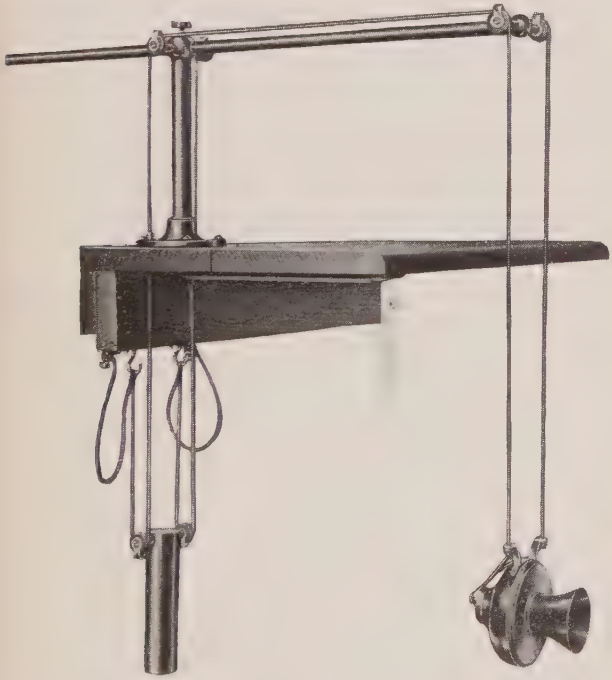


Figure 109.—Suspended Transmitter.

circuit is extremely simple, the two line wires being carried to the tip and sleeve of the jack, with the line drop *LD* connected to the sleeve directly and to the tip through an inside contact, which is

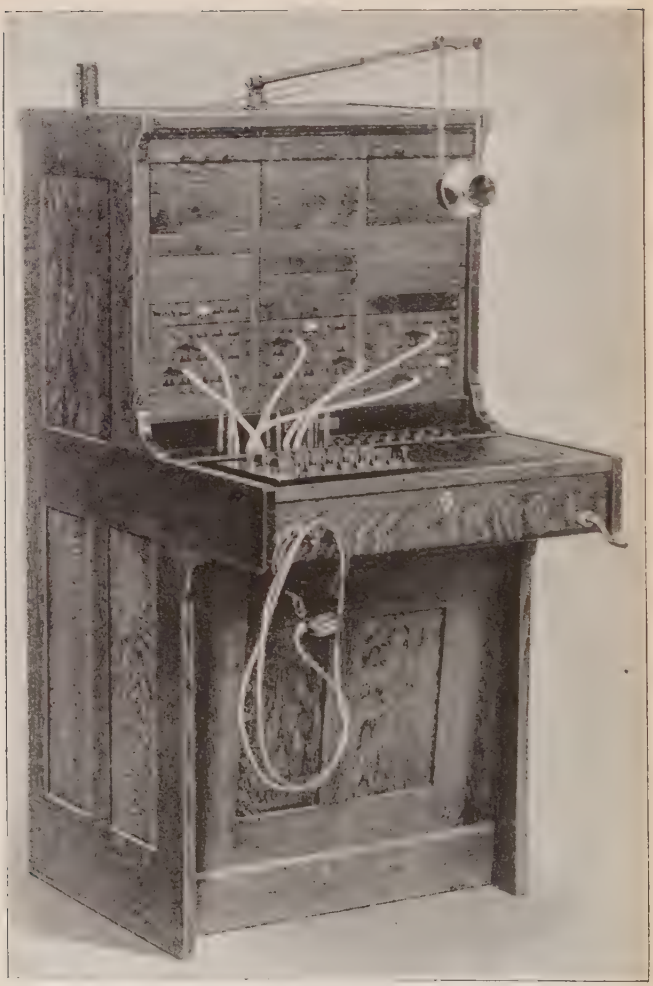


Figure 110.—Small Magneto Switchboard (Stromberg-Carlson).

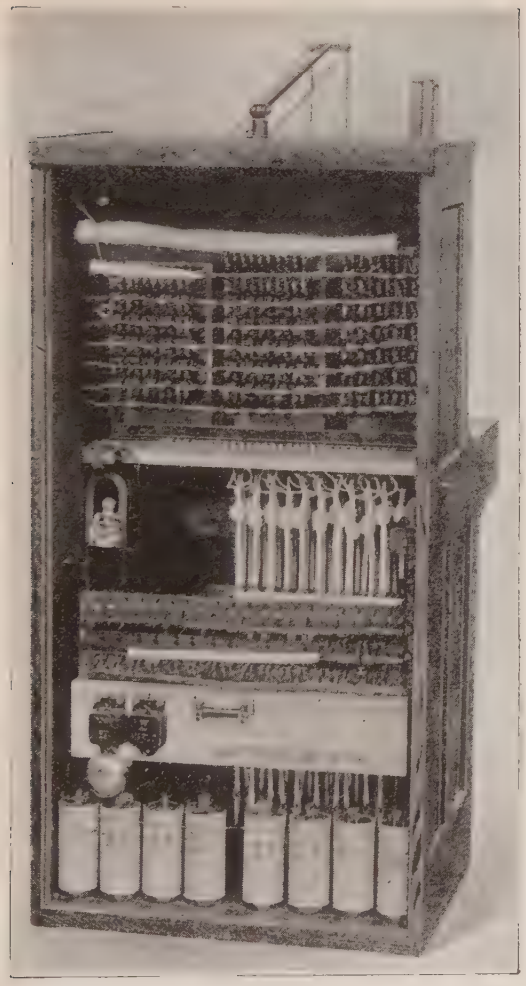


Figure 111. Small Magneto Board (Rear).

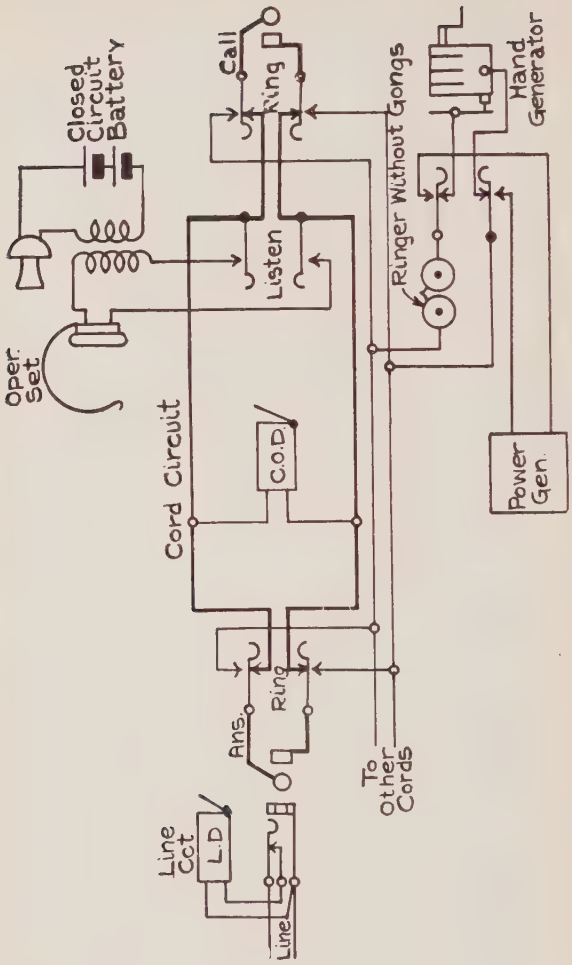


Figure 112.—Magneto Board Circuits, Bridged Clearing-Out Drop.

broken when the plug is inserted in the jack. Some jacks break both sides of the circuit, as will be seen later.

The cord circuit here shown has a bridged clearing out drop, *COD* which has from 500 to 1000 ohms resistance, some being as high as 1600 ohms. There is a ringing key for each end of the cord circuit so that the operator may ring either way at will. There is a switching key to enable a power generator to be used instead of the hand generator. When the ringing key is operated, it cuts off the cord circuit back of it and projects ringing current onto the line. The listening key bridges the operator's telephone set across the cord. The simplest of circuits is used, and the battery is connected all the time. Therefore it must be of the closed circuit type, like the gravity cell, the Gordon, or the Edison primary cell. Later boards have the battery open except when talking.

POWER RINGING

Even in a small exchange it is always desirable to install a power-ringing machine of some description. It relieves the operator of a great deal of manual work, and enables her to answer calls more promptly and therefore to handle a greater number of lines than she possibly could using a hand generator; in case code signals are used for party lines, they may be given evenly and distinctly.

There are several classes of power-ringing machines in use; battery pole-changers, belt-connected motor-magneto-generator sets, dynamotors, and direct-connected motor-generator sets. Any of these may be equipped with an attachment to give positive and negative pulsating current.

For use in exchanges of less than 600 lines, either a battery pole-changer, a dynamotor for

direct current power, or a belt-connected motor-magneto-generator set for alternating current power may well be used.

The first switchboards designed, being for use with lines equipped with the series telephones of early days, were very properly provided with series "ring-off" drops. These earlier boards were all of the single conductor type for use with the grounded or common return lines of that time.

After a time, the bridging telephone with its high resistance bells (1000 to 1600 ohms) came into general use for rural or farmer lines.

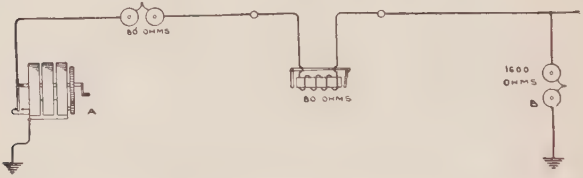


Figure 113.—Series Telephone Connected to Bridging Telephone.

The very first thing discovered in connection with the new 1,000 ohm and 1,600 ohm bridging telephones was that they could not be used one on a line with the series ring-off drop boards of that time. The condition prevailing when this was attempted is shown in Figure 113.

It is to be noticed that when party *A* tried to "ring off," the high wound bell of party *B* would not allow enough current to pass to operate the ring-off at the board and in his efforts to "get loose" and get central's attention, party *A* would only ring through the board without throwing the drop and annoy party *B*.

It was found that if two or more bridging tele-

phones were added to *B's* line, as indicated in Figure 114, this trouble disappeared, since with four bells bridged from *B's* line practically four times as much current passed through the ring-off drop, enabling the same to operate. Parties on *B's* line (Figures 113 and 114) had no trouble ringing off, because no matter what number of bridging telephones were on *B's* line, a large part

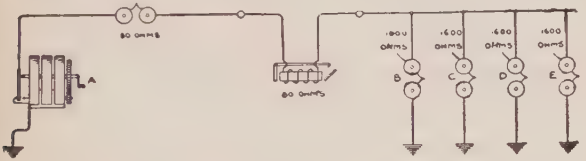


Figure 114.—Series Telephone Connected to Line of Bridging Telephones.

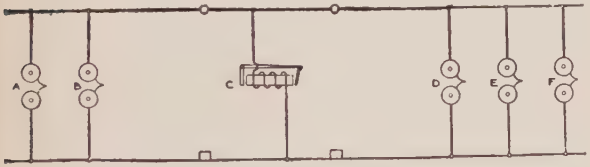


Figure 115.—Bridging Ring-Off Drop Between Bridging Lines.

of the current generated would pass through the ring-off drop on its easiest path back to ground through *A's* 80-ohm bell.

To overcome various difficulties it became necessary to use a bridging ring-off drop, as shown in Figure 115.

This drop is high wound like the bells in the bridging telephones and, the line being connected through the switchboard direct, it is as easy to talk through the switchboard as to talk past one

of the bridging telephone stations out on the line.

Through ringing has been prevented by placing a condenser in the cord circuit between the two lines. The condenser lets the relatively weak and high frequency voice current pass through, while the relatively stronger and low frequency ringing current is diverted to the drop.

Figure 116 shows the simplest condition for the connecting of two series city telephones. The lines are connected with each other through a special condenser.

When either of the two connected subscribers attempts to ring-off or call central again, most of

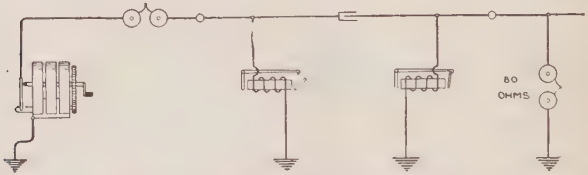


Figure 116.—New Cord Circuit Connecting Series Telephones.

the ringing current produced by his generator goes through his own ring-off drop at the central office, little of it escaping to the connected party's bell or drop. The calling party's ring-off drop, therefore, operates in a reliable manner; the operator knows immediately which of the connected parties is ringing, and the second party's bell is not disturbed.

The Monarch cord circuit, Figure 117, possesses the novelty of carrying both bridging windings on the same clearing out drop. The same company makes a cord circuit with two separate clearing out drops, Figure 118, each equipped with a lamp, which lights only while the subscriber is ringing

off. The contact is operated by the armature not by the shutter. If the first ring off fails to attract the attention of the operator, a longer ring will hold the lamp lighted long enough to get results.

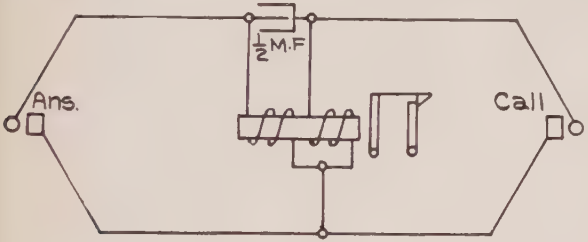


Figure 117.—Cord Circuit with Bridged 2-coil C. O. D. (Monarch).

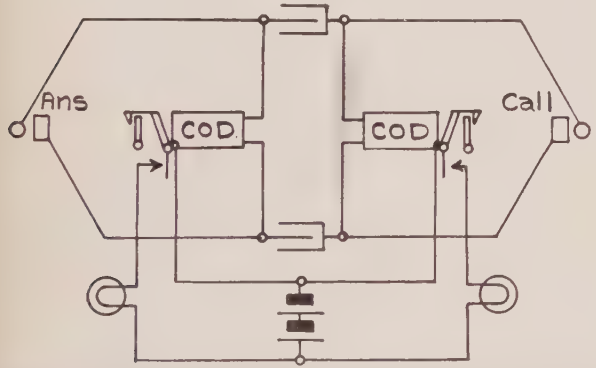


Figure 118.—Cord Circuit with C. O. Drops and Recall Lamps (Monarch).

REPEATING COILS

The use of repeating coils in connection with telephony is mainly for the purpose of providing a quiet connection between dissimilar telephone lines.

In the majority of cases in magneto work the dissimilar lines to be connected are grounded or common return lines and full metallic lines, it being taken for granted that the wires of a metallic circuit subjected to disturbances are properly transposed.

Figure 119 shows the effect of a disturbing wire on a single wire earth return telephone line due

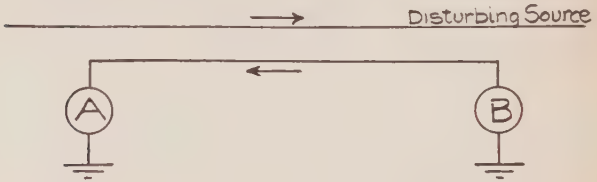


Figure 119.—Earth Return Telephone Line, Electromagnetic Induction.

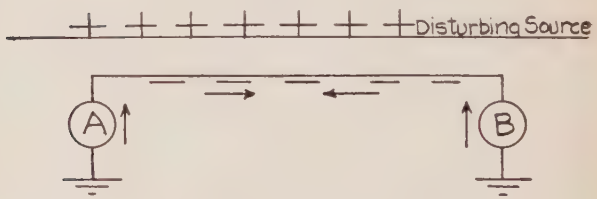


Figure 120.—Earth Return Telephone Line, Electrostatic Induction.

to the current in the disturbing wire. The latter produces a magnetic field around it, part of it cuts the telephone line, thereby inducing a current in the telephone.

Figure 120 shows the effect of electrostatic induction. This is due entirely to the voltage on the disturbing wire. At a moment when the latter is charged positively, the electricity in the telephone wire is repelled to earth, producing a

negative condition on the telephone line. The rapid reversals of conditions produce noise in the telephones. This noisy current due to static induction flows to and from a neutral point in the telephone line.

In localities where the disturbing elements are slight, a common return or grounded line is sufficiently quiet to give good service. The only remedy for noisy lines of this character is to make the circuit metallic and transpose the two wires in respect to the disturbing source, as shown in Figure 121. It will be seen from the drawing that the transposition of the wires causes each side of the line to take turns in passing close to the disturbing

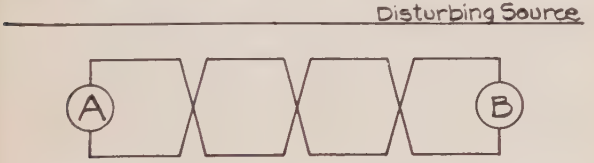


Figure 121.—Transposed Metallic Telephone Line.

source, thereby preserving the equilibrium, and as a result little induced current passes through the telephones at *A* and *B*.

An ideally perfect transposition will absolutely stop electromagnetic induction, but will only reduce electrostatic induction to a commercially satisfactory value, if the induction is not too strong. There are cases of strong static induction which no transposition can cure—the line must be moved away from the disturbing wire.

Figure 122 shows a balanced metallic line connected to a grounded or common return line through the cord circuit of the switchboard. Now, if the disturbing source is the line *P W*, we can easily

see that the single wire of the grounded line will be affected as it is a similar case to that shown in Figure 119. Both of the telephones *A* and *B* will receive the induced disturbing current, as it will have to pass through the entire circuit in its efforts to come to equilibrum. Furthermore, if the disturbing source is the line *C D*, in close proximity to the normally balanced metallic line, it will be rendered unbalanced as soon as connection is made through the cord circuit to the grounded line. This is due to the fact that the connected circuit presents unequal conditions on either side of the completed line. Both of these lines may be nor-

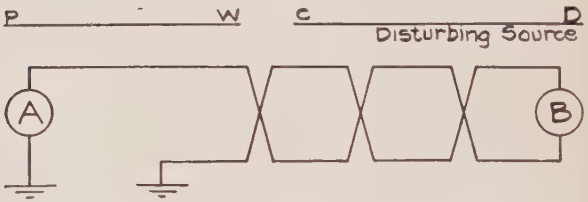


Figure 122.—Induction on Connected Lines.

mally quiet before being connected, but as soon as the ground of the single wire circuit is metallically connected through the cord circuit of the switchboard to the metallic line, an unbalancing exists, as the disturbing element which is tending to induce charges on both sides of the line will then find two paths of unequal impedance to earth. Therefore, when a long, quiet toll line is connected to a short and normally quiet grounded or common return line, the completed circuit often becomes too noisy to give service. The detrimental results of the latter conditions can be partly or entirely eliminated by the use of a repeating coil for

metallically separating the two lines, as shown in Figure 123. Both the common return or grounded line and the metallic line are now in their normal and quiet condition, as no metallic circuit exists from one to the other and no flow of induced current is possible. While the repeating coil separates the two lines from metallic connection, it serves as a means of accurately repeating the voice currents through this separating gap with only a small loss of energy.

The repeating coil may either be placed permanently in the exchange end of the line circuit or in one or more of the connecting cords, so as

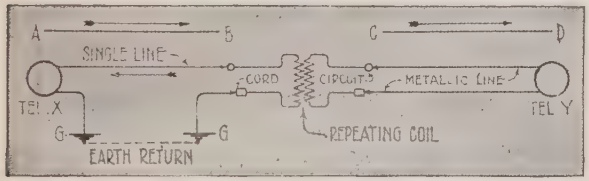


Figure 123.—Use of Repeating Coil to Keep Connection Quiet.

to be available for use in joining any two unbalanced lines. When the repeating coil is located in a cord circuit, the operator can easily determine the condition of the connected lines when listening in, and only inserts the coil when necessary.

When only a few of the lines are ground or common return and the remainder metallic, it might be advisable to place repeating coils in the line circuits giving the trouble from unbalancing rather than bother with repeating coils in the cord circuits. This would also apply when a few of the lines are metallic and the remainder of a mixed nature.

Figure 124 shows the location of a repeating coil in the cord circuit, connecting two dissimilar lines, while Figure 125 shows a repeating coil located permanently in a subscriber's line. The actual talking circuits of these two connections are the same, but in the second case it will be necessary to ring through a repeating coil in signaling the subscriber on that line, while in both cases the ringing-off current from the subscriber's station

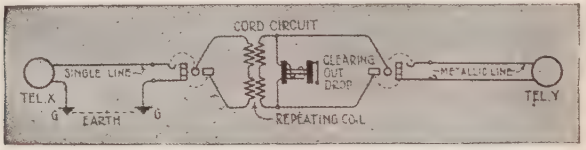


Figure 124.—Simplified Cord Circuit with Repeating Coil.

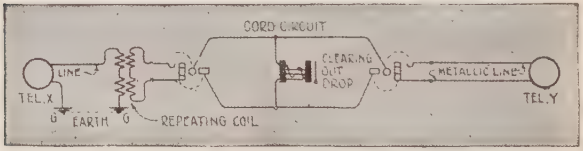


Figure 125.—Repeating Coil in Ground Return Line.

will have to be repeated by the coil in order to operate the clearing-out drop. This drop is usually made with a large margin of sensitiveness so that any loss of energy in the repeating coil will not affect the operating of the clearing-out signal. This loss of energy in the repeating coil would, however, be of a serious nature in ringing the less sensitive bells on the long line, thus the method of placing the repeating coil in the cord circuit, as shown in Figure 124, is preferable from a signaling standpoint.

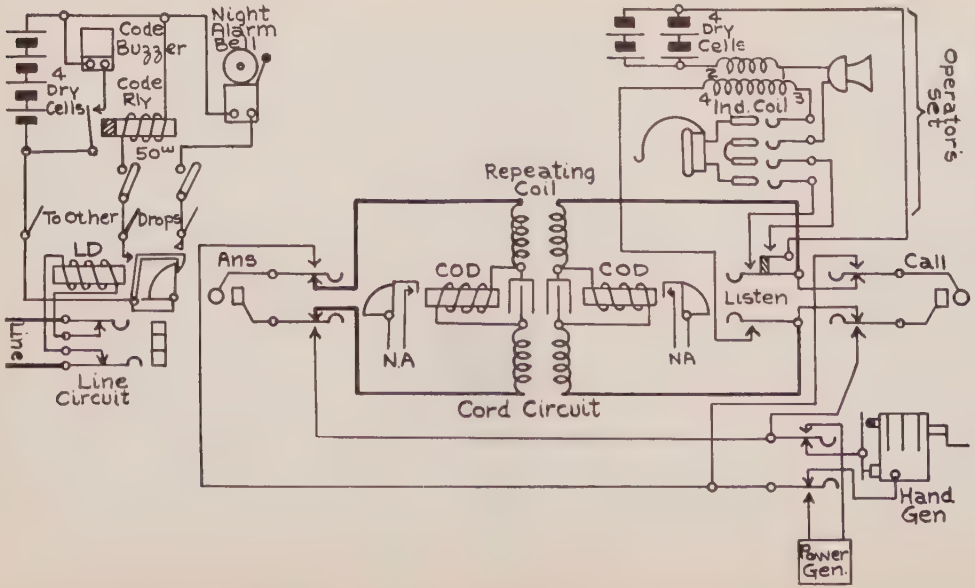


Figure 126.—Magneto Board Line and Cord Circuits (Stromberg-Carlson).

The Stromberg-Carlson magneto switchboard, Figure 126, possesses a number of interesting features, which are typical of modern structure. The line jack cuts off both sides of the line drop, an advantage on toll lines which pass through strong induction. The structure of drop has been described. Two signals are given, the regular night alarm, a bell operated by the shutter or signal member, and a code signal, a buzzer operated by a relay controlled by the armature of the drop. The latter repeats the code signals rung on a code

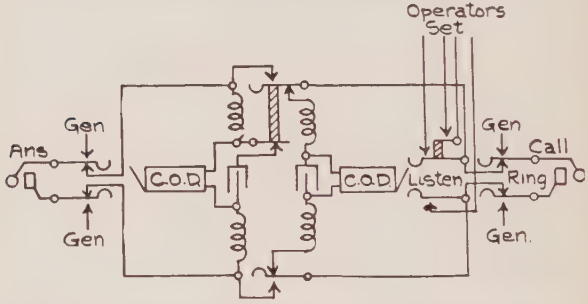


Figure 127.—Magneto Cord Circuit with Repeating Coil Key.

party line and is very useful for evening work, for the operator need not answer calls made among the subscribers on one line. The relay is slow, so that it will remain energized between half cycles of ringing current, but it will fall back between code rings.

The cord has a repeating coil permanently connected, so that for signalling, the cord is divided into two halves. The condensers in the center of the coil permit talking current to pass easily and escape the high impedance of the drops. If the repeating coil is carefully made, the transmission

loss is small, and the value of having a separate clearing out signal for each subscriber is great. The operator knows who it was that rang off.

The operator's set is equipped with a transmitter battery of dry cells, which are cut in by an auxiliary contact on each listening key.

For connecting toll lines to each other, where the highest efficiency is necessary, even a good repeating coil must be cut out. The cord circuit of Fig. 127 has a repeating coil switching or cutout key, which removes the right hand half of the coil, and the condenser of the left part, leaving

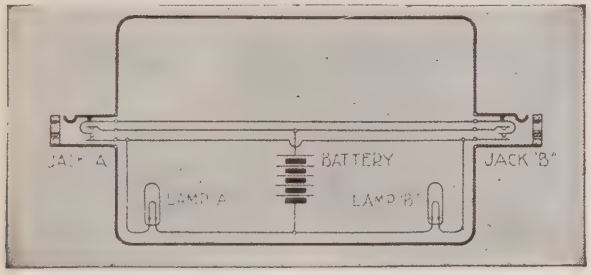


Figure 128.—Transfer Circuit.

two windings of the coil and the clearing out drop across the cord. This gives a high impedance bridge, which produces a very small loss to trasnmission of the voice.

MAGNETO EXCHANGES LARGER THAN 100 LINES

It is customary to serve two hundred lines by placing two 100-line boards side by side and adding another operator when one can no longer handle the work. The two operators reach over both boards and give very creditable service. We have seen as many as three such boards worked side by

side, although cases arise in which the middle operator must be called upon by either of the other to bridge the gap between extreme jacks. During periods of light traffic, one operator sits at the middle board and cares for all calls.

Larger exchanges brought in the use of the transfer line, a device for enabling any operator to extend her cord to reach any jack on the board.

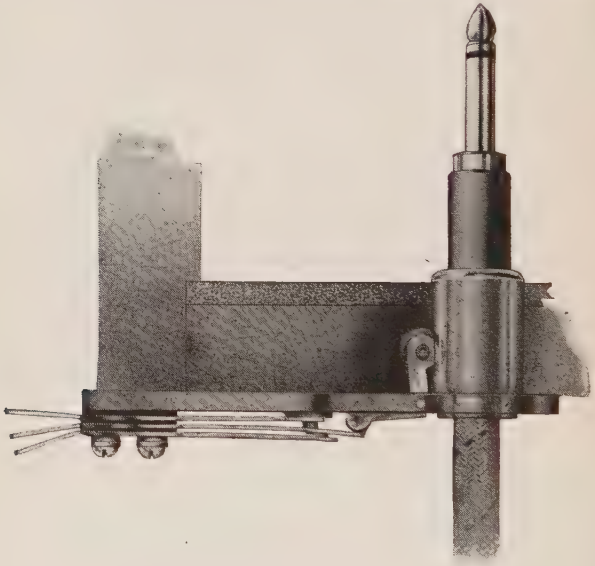


Figure 129.—Plug Seat Switch.

Rather large boards have been made and used on this plan, but it brought in many serious evils and much aggravation to subscribers and operating company. Most of the calls required two operators to complete—slow connections and much slower disconnections, with many mistakes. We show in Figure 128 a typical transfer circuit, for there are

still conditions where its use may be justified. The circuit shown has a jack at each end, fitted with three auxiliary springs for switching the lamps. It is readily seen that if only one jack has a plug in it, both lamps will light, but that if both jacks have plugs or free, both lamps will be dark.

In order to speed up the service, one end of the transfer line is sometimes plug-ended. A very good switch, Figure 129, has been made to operate when the plug is lifted into service, or is dropped back into its socket. It is especially made to keep dust from the contact.

CHAPTER VIII

THE LOCAL BATTERY SUBSCRIBER LINE AND TELEPHONE

There are certain things in which the telephone instrument, the line, and the switchboard are very closely interlocked. The party line is such. As long as we have only individual lines, the matter is simple. Even the addition of a few extension bells or extension stations does not complicate matters seriously. But when we have from four to ten or twelve stations on the line, with or without selective ringing, more care must be given to circuits and apparatus.

The simplest party line is made of bridging telephones and each station is run by a code signal—several rings, some short, some long. These have been in use many years. The line is the common meeting place of the neighbors who use it, and because of its openness it has often served nobly in an emergency to an extent which the selective line could not do. It is enough if the bells have high impedance (1,600 ohms resistance and sometimes as much as 40 henries inductance) and the generators are powerful (five bars and low armature resistance), and there are not too many stations on one line. From eight to ten stations are all that one line can well serve, but twelve people sometimes get along with each other very well. It depends much on the people.

The ordinary open ringing code line has the

central office as one of the stations, with one short ring as her signal. The buzzing of the drop enables the operator to distinguish the codes. But in small offices, where the night operator sleeps and depends on the night bell for emergency service, the code lines needlessly waken the operator when calling each other on the same line. The non-interfering system of ringing is perhaps the surest way to avoid this. Figure 57 gave the circuit of a non-interfering telephone, showing how it is connected to the switchboard. The subscribers ring each other without pressing the button, and it does not disturb the operator. If the operator is to be called, the button is pressed while the crank is turned, thereby throwing the drop over the ground circuit. Other means for securing non-interfering ringing have been tried, but we believe that the above is the best.

Central Checking Telephone.—There are some cases in which the operating company desires to prevent the subscribers on a line from ringing each other. They require that the subscriber shall call the operator, who will do the ringing for him. It enables the company to check all conversations. This may be done by wiring all telephones on the line so that the generators ring to ground, and can not ring bridged. This throws the drop as was described for the non-interfering telephone. It can also be done by arranging each hand generator to produce only direct current, which will not ring the polarized bells, but will throw the drop. The hand generator must have a commutator.

Two-Party Selective Line.—A very simple two-party selective line may be had by bridging each bell from one line to earth. Figure 130. Station A has its bell from tip line to ground, station B from sleeve to ground. One side of the generator

is grounded. The arrangement of ringing keys and their operation is evident.

Four-Party Biased Bell Selective System.—Long ago it was discovered that if a polarized bell be fitted with a spring which draws the clapper to one side, the bell will not ring on current which pulsates in the direction which causes the armature to pull the clapper in the same direction, but will ring with pulsations the other way. Such a bell is said to be "biased" and it was ordinarily rung by pulsating current. The latter is alternating current whose alternate half cycles have been wiped out.

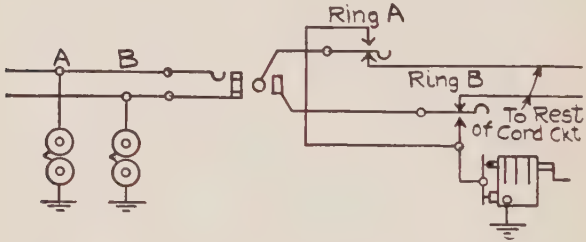


Figure 130.—Two-Party Line, Ringing to Ground.

Let us take four stations, Figure 131, called *A, B, C* and *D*. The bell at *A* requires that the current pulsate from the tip line to earth to ring it. The bell at *C* requires that the current pulsate from earth up to the tip line to ring it. *B* and *D* are similarly related to the sleeve line.

The generator is equipped with a two-part commutator, one segment of which is insulated and dead, the other carries the ungrounded end of the armature winding. One of two brushes connects positive pulsations, the other negative pulsations. The other end of the armature is grounded.

The example shown has a ringing key on each

cord, with one master key for the operator. The ringing key will ring with whatever current the master key gives it. The first part of the master key furnishes straight alternating current. This must not be used on a biased bell line, for it will ring all the bells. The key marked *A* will furnish positive pulsating current over the tip line to ring station *A*. The others may be followed out by the reader.

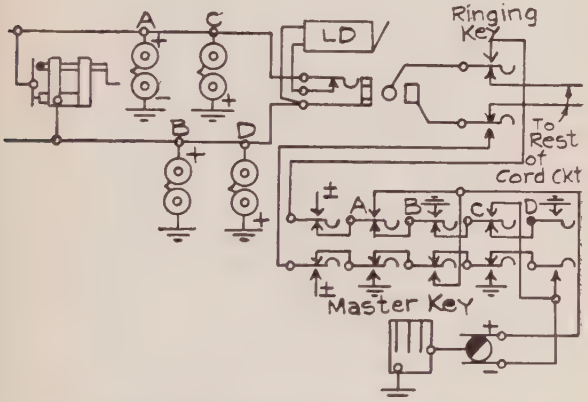


Figure 131.—Biased Bell Selective System.

The hand generators in the telephones must be weak, or they will ring other bells while calling central. This is often done by removing the middle magnet of a three-bar generator. This usually weakens it enough to prevent false rings, and yet permits it to throw the drop.

If the operator rings when a subscriber has his receiver off the hook, it may give false rings, for current will pass through the low resistance receiver and induction coil and try to return by

way of the bells on the other side of the line. But the master key grounds the line which is not being rung, so that this danger is not great.

Later it was found that a biased bell responds selectively to current from a straight alternating current generator with a battery of sufficient voltage in series with it. This was put out as long ago as 1905 or before as the Knox-Dickey system. It

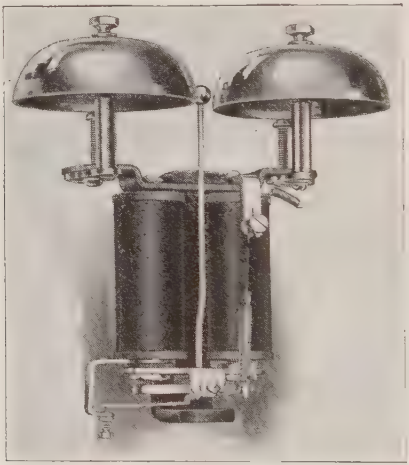


Figure 132.—Monarch Direct Current Bell.

is now being used by Bell companies under the name of "superimposed ringing."

Modifications of biased bell operation necessary for common battery switchboards will be treated under that subject.

Monarch Direct Current Selective Ringing.—Though some early telephones were rung by vibrating battery bells, they fell into disuse because of excessive sparking, for which there seemed to be

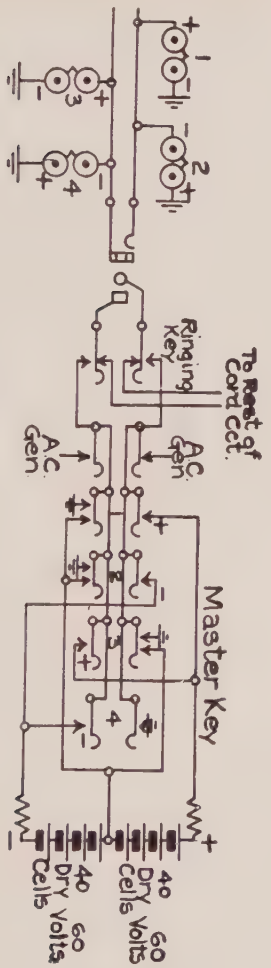


Figure 133.—Direct Current Selective System.

no remedy. The magneto generator with its polarized bell became preferred.

The Monarch company has produced a selective system by combining the self-interrupting feature of the battery bell with the efficiency of the polarized bell. Figure 132 shows the bell with the contact and biasing spring. Figure 133 shows the circuits by means of which any one of four stations can be rung selectively. The source of power is an arrangement of eighty dry cells, in two parts of forty cells each. Each half merely furnished direct current from ground to tip or sleeve of line, and of either polarity. The battery is normally insulated, but is grounded at the center by the master key. It will be seen that pressing the *No. 1* member of the master key permits the ringing key to send positive current out over the tip line, which actuates the bell at station *No. 1*. Current also goes through bell *No. 2*, but it is in the wrong direction to operate it, because the bell is polarized as well as being biased by a spring. But it is the bell itself which causes the vibration by controlling its own power. The system has the advantage of requiring little mechanism in the central office and of causing little or no induction on adjacent lines.

CHAPTER IX

COMMON BATTERY SWITCHBOARDS

Common battery working has become the accepted standard for all exchanges of any considerable size, and is also used in many small exchanges. This is because of its simpler telephone instrument, and the centralizing of apparatus and equipment where it can most efficiently be cared for. The central office circuits are a little more complicated than those of magneto systems, and some people have taken a back seat rather than learn to handle the new apparatus. There is no need for this. The difference between local battery and common battery is too slight to deter anyone from learning the latter. It is true that there may be a feeling of helplessness the first time a person takes hold of a case of trouble in a common battery telephone. The local battery set was self-contained. Within it were all the things necessary to test it and to make it reveal its condition. But the common battery set is dependent on the slender pair of wires and the current which may come over them for its operation and testing.

The same feeling has been shown whenever the change from manual to automatic is in progress. Some people give up and let the others go ahead into the new system. But there is no need for it. Any new thing which someone has invented and made can be understood by others, especially since there is such a wealth of help available. Both

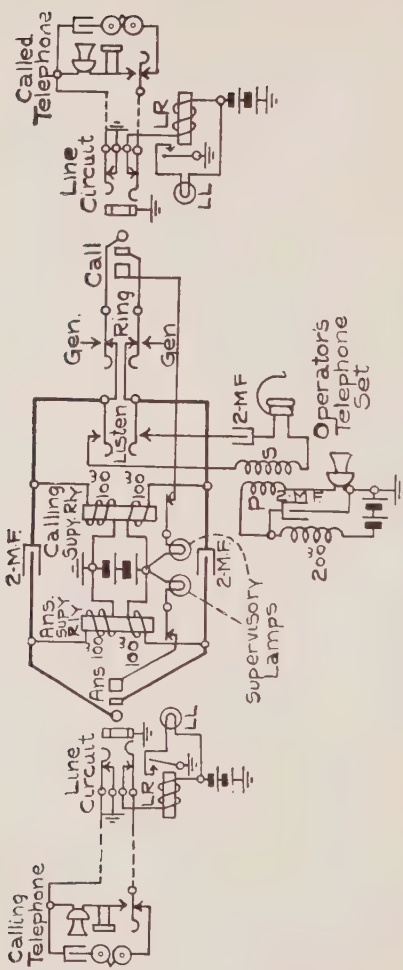


Figure 134.—Simple Common Battery Board.

common battery and automatic are here and will be standard for most of the conditions of telephone service. Only a little patient study is necessary to master all of either that we need in our daily work.

Simple Common Battery Board.—A simple form of common battery line and cord circuit is given in Figure 134. There is enough here to illustrate a complete connection between two telephones. The latter may be of any circuit, but for simplicity we show the series transmitter and receiver.

The line circuit consists of line jack, with two inside contacts, a line relay, and a line lamp. There is battery on the line all the time, with positive on the tip side.

The cord has two current supply relays, one for each telephone. There is also a supervisory lamp for each end of the cord, a listening key, and a ringing key.

The battery current on the line can not get through the condenser in the telephone. When the subscriber takes the receiver from the hook, the line is switched from the bell to the transmitter and receiver. Battery current now flows from ground, through the tip line, transmitter and receiver, ring line, winding of line relay, to negative battery. This pulls up the line relay, which closes the circuit of the line lamp.

The operator sees the line lamp glowing and plugs in with the answering plug. The plug presses the tip and ring springs and opens the inside contacts, cutting off ground and the line relay. The latter falls back and puts out the line lamp. Current now flows through the battery feed relay on the cord, and supplies the calling telephone. The answering supervisory lamp will not light.

The operator presses the listening key, connecting

her set to the cord. She can now talk with the subscriber and get the desired number. She will then plug into the called line. This act clears the called line of attachments (line relay and ground) so that the ringing will be without leaks. The calling supervisory lamp will light by the sleeve current.

When the called station answers, the calling supervisory relay pulls up and puts out the calling supervisory lamp, so that now both supervisory lamps are dark, and the operator knows that the subscribers are ready to talk.

The ringing and the listening keys are usually operated by the same lever and handle, so that the act of ringing disconnected the operator's set from the cord.

When the subscribers finish the conversation, they hang up. This switches each subscriber line from the talking set to the bell and condenser. Battery current fails, and the supervisory relays on the cord fall back and light both supervisory lamps. Seeing both of them, the operator knows that she should pull down the connection.

If only one of the subscribers hangs up, the operator will see only one lamp light. She then gets in on the cord and takes care of the one subscriber according to the rules of operation. The supervisory lamps give definite information as to which subscriber is still desiring attention.

The operator's set has a condenser in the secondary circuit to prevent the passage of battery current, which would make a click in the operator's receiver, and would also operate the calling supervisory relay.

The primary of the operator's set has a condenser to give better transmission. The voltage of the common battery, from 24 to 30 and even 40

Figure 135.—Two-wire Common Battery System (Kellogg).

volts, is too high to permit it to be used directly on the transmitter and induction coil. Hence a resistance of 200 ohms or more is inserted in the circuit. But the transmitter will not talk very loudly in a 200-ohm circuit—it works best in a low resistance circuit. By putting the condenser where it is, there is formed a circuit containing the transmitter, primary of induction coil, and the condenser, which has low impedance to alternating current. When the operator speaks, the varying resistance of the transmitter causes the battery current to undulate. The alternating portion of these undulations passes easily through the condenser, and the talk is commercially loud.

Two-Wire Common Battery Switchboard.—There was a time when it was considered well worth while to cut down the number of conductors in the cord circuit as much as possible. To this end the Kellogg line and cord circuit was invented and used in very many boards. It is shown in its simplest form in Figure 135. The tip of the jack is permanently connected to line, with a connection through a back contact on the cut off relay to the line relay and negative battery. The sleeve of the jack goes to the cut off relay *COR* 500 ohms (to ground). The sleeve line from the telephone gets ground at the back contact of the cut off relay, but is switched to sleeve of jack by the *COR*.

The cord circuit has four battery feed relays, two for each end of the circuit. One of them may be called the control relay because it controls the line conditions and the circuit of the supervisory lamp. The other is the supervisory relay, for by it the subscriber lights the supervisory lamp. The operator's set is bridged across the cord by the listening key as usual. The ringing key is different in that it must provide battery current to hold up

the cut off relay while ringing. This is done by a resistance coil between negative battery and the sleeve contact of the ringing key.

The removal of the receiver lights the line lamp as has been described. When the operator plugs into the jack, current from ground flows through the cut off relay, sleeve and control relay to negative battery. Both relays pull up. The cut off relay clears the line of attachments and switches the sleeve side to the jack. The control relay prepares a circuit for the answering supervisory lamp. It would light, but since the calling subscriber is on the line, the supervisory relay pulls up quickly, and opens the supervisory lamp circuit.

When the operator plugs into the called line, the cut off relay clears that line for ringing. The control relay prepares the circuit for the supervisory relay, which lights.

When the operator rings, the cut off relay is held up by the battery current fed through the resistance. The ringing current passes out over the tip line, through the bell and condenser, back over the sleeve line, through the resistance to battery, ground and the generator.

When the called station answers, the supervision is as usual. Further description is hardly necessary.

Common Battery Transfer Board.—Common battery central offices grow as magneto offices grow, and are subject to the same expedients to give service. More than one unit has been placed side by side, and operated by the same operators, reaching over each other's positions. Transfer lines have also been used, like the circuit shown for magneto boards, except that the battery voltage is higher. Usually the far end of the transfer line ends in a plug, with a plug seat switch like that illustrated, although the sleeve circuit has been used to control

the lamps. Since by the time common battery was accepted as best, the multiple switchboard was also accepted, little need be said about the transfer line on common battery boards.

CHAPTER X

COMMON BATTERY SUBSCRIBER LINE AND TELEPHONE

The simplest common battery telephone, Figure 136, has merely a bell and condenser in the signalling circuit and a transmitter and a non-polarized receiver in the talking circuit. Sometimes a polarized receiver is used, but it needs to be connected so that the line current strengthens the permanent

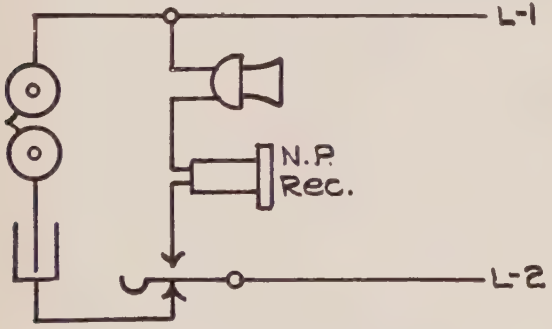


Figure 136.—Series C. B. Telephone.

magnet, or reception will not be strong and in time the receiver will be permanently weakened. The non-polarized receiver, Figure 137, is a revival of an early type made by Alexander Graham Bell, and is used most widely in automatic systems, particularly private automatic exchanges. It works equally well on current in either direction.

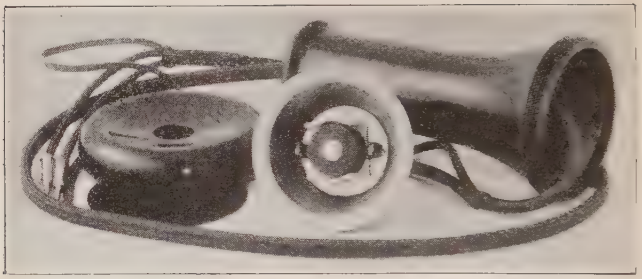


Figure 137.—Non-polar Receiver.

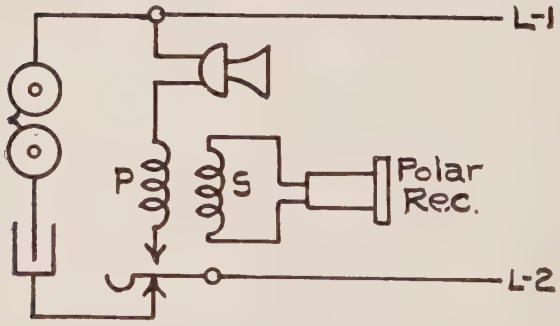


Figure 138.—Series Induction Coil C. B. Telephone.

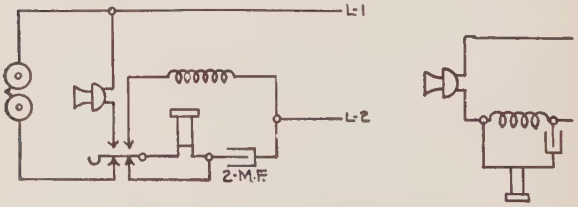


Figure 139.—Kellogg C. B. Telephone, Series Impedence Coil.

The series induction coil common battery telephone, Figure 138, was used for some time. The induction coil transforms the alternating talking current over into the local circuit containing the polarized receiver, and keeps the direct current out. But it is not an efficient telephone—not nearly as good as the series telephone with a well-made non-polar receiver.

The impedance coil circuit, Figure 139, formerly used exclusively by Kellogg, was an attempt to put the polarized receiver directly in the path of the alternating talking current, but shunt the battery current around it. By a cleverly arranged switching device, the same condenser served to keep battery current out of the receiver and also out of the bell. While the hook is down, the receiver is short circuited. The talking condition is shown in the little sketch.

Some form of "booster" circuit is now used for most telephones. The "booster" idea applies to the action of the induction coil, which is made to assist the transmitter in causing the direct line current to undulate. This it really does. Any transmitter will send very much better with such an induction coil arrangement than without it.

The booster circuit with a non-polarized receiver, Figure 140, may be used to illustrate the mode of action. The numerals on the induction coil indicate the exact order of winding. *No. 1* is the start end of the first winding and *2* is its end; *3* is the start end of the other winding and *4* its end. The *1-2* winding with the condenser form a shunt in parallel with the transmitter. Normally the condenser is charged to the potential which exists across the transmitter.

During conversation, the resistance of the transmitter rises and falls. The voltage across the trans-

mitter rises and falls with it. This undulating voltage drives an alternating current through the condenser and the *1-2* winding. This latter current induces a voltage in the *3-4* winding which is sufficiently in phase with the resistance change of the transmitter to assist it in causing the line current to undulate.

The booster circuit with polarized receiver, Figure 141, is very widely used, being the standard for the Bell companies. The receiver is placed in the

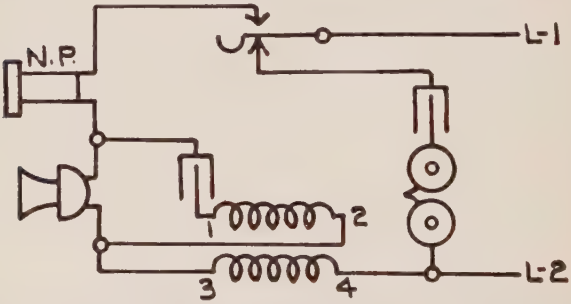


Figure 140.—Booster C. B. Telephone with Non-polarized Receiver.

shunt circuit above mentioned. Therefore, during the sending of speech the receiver will be very strongly affected, and produce strong "side tone." Its presence in this local circuit slightly weakens the speech sent because its impedance lowers the alternating current through the condenser.

The numerals on the induction coil do not indicate the order of winding, but the coil is drawn so as to show the relative polarity of the two windings.

The bell is connected so as to use the same condenser for talking and for signalling. But there is a little leakage of battery current through the

receiver while the hook is up. It is small, because the resistance of the winding which is in the main line is low.

During the sending of speech, the local winding

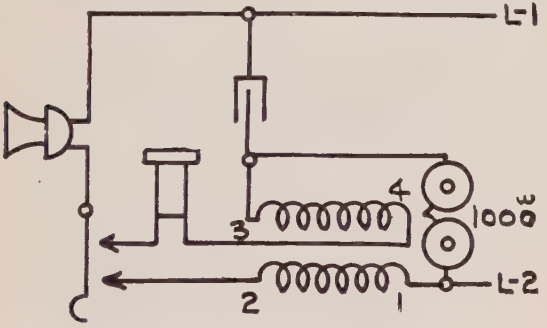


Figure 141.—Booster C. B. Telephone with Polarized Receiver (W. E. Co.).

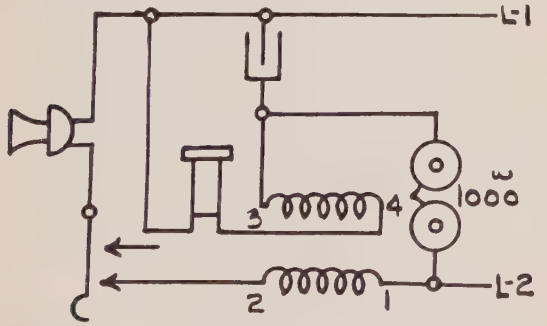


Figure 142.—Anti-Side Tone Circuit (W. E. Co.).

acts as a primary, repeating the energy of the local current into the main line. During the reception of speech the line winding acts as primary, repeating the energy of the line current into the

receiver. It is hardly proper to speak of either winding as being the primary for each acts at primary in turn. But in Figure 140 the local winding is always primary, because the coil exists for sending only, not being of any help in receiving.

To reduce the side tone, two circuits are in use. Figure 142 shows the arrangement employed in the Western Electric and other telephones. It is secured by moving one receiver terminal from one side of the transmitter to the other. It results in

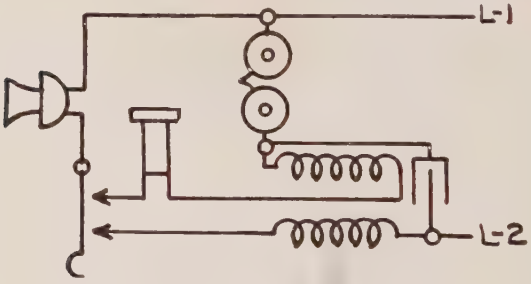


Figure 143.—Anti-Side Tone Circuit.

putting the receiver into a local circuit much like Figure 138. The transmitter is deprived of any assistance from the induction coil. Another circuit sometimes used is shown in Figure 143. It is secured by transposing the line terminals of condenser and bell. It also deprives the transmitter of any "boosting" assistance from the coil. It puts the receiver into a semi-local circuit, there being one member of a quadrangle in the main line.

Common battery telephones are made in a few forms, fewer than in years past. The desk set, and the residence type wall set, practically divide the field between them. The old wall set with a

writing desk is practically no more made. Steel is much in demand for bell boxes and wall telephones, although for tropical countries steel often fails and some insect-resisting wood (like American black walnut) must be used.



Figure 144.—Desk Stand.

A typical desk stand is shown in Figure 144. Its form has been worked out through years of experience, and is very simple. The transmitter is usually pivoted, although there is no need for its being so, and some pioneers have begun tentatively to make it solid. Figure 145 shows the base with the base plate removed.



Figure 145.—Desk Stand with Base Plate Removed.

The bell box, Figure 146, closed and open, is also of steel. The induction is at the bottom with the terminal strip on top of it. The condenser is at the right of the bell.

There is a new bell box with enclosed gongs com-

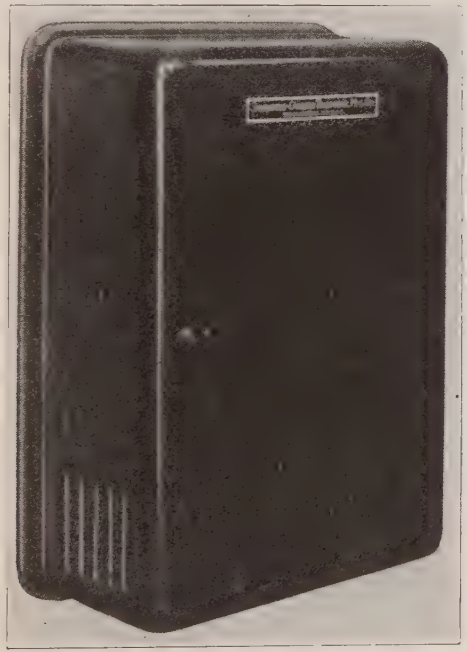


Figure 146.—Desk Set Bell Box.

ing into use. It is shown in connection with the automatic telephone instrument.

To a very little extent, the combination hand telephone, Figure 147, is used. There is prospect that it may be more used if certain difficulties con-

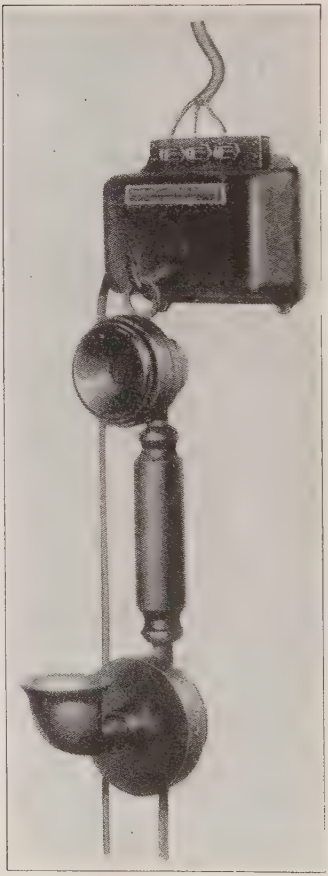


Figure 147.—Combination Hand Telephone.

nected with its use in automatic systems can be overcome. It certainly is a handy set.

The residence type steel wall set, Figure 148, is almost standard in America. It is shown opened



Figure 148.—Residence Type Wall Telephone.

in Figure 149. Although both desk stand and wall set here shown are of one make (Stromberg-Carlson) they are sufficiently typical to give the reader an idea of modern forms. In general, the

desk set bell box is the basis on which the wall telephone is made. In fact, one set is made so that only the cover need be changed to make a wall set out of the bell box of a desk set. See the automatic telephone instrument.

Party Lines, Common Battery.—The common battery switchboard affects the party line, because of the presence of a potential on the line all the time.

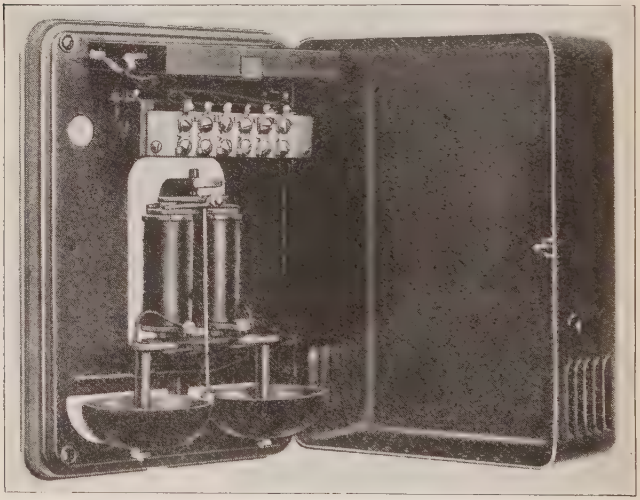


Figure 149.—Residence Type Wall Telephone (Open).

The biased bell system is most affected, for it requires bells from each side of line to earth. Figure 150 shows the condition and one method of remedying it. There is normally a path from each line to ground through the bells in parallel. Only the bells on the negative battery side ("wet side") cause any leakage, for those on the other side are short circuited by the ground on the battery at the

central office. The normal leakage is reduced by using 2,500-ohm bells and putting a high resistance in series with each bell. Sometimes as high as 10,000 or 20,000 ohms have been used. Such re-

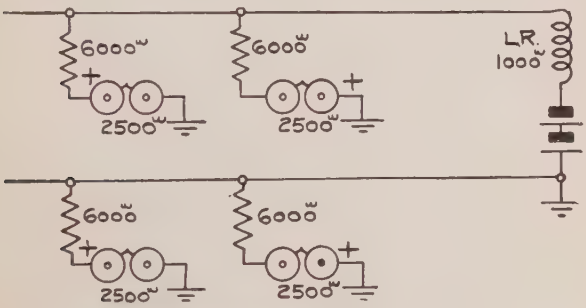


Figure 150.—Biased Bells on Common Battery Line.

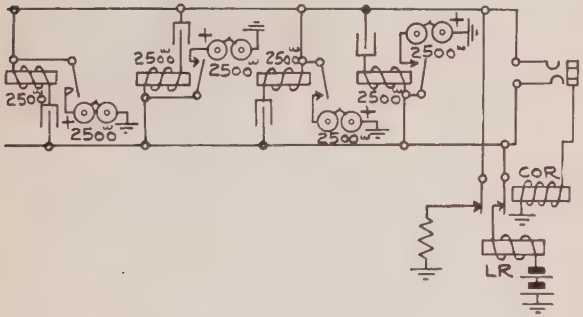


Figure 151.—Biased Bells with Relays on Common Battery Line.

sistances will prevent the line signal from being displayed, and also reduce the drain on the battery.

Another method, which has become standard practice among Bell companies, is shown in Figure 151.

There is a sluggish relay in each telephone, which connects the bell to the line when ringing is going on. Normally the line is clear of grounds. During ringing, the bells are all connected, but only the one responds, as was described.

A much simpler method of selective signalling is the harmonic system. It consists in using several frequencies of alternating current, and equipping each station on a line with a bell which responds to only one of the frequencies. Though the idea was simple, people spent many years finding out the

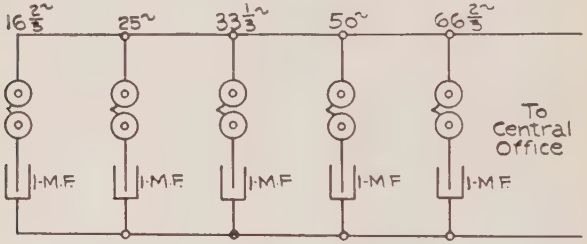


Figure 152.—Harmonic Selective Party Line.

best way to do it. Some systems used electrical resonance in the circuits of the telephone, others depended upon tuning the clapper of the bell to the frequency desired. The latter has won out completely. The simplicity of the telephone as to apparatus and circuits and the absence of any signalling ground at the telephone are factors in its favor.

The line circuit, Figure 152, is very simple. Each bell has a condenser in series with it—that is all.

Two systems of frequencies are in use, the multiple and the non-multiple systems. The frequencies of each are as follows:

Multiple harmonic.....	16 2/3	25	33 1/3	50	66 2/3		
Non-multiple harmonic..	20	30	42	54	66		

The multiple harmonic had only four frequencies at first, but the 25-cycle bell was added to make

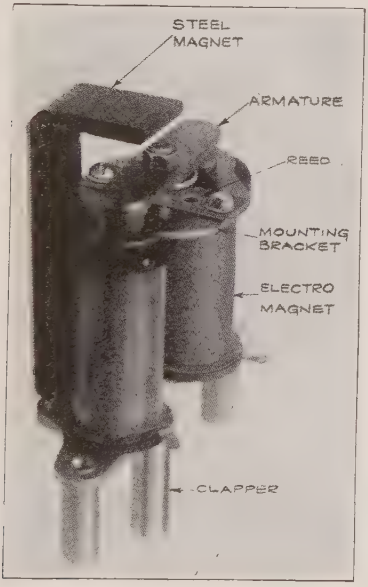


Figure 153.—Harmonic Ringer Movement.

it five. Otherwise the frequencies are multiples of the first (16 2/3).

The harmonic bell, Figure 153, differs from the ordinary bell in having its armature and clapper mounted on a reed instead of a pivot. The weight of the clapper and the stiffness of the spring are selected so as to make the natural vibration of the

assembly the same as that of the ringing current. Other frequencies may make the clapper tremble, but will not make it strike the gongs.

At first the harmonic party line was rung by a motor generator set. This fixed the frequencies in

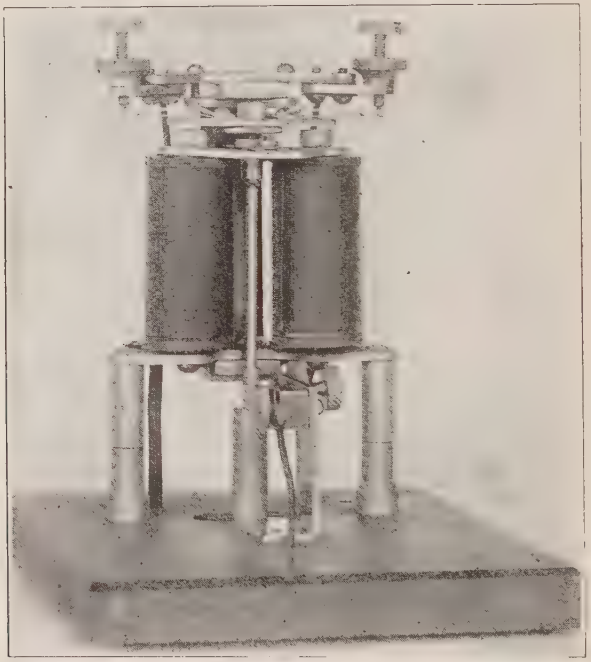


Figure 154.—Pole Changer of Harmonic Converter.

a multiple relation. Later the polechanger was so greatly improved that people cut loose from the motor generator and used the "harmonic converter" exclusively. Figure 154 shows one such pole changer. It is like a polarized bell but is made

self-interrupting by adding an interrupter spring to be actuated by the clapper rod. The moving system is tuned as the bells are tuned. At the

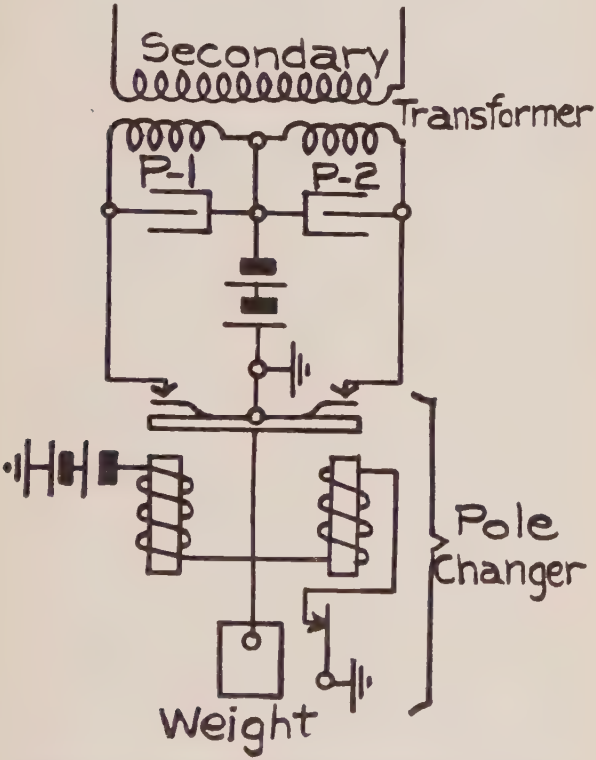


Figure 155.—Harmonic Converter Circuit (One Unit).

top are the springs carried by the armature, which make and break the battery current through a transformer.

The circuit, Figure 155, gives a clear idea of the action. The transformer has two primary windings and one secondary. The primaries are in series. When the vibrator swings to the right, battery current passes through *P-2*. When the vibrator swings to the left, battery current flows through *P-1*, which completely reverses the magnetism in the core of the transformer. The condensers absorb the arc which would be formed at the contacts. Even with them, there is some corrosion of the contacts. It is customary to reverse the polarity of battery on the transformer, periodically, which equalizes and reduces the wear and gives longer life.

CHAPTER XI

THE MULTIPLE SWITCHBOARD

The multiple switchboard came into use because the transfer board was too slow and caused too many mistakes. It was desirable for each operator to complete all connections herself. For a time the full multiple principle was pushed too ardently, and resulted in the one-office per city idea. From this the art has had to recede, but the transfer board died in the process. Though large multiples

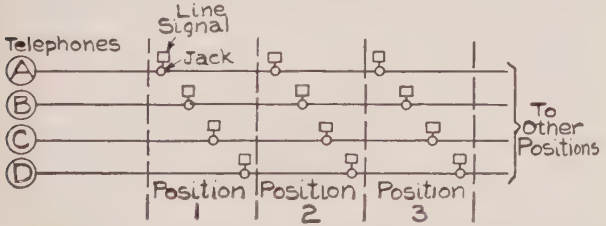


Figure 156.—Principle of Multiple Switchboard.

of nearly 20,000 lines have been built, time has shown that 10,000 lines is about the limit. This, together with the factor of length of subscriber lines, has fixed the maximum size of the office.

Imagine, Figure 156, a number of subscriber lines, from telephones *A*, *B*, *C* and *D*, brought into the switchboard and run to as many jacks and line signals as there are operators. Then each operator may answer any call, and may connect it directly

to any other line. In recent times this has actually been done in small multiple boards, and the element of competition introduced into the work of the operators. But for large boards, there is not room enough for so many line signals.

The multiple board, Figure 157, which has seen the largest use has a separation of answering facilities from calling jacks. The intermediate distributing frame, *I D F,* was introduced to distribute the traffic among the operators.

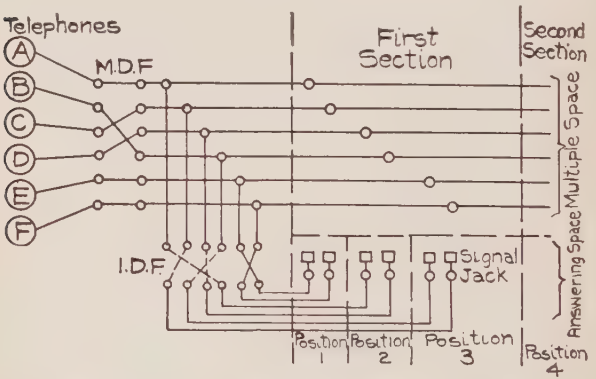


Figure 157.—Principle of Multiple Switchboard with I. D. F.

It is usual to build the switchboard in sections, each of which has three positions for operators. There is only one multiple for the section, because an operator can reach over the field which is above three positions. Some two-position sections have been built.

From the switchboard side of the *MDF* the lines run to the multiple jacks, permanently. Through the *IDF* the lines are connected to any position desired. By proper cross connections, the more

busy lines can be distributed among the positions and avoid overloading any one position.

The multiple switchboard brings with it the necessity of a reliable busy test. The operator can not see all the connections which are up, and she has not the time to look even if she could. So it is arranged that by touching the tip of the calling plug to the sleeve of the desired multiple jack the operator will hear a distinct click if the line is busy, and hear nothing if the line is free.

The most largely used set of circuits for the multiple board is that of the Western Electric Co., Figure 158. It has a full three-wire plug and jack, repeating coil battery supply, and series supervisory relays.

The line and cut off relays are similar to those which have been described. But the line relay has two windings, which reduce the noise when the operator plugs in. The cut off relay is low resistance 30 ohms, because the supervisory lamp must light through it.

The supervisory relay is shunted by a non-inductive resistance which reduces the transmission loss. The joint resistance is about 12 ohms. A 12-volt lamp is used for supervision, with an 83-ohm resistance in series to reduce the current to a safe value. It is extinguished by a 40-ohm shunt, which increases the sleeve current.

When the subscriber calls, the line lamp lights as usual. The operator plugs in and answers with the listening key, talking to the subscriber through the repeating coil. Having received the number, she tests by touching the tip of the calling plug to the sleeve of the desired jack. If the line is free, there will be no plug in any jack on that line, and the sleeve will be at ground potential. There will be no flow of current in the *T* quarter of the re-

Figure 158.—Common Battery Multiple Board (W. E. Co.).

peating coil. But if the line is busy, there will be a plug in some jack on the line, with current flowing in the cut off relay. This raises the potential of the jack above earth, so that when the operator tests, the *T* quarter of the repeating coil will get a little current, enough to make the click in the operator's ear. The rest of the operation is clear from the diagram.

An illustration of a very different way of doing the same things is found in the Stromberg-Carlson circuits, Figure 159. The line circuit is about the same as others, but the plug has only two conductors. When inserted in the jack, it connects ring and sleeve of jack together. Then it is like the Kellogg board.

The interaction of control relay and supervisory relay is mechanical. Normally the control relay presses the armature of the supervisory relay up into the operated position, holding the contact open. When the control relay is energized, it pulls its armature down and lets the supervisory armature drop, closing the contact. See small sketches. If now the supervisory relay is also energized, it pulls up and opens the contact.

The calling relays have more to do than the above. During the time of busy test, with the operator's listening key operated, there is a path from tip of calling plug, through a contact on the supervisory relay (normal) through contact *a* on the listening key, and through the third winding on the induction coil to ground. Thus the busy test is made somewhat like that of the Western Electric, except that the click is carried directly into the operator's set.

Plugging into the desired jack causes the control relay to pull up through the sleeve circuit and cut off relay of line. This cuts out the busy test break

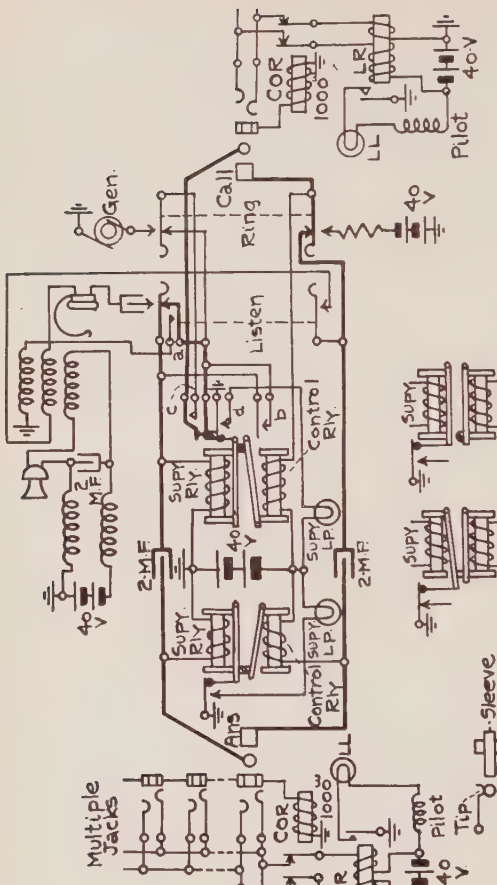


Figure 159.—Common Battery Multiple Board (S-C Co.).

in the tip of cord by closing contact *b*. It also lowers the supervisory armature and connects the ringing key (contact *c*) and lights the supervisory lamp (contact *d*).

Ringing is done about as was done in the Kellogg circuit, holding the cut off relay by resistance to negative battery, in this case in parallel with the control relay to give an easy path for ringing current. When the called subscriber answers the supervisory relay pulls up, puts out the supervisory lamp and cuts off the generator side of the ringing key.

CHAPTER XII

THE "FEATURE" SWITCHBOARD

The rise of automatic switching of telephone lines brought with it many desirable features of service. Secret service, almost instantaneous disconnection, immediate recall, were fully appreciated by the using public and the operating company, in addition to the quickness of obtaining connections and the ease and accuracy of dialing the call number. Commercial competition led some independent manufacturing companies to try to incorporate some of these desirable automatic features in their manual boards. The result has been the so-called "feature" board, now made by Kellogg and by Stromberg-Carlson and to some extent by Western Electric.

The feature board has brought into the circuit the very complications which people used to fear, and against which many good arguments were offered. But it developed that the improved service is worth the cost.

The feature board is well illustrated by the cord circuit of Stromberg-Carlson, Figure 160. We will briefly describe what it does, call attention to a few circuit devices, and follow a call through.

The distribution of traffic is one advantage of automatic switching which the public can not see, but whose results are evident. The manual people tried it in a number of ways, among which may be mentioned the full multiple of line lamps with jacks, and the use of non-numerical automatic switches

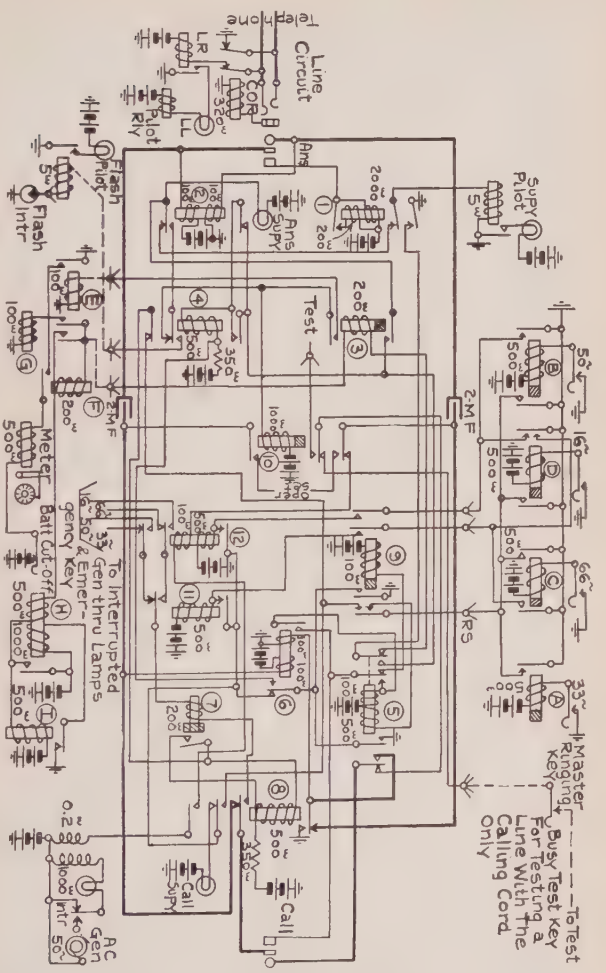


Figure 160.—Cord Circuit, Feature Board (Stromberg-Carlson).

to select idle trunks or idle operators, or to connect the calling line to an idle trunk which appears before all operators. The circuit shown in Figure 160 is designed to work with the full multiple of line lamps.

When the full multiple of line lamps is used, the operator may be permitted to plug into another call before she has finished the one to which she is attending. This advance plugging in requires something to prevent two operators from being cut in on the same call (operator's bar). A lamp also burns dimly on the cord to which the operator is connected, to indicate the place of action. It guards against mistake.

The operator is automatically connected to the cord used and again automatically cut off when she has started the ringing. This gives secret service, formerly called "keyless listening."

Calls answered by the operator are registered on a meter.

The ringing is done periodically by the ringing machine, and continues until the subscriber answers, or the calling subscriber hangs up, abandoning the call. If party lines are used, there is one master key per position. During the ringing, the calling subscriber hears a tone which indicates that the station is being called.

There are no lamps burning on the cord when the operator has started the ringing and thereby been cut off from the cord. The key shelf is dark. There is no need for lamps, because the operator is through with that call for the time being—the machine is doing the ringing.

As to how to terminate the call, people are divided in opinion. Some think that when the subscriber hangs up and calls again at once, the supervisory lamp should flash regularly, the "flash re-

call." Others think that under the same conditions the cord ought to be cut off completely, as much as if the plug had been pulled out, and that the line lamp should light as if it were a new call. This latter is the "instantaneous disconnect" with "instantaneous recall." Both have merits. The circuit shown by the diagram of Figure 160 gives the flash recall.

There is nothing novel about the line circuit used in Figure 160. The resistance of the cut off relay *COR* must be suitable to the sleeve relay of the cord and the conditions under which they must operate.

The cord has the impedance-condenser type of feed. Relay *2* feeds the calling station and relay *6* the called station. The operator's set is cut into the cord by relay *10*, which also connects the busy test wire marked *test*.

The cord is equipped for four-party harmonic selective ringing. The four keys of the master key are at the top. Each controls a relay *A* to *D* which operate relays *11* and *12* singly or together to select the frequency. The ringing current goes through relay *7*, which is the ring cut off relay. There is a common ringing interrupter machine which is referred to in Figure 160.

The flash recall is controlled by relay *4*, Figure 160, which brings in the common flash interrupter shown below at the left.

Let us follow the operation of a call.

The operator plugs in on the calling line. If some other operator has plugged in first, there will be such a high voltage drop across the cut off relay that the 2,000-ohm sleeve relay *1* of the cord can not pull up, and the operator will not be connected. But if there is no plug in any jack on that line, the sleeve relay *1* will pull up and cut

in the 200-ohm winding, which bars another operator.

Relay *2* pulls up because it supplies the calling telephone.

Relay *3* now pulls up from a ground at relay *1* through a contact on relay *5* and in series with relay *F* the latter being common to the position. But this operation is delayed by relays *I* and *H*. *I* will not permit the others to operate until it has pulled up and helped *H*, which cuts *I* out.

The answering supervisory lamp and relay *10* are now in parallel with each other and in series with relay *E* 100 ohms. The lamp lights dimly as a listening indication, and the relay pulls up, connecting the operator's set.

If the operator should plug up another call in advance, before clearing from this cord, relays *1* and *2* in the second cord will operate, but relay *3* will not, for it is shunted by coil *G* 100 ohms, which was connected by the common relay *E*. Hence the operator's set will not be connected to the second cord until the first cord has cleared, as will be shown later.

The cutting in of the operator as described operated the meter through contacts on relays *E* and *F*. If a second cord was plugged up in advance, relay *E* must fall back when the first cord is cleared. This insures the registry of the second call separate from the first.

The operator makes the busy test in the usual manner, touching the tip of the calling plug to the sleeve of the desired jack. The test circuit leads from the tip of plug, through a back contact on relay *5*, front contact on relay *10* to the operator's set of Figure 161, where it arrives on the wire marked *test*. If the line is busy, the test relay is pulled up, taking the short circuit from

the 100-ohm relay in the transmitter circuit and connecting the condenser. This produces the click.

The operator plugs into the called line and presses the master key. Each relay *A*, etc., is slow to release, and will hold for a moment after the operator has released the key.

The sleeve current operates the cut off relay *COR* of the called line and also pulls up the master key control relay *9*. This relay prepares the locking ground for the frequency selecting relays *11* and *12*, extends the pull up circuits from the common

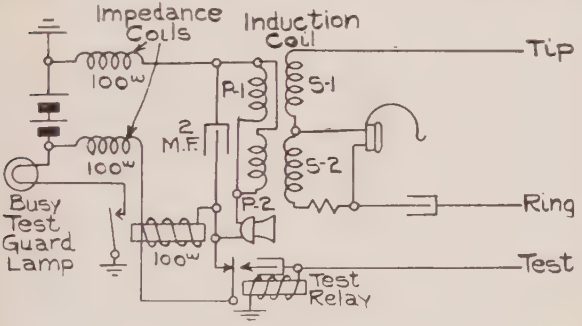


Figure 161.—Operator's Set, Feature Board (S-C Co.).

master key relays to the relays *11* and *12*, and connects relays *8* and *5* (500-ohms) in parallel to the starting wire *RS*.

No matter which key is pressed, the start wire *RS* will be grounded and relays *5* and *8* pulled up and locked to start the ringing. Relay *9* is cut off by *5* but releases slowly enough to insure the operation of *11* and *12*. But the action of relays *11* and *12* depend on the key used. The first key operates relay *A* and leaves relays *11* and *12* normal, giving 33 cycle current. Relay *C* operates

11 and gives 66 cycle current. The frequency selecting relays lock themselves through a back contact on relay *6* to ground at relay *5*. Relay *5* on operating, releases *3* which puts out the answering supervisory lamp and releases *10*, cutting off the operator's set.

Ringing current passes through relay *7* to the ring side of line and back over the tip side to ground, returning to the generator through the battery. Ringing tone (50 cycle) is sent to the calling subscriber from an induction coil through contact on *8*, winding on *12*, contact on *10*, to tip of cord. When the called station answers, the ring cut off relay *7* pulls up by means of the direct battery current. Relay *7* short circuits relay *8*, which falls back and cuts off the ringing current, connecting the supervisory relay *6* to the called station. The latter now pulls up, holds relay *5* (100 ohms) locked to the sleeve conductor, releases the frequency selecting relays, and as a precaution prevents the possibility of relay *4* being energized.

If the calling subscriber had hung up before the called subscriber answered, the ringing would be stopped as follows. Relay *2* falling back permits relay *4* to pull up (relay *6* not having operated because the called station has not answered). This breaks the circuit of relay *8*, which falls back and cuts off the ringing. Both supervisory lamps are lighted, one by relay *2* through a contact on *1*, the other by relay *8* through back contact on *6* and front contact on *5*. The operator will pull the cord down.

Return to the completed connection. The subscribers are talking. Relays *1*, *2*, *5* and *6* are energized. Either subscriber can signal the operator as in an ordinary cord circuit. But if the called subscriber hangs up first, the calling sub-

scriber's recall is converted into flashing recall. The release of relay *6* takes the ground off the 350-ohm resistance associated with relay *4*. If now the relay *2* falls back, relay *4* will pull up through front contact on *5* and on *1*. It locks itself so that if *2* pulls up again, *4* remains energized. The latter relay switches the front contact of *2* to the flashing ground wire, which passes through a 5-ohm relay to the flash interrupter.

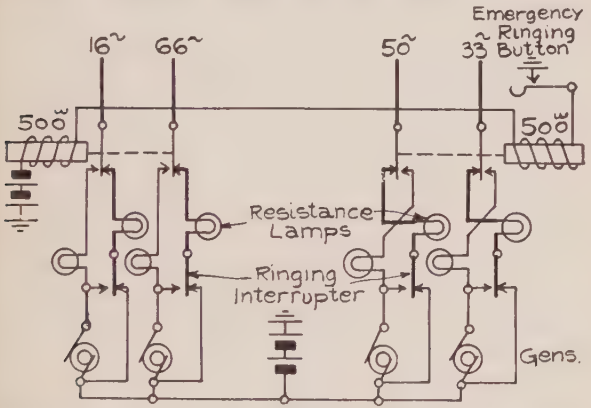


Figure 162.—Emergency Ringing Circuit, Feature Board (S-C Co.).

The operator will answer by pulling out the calling plug. Relay *5* falls back, switching the ground of *1* from *4* to relay *3*. The latter pulls up and operates relay *10*, connecting the operator's set as at the beginning.

If there should be a failure of the ringing interrupter machine she could ring by using the emergency ringing button shown in Figure 162. It pulls up two 500-ohm relays in series, which switch

the frequency wires around the interrupter through other resistance lamps to the generators.

It may be noted that this cord circuit has twelve relays, whereas an automatic selector switch has only eight and a party line connector thirteen, counting every magnet as if it were a relay. If there are desirable things to be done automatically, it requires some amount of apparatus to do it.

CHAPTER XIII

THE AUTOMATIC SWITCHING OF TELEPHONE LINES

The switching of telephone lines has justly occupied very much of the attention of telephone people. The larger the exchange, the more the congestion of traffic which exists, and the greater the need for very prompt handling of calls. The expense of manual switching also becomes such a serious item that it is sometimes a deciding factor in rate making.

Attempts at automatic switching began long ago. In 1879 the first work was done. In 1889 Strowger started his development. Since then, the work has gone ahead in a number of parallel lines, nearly all makers of telephones having contributed something to the total effort. Today the movement to convert existing exchanges to automatic is in full swing. No telephone worker can afford to be without knowledge of it, for it will press its way to practically every exchange.

At the present time there are three systems of chief importance although more are in process of development and many have fallen out of the race. The Strowger system is represented in America by the Automatic Electric Company and the Northern Electric Company and in Europe by the Automatic Telephone Manufacturing Company, (England), the French Thomson-Houston Company (France), and Siemens and Halske Company (Ger-

many). The panel system is being made by the Western Electric Company and being installed in some large cities. The Western Electric rotary system is being made in Europe.

Attempts have been made to secure some automatic advantages in a manual system by a partial introduction of automatic switches. They are of two kinds, traffic distribution and the Automanual. The former interposes automatic switches between the subscriber lines and the operators, so as to distribute the traffic evenly to all of them. The latter consists of a complete automatic central office with operators interposed between the subscriber lines and the equipment. The call is passed to the operator who completes it by means of the switches.

The present status in America is that the Strowger system is most largely used and receives most attention. Since the panel system is still restricted to the large cities, we will give our attenion to the Strowger system. The principles governing automatic switching are more or less fundamental and he who masters the one system, will easily grasp others. Accordingly we invite the attention of the telephone man to the Strowger automatic telephone exchange.

If we were to walk into the central office of an automatic exchange, we would see a number of things wihch would call forth questions. First of all, we would see a room something like Figure 163. It is filled with many frames on which hang many machines. There are cables on runways overhead, apparently connecting the apparatus together.

The subscriber lines come into the office just as they do in a manual exchange, through a main distributing frame. From the M. D. F. there are



Figure 163.—Automatic Switch Room.

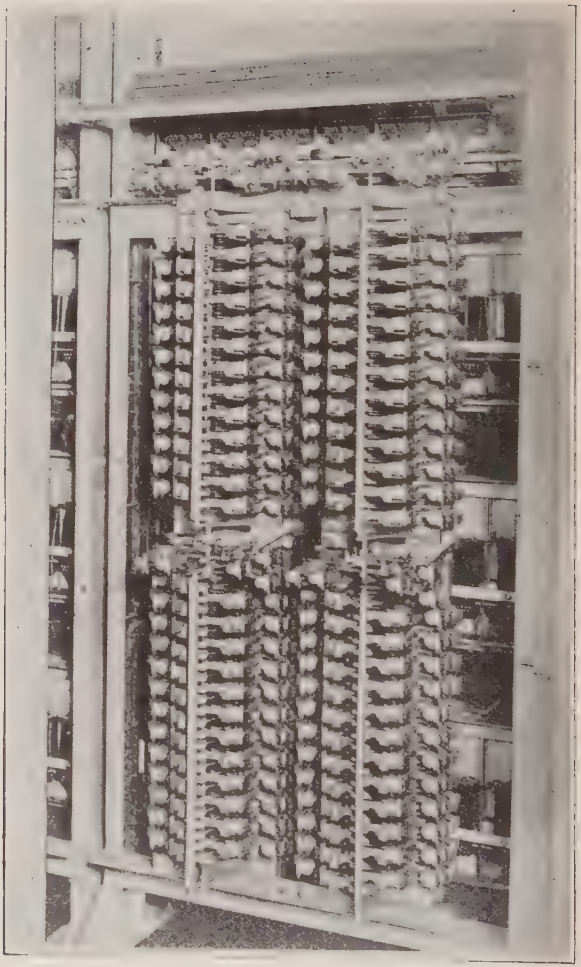


Figure 164.—Lineswitch Board.

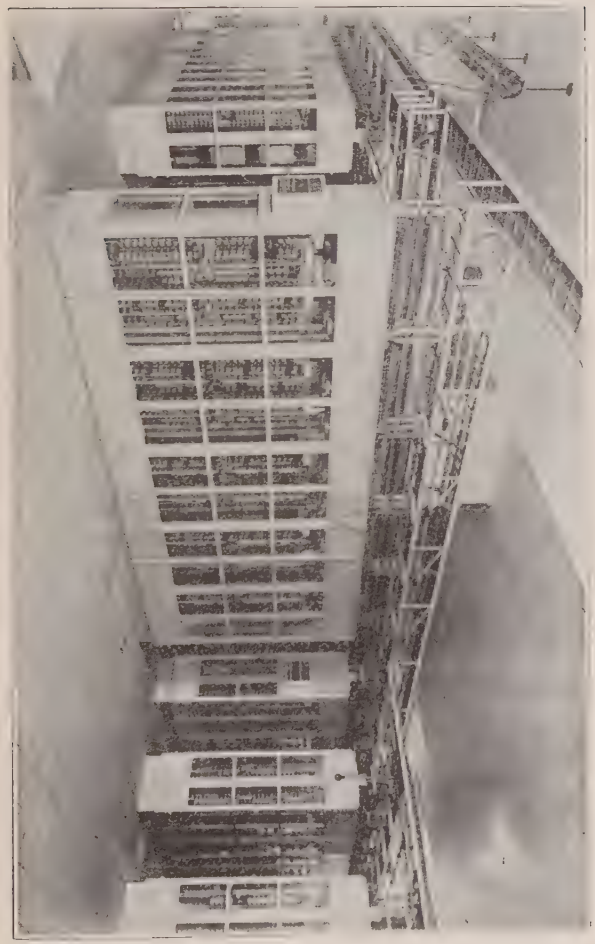


Figure 165.—Secondary Lineswitch Board.

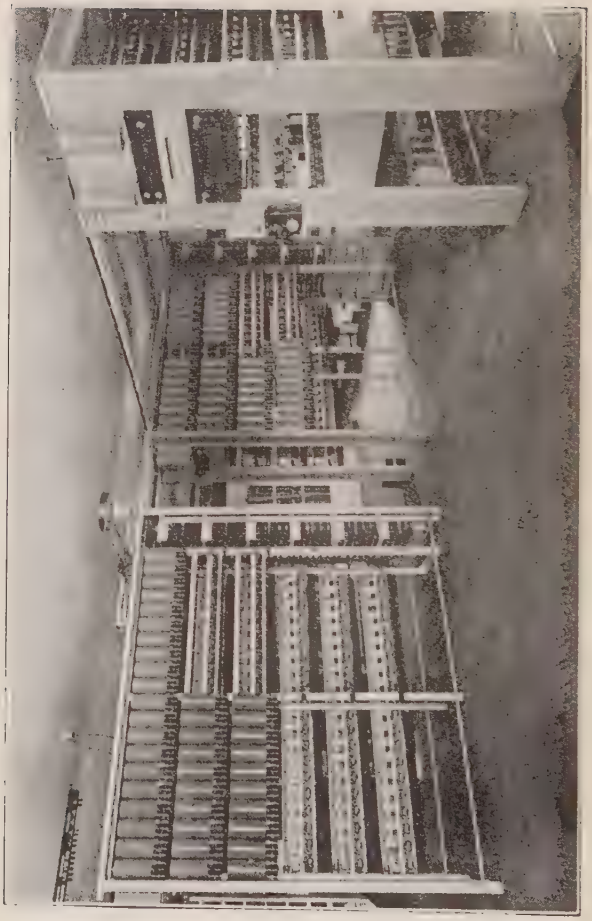


Figure 166.—First Selector Boards.

cables which connect the subscriber lines to upright frames called "lineswitch boards." Figure 164. They are in a glass housing. Cables connect these lineswitch boards to an intermediate distributing frame from which run cables to other glass-encased frames which look very similar. Figure 165. They are called "secondary lineswitch boards." Cables run from here through an I. D. F. to an open framework, Figure 166, which has five or six horizontal rows of machines on each side. These machines are called "first selectors" and the frames are known as "selector boards."

From the first selector boards the path of the cables is not simple. There is much deviation in different directions. But nearly all of them terminate in other selector boards which look practically identical to the first selector boards. They are called "second selector boards." From them there are cables which run to machines located on the back side of the lineswitch boards, Figure 167. These are switches called "connectors." Examination of the interior cabling of the lineswitch board reveals that the connector switches are cabled to the subscriber lines which we saw at the first, coming from the *M. D. F.*

The above view is fairly typical of an automatic exchange. Many variations will be found by the observer, some of which we will discuss later in this book.

Now, if we stand beside a lineswitch board while the traffic is fairly heavy, we will often hear a little click inside the case. Figure 164. This is caused by a subscriber initiating a call. The removal of the receiver from the hook causes a little lever to move, connecting the subscriber to idle switches, which can serve to build up a connection. If we observe a selector switch, we will from



Figure 167.—Lineswitch Board, Connector Side.

time to time see it move a rod with springs mounted on it. It lifts and rotates the rod with a ratchet action. The connector switches perform the same actions.

How does each switch act?

How are the switches linked together to form a working exchange?

In answering these questions, we will study the mechanism of switches, their electrical circuits, and how they are linked together. It is an advantage to carry the three features along more or less together. We will start with the simplest case and build up to the complete public exchange.

The general plan of an automatic exchange of any size is that of group and sub-group, and successive selection. For instance, we may have a number of hundred line units. Each serves one hundred subscriber lines. To get any line we will select the desired unit first, then connect to the line by means of tens and units sub-division. This gives us a 1,000-line exchange. Again we may put together several such 1000-line assemblies to get a 10,000-line exchange. We now first select the 1,000-line group, then select the 100-line unit, then connect to the line as before. In this way we build up an exchange of any desired size.

What size of group shall we use? Too small a group has been found to require too much machinery. Too large a group has been found to be unwieldy and also expensive. It has also been found that when we depart from the decimal system in grouping, we introduce complications in the switching apparatus which are expensive to make and to maintain. It seems to be the result of some thirty or more years of competitive manufacture, that the decimal system of grouping is the simplest and cheapest to build, and the easiest

and cheapest to maintain. Hence the unit switch is made to connect with 100 lines, and the 100-line switchboards are grouped by tens.

SWITCH STRUCTURE

Fundamentally, the switch is very much like the plug and jack. Figure 168. One plug may connect the cord circuit to any one of many jacks. The automatic switch has a bank of one hundred

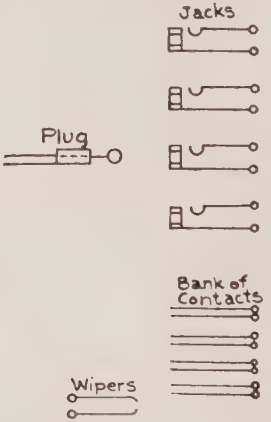


Figure 168.—Plug and Jacks, Wiper and Bank.

sets of contacts. It has also a set of springs mounted on a shaft. The shaft can be lifted, so as to bring the springs or "wipers" opposite any horizontal row or "level" of contacts. Then the shaft may be rotated so as to cause the tips of the wipers to touch any one set of these bank contacts. This is the most elementary and fundamental of the duties of a switch.

Two methods of moving the wipers have been proposed and tried. They are ratchet magnet drive

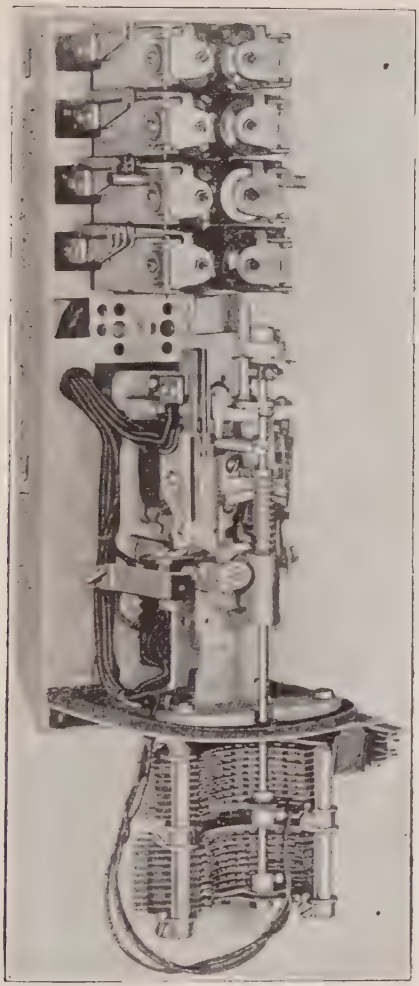


Figure 169.—Connector Switch.

and power drive. The latter is expensive to build and to operate, for motors must be kept running

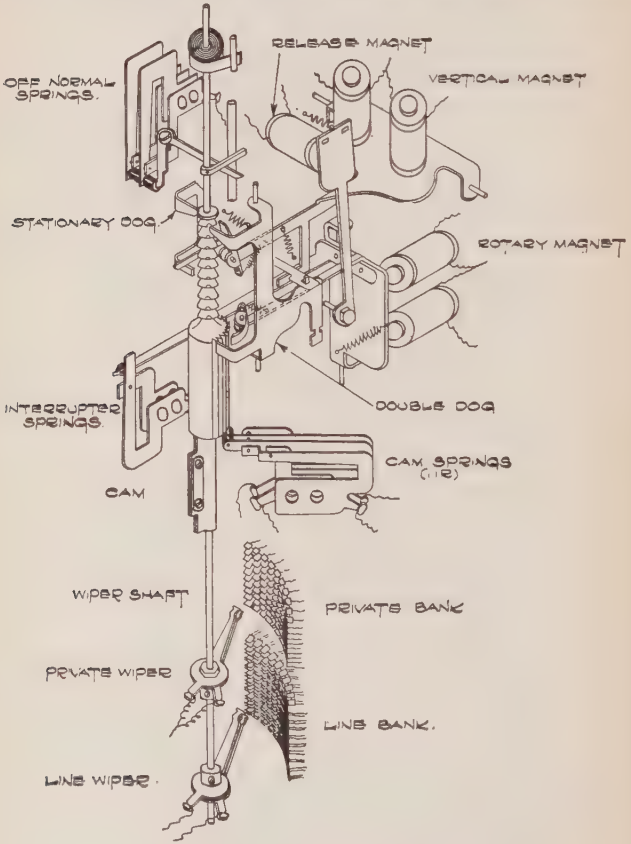


Figure 170.—Selector Switch.

day and night, whether there be traffic or not. There is much common mechanism upon which the whole central office depends, and its failure will stop

traffic entirely or to a very great extent. The ratchet magnet drive is individual to each switch, so that each switch is independent of all others. One switch failing has practically no effect on the traffic, for the continued operation of the other switches will carry the load.

The small unit switch makes a very flexible device. Such switches may be associated with each other in a wide variety of ways, to meet any condition found in practice. For this reason they are now increasingly used, and their capabilities are yet not fully known.

The connector switch, Figure 169, has its banks of contacts at the bottom. There are two banks, the lower one contains the contacts for the line wires to telephone stations. The upper one contains contacts which correspond to the sleeves of manual jacks. They protect the connection from intrusion. On them the busy test is made, and through them other valuable things are done. This bank is called the private bank.

Above the banks will be seen the ratchet mechanism for lifting and rotating the wiper shaft, so as to bring the wipers to any set of contacts. Above this are the relays which govern the action of the magnets. There is a cover which keeps the dust off the relays and mechanism.

The mechanical structure is more easily seen in Figure 170. No relays are shown. The banks consist of ten rows of contacts, each row having ten sets of contacts. They occupy positions on the surface of a cylinder. See Figures 171 and 172. The wiper shaft is at the axis of this cylinder, and carries the wipers at the lower end. See Figure 170.

The two bearings which hold the shaft are not shown. Above the wipers is a cam which under

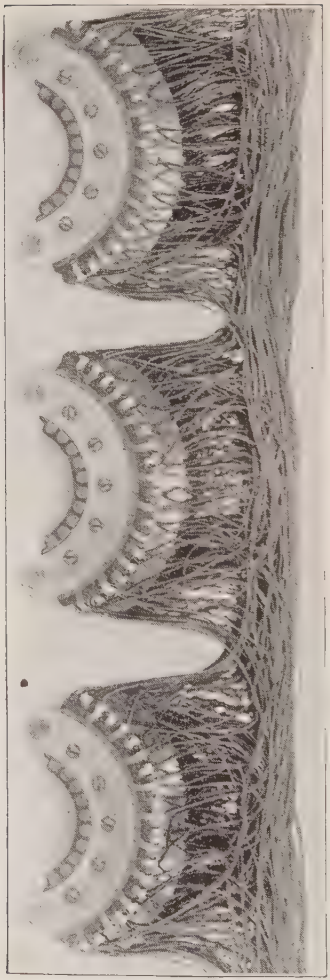


Figure 171.—Switch Banks.

certain conditions will operate the cam springs. Above the cam is the ratchet cylinder, familiarly known as the "hub." This cylinder has two parts as to use, though they are one piece mechanically. The upper part is the vertical ratchet cylinder for by it the vertical magnet lifts the shaft. The lower part is the rotary ratchet cylinder, for by it the rotary magnet rotates the shaft.

The vertical magnet is provided with a lever,

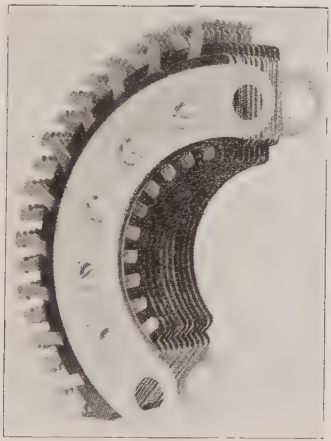


Figure 172.—Switch Bank (Top View).

the outer end of which carries a pawl. When the magnet is energized, the lever rises and the pawl engages the vertical ratchet cylinder, lifting the shaft one step. The magnet is capable of lifting the shaft at from eight to fifteen steps per second with certainty. During this vertical motion, the upper prong of the "double dog" holds the shaft from falling back.

The rotary magnet is similarly provided with

an armature, whose end carries a pawl. When energized, the magnet attracts the armature and causes the pawl to rotate the shaft one step. The lower detent on the double dog prevents the shaft from rotating backward by the shaft spring, which is at the top of the shaft.

As the shaft rotates its first step, the weight of the shaft is taken from the upper detent of the double dog and borne by the stationary dog.

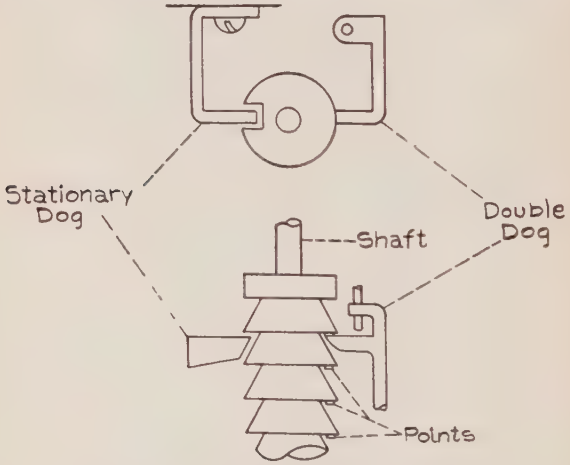


Figure 173.—Vertical Ratchet Cylinder.

This is done by means of little points which project from the under side of the teeth of the vertical ratchet cylinder. See Figure 173. During the vertical motion, the vertical detent (upper prong of double dog) holds the shaft on these points. As the shaft steps around on the first rotary step, the points swing away, leaving the vertical detent clear. The stationary dog is set high enough to hold the shaft clear.

CHAPTER XIV

HUNDRED LINE EXCHANGE

We may build out of connector switches and telephones a simple 100-line exchange. Figure 174. Suppose that we have one connector for each subscriber line. There will then be 100 connectors. The connector for any telephone, as No. 15, is represented by a line bank with wipers, and a private bank, with wipers. The mechanism and relays can be imagined for the present. The banks of all the connectors are wired in multiple. Only a few of them are shown, but the complete multiple must be understood.

For each pair of line wires, there is one "private" wire, connected to a contact in the private bank which corresponds in position to the two line contacts. When the line wipers are resting on the line contacts, the private wiper is resting on the private contact for the same line. This private wire corresponds to the sleeve wire in a manual switchboard. It makes the line busy, operates the cut off relay, and performs other functions when desired.

If telephone No. 15 is to be connected to another, such as No. 89, the subscriber lifts his receiver from the hook, and dials the figures "8" and "9." While the calling device dial is rotating back to normal, the connector is lifting its wipers to the eighth level. While the dial is returning the second time, the connector wipers are

rotating over the eighth level and stop on the ninth set of contacts, which lead to telephone No.

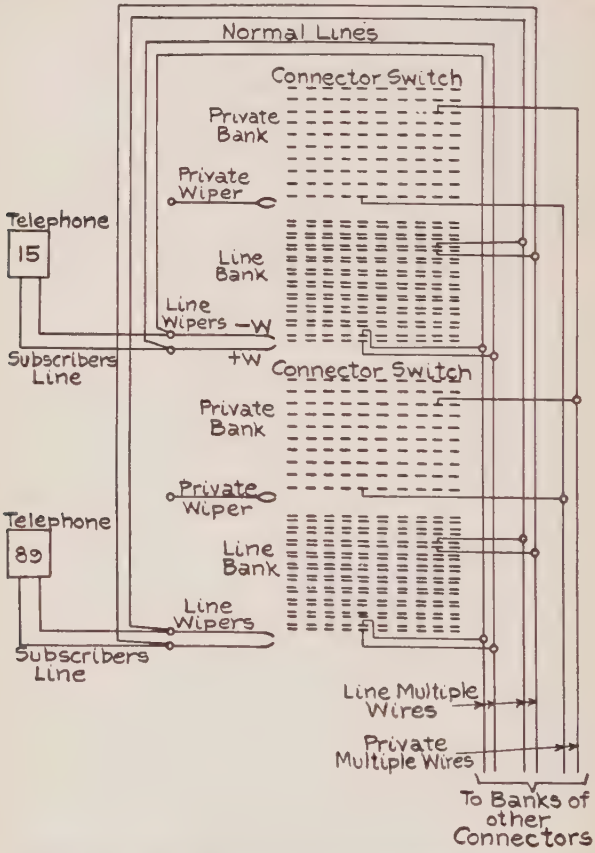


Figure 174.—One Hundred Line Exchange (Linkage).

89. At the same time, the private wiper has placed a ground on the private wire of the called line,

clearing the line of attachments and preventing another connector from seizing that same line.

Connector Switch Circuit.—The electrical circuits by means of which the switch mechanism is controlled, Figure 175, are very interesting. They are the result of many years of steady development and have been influenced by many conditions which practical operation have revealed.

The subscriber line enters at the left, marked $-L$ and $+L$. The circuit passes through two windings of a line relay *LR* to the positive and negative ends of a 48 volt battery, whose positive end is grounded. In all the automatic diagrams here shown, 48 volts and the positive grounded are understood.

Following the heavy lines we pass through two condensers and the contacts of two relays (if operated) to the line wipers, —W and +W. This is the main circuit connecting the two telephones. The line out through the line wipers leads to the called subscriber. He gets his battery current through the back bridge relay, *BBR*.

Look over the rest of the diagram, briefly, to see what it contains. The vertical magnet *VM* is the means for lifting the wipers. The rotary magnet *RM* rotates the shaft and wipers. The release magnet *Rlse*, when energized, removes the detents (double dog) and permits the shaft to rotate and drop back to normal. The off normal springs *ONS* are operated by the shaft when it moves up one step, and become again as shown when the shaft drops to normal. Those relays which have a shaded space at one end are equipped with a copper collar. This makes them a little slower to operate, and very much slower to release. For instance, the release relay *RlRy*, the series relay *Se*, and the rotary relay *RRy*, will remain ener-

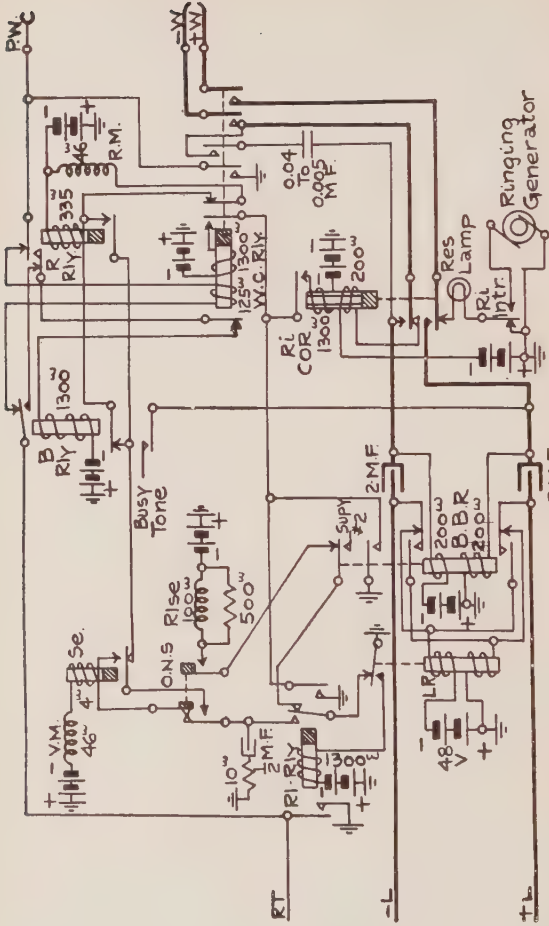


Figure 175.—Connector Circuit.

gized even when the current through them is pulsating. The wiper closing relay *WCRy*, has a copper collar to make it a little less quick to energize.

The reason for the slow action of a copper collar relay is as follows. As long as the current in the coil of a relay is constant the magnetism in the iron is constant, and there is no current in the copper. It is as if there were no collar. But if the current changes, the magnetism changes. This change of magnetism produces a current of electricity in the copper collar. Its resistance is very low, so the current is relatively large. Now, the direction of this "eddy" current is such that it tends to oppose the change which is being made. If the current is rising, and the magnetism in the iron increasing, the eddy current tends to prevent the magnetism from rising. Thus it rises more slowly. If the current is falling, and the magnetism decreasing, the eddy current tends to prevent the magnetism from falling. Thus it decreases more slowly. The more slowly the magnetism decreases, the longer it will be before the armature of the relay will move back.

The action of the connector circuit is as follows: When the subscriber takes his receiver from the hook the line relay is energized by the current flowing through the telephone. The line relay operates the release relay, which prepares a circuit from the back contact of the line relay to the series relay and the vertical magnet. When the subscriber dials the first digit of the call number, the line relay vibrates with the impulses. It repeats these impulses to the release relay and to the series relay and vertical magnet. But the release relay and the series relay remain energized, for they are slow-releasing. The vertical magnet

follows the impulses and lifts the wiper shaft. With the first step up, the off normal springs *ONS* operate. The series relay prevents the vertical magnet circuit from being broken. The release magnet can not operate because the release relay has the circuit open.

When the line relay ceases to vibrate (the impulses having come to an end) it does so in an energized position. The series relay soon falls back and switches the circuit of the line relay back contact over to the rotary magnet and rotary relay.

The second digit causes the line relay to vibrate as before, but now the impulses from its back contact pass to the rotary magnet and rotary relay in parallel. The former rotates the wiper shaft. The latter remains energized throughout the impulses. At the end of the impulses, the rotary relay falls back and permits the busy test to become effective.

While the wipers were rotating over the bank, the rotary relay was holding the busy relay *BRy* connected to the private wiper. If now the called line is busy, the busy relay will be energized by the ground on the private contact (ground is the sign of busy). When the rotary relay releases, the busy relay promptly locks itself to the ground at the release relay. The busy relay cuts off the rotary magnet and its relay and puts a busy tone on the calling line. The calling subscriber must hang up and thus release.

If the called line is free, there will be no ground on the private contact, so that the busy relay will not operate. Thus when the rotary relay falls back, it closes the circuit from ground at the release relay through the 125-ohm winding of the wiper closing relay to the private wiper, which gets negative battery connection through the cut

off relay of the called line. This energizes the wiper closing relay, which locks itself to ground through another contact on the release relay.

Ringing current is now sent to the called telephone from the ringing generator. It is interrupted by the ringing interrupter *RiIntr*. But whether ringing or not, there is a closed path through the ring cut off relay *RiCOR* and battery. The calling subscriber hears a small portion of the ringing current through the small condenser (0.04 to 0.005 MF). If the called subscriber answers in the ringing period or in the quiet period, the battery current will energize the ring cut off relay, which locks itself to the ground at the release relay, used also by the wiper closing relay.

The called subscriber is now supplied with battery current through the back bridge relay *BBR*. In pulling up, this relay reverses the polarity of current which goes to the calling telephone. This is useful in larger exchanges for operating meters.

During conversation, the telephones are supplied with current on the condenser-impedance system. The switch is prevented from releasing because the line relay and the back bridge relay are energized. If the called subscriber should hang up, the back bridge relay would fall back, but the release magnet circuit would still be open at the release relay (held operated by the line relay). If the calling subscriber alone should hang up, the release magnet circuit would yet be open at the back contact of the back bridge relay. But when both subscribers hang up their receivers, the line relay and the back bridge relay both release, the former allows the release relay to de-energize, and the release magnet circuit is closed. When the shaft has reached its normal position, the off normal springs open the release magnet circuit.

The Lineswitch.—Some exchanges have been made as above described. But the connector switch is relatively costly. Moreover, it is in use only a small part of the day, even a small part of the most busy hour of the day. Hence the lineswitch

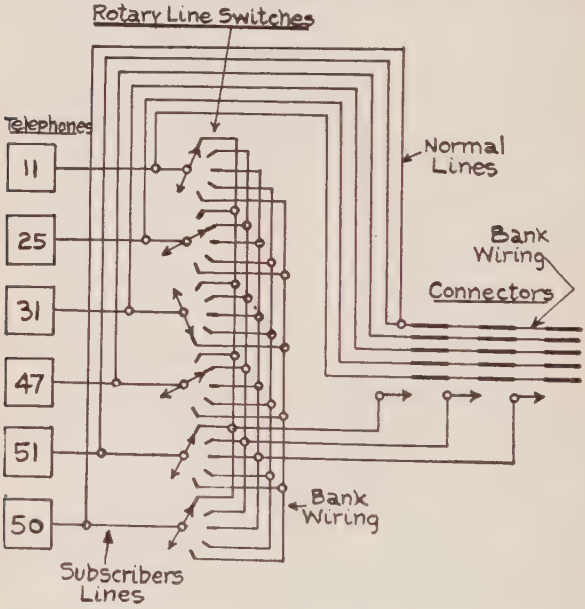


Figure 176.—Hundred Line Exchange with Rotary Lineswitches.

is used to permit many subscribers to use a few connectors. And it works out very economically and with very good service.

Suppose, Figure 176, that each subscriber is provided with a small inexpensive switch whose sole function is to connect the subscriber line, on de-

mand, to an idle connector. A very simple form of lineswitch has some wipers on a shaft, with a magnet to rotate the wipers over a bank of contacts. Ten contacts have been used, twenty-five contacts are also used. Each set of contacts leads to one connector switch. Here we represent a complete connector by one arrow for the wipers and a few heavy lines for the banks. The rest will be imagined. The banks of the connectors are wired together in multiple as described, and connected each to its proper subscriber line at the lineswitch.

When a subscriber takes his receiver from the hook, his lineswitch connects him to an idle connector. Then the subscriber dials the number and gets the connection just as if that connector belonged to him alone. When he gets through and hangs up his receiver, the lineswitch disconnects the subscriber line from the connector and another subscriber may use it. Thus we need to provide only enough connectors to care for the maximum traffic at any instant. One hundred lines often find ten connectors sufficient. Sometimes a few more are necessary.

The lineswitch is made in two forms, the rotary lineswitch and the Keith, or plunger type, lineswitch. The latter is the older and was invented by A. E. Keith, to whom are due many automatic improvements. The rotary lineswitch is now coming into larger use and will be described first. It is simpler and more easy to understand.

As mounted on shelves, rotary lineswitches look like Figure 177. The little boxes contain the relays. There are two for each lineswitch, a line relay and a cut off relay. The covers keep off the dust.

A single lineswitch with its relays is shown in

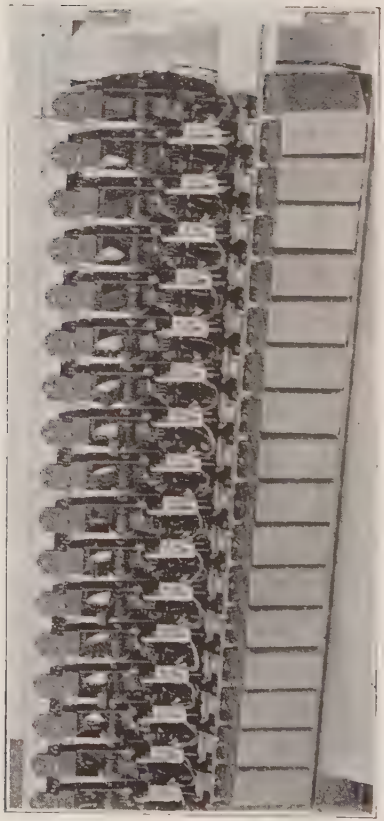


Figure 177.—Shelf of Rotary Lineswitches.

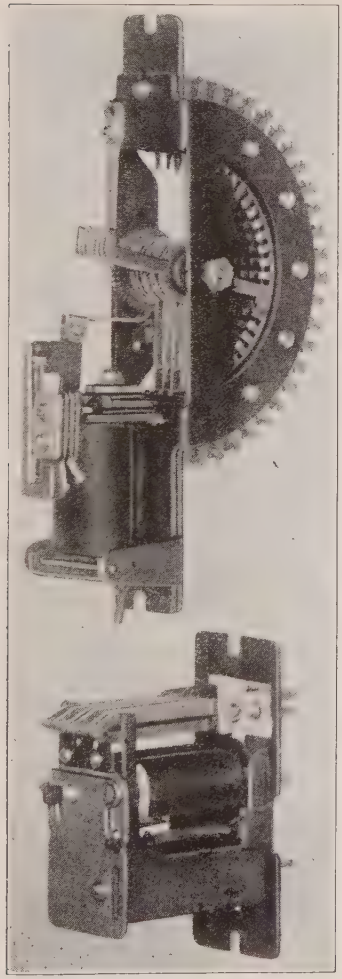


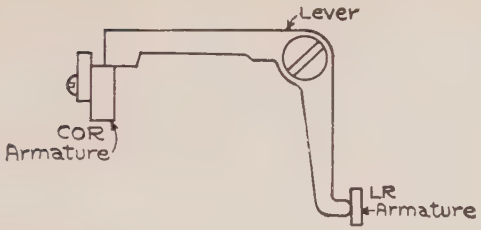
Figure 178.—Rotary Lineswitch.

Figure 178. The switch proper consists of a bank of 25 sets of contacts with a double ended wiper for each row of contacts. The connection is made to each wiper by springs which lie behind the magnet. As one end of a wiper leaves contact *No. 25*, the other end of the same wiper comes into contact *No. 1.*

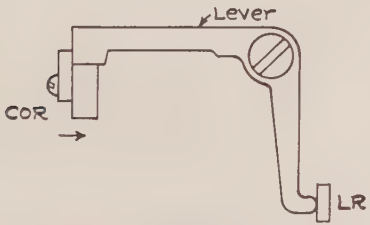
The wipers are moved by a ratchet magnet. When the magnet is energized, the pawl is drawn back and catches another tooth. When the magnet is released, the spring drives the pawl forward and rotates the wipers one step. Thus it is a spring drive mechanism. Mounted on the magnet is a pair of contact springs. These are wired in series with the magnet winding, so that the magnet is self-interrupting. It acts like a door bell. It is capable of rotating the wipers over 60 to 80 contacts per second. As usually used there is no "home" position—the wipers rest where they were during the last period of use.

The line and cut off relays are mounted together below the switch, and have an interesting interlocking device. If the cut off relay is energized first, it can move its springs only part way, just far enough to break the back contacts but not to close the front contacts. But if the line relay has been energized first, it removes the stop and permits the cut off relay (if energized) to move its springs through the full stroke.

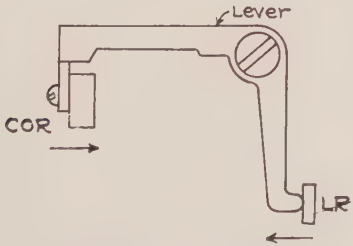
Figure 179 shows the interlocking device more clearly. The line relay coil is below in the relay assembly and has two lugs, a long one reaching up to operate its springs, and a short one which operates one end of the bell crank lever. Only the latter lug is shown in Figure 179. The cut off relay coil is above in the assembly, and also has two lugs, a longer one which operates the springs,



A-Normal



B-Cut-Off Relay Energized First.



C-Line Relay Energized First.

Figure 179.—Rotary Lineswitch Relay Interlock.

and a shorter one which engages the lever. Only the latter is shown in the figure. If the cut off relay operates first, it is stopped by the horizontal end of the lever. See *B*. But if the line relay pulls up first, its short lug moves the lever so that its horizontal end is not in the way of the cut off relay armature, and the cut off relay coil can pull the armature over as indicated at *C*.

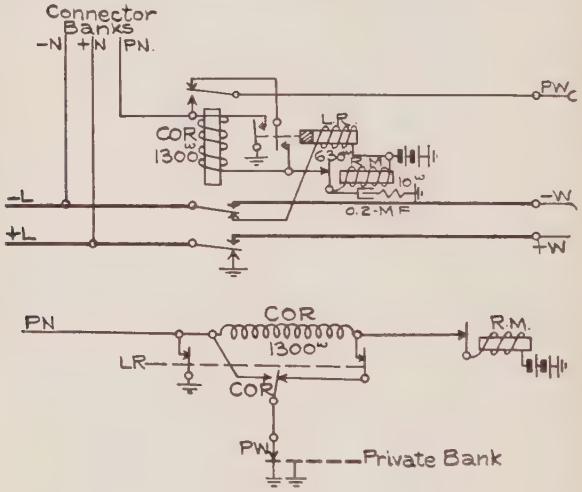


Figure 180.—Rotary Lineswitch Circuit.

The circuit of the rotary lineswitch is shown in Figure 180. The telephone is connected at the two line wires marked $-L$ and $+L$. Therefore, when the subscriber removes the receiver from the hook, battery current may flow from ground, through a back contact on the cut off relay, positive line, telephone, negative line, back contact on cut off relay, winding of line relay, to negative battery.

The line relay will energize, closing its *X* contact a little before the other contact. This produces the condition shown in the simplified diagram in the lower part of the figure. There is a circuit from ground through the cut off relay winding and the rotary magnet to battery, so that the former could pull up. The rotary magnet can not operate in series with the high resistance (1,300 ohms). But the line relay has also made a connection from a point between relay and magnet to the private wiper. If the trunk upon which the private wiper is resting is busy, there will be a ground on it. The cut off relay is short circuited. The magnet can operate and by means of its door bell action can drive the wipers to the next contact. If it also is grounded, the magnet will drive on, and continue to rotate the switch until no ground is found. Then the cut off relay pulls up and switches the private wiper to the other end of its winding, cuts off the line relay and ground, and connects the telephone line to the connector, or other switch ahead. Immediately, and before the line relay of the line switch has had time to fall back, the connector puts ground on the release trunk, so that the cut off relay will remain energized, drawing current through the rotary magnet (which can not operate because of the high resistance of the cut off relay).

At the same time that the line relay operated, it grounded the private normal wire, so that another connector can not seize this line which is calling.

During conversation, the cut off relay holds the connection. When the subscribers release, the cut off relay fails because the release trunk ground is removed, and its springs return to normal.

The 0.2 M F condenser and 10-ohm resistance prevent sparking at the rotary magnet contact.

When a call comes from a connector for this line, the connector grounds the private normal wire, as was described. This pulls up the cut off relay. But the interlocking lever stops the motion when the springs have broken their back contacts, but the front contacts are still open. Thus the line is cleared of attachments, for ringing and talking.

The reader can with profit study the complete circuit from telephone to telephone shown in Figure 181. All parts of the switches are shown in their normal conditions. The connections between the switches are indicated clearly, so that there is no doubt of any path from one to the other.

It is a very good exercise for the student of any system of apparatus to consider what is the effect of any irregularity or fault in the apparatus. It will lead him to a more perfect knowledge of the apparatus than a long study of the normal and expected action.

An example or two will suffice to show how this may be done. Suppose that there is a break in the winding of the line relay of the lineswitch of a telephone. The initial circuit being open, the subscriber can not make any call. But the line relay winding is not in the circuit when that telephone is called. It is cut off by the cut off relay. Hence the telephone whose lineswitch has this trouble can receive calls as well as ever.

Take another case. Suppose that one or both of the front contacts of the ring cut off relay (in the line circuit) fail to close. A little consideration shows that the call proceeds normally until the called subscriber answers. The ringing stops, but conversation can not take place. The subscriber would report, if he reported fully, that he could call others, that others could ring him, but that

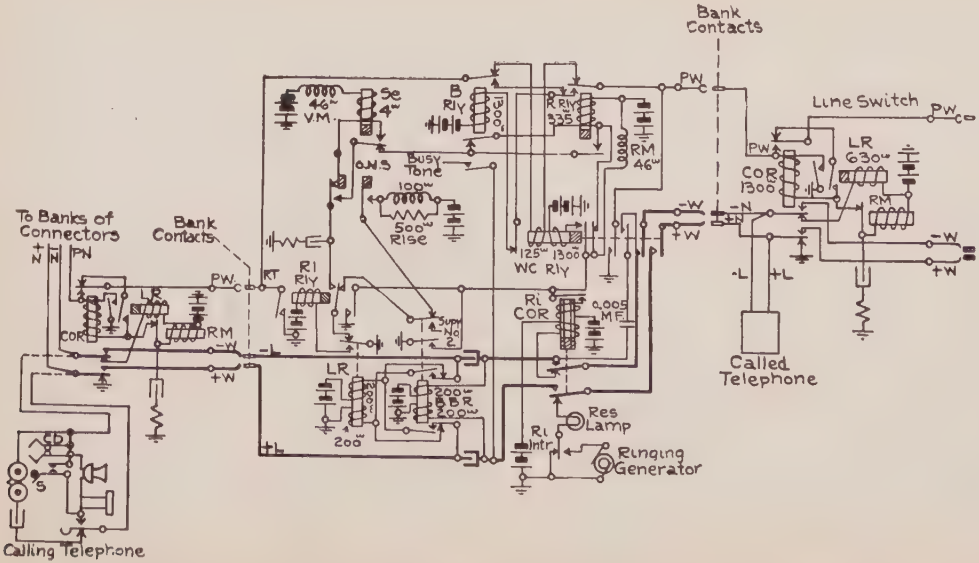


Figure 181.—Circuit from Telephone to Telephone (100 Line Exchange).

when he attempted to answer he could not hear or be heard.

If the calling subscriber hangs up first, his lineswitch will be released, but the connector will be protected from being taken by another lineswitch, until the called subscriber also hangs up. This is secured as follows. When the line relay falls back it energizes the rotary relay *RRy*. This severs the connection between the release relay

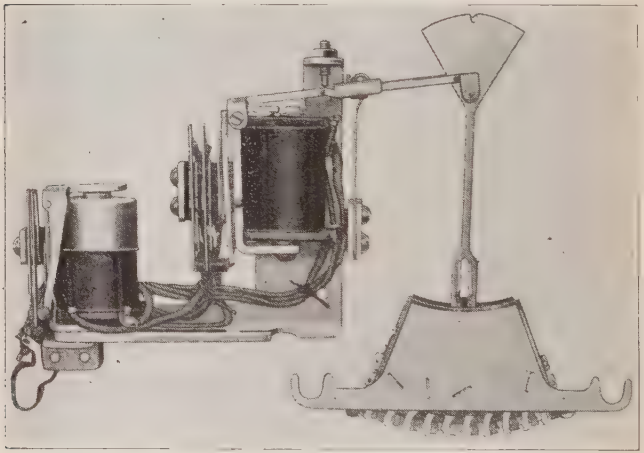


Figure 182.—Keith Lineswitch.

ground and the wiper closing relay ground. Then the release relay falls back, letting the rotary lineswitch of the calling subscriber release. A moment later, the rotary relay falls back and restores the ground on the release trunk, so that no lineswitch can seize it.

Keith Lineswitch.—The Keith, or plunger type, lineswitch is made upon a very different plan. It is a compact, unified device, and has filled a

unique place in the history of telephony. Upon it the great bulk of automatic exchanges have been built, exchanges which have served acceptably for many years and which still show no signs of wearing out.

The unit is the hundred line board, some of which we saw when we first entered an automatic exchange, Figure 164. Each such unit is made up of one hundred individual lineswitches, like Figure 182. It consists of a bank, lower right hand corner, a plunger, whose point is hidden in the bank, a plunger arm which carries the plunger, a magnet, at the center of the figure, and a line relay at the left, having a copper collar.

The frame on which these parts are mounted has a jack at the lower left hand corner, by means of which the circuits are brought into the switch

The upper end of the magnet acts on two armatures. The plunger arm is pivoted at the left, rests against a back stop above, and carries the fan-tailed plunger at the right. The cut off armature is pivoted with the plunger arm, but its end rests in a notch clearly visible in the end of the magnet pole. This cut off armature operates the spring contacts which cut the line relay and battery from the line.

The bank is made as shown in Figure 183. This is a cross sectional view from one side. The tip of the plunger is shown entering from the left. It carries two insulating rollers which may bear against the two flexible springs, *S-1* and *S-3*. When the plunger is pulled into the bank by the magnet acting through the plunger arm, these rollers press the four springs *S-1*, *S-2*, *S-3*, and *S-4* into contact with stationary metal strips. There are thus ten sets of four contacts each in one individual bank. All the ten flexible springs

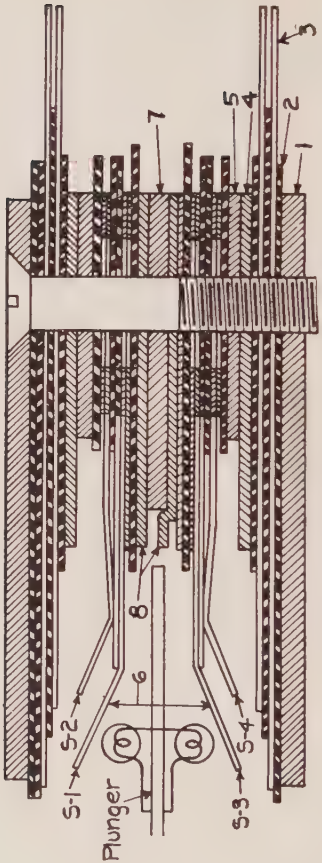


Figure 183.—Keith Lineswitch Bank.

S-1 are mechanically and electrically one unit. This is true of each of the other springs. But each stationary metal strip is separate electrically. The four "combs" as the springs are called, belong to one subscriber line. Each set of four metal strips belongs to one trunk. Thus this subscriber line may be connected to any one of ten trunks.

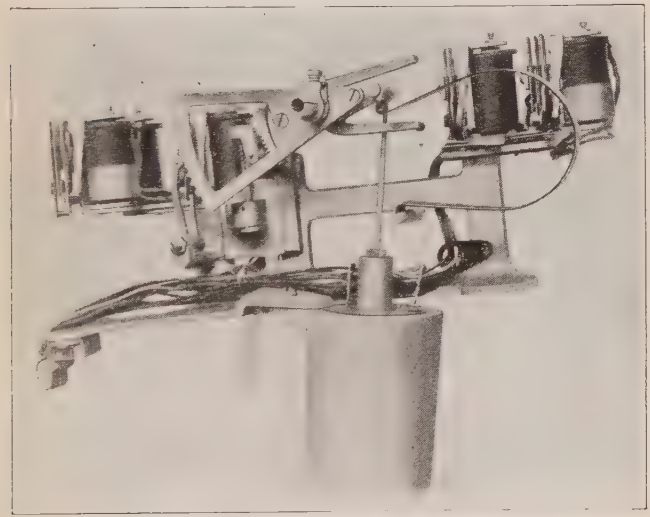


Figure 184.—Master Switch.

A number of these individual lineswitches are presided over by one master switch, Figure 184. This switch causes all the idle plungers to stand opposite an idle trunk. When any lineswitch seizes a trunk, its plunger is removed from the control of the masterswitch, and the masterswitch moves all the idle plungers to an idle trunk.

The tailpieces of the plungers are controlled by

a guide shaft which passes through the hole in the sector of the master switch, shown at the lower center of the figure. The U-shaped spring at the left tends to turn the shaft counter-clockwise. It

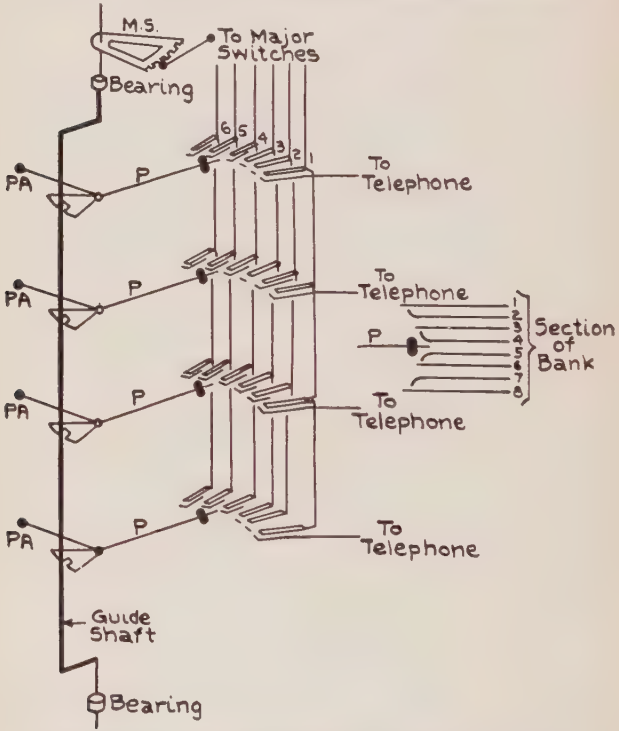


Figure 185.—Keith Lineswitch Assembly (Skeleton).

is prevented from turning by the lock magnet, whose lock lever engages notches in the edge of the sector. Under the sector is a governor which regulates the speed of the shaft. In the upper

part of the figure is the solenoid magnet, which by means of a plunger pulls the shaft back to normal when the U-shaped spring has driven the shaft as far as it is allowed to go.

The associated relays are visible at the right and at the left.

These parts of the Keith lineswitch board are assembled somewhat as indicated in Figure 185. The guide shaft is held by two bearings, and is offset between them. The masterswitch is indicated at the top *MS*. Each plunger arm *PA* carries on its end a plunger *P*. The joint is in line with the center of the guide shaft. A notch in each tail permits the plunger to partake of the motion of the shaft.

At the right the banks are indicated, only one pair of contacts for each set being shown. The trunk wires are multiplied vertically, and lead to major switches, which means any switches which handle call numbers.

The circuits of lineswitch and masterswitch are shown in Figure 186. The reader must keep in mind that there may be only one masterswitch for 100 lineswitches, although sometimes there is one masterswitch for fifty lineswitches. Extreme cases have been known in which one masterswitch for twenty-five lineswitches was considered necessary. The reason for these differing numbers is that there must be one masterswitch for each group of ten trunks. If ten trunks are enough for 100 lines, then one masterswitch per hundred is provided.

The subscriber line comes to a line relay and battery as usual. The line relay controls the pull down coil *PDC*, 45 ohms resistance. It is strong enough to operate both armatures. The bridge cut off coil *BCO*, 1,200 ohms, can operate the cut off armature *BCO* only. But if the pull down coil has

operated both armatures, the *BCO* coil can hold both from releasing.

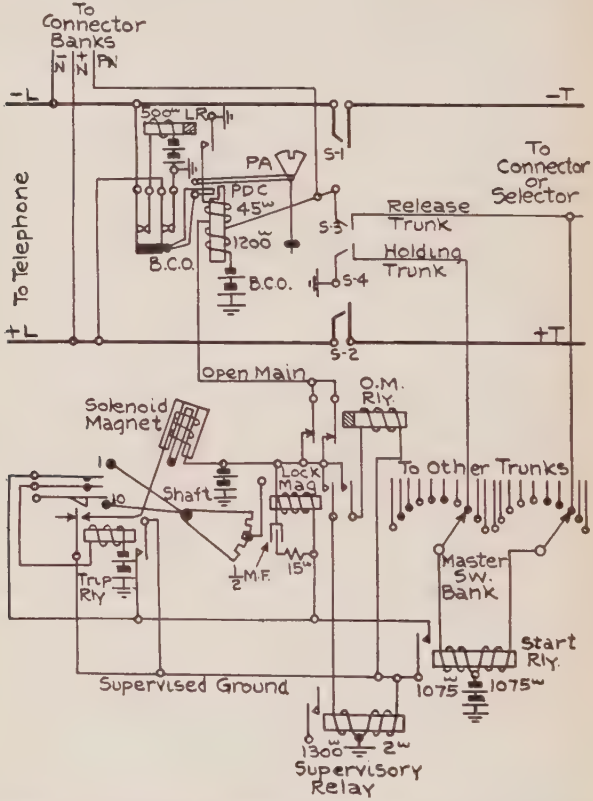


Figure 186.—Keith Lineswitch and Master Switch Circuits.

In the masterswitch the start relay directly controls the lock magnet, which in turn controls the escapement (sector). On the shaft are two fingers

marked *1* and *10*. The former presses together two springs when the shaft is opposite trunk *No. 1*. The latter unlatches the trip relay when the shaft is opposite trunk *No. 10*. The natural selection of trunks is from *10* backwards to *1*.

When a subscriber removes his receiver from the hook, the line relay pulls up and energizes the pull down coil. This pulls the plunger into the bank and extends the subscriber line to the connector or other switch ahead. At the same time it cuts off the line relay and ground, but the line relay, having a copper collar, holds on for an appreciable time, until it is no longer needed.

The connector, because the telephone is drawing current from its line relay, operates its release relay and grounds the release trunk. This causes current to flow through the *BCO* coil of the line-switch, thereby holding the plunger in the bank. Now the line relay may fall back.

The action of the plunger clears itself from the shaft and starts the masterswitch to hunt an idle trunk. The bank spring *S-4* energizes the start relay of the masterswitch, although the grounding of the release trunk by the connector does the same thing by another coil on the start relay. The start relay energizes the lock magnet, which lets the escapement open and the shaft rotate. When the shaft moves, it moves the wipers on the masterswitch bank. When they reach an idle trunk they find no ground. The start relay falls back, the lock magnet does likewise, and the shaft stops with the idle plungers pointing to an idle trunk.

When the shaft reaches trunk *No. 1*, finger *No. 1* closes the springs mentioned above. If now another call comes in, the start relay will energize the trip relay as well as the lock magnet. The former is latched with its contacts closed. This

gives battery current to the solenoid magnet, so that the latter pulls the shaft back to trunk *No. 10*. The trip relay also holds the lock magnet energized. The start relay may energize or not, depending upon the condition of the trunks over which the master wipers pass.

When the shaft arrives at trunk *No. 10*, finger *10* trips the armature of the trip relay loose, opening the circuits of the solenoid magnet and the lock magnet. Further action depends on the condition of the trunks.

During the hunting of an idle trunk, the open main wire is broken by the open main relay *OMRly*, so that no subscriber can plunge in his plunger until it is certain that an idle trunk is found.

In the masterswitch there is a supervisory relay. All the ground connections are carried through a two-ohm winding on this relay. Every time the switch operates, this relay pulls up. Its contact starts a time limit device which will sound an alarm if the action continues too long. There is also a 1,300-ohm winding on the supervisory relay which is active if for any reason the escapement sticks between two notches. Both these precautions are necessary, because the masterswitch is common to many lines, and if it gets into trouble it puts all those lines out of service until it is repaired.

When a call comes from a connector for this line, the connector grounds the private normal as was described before. This operates the *BCO* coil alone. It is able to operate only the cut off springs, clearing the line for ringing and talking. It is an action similar to that of the interlocking relays of the rotary lineswitch.

Release of the Keith lineswitch is accomplished by the mere removal of ground from the release

trunk. This lets the *BCO* coil de-energize, so that the armatures fly back to normal.

If the calling subscriber hangs up first, we have

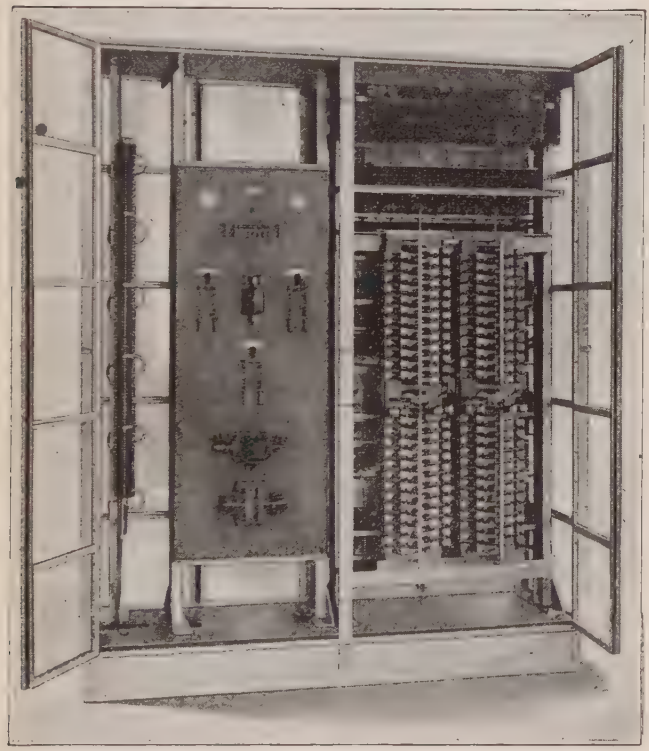


Figure 187.—Hundred Line Board (Keith Lineswitches).

seen that his lineswitch is released, but that the connector is held and protected. In the case of the Keith lineswitch, this means that the holding trunk ground is removed. But the release trunk

has been re-grounded by the connector switch, so that the trunk will test busy to the masterswitch.

Complete 100-line Switchboard.—Figure 187 shows the appearance of a typical hundred-line switchboard with Keith lineswitches. There is a little main distributing frame at the left, where the subscriber lines enter. There is a simple power panel, on which are mounted switches, meters, fuses, and the ringing current generator. In the space to the right are the lineswitches. This board has two masterswitches, visible at the middle of each vertical "shelf." Just above the lineswitches is an assembly of terminals. At the top is a little fuse panel with a few relays and lamps used for control purposes. The connectors are mounted on the back of this upright frame.

A hundred-line unit with rotary lineswitches is shown in Figure 188. There is the same *M D F* at the left, also a power panel. Each of the two upright frames at the right can hold fifty rotary lineswitches. Only eighty are equipped on this board. The same terminal assembly and fuse panel may be seen above.

Switchboards like these are often used for very small communities. They are also very largely used for business houses, to bind the business together with a 24-hour telephone service. They are then called "private automatic exchanges" abbreviated *P.A.X.* When used in small towns or rural regions, they are called "community automatic exchanges," abbreviated *C.A.X.* The design of the two differ very slightly, except in special cases.

The Finder Switch.—Another kind of non-numerical switch has been used to a small extent. It is the finder switch. Imagine a lineswitch, whose wipers are connected to a trunk and thence to a major switch, a connector or something similar.

Its bank is connected to subscriber lines. When a subscriber calls, the finder rotates its wipers and connects the calling subscriber to the trunk. There will be one finder for each trunk. Their banks are multipled together. Some means is provided for

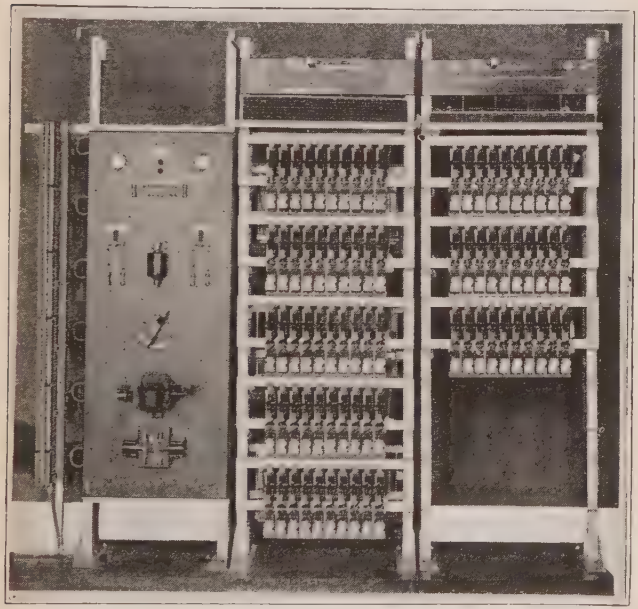


Figure 188.—Hundred Line Board (Rotary Lineswitches).

deciding which finder shall act when a call comes in. This may be another switch, called a distributor, or the extended starter wire may serve.

Up to date the finder switch seems not to have proven in as to cost. And there is a little more time delay than with lineswitches.

CHAPTER XV

THE AUTOMATIC TELEPHONE INSTRUMENT

The automatic telephone is essentially like any other telephone except that it has provisions for

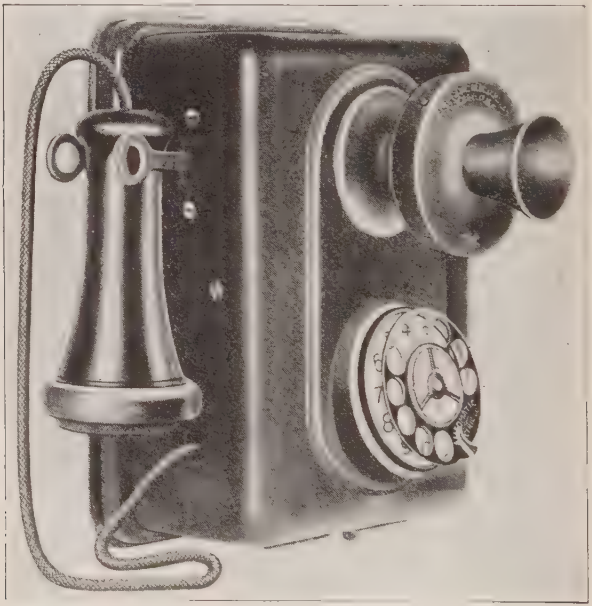


Figure 189.—Automatic Wall Telephone.

controlling automatic switches. Externally one will notice first of all the presence of a calling device of the dial type. Figure 189. On the wall tele-

phone the calling device is mounted under the transmitter, although sometimes it is placed above the transmitter. The reason assigned for the former location is that because the mouth of the user is approximately on a level with the transmitter, and the hand is below the mouth, it is easier to operate the dial if one does not have to reach around or past the transmitter to do it.

The opened wall telephone, Figure 190 reveals

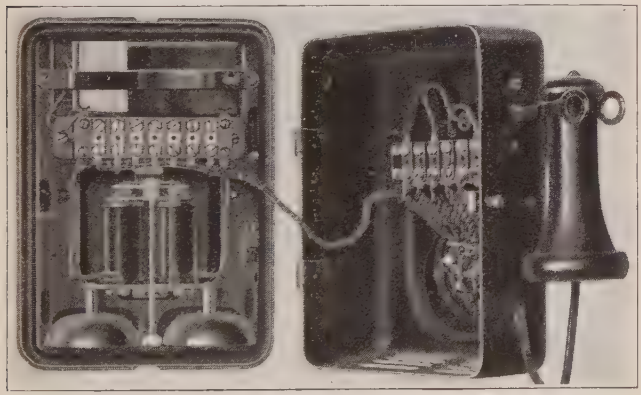


Figure 190.—Automatic Wall Telephone (Open).

the usual bell, condenser or condensers, a terminal strip, with the induction coil under it, all mounted on the steel back of the box. A cable of three wires connects the back to the hinged front, which carries within it the hookswitch, a terminal strip, and the calling device. This is the arrangement of the latest model produced by the Automatic Electric Company. Other makes comprise the same apparatus, with slightly different arrangements, but essentially the same organization.

The hinges of the box permit the cover or front to be removed from the back, as shown. A little catch just above the lower hinge locks them together normally.

In this set, the back of the box is used for the bell box of the desk set, without any change. The



Figure 191.—Automatic Desk Stand.

three conductor cord of the desk stand replaces the three wires shown in this illustration.

The latest desk stand, Figure 191, has the post set back of the center of the round base. When the first of these appeared, brought out by the Western Electric Company, they looked odd, and

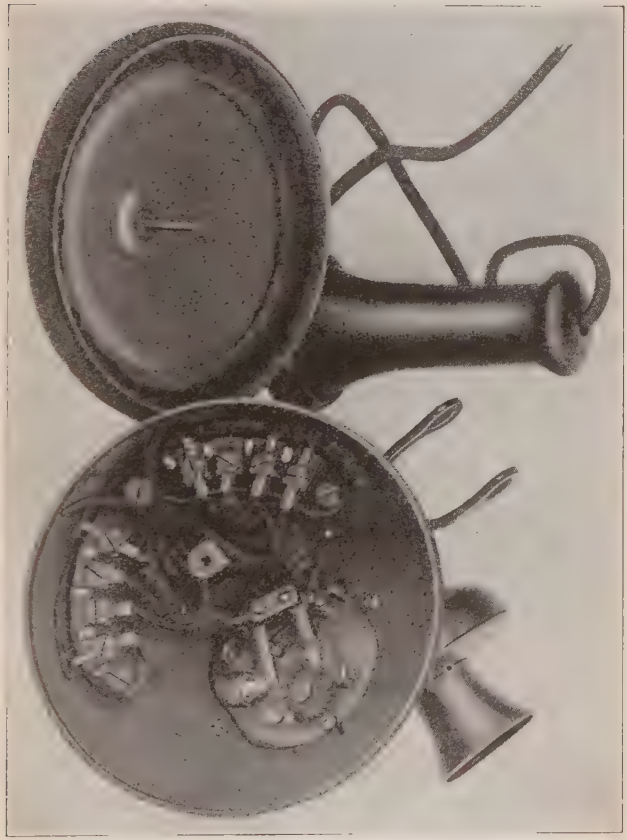


Figure 192.—Automatic Desk Stand (Base Open).

to some people made a bad impression. But this setting back of the post is a good thing, for it permits the calling device to be mounted at a better angle—more easily seen by the user. The hookswitch is in the upright tube, a position well adapted to rigidity and certainty of action, but not very accessible. However, when properly made and adjusted, the hookswitch operates for long

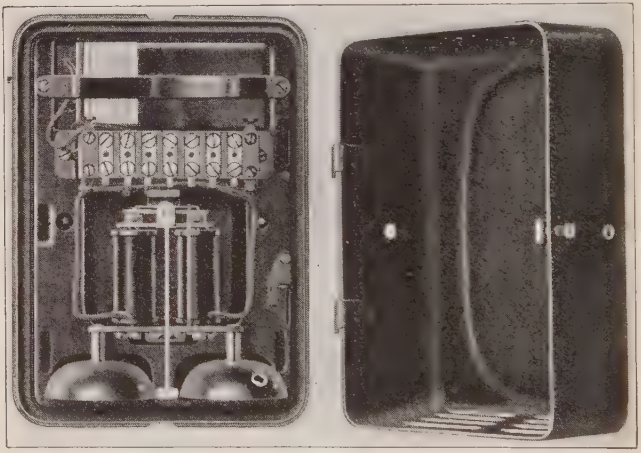


Figure 193.—Automatic Bell Box.

periods of time without attention. The inside of the base, Figure 192, has plenty of room for terminals and for the back of the calling device. Inspection of the latter can be made without removing it from the base. The felt covering of the base plate is held on by a ring, pressed inside of the flange.

The bell box for this desk set, Figure 193, is the same as the box of the wall telephone, except that

there is nothing mounted on the cover. The stand cord enters through the hole in the hinged side of the cover.

The Dial Type Calling Device.—The dial type calling device, Figure 194, consists of a plate upon which are mounted the various parts which send impulses to the central office. The object of the device is to interrupt the line circuit a number of times, depending upon the digit called. It must interrupt it three times for the digit 3, five times for the digit 5, and so on. It must also short circuit the talking apparatus in the telephone during

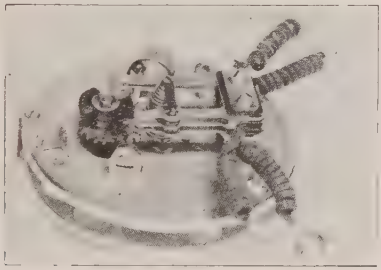


Figure 194.—Calling Device (Dial Type).

the time that impulses are being sent, so that the impulses may rise and fall in a circuit of fixed resistance, and so that the user may not be unduly annoyed by noise in the receiver. The transmitter at least must be shunted; some telephones shunt the receiver also, some merely open the receiver circuit.

The finger dial, containing ten holes, is mounted on a shaft which passes through the mounting plate, and which carries on its back end a coiled spring which may be seen in Figure 194. The end of the spring is bent over and provided with

an insulator. This operates the shunt springs. Inside the device is a large gear wheel, driven through a ratchet by the finger wheel (or its spring). This large gear drives a small gear on a second shaft, which carries on its back end the double fan shaped insulating cam and the spur gear visible just below it. Near the cam are the ends of the impulse springs, which normally make contact with each other.

The spur gear drives a governor by means of a worm on the governor shaft. This drive gives the governor a high speed, at which two balls fly out and rub on the inside of a cup, and thereby limit the speed of the device. The normal speed averages ten per second, though it may vary from nine to eleven with safety. The automatic switches are adjusted to operate perfectly at fourteen impulses per second under more severe conditions than are met in practice. The dial may be forced by the hand to a speed about fifty per cent above normal. Some makes can be forced to nearly double the normal speed. But in any case, the subscriber must not force or retard the dial, because it may spoil the call. It is as essential to let the dial alone during its return as it is for the user of a manual telephone to speak the call number distinctly.

When the dial is turned from normal, the shunt springs act while the ratchet clicks backward over the large gear. When the subscriber removes his finger and lets the dial go, the spring drives the main shaft toward normal, rotating the second shaft and with it the impulse cam and the governor. The ends of the cam pass between the ends of the impulse springs and separate them twice per revolution. The actual break occurs at contacts made of noble metal, not at the tips. When the dial

shaft gets back to normal, the shunt springs return to normal also.

AUTOMATIC TELEPHONE CIRCUITS

There are a number of circuits in use in automatic telephones of which the most typical will be discussed. For the sake of clearness we show only simplified diagrams. From these the reader can learn the principles, and can readily read the wiring diagram of any of them, for he will know what to expect.

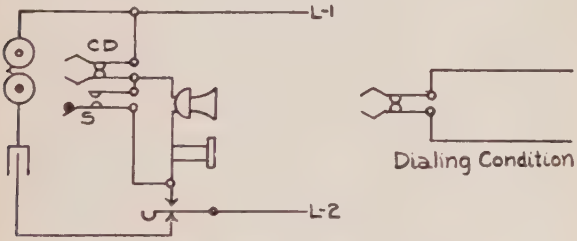


Figure 195.—Series Automatic Telephone.

Series Telephone.—The series telephone, Figure 195, resulted from a revival of the non-polar receiver of Dr. Alexander Graham Bell. It has been greatly improved, so that it is a serious competitor of the polar receiver. The transmitter and receiver are in a simple series circuit. The receiver gets all the incoming undulations and is in the very best possible position to work. There is nothing to shunt any current away from it or to weaken its energy. But the transmitter operates simply as a rheostat, with no help from induction coils. The sending of speech is weaker than if a properly designed and connected coil is used.

The impulse springs of the calling device are

shown at *CD*. The shunt springs are at *S*. The black circle at their left is the cam which operates the shunt springs when the dial is away from normal.

Booster Telephone with Non-Polar Receiver.— This circuit, Figure 196, uses the same receiver as the series telephone, but gives the transmitter the support of an induction coil. The winding marked *1-2* is wound on the core first, with the *3-4* winding on top. While speaking, the *1-2* winding may be regarded as the primary. It is in shunt (with the condenser) around the transmitter. Undula-

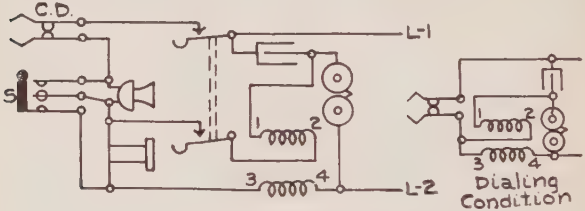


Figure 196.—Automatic Telephone (Booster Circuit, with Non-polar Receiver).

tions of resistance in the transmitter produce undulations in the line current and of voltage across the transmitter. These drive an alternating current through the shunt circuit containing the condenser and the primary of the induction coil. This induces an alternating voltage in the *3-4* winding, which, being in the main line, assists the undulations of the line current which are being produced by the direct rheostatic action of the transmitter.

In this circuit, there are three shunt springs, so as to shunt the transmitter and receiver separately. The hookswitch has two contacts, one in

the line and the other in the local or primary circuit.

Booster Telephone, with Polar Receiver (*A. E. Co.*).—This circuit, Figure 197, is the same as that described above, except that the receiver is polarized (the permanent magnet type) and placed in the local circuit in parallel with the transmitter. While in the talking condition, hookswitch up, it is identical with the common battery telephone circuit which has been used for years by the Western Electric Company. The "boosting" effect of the

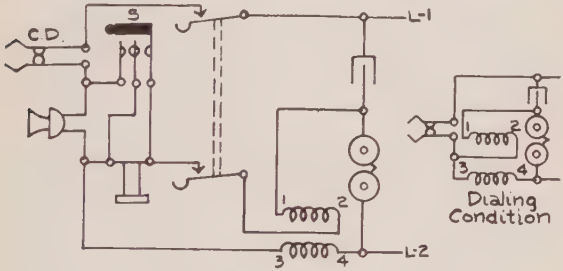


Figure 197.—Automatic Telephone (Booster Circuit, with Polar Receiver).

induction coil while sending speech is very appreciable. The receiver, being in the primary circuit, gets the full effect of the current which is oscillating through transmitter, condenser, and the *1-2* winding of the induction coil, so that it has a heavy side tone. While receiving speech, the receiver gets its current partly by transformation through the induction coil and partly by shunting around the transmitter.

The dialing condition is shown in the small sketch at the right. The impulse springs are shunted by the condenser and the *1-2* winding of

the induction coil, while the *3-4* winding is in the line. The bell has such high resistance and reactance that it seems not to be a factor. Contrary to expectations, this dialing condition does not harm the impulses. In some cases there is a slight improvement over the condition in the series telephone, Figure 195. But the difference is slight.

Booster Telephone with Polar Receiver (W. E. Co.).—The Western Electric automatic telephone circuit, Figure 198, differs from that just described

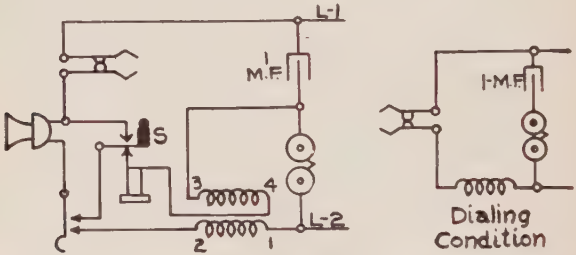


Figure 198.—Automatic Telephone, Western Electric Circuit.

in the hookswitch and the shunt springs on the calling device. The former is their time-honored arrangement. The shunt springs are three. The main spring is connected to one of the hookswitch contacts, and is in the receiver circuit. When the dial moves from normal, the mainspring opens the receiver circuit and shunts the transmitter. The dialing condition is shown at the right. The condenser has been reduced from 2 M.F. to 1 M.F. The larger the condenser the worse the effect on impulses. But the arrangement shown with the 1 M.F. condenser dials very well.

CHAPTER XVI

THE THOUSAND-LINE EXCHANGE

The thousand line exchange is made up of ten hundred line units. How this is done may be illustrated by Figure 199. Only three 100-line units are shown, but the principle holds true for any number up to ten.

Consider the first hundred. The rectangle with five arrows represents a Keith lineswitchboard, with the subscriber lines coming in from the right. The ten connectors are indicated above, with their banks multipled together and connected to the subscriber lines at the lineswitches.

In this exchange we introduce a new switch, called the "selector." It is structurally very much like a connector. Its duty is to interpret the desire of the calling subscriber as to the group or 100-line unit in which the called number appears. It also selects an idle trunk to an idle connector. The trunks from the lineswitch banks run to the wipers or jacks of these selectors. There are ten of them, though but three are drawn.

The other hundred line units each have their selectors. The banks of all the selectors are multipled together, by levels. The ten trunks from level *1* are wired to level *1* of all the selectors, level *2* to level *2*, etc.

The ten trunks of level *1* are carried to the ten connectors of the first 100-line board. The ten trunks of the second level run to the connectors of

the second hundred board. This is continued to all the levels and boards.

Suppose that subscriber 125 calls No. 328. When

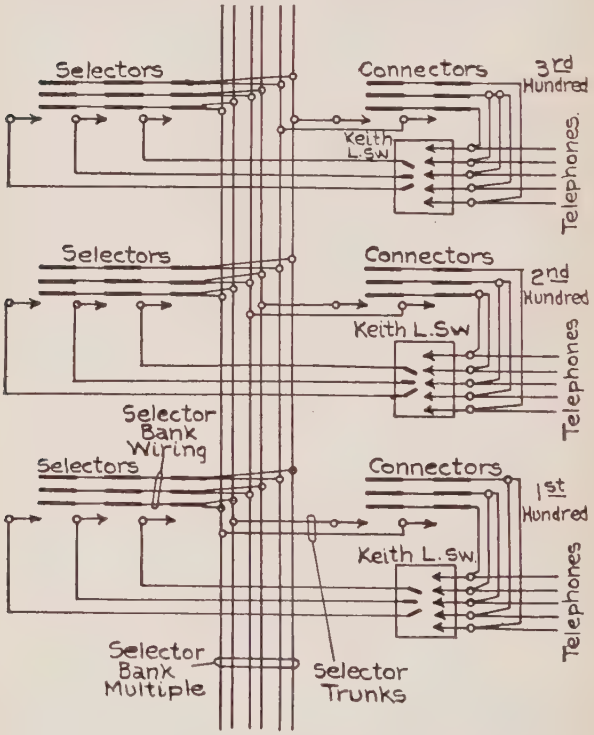


Figure 199.—Thousand Line Exchange, Keith Lineswitches, Link Diagram.

he removes the receiver from the hook, his line-switch will connect him to an idle selector. First he dials "3". This causes the selector to lift its wipers to the third level. Then it automatically

rotates the wipers to find an idle trunk, leading to an idle connector in the third board. Then the calling subscriber dials the digit "2," which causes the connector to lift its wipers to the second level. Lastly, the subscriber dials "8," which causes the connector to rotate its wipers to the eighth set of contacts in that level, which leads to telephone No. 328. The connector now tests the line to see if it is busy. If it is free, it rings the called telephone, and performs as described above.

The appearance of the selector switch, Figure 200, is very much like that of the connector. It has not as many relays. There is a pair of interrupter springs operated by the rotary magnet, visible to the left of the rotary ratchet cylinder or "hub." There is also a set of springs to the right of the shaft, opposite the interrupter springs. They are called the cam springs, or *11-R*, because they operate when the wipers have rotated off the bank on any level.

But as to structure of wipers, bank, and ratchet actions, the selector and the connector are identical.

Selector Switch Circuit.—The electrical diagram of the selector switch is shown in Figure 201. It has the same combination of line relay *LR* and release relay *RlRy* that we found in the connector. It is a useful device. It permits the line relay to respond to impulses while it holds a ground on the release trunk, which we have found necessary to hold the lineswitch from releasing. It also prepares a circuit for controlling the vertical magnet and the release magnet.

In this circuit, the rotary magnet has a rotary interrupter relay *RIR* associated with it, to give it the automatic vibration. Former selectors were used in which the rotary magnet interrupted its circuit like a door bell, and like the rotary line-

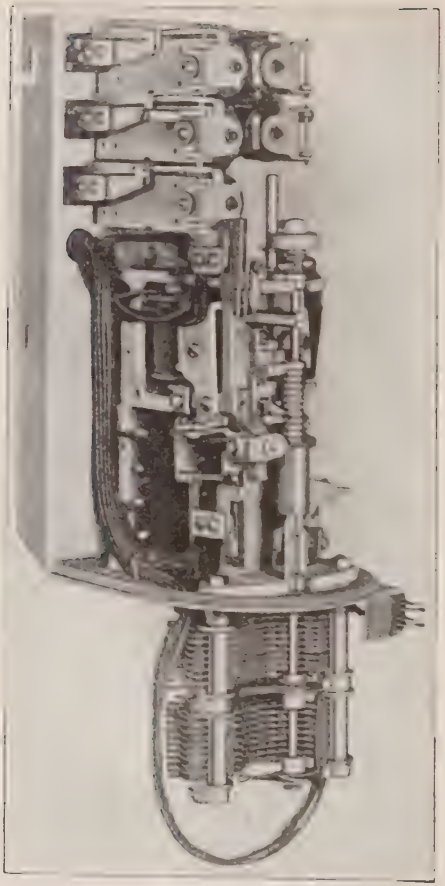


Figure 200.--Selector Switch.

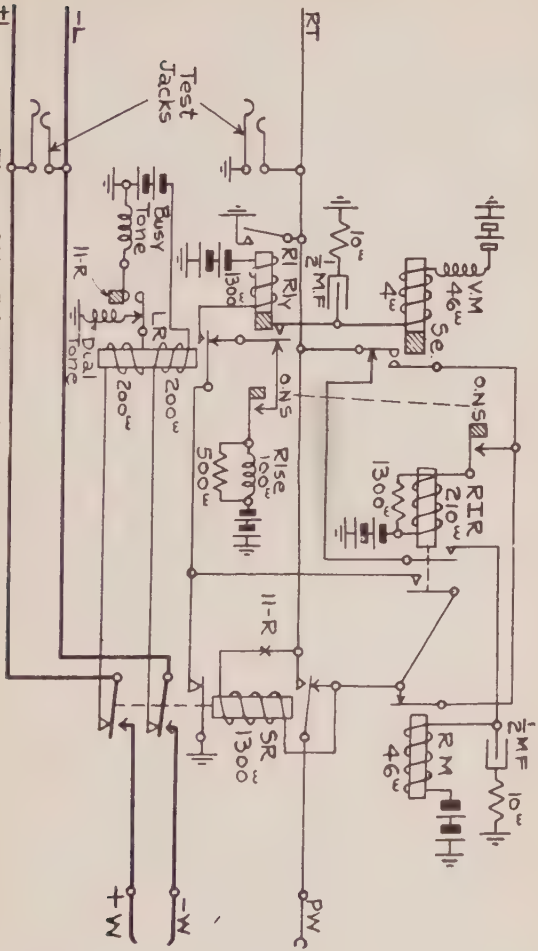


Figure 201.—Selector Switch Circuit.

switch. But although they rotated at a higher speed than the present switch they were much harder to adjust, and were not as certain in action.

Consider the action of this selector. Suppose that the subscriber has removed the receiver, and has thereby been connected by his lineswitch to this idle selector. Immediately the line relay of the selector pulls up and energizes the release relay. The latter grounds the release trunk, so that the lineswitch will be held in connection. The release relay also opens the release magnet circuit, and prepares the circuit to the vertical magnet *VM*.

When the subscriber dials the first or "hundreds" digit of the call number, the line relay vibrates as many times as there are units in the digit. The release relay, being slow-releasing, remains energized. The impulses from the back contact of the line relay pass to the series relay *Sc* and the vertical magnet. The series relay pulls up and remains up. The vertical magnet vibrates with the line relay, stepping the wiper shaft up. At the first step up, the off normal springs *ONS* operate. One pair closes part of the release magnet circuit, but it is open at the release relay. The other part of the *ONS* closes the rotary interrupter relay to the series relay contact. Since the latter is energized, the interrupter relay pulls up and locks itself to the ground at the switching relay *SR* contact. (The same ground as used by the line relay.)

When the line relay comes to rest, it is energized. After a moment, the series relay falls back, switching the release trunk ground from the interrupter relay to the rotary magnet (through the interrupter relay contact).

Now begins the trunk hunting. The rotary magnet pulls up and rotates the wipers onto the first set of contacts. Assume that the trunk is busy, and

that therefore there is ground on the private contact. The pulling up of the rotary magnet also opens the interrupter relay circuit, so that it falls back. This cuts off the rotary magnet, so that it falls back, reclosing the interrupter relay circuit. But now the interrupter relay must depend on the private wiper, because its connection to the ground at the switching relay *SR* has been lost. This now is the busy test for the trunk. If the trunk is idle, no ground on the private contact, the interrupter relay can not pull up, and rotation will stop.

We assumed that the first trunk at least is busy. Hence the interrupter relay will pull up the second time. It will again energize the rotary magnet and cause it to move the wipers to the second trunk. Thus the interrupter relay and the rotary magnet will continue to interrupt each other's circuits, rotating the wipers until the private wiper finds no ground, and the interrupter relay stops.

During the rotation, the switching relay has had ground at both ends of its winding. But when the private wiper fails to find ground, there is a path for current through it, getting ground at the release relay (release trunk ground) and negative battery through the interrupter relay. The latter will not energize through the 1,300 ohms of the former, but the switching relay will operate and switch the lines from the line relay to the connector. It also connects the release trunk straight through to the connector.

The telephone now draws current from the line relay of the connector, which operates its release relay and grounds the release trunk. This happens before the release relay of the selector has had time to fall back. Now we have three wires straight through the selector. The line wires are clear of

all attachments. The release trunk has the switching relay hanging on it to hold the switch from releasing.

Here we notice four springs called the "test jacks." They are to be found on all selectors, connectors, and on most lineswitches. They are very useful in exchange operation. At the line test jacks, the switch man can connect a hand test telephone and operate the switch with a calling device, to see if it is in working order. If the switch is out of order, he can put it out of service by inserting a piece of metal in the release trunk test jack. This grounds the release trunk and makes it busy to the lineswitches.

The line relay gets its ground connection through the cam springs marked *11-R*. Normally the current comes through a common induction coil supplied with a tone called the "dial tone." To hear this is a sign that the selector is connected to the subscriber line and ready to receive calls. The line switch has no dial tone. If the ten trunks on the level being tested (for an idle trunk) are all busy, the selector will rotate off the bank. Then the cam springs *11-R* switch the dial tone off the line relay and put in place the busy tone, to induce the subscriber to release. It also opens the switching relay circuit, to prevent that relay from cutting off the line relay, with the tone which it has.

The manner in which the trunks on the banks of the selectors are protected is illustrated by Figure 202. Each selector is represented by one level, and as if that level had only five contacts. Switch No. *2* is shown as occupying trunk No. *1*, while switch No. *5* occupies trunk No. *2*. The release trunk of each is grounded in the connector to which the trunk leads. The private wiper of any selector which is hunting an idle trunk will carry test ap-

paratus which must find ground in order to continue rotation. Thus it will run past trunks *1* and *2* and stop on trunk *3*.

Complete Circuit Between Telephones.—To facilitate the study of the circuits, Figure 203 has been prepared, giving the telephones, lineswitches, selector and connector all in normal condition, but so related that the reader can most easily follow the actions through to the completed connection.

Normally each telephone is open to direct current, but permits the passage of alternating current for ringing the bell. The rising of the hook lever

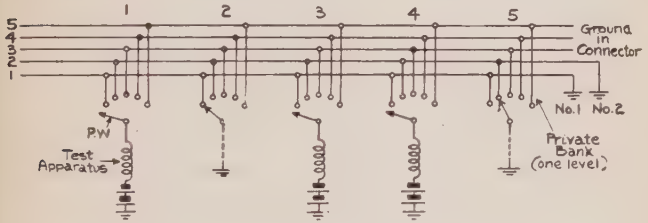


Figure 202.—Protection of Trunks at Selector Banks.

switches the line from the bell to the talking circuit, which is closed to direct current, and pulls up the line relay of the lineswitch. This is also the path which holds the connection of each switch in succession, as the connection is built up.

Normally each lineswitch holds its telephone line ready for calls to come from any connector. The three wires from the connector banks to the lineswitch are called "normal lines."

Notice that, as the connection is built up, the two line wires $-L$ and $+L$, are cleared of attachments, until the connector is reached. Here are located the two relays (line relay and back bridge

relay) which feed battery current to the telephones. The line relay also is the means for holding the entire connection, preventing any of the switches from releasing. The calling subscriber controls the connection. But the called subscriber shares in the control of the connector.

The completed connection consists of three wires, carried through from calling lineswitch to connector. The release trunk *RT* has one relay on it in each switch, and by this one relay that switch is prevented from releasing. It is the cut off relay *COR* in the lineswitch, the switching relay *SR* in the selector, and the release relay *RlRy* in the connector. In a certain sense the release trunk is carried through even to the lineswitch of the called line, passing through the 125-ohm winding of the wiper closing relay *WCRy* in the connector. But there are two dead grounds on it in the connector, one on each side of the winding mentioned.

One fundamental condition in the design of automatic switches is that the opening of most circuits shall cause the switch to release. If the release trunk opens, the connection releases. The same happens if either line wire breaks.

It is also a principle that if any switch is at rest, and it is artificially disturbed, it will return to normal when the disturbance ceases. For instance, if you stand in front of any switch and at random press the armature of any relay or magnet, it may cause something in the switch to act, but when you remove your finger, the switch will go back to normal and be ready for service. The switches can not be put out of order or "stuck" in this way.

Trunk Slip.—When a large number of selectors have access to ten connectors, trunk slip is used to shorten the time required to find a nidle trunk and

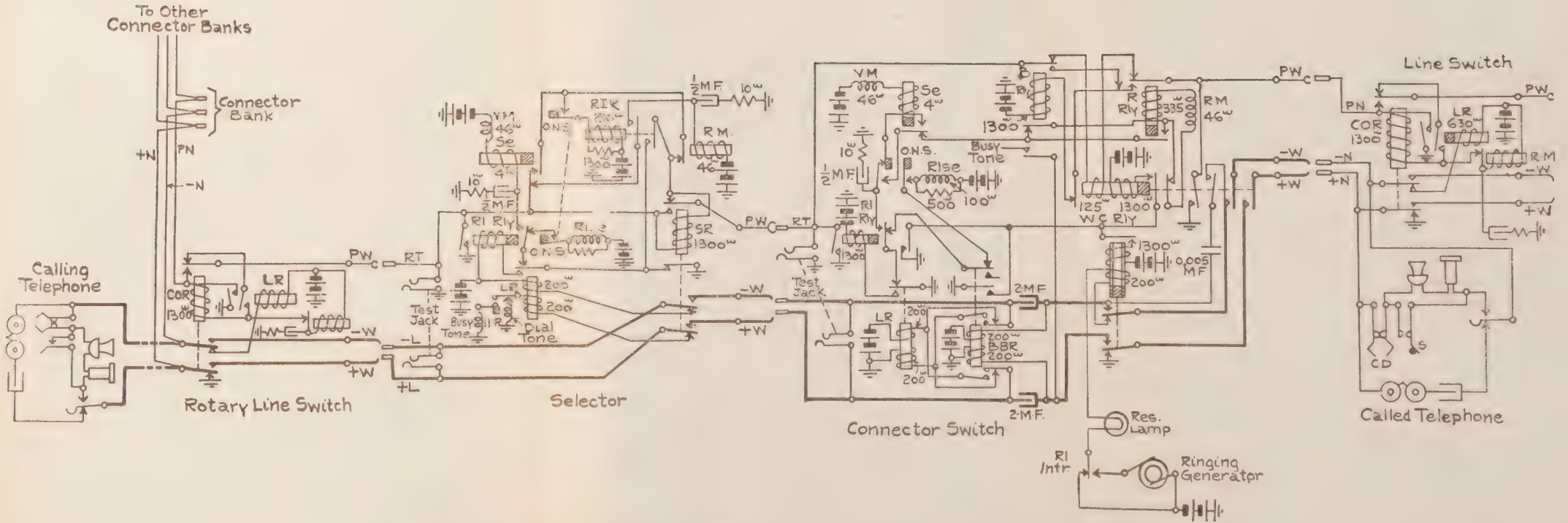


Figure 203.—Circuit from Telephone Through Rotary Lineswitch, Selector, and Connector to Telephone.



Figure 204.—Trunk Slip.

to distribute the traffic over all the connectors. Activity is good for automatic switches. They are more easily kept in order.

Figure 204 shows how the trunks are arranged. At the top of the illustration are five switches represented by one level each. The switches are numbered from left to right. There are usually ten or more of them.

The trunks do not occupy corresponding positions on all the switch banks. Trunk *1* has contact *1* on switch No. *1*, but it is on contact *10* of switch No. *2*, contact *9* on switch *3*, contact *8* on switch *4*, etc. All the other trunks drop back one contact as they are carried from bank to bank. It is called "retrograde" slip.

When a selector hunts for an idle trunk, it tests contact *1* first, contact *2* next, etc., and will stop on the very first idle contact. If the banks were multipled "straight" or "point-for-point," the trunk No. *1* leading to connector No. *1* would be busy all the time, while connector *10* would be idle most or all of the time. But by trunk slip, each switch has a different "first choice" and the traffic is distributed. Also, each selector does not need to rotate as far to find an idle trunk.

A compact symbol showing how ten switches trunk to ten trunks is shown in the lower part of the figure. Switch *1* has trunk *1* for first choice, switch *2* has trunk *2* for its first choice, and so on to the tenth switch and the tenth trunk.

But a 1,000-line exchange will have about 100 selectors. These are grouped by tens. Ten of them are wired as if they were No. *1* switches, ten more as if they were No. *2* switches, etc. Thus the whole traffic is distributed.

CHAPTER XVII

TEN THOUSAND-LINE EXCHANGE

In the same way that we built a thousand-line exchange by putting together ten 100-line boards, we can build up a 10,000-line exchange by putting together ten 1,000-line groups. See Figure 205. Let each rectangle represent a 100-line unit. The ten boards in the bottom row represent the first thousand. In an actual installation, there is an aisle between the fifth and sixth boards just as shown, to shorten the distance traveled by switchmen in caring for the apparatus.

In calling for any telephone line, we choose successively the thousand group, the hundred group, then secure the called line by means of a connector switch located in the 100-line board chosen. To call line No. 5475, we choose the fifth thousand, then the fourth board in that thousand, which is known as the 5400 board, then use a connector in that board to complete the connection.

Ten thousand lines is the usual limit for a one-office exchange. More than this number call for a multi-office exchange. Indeed, it is very common to find several offices in an exchange when each may care for only 5,000 or 6,000 lines, and even less, if the conditions warrant it.

The linking together of apparatus in an office of this size is illustrated in Figure 206. Not all switches and connections can be shown, for there are too many, but the few shown give an idea of

10th Thous.	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900
9th Thous.	9000	9100	9200	9300	9400	9500	9600	9700	9800	9900
8th Thous.	8000	8100	8200	8300	8400	8500	8600	8700	8800	8900
7th Thous.	7000	7100	7200	7300	7400	7500	7600	7700	7800	7900
6th Thous.	6000	6100	6200	6300	6400	6500	6600	6700	6800	6900
5th Thous.	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900
4th Thous.	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900
3d Thous.	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900
2d Thous.	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900
1st Thous.	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900

Fig. 206. Ten Thousand Line Exchange. Plan of Unit Boards.

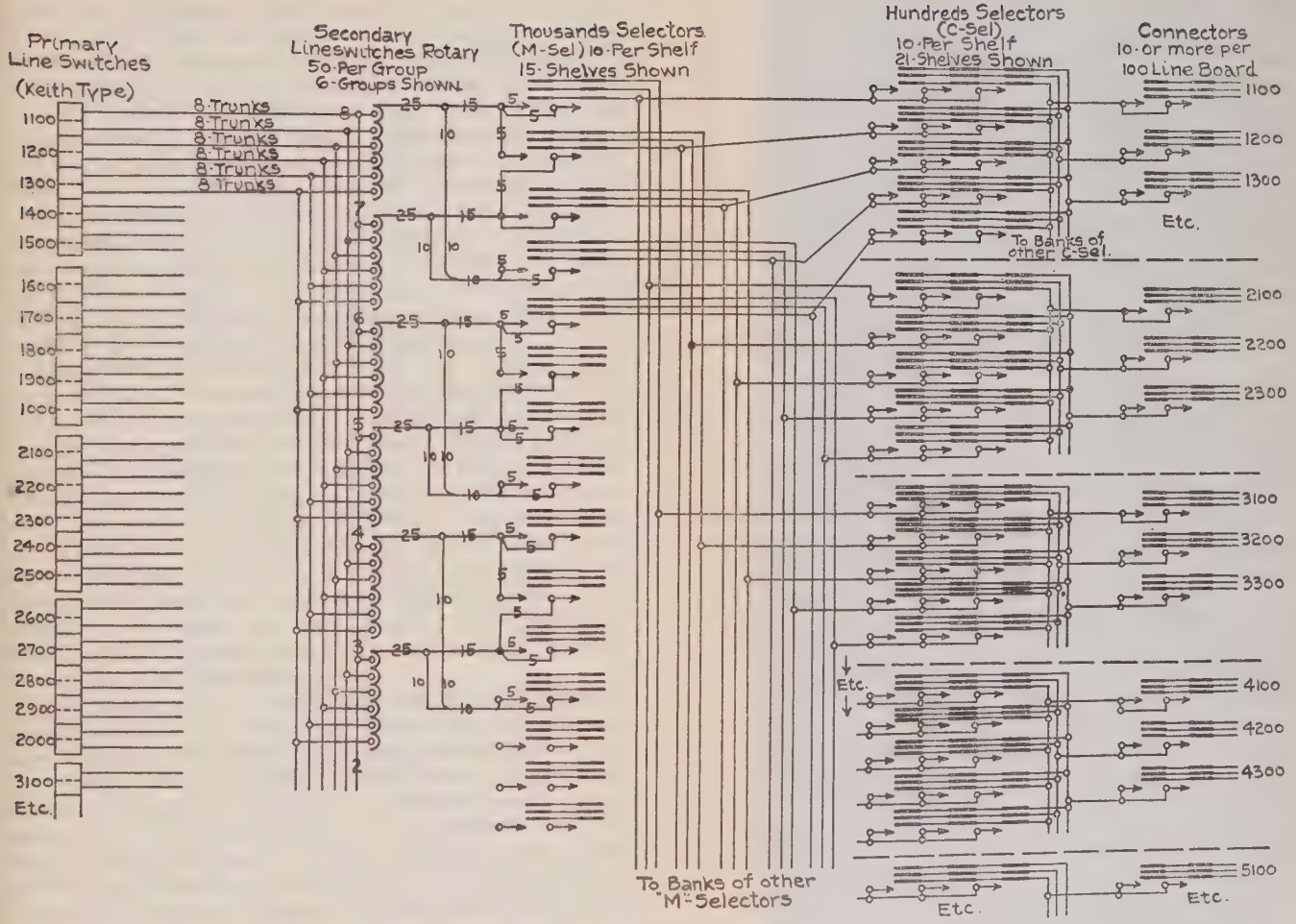


Figure 206.—Ten Thousand Line Exchange.

how all are connected. The switches may be divided into two divisions, non-numerical and numerical. The former have nothing to do with the selection of the called station—no relation to the call number. They merely give the calling subscriber connection to idle numerical switches. The latter are those switches whose action depends upon the call number.

The non-numerical switches are shown at the left. They are Keith type primary lineswitches and rotary secondary lineswitches. Each solid rectangle represents the lineswitches for 100 lines. The division into two shelves or sections of 50 each is shown by a dotted line. Each section of fifty has eight trunks, with a possible maximum of ten. The exact number used varies with the conditions.

The trunks from the banks of the primary lineswitches pass to rotary secondary lineswitches. The latter are in groups of fifty. The trunks from any one primary section are scattered to the different groups of secondary lineswitches, so that the traffic will be merged as much as possible. This is indicated in the diagram as follows. One section of the 1100 board has eight trunks to the first group of secondaries, but there it drops one trunk to the first switch and proceeds with seven trunks. One trunk is dropped at each group of secondaries. This is not the actual path of the trunk cables, but illustrates the scattering.

The banks of the rotary switches have 25 trunks, each running to a selector. These thousands selectors (*M-sel*) are mounted in sections or shelves of ten each. The secondary lineswitches are trunked to the selectors so that fifty trunks go to forty selectors. The first fifteen bank contacts on the rotary switches run to fifteen selectors, the first section and half of the next. The first fifteen contacts of the next group of secondaries run to the

remaining five selectors on the second shelf and to all of the third shelf. Finally the last ten contacts of the first and second groups of rotary switches are multipled together and run to the fourth shelf of selectors. Thus the fifty trunks arriving at the rotary secondary lineswitches depart as fifty trunks but end up in forty selectors.

The ratio of selectors to subscriber lines varies with the traffic, and is engineered for each exchange on the basis of traffic expectations. There may be from 200 to 600 lines per 25 selectors, but a good average is about 300, the basis on which the present illustration was laid out. There should be as many secondary lineswitches in a group as there are trunks on the bank of any one of them, for when all trunks are busy (between secondaries and selectors) there will be one lineswitch for each trunk.

The numerical trunking begins at the banks of the thousands selectors. They are grouped anew in accordance with the demands of traffic, which is not the same to all parts of the board. Different levels of the selectors are grouped differently, so that no one scheme can be given. But the linkage shown in the figure will serve to show how it may be done.

If this exchange has a total of 8,000 lines, there will be about 400 thousands selectors. (*M-sel.*) There are only ten groups of 1,000 lines in the exchange. In general there should be approximately as many hundreds selectors (*C-sel*) as there are M-selectors. But not all the M-selectors can reach all the C-selectors. So the M-selectors are divided into groups for the purpose of trunking. The first shelf may be multipled to the eleventh shelf, the 21st shelf, the 31st, etc. In a similar way the second, 12th, 22d, 32d, etc., may form another group.

The C-selectors are grouped to receive the trunks from the groups of M-selectors as is clearly shown

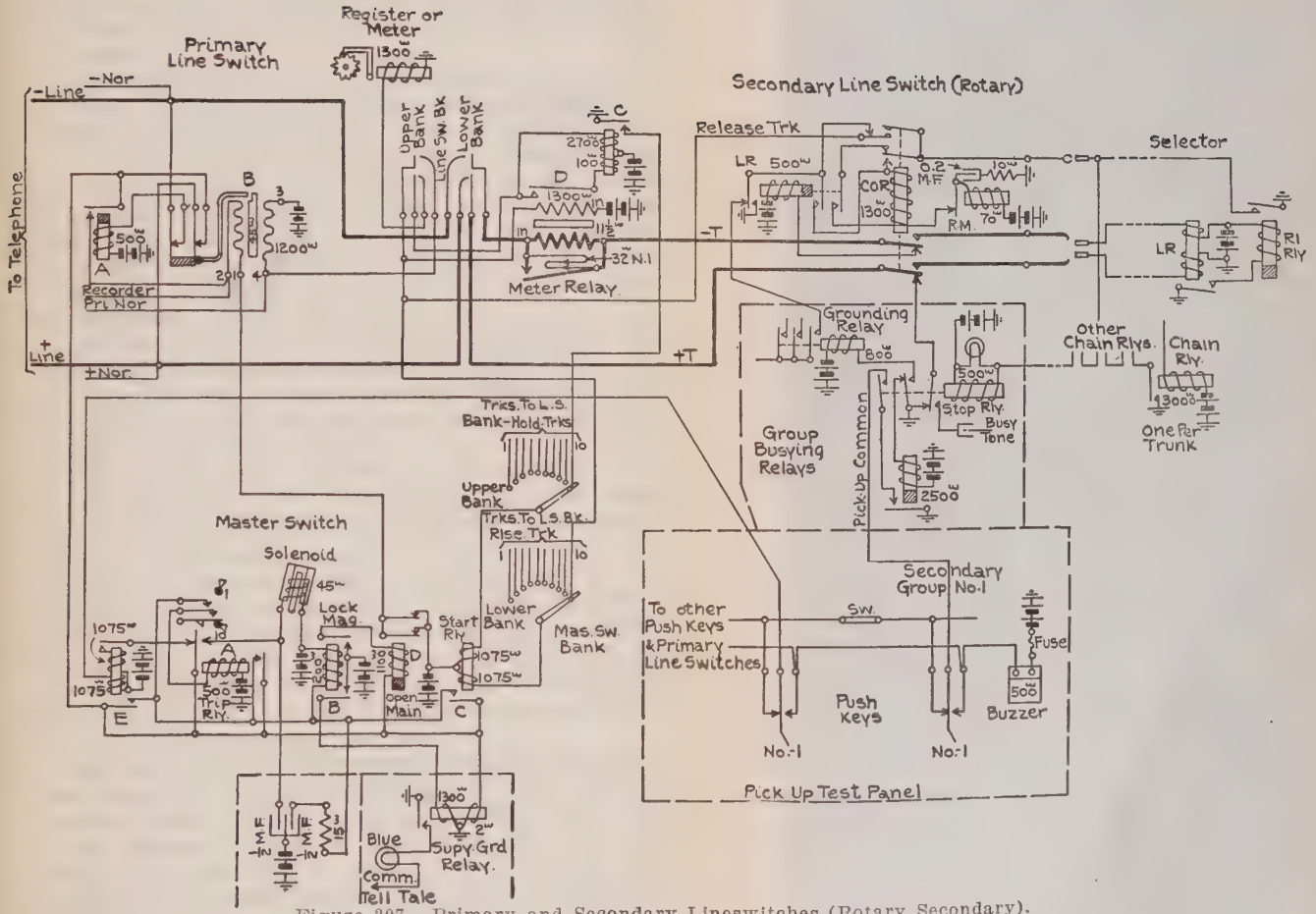


Figure 207.—Primary and Secondary Lineswitches (Rotary Secondary).



in the diagram. In this way the traffic from the subscriber lines is carried to the different thousands in such a way that any line can call into any thousand.

The bank multiples of the M-selectors form a kind of bond, tying the parts of the exchange together.

The banks of the C-selectors are multipled straight within the thousand group. Any C-selector can reach any connector in the thousand. In the groups of connectors we return to the grouping by hundreds. The connectors are associated with the primary lineswitches shown at the left of the figure. They can be related to their boards by means of the numbers, 1100, 1200, etc.

The circuits of the Keith primary and the rotary secondary lineswitches are shown in Figure 207. We will describe the normal operation, the use of the service meter, and what happens when all secondary trunks in a group are busy.

When a subscriber initiates a call, the Keith lineswitch operates as was described. The line relay operates the pull down coil, which pulls the plunger into the bank and extends the connection to the secondary lineswitch. The line relay and ground are cut off, but the line relay, being slow to release, hangs on until the line relay *LR* of the secondary puts ground on the release trunk. This holds the primary lineswitch by the bridge cut off coil *BCO*. We omit reference to the primary masterswitch, because it has been fully described.

The line relay of the rotary secondary lineswitch also connects one end of the cut off relay *COR* to ground after having connected the other end to the private wiper. We now have the same condition that we had in the primary rotary lineswitch. The rotary magnet automatically steps the wipers if the trunk on which they are resting is

busy. If not, the cut off relay pulls clear up at once and seizes the trunk. The action is very positive and quick.

When the cut off relay switches the lines and release trunk through to the selector, the telephone draws current from the line relay of the selector. The latter pulls up and operates the release relay, which grounds the release trunk, holding both primary and secondary lineswitches. After this the line relay of the secondary lineswitch may fall back. The copper collar holds the armature amply long for all this to occur. In fact, the whole action from hook switch to selector is completed in a fraction of a second.

When the called subscriber answers, the connector reverses the polarity of the battery current fed back to the calling telephone. This operates the call meter or message register as follows. In one side of the trunk between primary lineswitch and the secondary lineswitch is one winding of a differential relay marked "meter relay." It has a 1300-ohm polarizing winding which becomes energized when the ground comes on the release trunk. But the line current (in the $11\frac{1}{2}$-ohm winding) opposes the polarizing current, so that the relay does not respond. But when the called subscriber answers and the connector reverses the direction of the line current, the two windings assist each other and the meter relay pulls up. This sends strong current from the 100-ohm winding of relay *C* to the meter (1300 ohms), and operates it, recording one call. The meter relay also short circuits its own line winding, so that conversation proceeds without any loss due to it.

The relay *C* operates when the lineswitch plunges in, and grounds the hold trunk bank on the masterswitch. This is because the meter wire has occu-

pied the fourth and last path through the bank, and this is the best way to secure that end. The 2700-ohm winding of the relay *C* will not permit the meter to pull up.

Certain telephones such as wire chief, manager, fire, police, etc., must be called by anybody free of charge. This is done by putting such telephone lines onto connectors which do not reverse the battery. Thus the meter is not operated. But conversation must take place through the line winding of the meter relay. This is shunted by a 32-ohm non-inductive resistance, and the loss is not appreciable, since all such calls are local.

If all the 25 trunks leaving the banks of the rotary secondary lineswitches of one group are busy, all calls to that group must be diverted elsewhere. This is accomplished by making busy the trunks which lead to idle lineswitches in that group. It is done by the "group busying relays."

Attached to the release trunk of each secondary trunk is a 3000-ohm "chain" relay. It is energized whenever the trunk is busy. The contacts of the 25 chain relays of a group are wired in series. When all the trunks are busy, all the chain relays are energized and their contacts close the chain which pulls up the stop relay of the group busying relays. The stop relay operates the grounding relay, which puts a ground on the release trunk of each trunk leading to this group from primary lineswitches. Thus all the primary masterswitches will find these trunks busy and direct the traffic elsewhere.

The stop relay also switches the positive line $+L$ from ground to a busy tone. This is to take care of any subscriber who might have his call just that far when the secondary group became busy. It induces him to hang up. Within a second he starts

his call again and this time gets a trunk.

But there may be one or more primary line-switches which have finished a call, released, but their plungers have not yet been picked up by the masterswitch. If the secondary group is not busy, this will make no difference, because the subscriber can take the same trunk again and get service. But if in the meantime the secondary group has become fully busy, the masterswitch must be caused to pick up all such plungers, so as to give them trunks to idle secondary groups. This is secured by the "pick up common" wire.

In the group busying relays is a slow release relay which is normally energized by the back contact of the stop relay. When the stop relay pulls up, it connects the pick up common to the slow relay and cuts the current from the winding of the slow relay. Thus there is ground on the pick up common for a moment, or until the slow relay falls back. Follow the pick up common back to the primary masterswitch. It goes to the *E* relay. The momentary ground from the group busying relays (slow relay) causes relay *E* to pull up and to lock itself through the back contact of the trip relay. Another contact on the relay *E* is in parallel with the contact of the start relay of the masterswitch. Hence it does what the start relay would do—pulls up the lock magnet, lets the shaft rotate (by the spring) to trunk *1*, where the solenoid magnet takes hold and pulls the shaft back to trunk *10*. In doing this, all idle plungers which were disengaged have been caught by the shaft. This is the "pick up."

The pick up test panel is to enable switch men to test the pick up common by cutting it in two by the switch (normally closed) and putting battery and buzzer on either section. If there is a ground on the common, this test tells where to look for it.

Many exchanges are in operation with Keith secondary lineswitches as well as Keith primaries. Figure 208 shows such an arrangement of circuits.

The action as to the primary lineswitch and masterpiece is as was described before. But the secondary is different. The holding trunk circuit passes through the 85-ohm pull down coil of the secondary and the 9.5-ohm coil of the *A* relay, and the total winding of the *A* relay in the "secondary relay equipment" to negative battery at the secondary masterswitch. When the primary lineswitch acts, and thereby grounds the holding trunk, relay *A* of the secondary equipment pulls up first, followed by relay *A* of the secondary lineswitch and the pull down coil of the same. Relay *A* puts an early ground on the release trunk, without waiting for it to come back from the selector. The pull down coil operates the plunger and extends the connection to the selector, which grounds the release trunk and holds the connection as usual. The meter operates as before described.

When all secondary trunks are busy (in one group) the chain relays function as in the case of the rotary secondaries. They pull up the stop relay, which opens the battery supply to the secondary masterswitch and sends a momentary pulsation over the pick up common to the primary masterswitches to cause them to pick up all idle plungers. The slow relay *D* co-operates in this. Slow relay *D* also switches the holding trunk circuit from negative battery to ground, so as to busy the trunk back toward the primary lineswitch.

Notice this difference. The Keith secondary lineswitch is seized over the holding trunk. The rotary secondary lineswitch is seized over the trunk line wires.

CHAPTER XVIII

PARTY LINES IN AUTOMATIC EXCHANGES

Party line service has been given for years with the automatic system. In the days of the three-wire system, there were many troubles, chiefly from premature disconnections. But the coming of the two-wire system ended that source of trouble. It also simplified the sub-station equipment. Because of the desirability of keeping the subscriber line clear of ground attachments, the harmonic selective system of ringing bells has been most favored. The Western Electric Company still use biased bells legged to ground and rung by pulsating current or superimposed current (the Knox-Dickey plan). But it introduces undesirable complications. The harmonic system is used with success by the Automatic Electric Company, the Stromberg-Carlson Mfg. Co., the Kellogg Switchboard and Supply Co. and others.

When an automatic party line station calls another line, the conditions are not different from those of individual lines. But if two subscribers should dial at the same time, it would spoil both calls. Both must hang up to release, then only one can call again. This is the same as manual. If during the time that one party line subscriber is dialing another on the same line takes his receiver from the hook, the short circuit which he thus places across the line will stop the sending of any more impulses. For this reason sometimes a hook latch is provided, which permits the lever

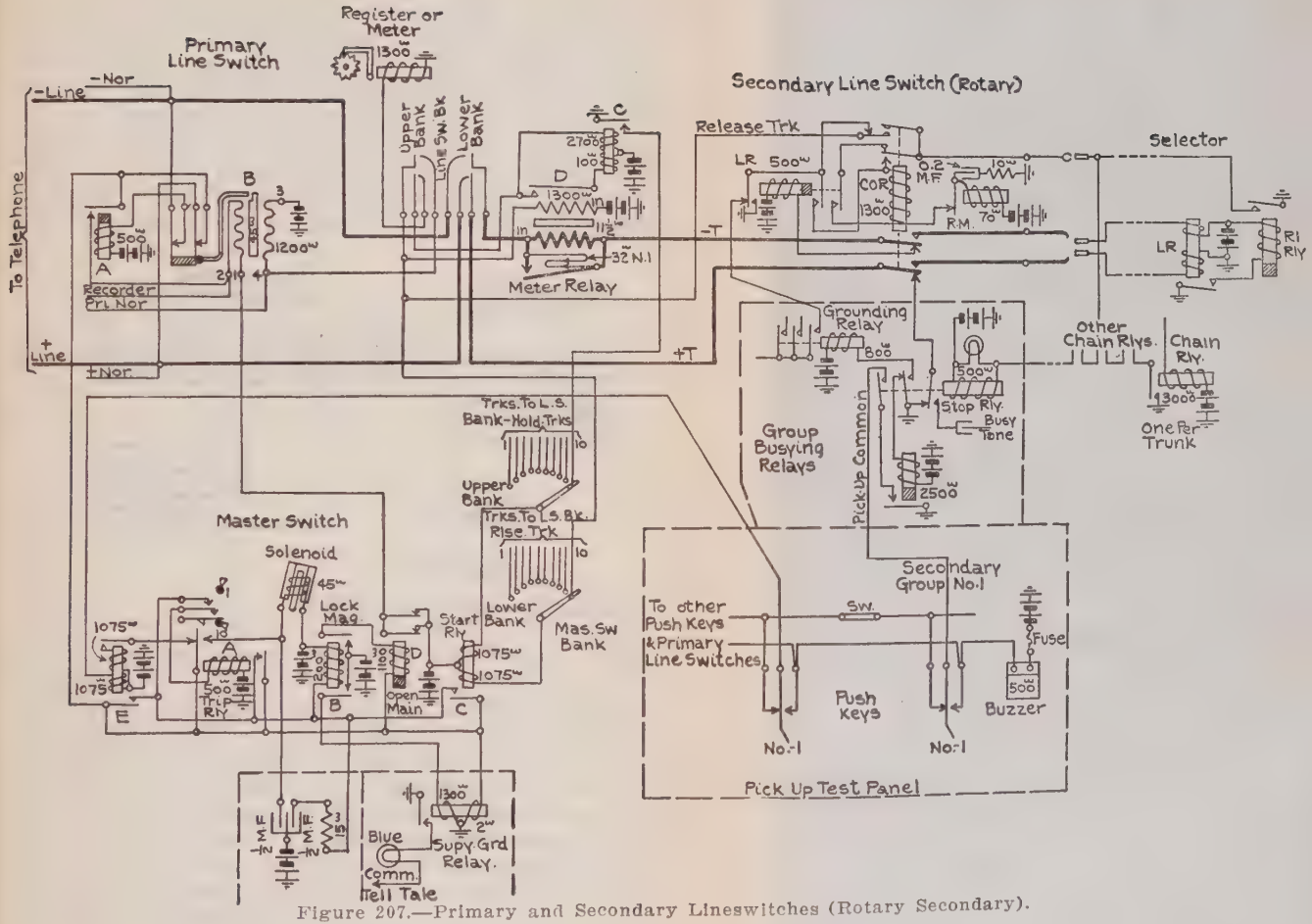


Figure 207.—Primary and Secondary Lineswitches (Rotary Secondary).



of the switch to rise only far enough to close the receiver circuit across the line, but not to close the path through the calling device and transmitter. It permits the subscriber to listen without interfering with the dialing which might be in progress. If the line is free, the user presses a small button, which releases the latch, so that the lever rises to the top and gives the circuit for dialing and talking. Telephone courtesy is always necessary among subscribers on party lines, even more than

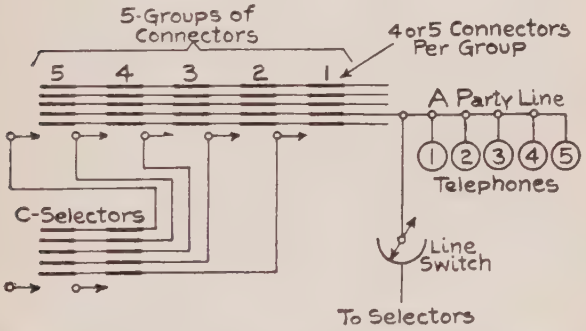


Figure 209.—Party Line Ringing by Groups of Connectors.

on individual lines, for they are more closely involved.

Selective Ringing.—In general there are two ways of ringing party lines selectively in an automatic exchange. The connectors may be grouped by frequencies, all connectors in a group having the same frequency and there being as many groups as stations on the line. Or the connectors may be in a common group, and each one equipped with a frequency selector, which enables it to ring any desired frequency.

Selective ringing by groups of connectors is

illustrated by Figure 209. Five stations on a line are shown, with five groups of connectors, numbered from one to five. There are usually from four to five connectors in a group, as many as are necessary to handle the traffic. The subscriber lines are multipled to all the banks of all the connectors, so that no matter what group of connectors is selected, the same line will be obtained.

The hundreds or C selectors pick out the frequency necessary to ring the bell of the desired station. Hence, the five stations on the same line will have call numbers which differ only in the hundreds digit. Let us consider line 25 on the banks of the connectors. Station 1 will have for its last three digits "125," station 2 will have "225," station 3 will have "325," etc.

There is only one lineswitch for the line for handling calls originated by the subscribers on this one line. Thus for one hundred 5-party lines, there are 100 lineswitches, and about 20 to 25 connectors. And the party line numbers may have the same number of digits as individual lines. Sometimes party lines are served by an extra order of selectors, so that party line numbers have one more digit than individual lines.

The party line connector with frequency selector, Figure 210, has two additional parts, the frequency selector, which is a minor switch, and a relay, the wiper reversing relay *WR*. The frequency selector has the duty of connecting to the switch the desired frequency of ringing current. It is set by the first digit which arrives at the connector, the second and third digits being used to lift and to rotate the wipers which connect the lines. The wiper reversing relay is needed only for ten-party lines, on which the bells are legged from each wire to earth. Five of the bells are rung from the nega-

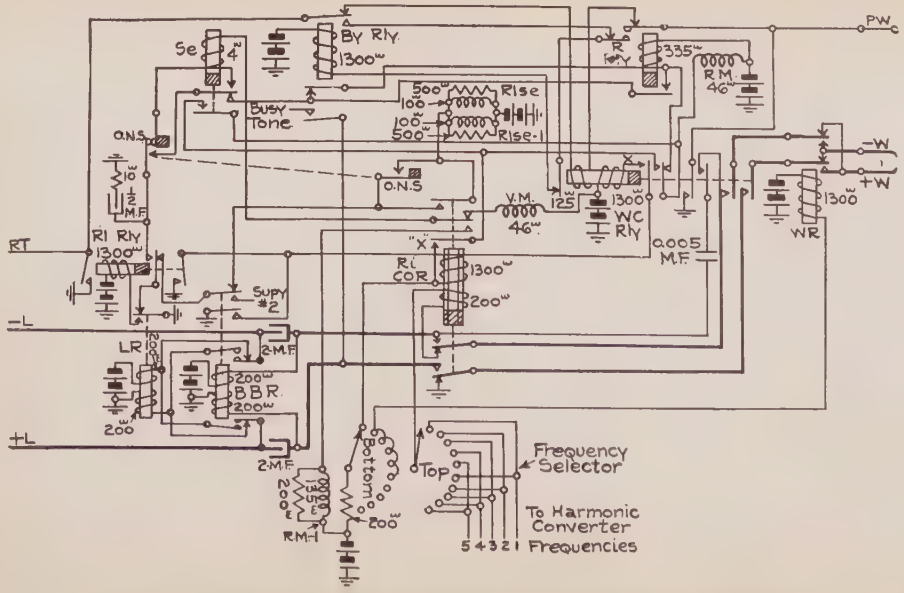


Figure 210.—Party Line Connector Circuit with Frequency Selector.

tive line —L to ground, and the other five from positive line +*L* to ground. If four-party and five-party lines are used, the wiper reversing relay is not needed, and the last ten contacts on the top bank of the frequency selector may be left unwired.

When the connector is seized, the line and release relays, *LR* and *RlRy*, pull up as usual. The right hand ground at the release relay operates the ring cut off relay *RiCOR*, which gets current from the battery through the bottom wiper of the frequency selector and a 200-ohm resistance. The ring cut off relay switches the impulsing circuit from the vertical magnet to the rotary magnet of the frequency selector, *RM-1*. The complete path is from the back contact of the line relay, *LR*, front contact of release relay *RlRy* winding of series relay *Sc*, front contact of ring cut off relay *RiCOR*, winding of rotary magnet *RM-1*, to negative battery.

The series relay operates on the first impulse and remains energized during the series of pulsations. It closes a path for the ring cut off relay, so that the latter gets negative battery connection through the rotary magnet of the major switch, *RM*. The latter will not energize, but the ring cut off relay will be held energized after the bottom wiper of the frequency selector has left its contact *1*.

At the end of this first series of impulses, the line relay comes to rest energized, and after a moment the series relay and the ring cut off relay fall back. The latter prepares the circuit for the vertical magnet *VM* of the major switch. The top wiper of the frequency selector is now resting on the contact which carries a frequency of current to ring the desired station. If it is a ten-party line, the wiper reversing relay *WR* is energized or not, so as to connect the ringing current to the neces-

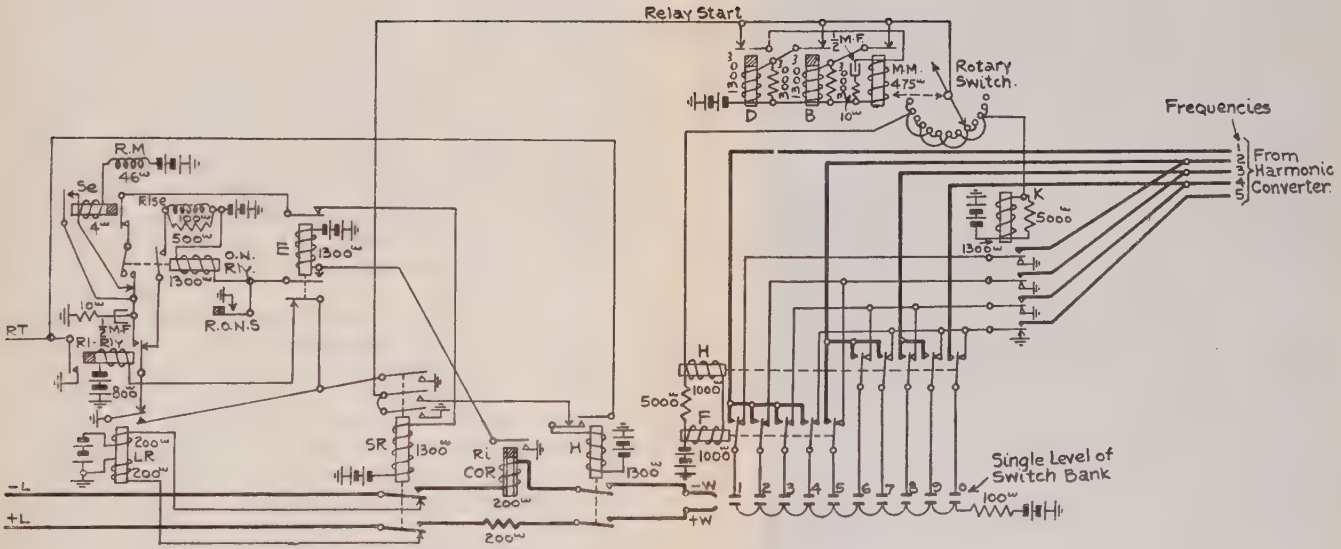


Figure 211.—Reverting Call Switch Circuit.



sary wiper. The first five numbers, *1* to *5*, operate the relay, connecting the line wipers "straight," the last five numbers, *6* to *0*, leave the relay normal, so that the wipers are reversed.

From this point the operation of the connector is the same as the ordinary connector which was described. See page 221 and Figure 175. There is a minor change in the way that the ring cut off relay locks itself when the called station answers. Contact *x* closes first, giving the coil negative battery through the rotary magnet, by way of a contact on the wiper closing relay *WCRy*. The other end of the 1,300-ohm winding of the ring cut off relay is grounded by the release relay.

When release occurs, the release magnets of the major switch and the minor switch act in parallel. The former controls the cutting off of the current for both of them, but the minor switch acts more quickly than the major switch, so that there is plenty of time.

Reverting Calls.—Calls from a subscriber on a party line to another subscriber on the same line (reverting call) have been handled in a number of ways, some good, others objectionable.

Some have provided an operator whose duty is to ring all such calls. She is reached by dialing a certain number which the subscriber finds posted on his telephone. This amounts to regarding the reverting call as a nuisance and discouraging it. But the reverting call has as much right as any other call, and should be completed automatically.

The calling of a reverting call like any other has been accomplished, but proved to be too complicated as to circuits and mechanism. When the subscriber calls his own line, the connector will find the line busy, for it has been made so by the lineswitch when the call was started. A special

circuit device was used to remove the protection for an instant—long enough for the connector to seize the line. Then it had to be rung by the pushbutton on the telephone, a high resistance preventing release. But this kind of switch is no longer used.

Out of all the experiences has come the following plan, which seems to meet all desires at the present time. A number of reverting call switches are provided, each of which can ring party lines by sending the ringing current back over the lines which seized the switch. On each telephone is a list of numbers for the other stations on the same line. When the subscriber dials one of these numbers, he will get one of these reverting call switches. Then he hangs up his receiver, upon which the reverting call switch rings alternately the calling station and the called station. When the called subscriber answers, the ringing stops, the calling subscriber comes in on the line again, and the reverting call switch is released, to be available to others. The subscribers talk by means of current supplied from a selector, for on release of the reverting switch, the lineswitch of the party line will seize a selector. The talking is done on the Stone system of current supply.

The circuits of the reverting call switch, Figure 211, involve the switch proper and its bank. There is only one level, so that only a rotary magnet is provided. It is under the control of the line relay.

We illustrate five-party line ringing. There are thus ten combinations of frequencies to be rung. The currents from the harmonic converter pass to three relays to be distributed to the bank contacts. If the wipers rest on contact *1*, we desire to ring alternately with frequency *1* and frequency *2*.

This is done by alternate operation of relay *K* and of relays *H* and *F* which act as one. But if contact *2* be chosen, we desire to get frequencies *1* and *3*. The same alternate action will give them.

The alternate operation of the two relays is secured by means of a rotary lineswitch. *MM* is the magnet which steps the wipers. *D* and *B* are two slow release relays which co-operate with each other and the motor magnet in producing a leisurely motion from contact to contact.

The bank contacts are grouped by twos, and alternate pairs are wired to one of the relays which control the frequencies.

When the subscriber, by dialing the posted number, has seized the reverting call switch, the line relay *LR* operates and pulls up the release relay, *RlRy*. The latter grounds the release trunk *RT* to hold the connection, and prepares the impulse circuit for the rotary magnet. When the last digit of the special number is being dialed, the line relay sends impulses to the rotary magnet, moving the wipers over the contacts. The series relay *Se* pulls up and insures the path, although with the first step the rotary off normal springs *RONS* operate the off normal relay *ONRy*, and tries to take it away. The latter relay also prepares the release magnet circuit, but it is ineffective because of the open at the back contact of the release relay.

When the line relay comes to rest at the end of the impulses, the series relay falls back and prepares the circuit to the switching relay *SR* which will start the ringing.

The subscriber now hangs up his receiver. The line relay falls back and gives an impulse to the switching relay *SR* over the following path, back contact line relay, front contact release relay, back contact series relay, back contact relay *E*, to wind-

ing of switching relay. The latter pulls up, locks the release relay energized (and therefore locks itself), starts the rotary switch to moving, and pulls up the relay *H*, which locks itself to release trunk ground. The latter together with the switching relay extend the lines to the wipers of the switch. Therefore the lines receive the currents which are being put on the bank by the relays of the bank.

The grounding of the "relay start" wire starts to pull up three things at once, relays *D* and *B*, and the motor magnet *MM*. But the motor magnet is too quick for the others and pulls up first, its pawl catching another tooth on the hub. This cuts off relay *B*, but relay *D* operates. This cuts off the motor magnet, which promptly falls back, rotating the wipers one step and closing the circuit of relay *B*. Relay *B* now pulls up and cuts off relay *D*, which after a moment falls back and operates the motor magnet. The latter pulls up, catches another tooth on the hub, and cuts off relay *B*. In this way the three magnets operate periodically, and move the wipers slowly over the bank. The selective relays *K*, *H* and *F* are alternately operated and released. The reader can easily see what pairs of frequencies are obtained from each bank contact. The ringing current returns by the positive wiper $+W$ through a 100-ohm resistance to battery.

When the called station answers, the direct current drawn by the talking apparatus in the telephone operates the ring cut off relay *RiCOR*. This energizes relay *E*, which locks itself to ground at the rotary off normal springs. Relay *E* cuts off the release relay, which on falling back operates the release magnet *Rlse*, so that the reverting call switch returns to normal.

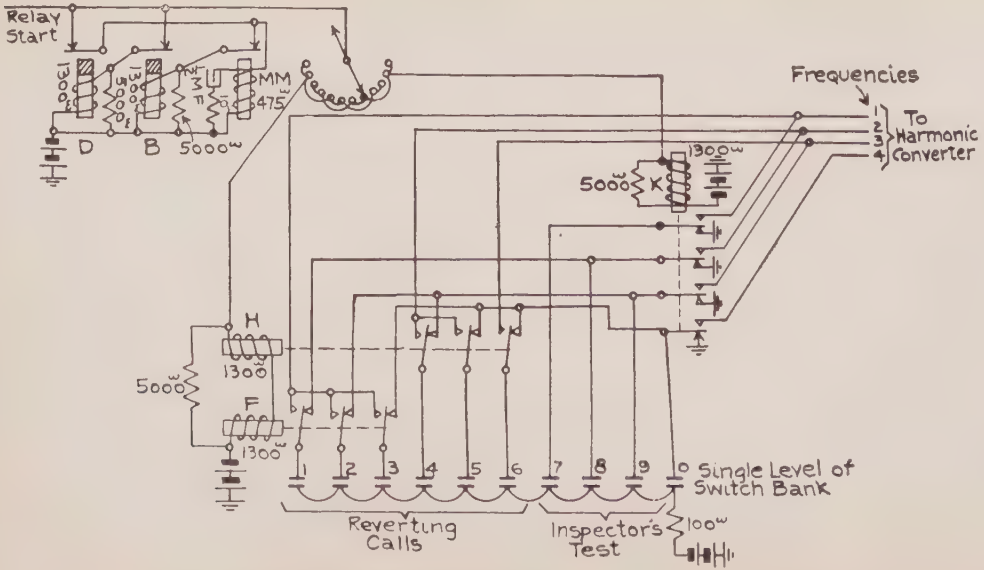


Figure 212.—Reverting Call Switch Bank with Inspector's Test.

It is a decided advantage for telephone inspectors to be able to do their own testing without calling on central office people for help. Automatic switchboards lend themselves with great ease to this idea, and have proven that the calling device on a telephone is an asset to the repair department as well as to the telephone user. All the testing can usually be done without calling the wire chief or inspection department, the inspector calling them only after the work is done to have it verified and to receive new assignments.

The reverting call switch used with four-party lines, Figure 212, is arranged so that an inspector can call any one of the last four sets of contacts and get any one of the four ringing currents. It does it without bothering any other station on the line.

The 4-party reverting switch requires only six bank contacts for regular reverting calls. This permits the last four contacts to be connected directly to the mainsprings of relay *K*, which periodically pulls up and rings the line.

If the called station fails to answer, the calling subscriber merely lifts the hook for a second and lets it down again. This releases the reverting switch.

CHAPTER XIX

THE MULTI-OFFICE EXCHANGE

When a telephone exchange gets too large to be housed in one building, it is split up into a number of separate offices. The term "branch office" came into use to describe an office opened to relieve the "main office" which was the first to be established. Thus the exchange came to consist of one main office surrounded at varying distances by a number of branch offices. The main office was the oldest and usually was associated with the business offices of the operating company, and in most cases the toll office as well. But these branch offices have come to be as important as the main office. Often we can not tell which is main and which are branches. Most of the offices are co-ordinate, each is a self-contained switching center, with direct trunks to all other offices. The term "branch" office should die out, unless there is an office which is really the branch of something. The simple term "central office" or at most "main office" should suffice for clearness.

The size of a central office is limited by the ease of working the multiple (manual), the cost of equipment, and the length and cost of subscriber lines and trunk lines. Operators can reach over a limited height and width of multiple. It is desirable to keep the subscriber loops fairly short. All factors combine to set the limit of 10,000 lines per office, and in many cases a much smaller office pays.

In some cases an office may be made tributary to a main office in that it does all its trunking through the latter. The tributary office is called a "sub-office." Because it is best handled by automatic switches, the sub-office is treated under the head of automatic switching.

The manual inter-office trunking system looms large in the multi-office exchange. The larger the city, the more the offices and the greater the number of groups of trunks and of order wires. It complicates the system, slows the service, and increases the errors in connections until conversion to automatic is the only answer.

Trunk lines between offices are almost always worked in one direction. They start on multiple jacks just below the subscribers' multiple and end in plugs before trunking operators in other offices. The subscriber's operator is called the *A* operator and the trunk-operator the *B* operator, working at the *B* board. The call is passed from the *A* operator to the *B* operator over an order wire or call circuit, variously named. The *B* operator assigns the trunk to be used, the *A* operator verifies that it is free by the usual busy test, and plugs in. The *B* operator tests the called line and if free, plugs in and starts the ringing. If busy, the *B* operator plugs into a "busy back" jack, which gives a busy tone to the calling subscriber.

Two trunk circuits of the Bell type will be given to illustrate the subject. The first uses manual or hand ringing. The *B* operator must follow the ringing until the called station answers or the call is abandoned. The second uses machine ringing, started by plugging in and cut off automatically by the answering of the called station.

The manual ringing trunk circuit, Figure 213, has a repeating coil to separate the inter-office

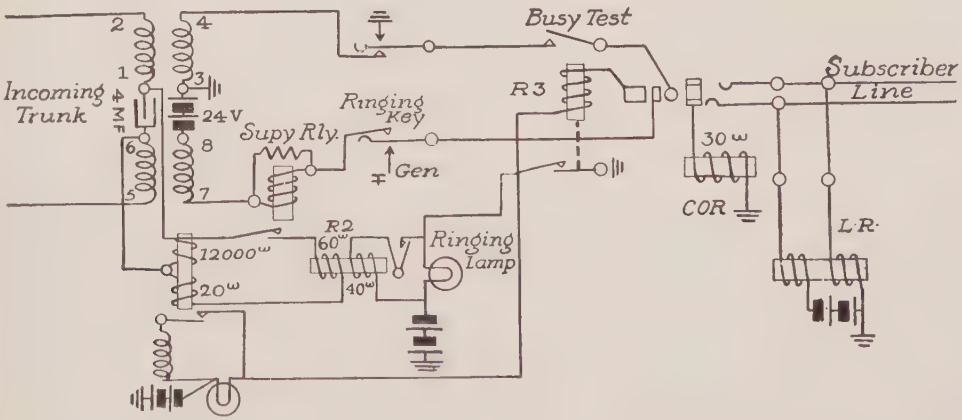


Figure 213.—Manual Trunk Circuit, Manual Ringing (W. E. Type).

trunk wires from the subscriber loop. There is a high resistance relay *R-1* bridged across the condenser and therefore across the trunk line. It will pull up if the *A* operator plugs into the trunk, but will not permit the *A* cord supervisory relay to operate. There is no listening key for the *B* operator for she does not need to listen. She gets her information over the order wire, and from watching the lamps. There is normally a test connection from the tip of each plug to the operator's set, so that she can test the lines. It is cut off by plugging into a line.

The *A* operator and the *B* operator are supposed to make their connections almost at the same time. But if the *A* operator plugs into the outgoing trunk first, relay *R-1* will pull up and shunt the disconnect lamp, but there is no sign of any kind to the *B* operator. If it is the *B* operator who gets there first, plugging into the called line with *R-1* normal, the sleeve relay *R-3* will pull up, lighting the ringing lamp and the disconnect lamp. The latter goes out when the *A* operator plugs in, so that the *B* operator knows what has happened. The sleeve relay *R-3* also switched the tip of the plug from test to the repeating coil.

The *B* operator now rings. The ringing lamp will burn until the called subscriber answers, operating the supervisory relay, which pulls up relay *R-2*, self-locking with its 40-ohm winding in parallel with the ringing lamp. This shunts the lamp out. The parallel connection of the 60-ohm winding of *R-2* with the 12,000-ohm winding of *R-1* (20 ohms being in series with 60 ohms) lowers the trunk resistance so that the supervisory relay on the *A* cord pulls up and gives supervision to the *A* operator. *R-1* is held. Both operators know that the call is answered.

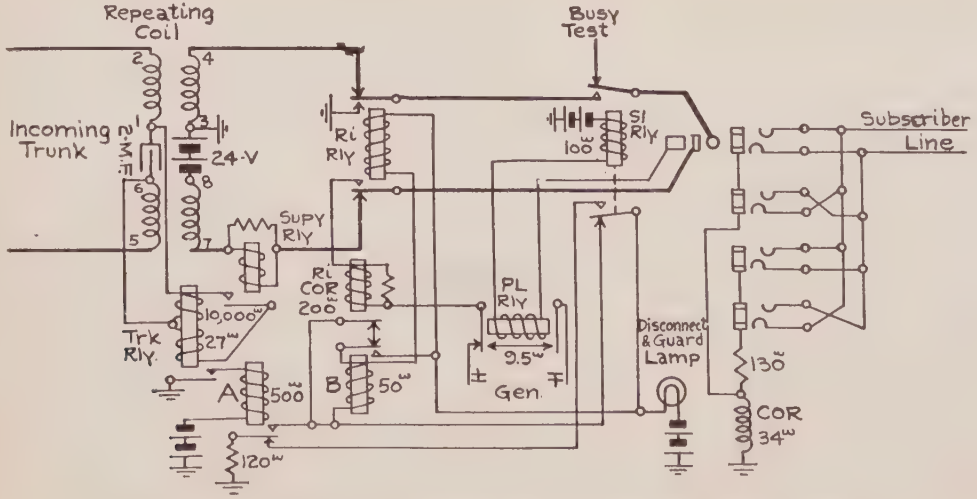


Figure 214.—Manual Trunk Circuit, Machine Ringing (W. E. Type).

The *A* operator gets all the subscriber supervision. *R-2* does not respond to the trunk supervisory relay, but the latter passes the conditions back to the *A* cord.

When the *A* operator pulls down the connection, relay *R-1* falls back and lights the disconnect lamp. The *B* operator pulls down the trunk plug, and all is normal.

The machine ringing manual trunk circuit of Figure 214 has the same general features of current supply, but there is only a disconnect and guard lamp.

If the *A* operator plugs in first, the guard lamp will light. If the *B* operator plugs in first, the lamp also lights, but will go out when the *A* operator plugs in.

This circuit is arranged to ring 4-party lines with pulsating or superimposed current. The bells are biased, and legged to ground two from each line wire. There is one jack for each station. There is a party line relay *PLRy* in the sleeve of the trunk, which is marginal. It will operate in series with the sleeve relay *SlRy* and the cut off relay *COR* but not in series with them and the added 130 ohms. Normally the party line relay furnishes positive current, but when operated supplies negative current to the ringing relay *RiRy* through the ring cut off relay *RiCOR*. Reversal of line wires between jacks secures the ringing of oppositely placed bells.

When the trunk has been assigned, the *A* operator plugs in, followed by the *B* operator. The guard lamp may light momentarily. The trunk relay *TrkRy* operates and pulls up relay *A*. The latter closes the local circuit in which are the *B* relay, the ringing relay and the guard lamp. Relay *B* is short circuited out. The guard lamp can not light through

the resistance of the ringing relay, but the latter pulls up and connects ringing current to the plug.

After plugging in, sleeve current operates the sleeve relay, which cuts out the busy test and closes the tip line. Ringing current now passes to the line and rings the bell selected. If the line is an individual line, the bell will ring just as well, even

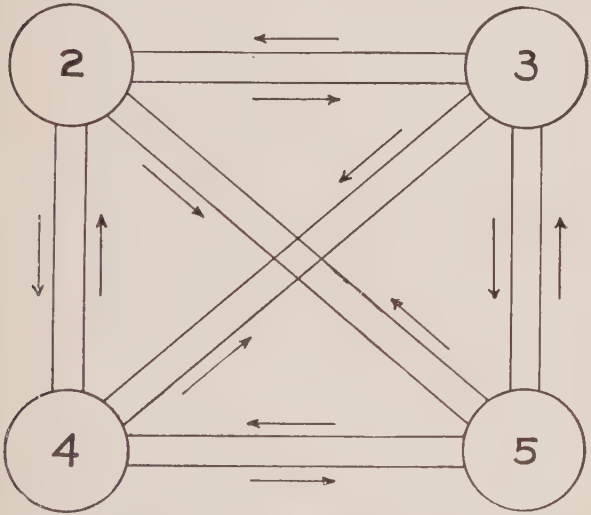


Figure 215.—Multi-office Exchange with Direct Trunks

though it is bridged across the line, for the ringing current returns by the tip to ground.

When the called station answers, the increased current pulls the ring cut-off relay enough to take the shunt off relay *B*. The latter locks up and short circuits the ringing relay, which falls back, cuts off the ringing current, and closes the tip and

ring circuits to the repeating coil. The *B* operator has had no care after plugging up the connection.

When the called station answered, the supervision was relayed back to the *A* operator as in the circuit before shown. She gets all the supervision.

When the A operator pulls down the connection, the trunk relay at the *B* board falls back and re-

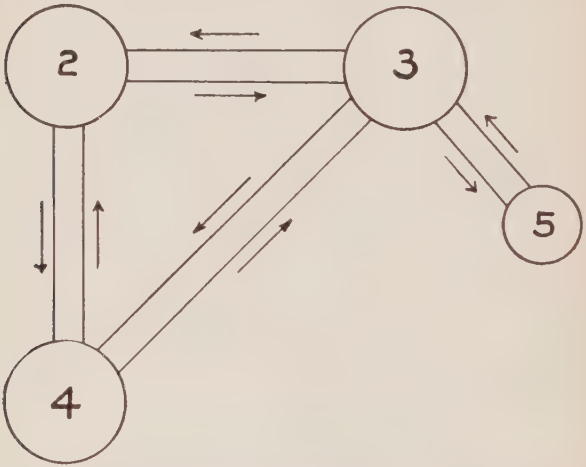


Figure 216.—Multi-office Exchange with Direct and Tandem Trunks.

leases relay *A*. The latter lights the disconnect lamp through the front contact of the sleeve relay. The *B* operator then pulls down the trunk, which restores all to normal.

The Automatic Multi-Office Exchange.—The automatic system works practically as easily in a multi-office exchange as it does in a single office exchange. The subscriber gets his connection just as quickly.

There is no delay because of having several offices and having to trunk between them.

Figure 215 illustrates a four-office exchange with direct trunks between all the offices. Between any two offices there are in general two groups of trunks, those carrying traffic from (for example) office 2 to office 4 and those carrying traffic from office 4 to office 2.

If the traffic to and from an office is small, or chiefly to one other of the main offices, indirect or tandem trunks, Figure 216, are sometimes used. In this case, all the calls between office 5 and the others must pass through office 3.

The trunks between two offices are handled as shown in Figure 217. Though only two offices are here used, the same principle applies to any number of offices.

Omit all consideration of primary and secondary lineswitches. We assume, for simplicity, that the traffic is delivered suitably to the "office selectors." These selectors are introduced to enable the subscriber to pick out the office in which lies the desired line. If there are less than ten offices in the exchange, we need only one order of office selectors.

On the banks of the office selectors are the trunks which run to all the offices. From level *2* run the trunks to office *2*, from level *3* to office *3*, etc. In our illustration, we have offices *2* and *3*. In office *3*, the third level is the local level, for from it run trunks to thousands selectors (*M-sel.*) in the same office. Level *2* is called an outgoing level, for its trunks run to "incoming" thousands selectors in office *2*.

To economize inter-office trunks, outgoing secondary lineswitches are used. They merge the traffic from different groups of office selectors into one group of trunks which run to the distant office

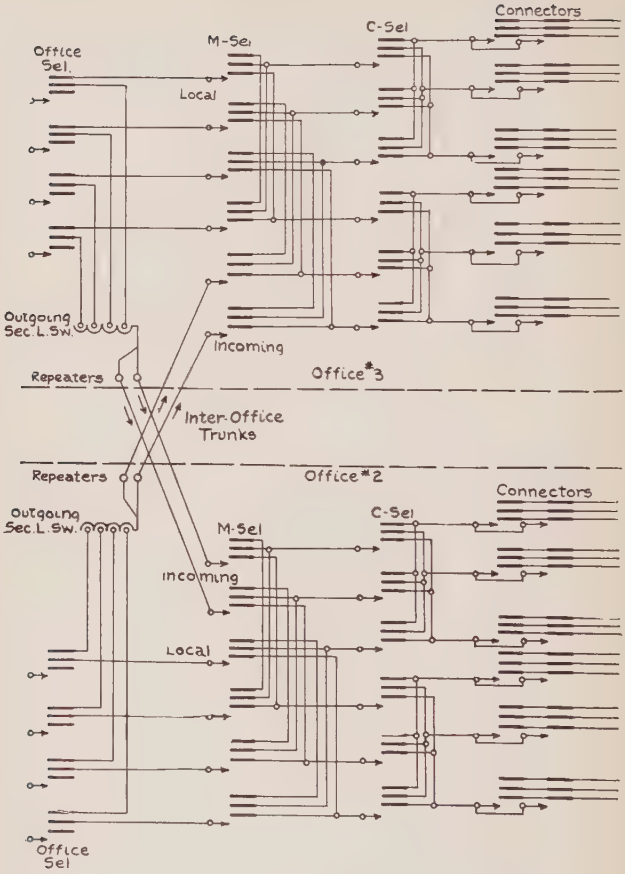


Figure 217.—Two Offices, in Multi-office Exchange (Link Diagram).

and deliver that traffic to incoming thousands selectors. By using the outgoing secondary lineswitches in this way it does not take as many inter-office trunks as would be necessary if they were in groups of ten each.

In the illustration, the office selectors are represented by only four switches in each office. Each of them must be taken to represent a group of selectors, all of which have their banks wired more or less in common. And there are usually more than four such groups.

The circuit of an outgoing rotary secondary lineswitch is given in Figure 218. It is like the local secondary rotary lineswitches which we have discussed, but the common busying relays are a little more simple. There is no pick up common, because no Keith primary lineswitches are involved. When all trunks in the group are busy, the busying relays ground the release trunk, so that any selector will find the trunk busy.

If more than twenty-five trunks are needed between offices, there will be several groups of twenty-five each. The trunks from each group of selectors are then scattered over these groups of outgoing trunks. If there were 125 outgoing trunks, there would be five groups of 25 each. From the banks of any group of selectors two trunks would run to each outgoing group. This scatters the traffic so that it is almost as good as one large common group, and much cheaper as to total cost than an adequate switch capable of reaching all the trunks with its own wipers.

The trunks within an office consist of at least three wires, $-L$, $+L$ and RT. Between offices the distances are relatively great and the trunks expensive. It is desirable to use only two wires per trunk. To care for the release trunk, the repeater is intro-

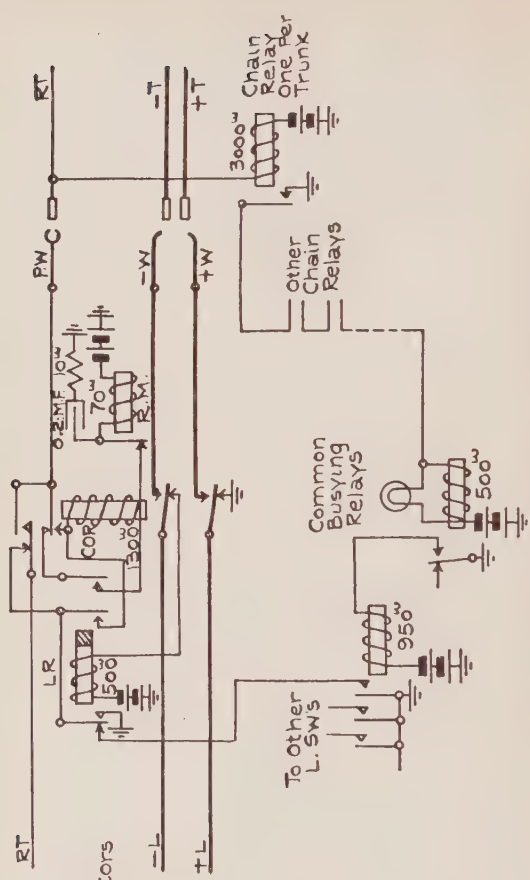


Figure 218.—Outgoing Secondary Lineswitch Circuit.

duced. Its presence permits other valuable objects to be secured.

Referring again to Figure 217, it is seen that the repeaters are introduced in each outgoing trunk just as it leaves the office. There is one per trunk.

Figure 219 shows the circuits. Three wires enter at the left. Only two depart at the right. The line wires are broken by condensers, preventing the direct current flow in the left side from mixing with that in the right side. The left is entirely local. The right receives its current from the distant office.

There is a line relay *LR* which supplies current to the calling telephone after it has worked its way through the lineswitches and the office selectors. This line relay controls a release relay *RlRy*, which grounds the release trunk and holds the switches in the home office.

There is a back bridge circuit which passes through the 60-ohm winding of the differential relay *DR* and the back bridge relay *BBR*. It is the main path for the trunk current from the distant office when the line relay and the release relay have closed the trunk.

When the trunk is seized, the line relay pulls up and closes part of the trunk and also operates the release relay. The release relay grounds the release trunk, closes the trunk circuit, polarizes the differential relay (1,900-ohm winding) and prepares a path for the shunting relay *ShRy* to the back contact of the line relay.

When the subscriber dials numbers, the line relay repeats the impulses into the trunk, thus operating switches in the distant office. It also pulls up the shunting relay by impulses from its back contact. This shunting relay provides a path of negligible

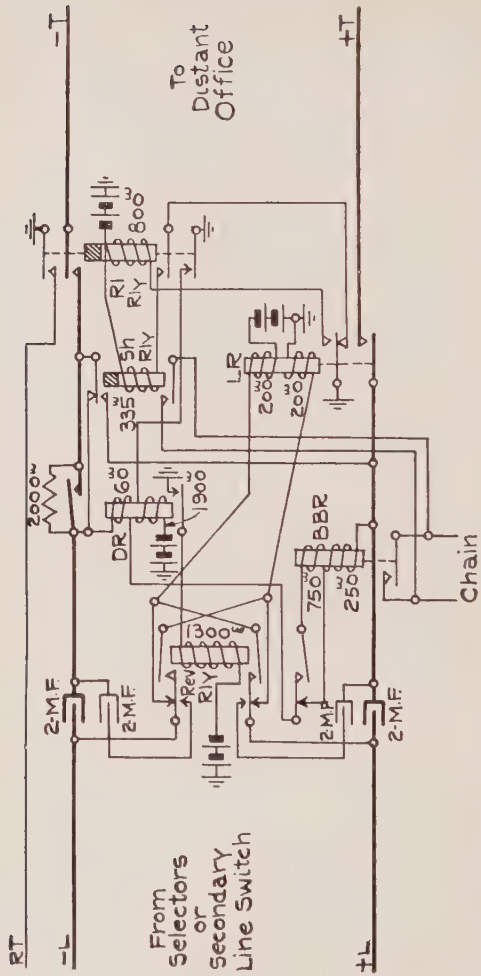


Figure 219.—Repeater Circuit.

resistance across the trunk, cutting out the back bridge relays. This shunt path is indicated by a heavy line. It makes no difference to the differential relay. It would not operate anyway, because it can not pull up until the line current assists the polarizing current. The release relay and the shunting relay remain energized during the impulses.

At the end of the impulses, the line relay comes to rest energized, holding the release relay, while the shunting relay falls back. This process is repeated as often as there are digits in the call number. The same repeater can repeat as many digits as desired, without any change of structure.

When the called subscriber answers, the connector reverses the line current. This causes the differential relay to pull up, for now the line current assists the polarizing current. The differential relay operates the reverse relay *RevRy*, which reverses the current supplied to the calling telephone. This operates the meter if one is used. It also increases the resistance of the back bridge relay from 250 ohms to 1,000 ohms, to reduce transmission loss and doubles the capacitance of the condensers. The differential relay holds on the reduced current.

The circuit marked "chain" is used in case the secondary lineswitch has no chain relay on the release trunk. With the rotary secondary lineswitches described, this chain is not necessary.

The release is accomplished by merely opening the line circuit. The line relay falls back, followed by the release relay and all the others.

The repeater accomplishes the following results:

1. Reduces the trunk from three wires to two wires.

2. Repeats the impulses into the trunk circuit,

so that the incoming selector on the distant office works over a trunk loop of constant resistance.

3. Supplies battery current to calling telephone from its own office, which gives better transmission.

4. Repeats the reversal of line current, for metering, etc.

SUB-OFFICES

Sometimes it occurs that a new region is being opened in a city, and it is necessary to supply the

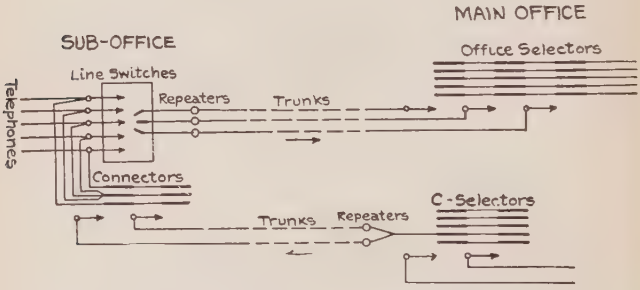


Figure 220.—Sub-office Link Diagram.

occupants of the region with telephone service. At first a few long subscriber lines are run from the nearest office. But before long, this becomes unsatisfactory, because of the number of them. It looks as if a central office will pay. But for the time being, until the permanence of the region is settled, the sub-office enables central office service to be given without re-arranging the trunking system of the exchange.

A small sub-office of one hundred lines can be linked to the nearest main office as shown in Figure 220. It is essentially a 100-line board carried out

to the desired location, and the necessary trunk lines run between. In order to avoid the use of three wires per trunk, a repeater is cut in on each outgoing trunk, as shown.

Sometimes, when the traffic is small, two-way trunks have been used. But this kind of trunk is not as satisfactory as the one-way trunk, so the latter are used wherever possible.

It will be noticed that when a subscriber in the sub-office calls another subscriber in the same office, he uses two inter-office trunks. It is unavoidable with this arrangement. But it does use too much wire for a conversation which is entirely local.

The saving of inter-office trunks on such calls has been secured by means of the switching selector-repeater. It is a device which cuts off the trunk if the call is for a number in the sub-office.

The arrangement of apparatus is shown in Figure 221. It is here assumed for the purpose of illustration, that one thousand numbers have been set aside for this office, but that only two hundred lines are installed. The working of a complete 1,000 lines will be clear from this illustration.

At the left are the two Keith lineswitchboards, with connectors. The trunks from the lineswitch banks, carrying traffic from the subscribers, pass through switching selector-repeaters to outgoing rotary secondary lineswitches. The use of these secondary lineswitches enables a smaller number of trunks between offices to be used.

Each switching selector-repeater consists of two parts united into one working unit, a repeater and a selector. The former is indicated by a little rectangle marked *R*, the latter by a bank symbol and a rectangle marked *S*.

Incoming calls pass from the other office to hundreds selectors (C-selectors) in the sub-office, from

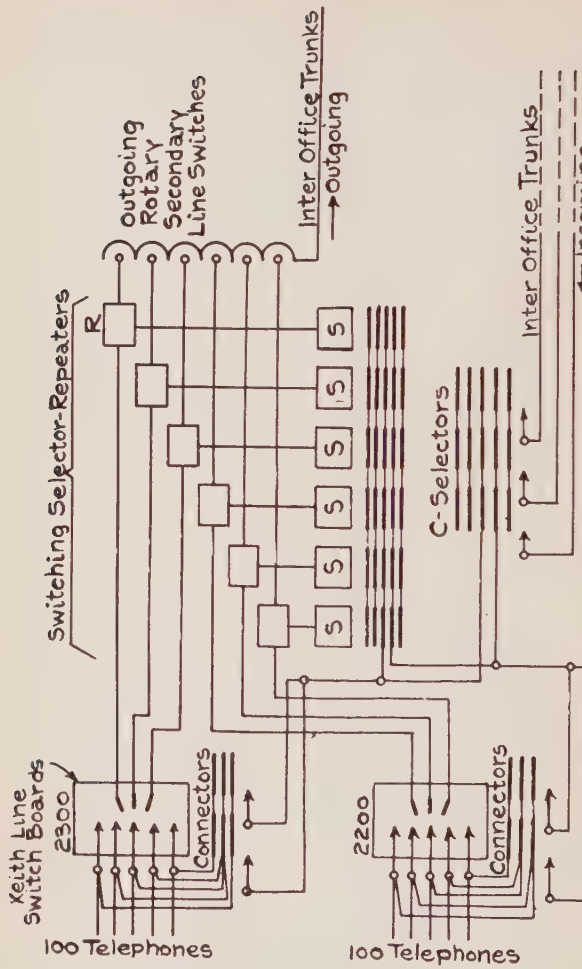


Figure 221.—Sub-office with Switching Selector Repeaters (Link Diagram).

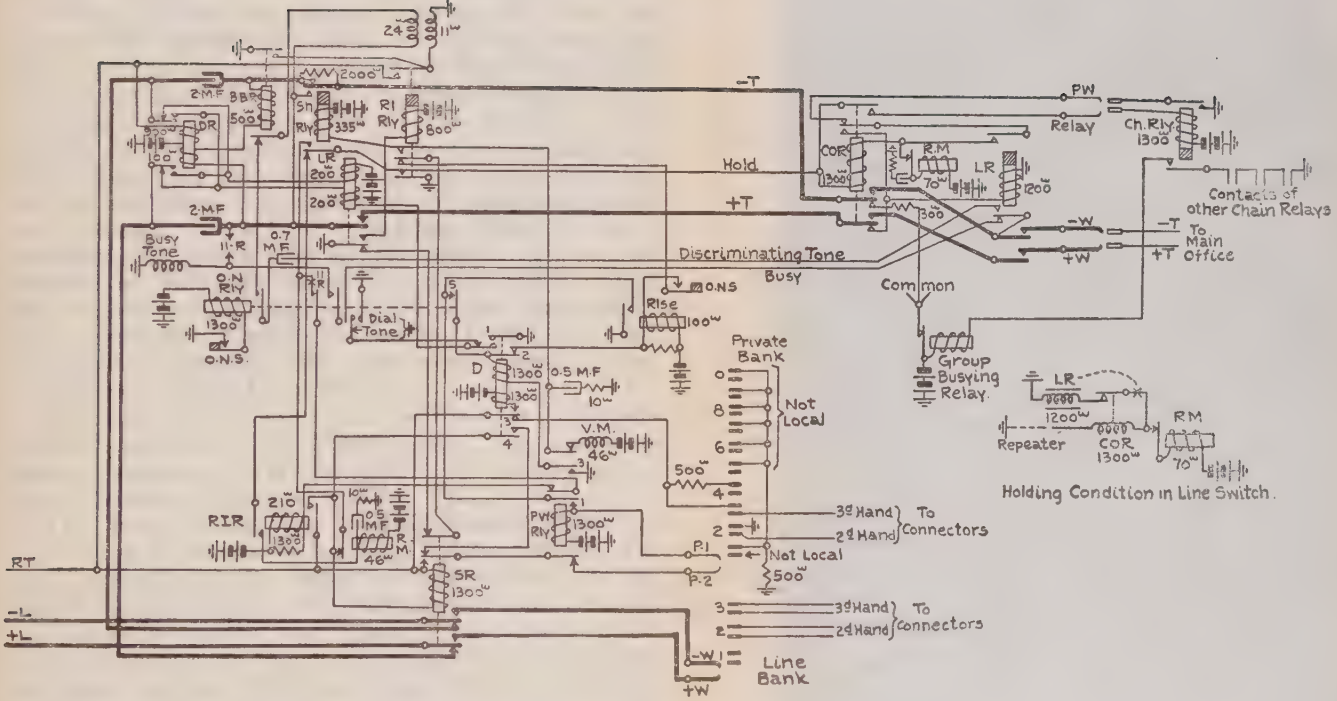


Figure 222.—Circuit Switching Selector Repeater with Lineswitch.



whose banks distribution is made to the connectors of the different boards.

When a subscriber in the sub-office calls, the removal of the receiver plunges in the Keith primary lineswitch, and causes the secondary to take a trunk. While the user is dialing the first two digits, the repeater is doing two things, repeating the impulses to the selectors in the main office, and extending the circuit in that direction, and operating the selector part of the repeater. The wipers are lifted and released according to the number called. If the number is for a telephone not in the sub-office, the wipers of the selector-repeater are released. But if the number dialed is for a telephone in the sub-office, the wipers will be released the first two times, but on the third figure the wipers will rotate in on the level and switch the connection from the inter-office trunk to a local connector, releasing the inter-office trunk, which may now be used by others.

The circuits by means of which this is accomplished are shown in Figure 222. The switching selector-repeater is at the left. The rotary secondary lineswitch is at the right.

The trunk from the lineswitchboard enters at the lower left-hand corner, and passes through the back contacts of the switching relay *SR* to the repeater proper above. The selector parts are grouped in the lower part of the figure as much as possible, while the repeater parts are above. Common parts are more or less between although the two functions are closely interlinked. But since the repeater function is chief, this has ruled in the arrangement. If the reader has become familiar with the repeater circuit, Figure 219, and the selector circuit, Figure 201, he will recognize many of the circuit devices in the selector-repeater of Figure 222. But the

line relay *LR* does double duty, repeating impulses to the outgoing trunk $-T$ and $+T$, and operating the vertical magnet *VM*. The release relay *RlRy* also does double duty, preparing the circuit for the shunting relay *ShRy* and for the vertical magnet *VM*. The off normal springs *ONS* have so much to do that it was necessary to put in the off normal relay *ONRy*. It is operated by one off normal contact, and operates five main springs.

The selector part is provided with two private wipers, *P-1* and *P-2*. The latter is the ordinary private wiper, and has no added function. The former has to do with cutting off the inter-office trunk on local calls.

The operation is as follows. When the repeater is seized, the line relay *LR* pulls up and operates the release relay *RlRy*. The line relay also closes the trunk lines $-T$ and $+T$ to the line switch. The latter extends them to the main office. The release relay grounds the release trunk, grounds the holding trunk to the lineswitch, and prepares a circuit from the back contact of the line relay to the shunting relay *ShRy* and the vertical magnet *VM* in parallel. There is dialtone on the line relay until the wipers have made one step upward.

When the subscriber dials, the line relay repeats the impulses to the trunk as usual. During the impulses, the shunting relay provides a low resistance path for the trunk impulses. At the same time the line relay has been operating the vertical magnet, which lifts the wipers. The first vertical step operated the off normal springs *ONS*. One contact operates the off normal relay *ONRy*, which does a number of things. It cuts off the dial tone, prepares a circuit for the busy tone to the rotary lineswitch, prepares a circuit for the discriminating tone to the same switch, prepares a circuit for

the release magnet (to be used if the call number requires it), and operates the rotary interrupter relay *RIR*. The latter locks itself to the release trunk by a circuit passing through contacts on the *PW* relay, the off normal relay, the cam spring *11-R*, the rotary magnet, and its own contact. The rotary interrupter relay *RIR* prepares a circuit for the rotary magnet which for the present ends at a back contact of the shunting relay.

When the line relay comes to rest, the shunting relay falls back. This closes the circuit for the rotary magnet, which energizes and pulls the wipers onto the first set of contacts of the level selected. Suppose that the call will come back into this office. Let the number be 2325. The level selected is the second. The private wiper *P-1* will rest on ground. This pulls up the private wiper relay *PWRy* whose contacts *1* and *3* close simultaneously. Since contact *5* on the off normal relay is closed, this action of the private wiper relay short circuits the upper 1,300-ohm winding of relay *D*, so that it can not operate, but provides an easy path over which the release magnet *Rlse* energizes and releases the switch shaft. During this time, the release magnet has locked itself by its own contact, and this also locks the private wiper relay. Thus the ground on relay *D* is held at contact *3* of the private wiper relay. When the wiper shaft reaches normal, the off normal springs open and release the off normal relay, which cuts off the release magnet at contact *5* of *ONRy*. This leaves the release magnet in series with the upper 1,300-ohm winding of relay *D* and ground at contact *3* of *PWRy*. Relay *D* now pulls up, its contact *3* closing first, locking it to the release trunk ground. After this, contact *2* opens and the release magnet falls back, also the private wiper relay.

The next digit to be dialed is *3*. This is repeated to the trunk, the wipers of the selector-repeater are also lifted to level *3*. The rotary magnet rotates the wipers in on this level and private wiper *P-1* rests on a wire which leads to back contact *3* of relay *D*. But this is open, because relay *D* is locked up. Hence the private wiper relay can not act. Trunk hunting proceeds as in any selector, such as the one which was described in Figure 201.

When the selector-repeater wipers, Figure 222, find an idle trunk, the switching relay *SR* operates and switches the lines from the repeater to the line wipers $-W$ and $+W$, which rest on a trunk to an idle connector in the third hundred, the 2300. This switching action releases the repeater part of the assembly, which causes the inter-office trunk to be opened and the switches in the main office to be released. Note, also, that the release trunk will not any longer be held by the repeater—it is cut through by way of wiper *P-2* to the connector switch, where the connection will be held as usual.

The key to the special action is in relay *D*. It changes the conditions so that when the wiper shaft goes up the second time, the second digit of the call number will decide the action. Relay *D* always energizes and locks.

Suppose that the first time the wipers rise, they stop at a level which is certain not to be in the local number. When the wipers cut in on that level, the private wiper *P-1* will find a 500-ohm ground. This resistance will not interfere with the operation of the private wiper relay *PWRy*, but the release magnet will not respond. But the upper winding of relay *D* gets enough current to close its contact *3*, which enables the lower 1,300-ohm winding to pull the armature all the way up and

lock. Now the selector stays in this position, while the repeater part of the apparatus completes the connection and permits conversation. The release magnet is cut off by relay *D*, and the switching relay *SR* does not act (this keeps the wipers clear and insures the main connection).

The conditions under which relay *D* may energize when the private wiper *P-1* rests on 500 ohms

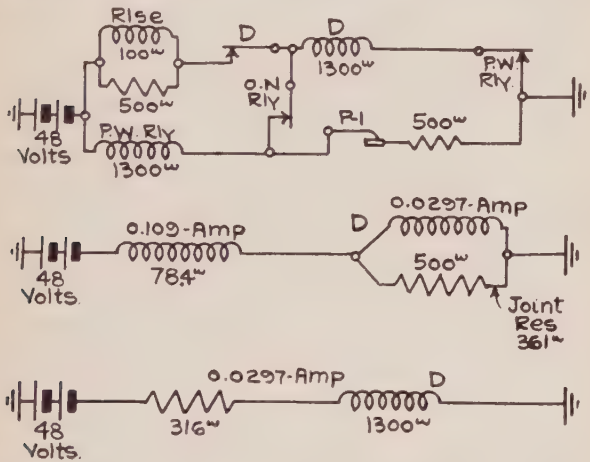


Figure 223.—Conditions Under Which Relay "D" May Operate.

are interesting and are shown in simplified form in Figure 223. At the top are shown all the contacts involved. The release magnet has 500 ohms in parallel with it to kill its spark. The contact on the off normal relay puts the private wiper relay in parallel with the release magnet. The upper 1,300-ohm winding of relay *D* is in parallel with the 500-ohm resistance, to ground. The joint re-

sistance of the three parallel resistances is about 78.4 ohms. The joint resistance of relay *D* and the 500-ohm resistance is about 361 ohms. This permits a total of 0.109 ampere to flow, of which relay *D* gets 0.0297 ampere. If the winding of relay *D* were alone in a series circuit with the battery, it would require 316 ohms to limit the current to the same value. This extra resistance is well within the limit which permits the relay to operate.

CHAPTER XX

LARGE CITY SYSTEMS

An automatic exchange for serving a large city does not necessarily require different switches from those used for smaller places. The same principle of organization of apparatus can be extended to any desired size. There are, however, two considerations which call for a little different treatment, if the city is very large and has a well-established manual system.

The relation between the directory, the call number and the calling device calls for first attention. If the city is large, it will doubtless need the one million line system, which has six digits for calling each telephone. If there are party lines, one more digit may be added for such stations as are on them. There will thus be six or seven digits to be taken from the directory, held in mind, and dialed correctly. Without doubt this is a burden on the mind.

Various devices have been proposed to lessen the mental burden of the large call number. Of them we mention the use of letters and figures on the dial, the use of larger orders of number systems, and the spelling out parts of office names.

Years ago (1910) calling devices were made with a letter as well as a figure in each finger space, with the exception of the last or "O" hole. Thus each number may be represented by a letter, for instance three impulses may be secured by dialing

"C" or "3." Any part of the call number may be expresesd in letters, but usually only the first two are used. Thus the number 323814 will in reality be dialed CB3814, although the subscriber will follow the letters and figures exactly as written. It is only a mental device.

In about 1918, or before, A. E. Keith suggested the use of the twenty-point system. Twenty units of one order would make up one unit of the next higher order. This would call for twenty levels in each selector and twenty levels with twenty points per level for the connectors. The comparison of numbers of digits in the decimal system with those in the 20-point system shows the saving.

	Decimal	*20-Point*
2 Digits.....	100	400
3 Digits.....	1,000	8,000
4 Digits.....	10,000	160,000
5 Digits.....	100,000	3,200,000
6 Digits.....	1,000,000	.....
7 Digits.....	10,000,000	.....

The 20-point system reaches one million lines with five digits, while the decimal system requires six digits. But to go beyond one million lines, even a little, the decimal system must use seven digits, while the 20-point system still needs only five digits. Switches have been made and operated on this system.

The latest endeavor to reduce mental effort is that being put into use by the Bell interests, based on spelling out the first two or three letters of the office name. This means the selection of office names which do not have the same beginning. In an exchange of less than one hundred offices, requiring only two digits to fix the office, "Madison"

and "Main" can not be used, for the first two letters are the same. One or the other must give way.

The number ring of the calling device must have practically the whole alphabet on it. The following arrangement is being used in various installations:

1 2 3 4 5 6 7 8 9 0
ABC DEF GHI JKL MNO PRS TUV WXY

Thus, "Madison 2345" is written "MAdison 2345," in order to indicate that only the first two letters are to be dialed. When dialed, it becomes "622345," since the "M" is in the "6" hole and "A" is in the "2" hole.

There is a further limitation as to office names, because several letters mean the same figure. Hence, "STanton" and "PUllman" interfere. Both are equivalent to "78." But even after all deductions are made, there are plenty of office names left.

In practice, it has already been discovered that mistakes occur because apparently there are two "0" digits, one in the "6" hole, which is the letter "O," the other in the tenth hole, which is the digit "naught." This is complicated by the custom of years, for in calling manual operators the public has been saying "Seven-oh-nine-one" for the number "7091." Those who use this dial must differentiate between the letter and the digit, but this is easy because the letters are black and the numbers red.

The likeness between "I" and "1" must be destroyed by careful choice of type. The likeness between the lower case "l" and the figure "1" must be avoided by never using the lower case "l"

in spelling office names, but stick to the full capital letter "L." With these precautions, the mistakes of subscribers due to these causes should not be many.

To avoid the above complications due to similarities of letters and figures, the following arrangement has been proposed:

1	2	3	4	5	6	7	8	9	0
IP	AJR	BKS	CLT	DMU	ENV	FW	GX	HY	O

It will be observed that "1" and "I" are in the same hole, and that the letter and the figure "O" share the tenth hole. But the natural sequence of the alphabet has been lost so that the user must familiarize himself with the locations of the letters.

The second consideration in the case of large cities is that of inter-office trunking and the retention of old office names. These are really one case.

If we were free to lay out the most economical trunk routes and use such office names as fit the system, there need never be any departure from the usual trunking system described above. A city of any size can be laid out in districts, and a trunking system applied to it which will cost less and give quicker service than any of the complicated systems which have been devised. For ease, operation and quickness of service, with low cost, nothing exists to equal the simple extension of the decimal system of switches and switching. But there are often local conditions which make it almost imperative to retain old, well-established office names. There are conditions in old cities under which cable routes can be changed only at very great cost. For these reasons it seems best to depart from decimal trunking and treat of inter-office

trunks as something apart from the trunking within the office. This gives rise to two distinct parts of the call number, the office name with the code which it represents, and the numerical part which is the number of the line or station.

The local conditions above mentioned often prevent the use of direct trunks between all offices. It may also prevent certain desirable sub-office trunking. Hence, a certain office may be reached from one part of the city by a two digit office code and require a three digit office code to reach it from another part of the city. But the call number in the directory must be the same everywhere. Also, it may later become necessary to change trunk routes, because of changes in telephonic population and in traffic. This calls for some device to direct each call over the route which will best lead it to the desired office.

The Automatic Director.—In the last few years the Automatic Electric Company of Chicago has brought out a device called the "director" which performs the above functions. It registers the entire call number as listed in the directory, directs the call through such selectors as are necessary to lead it to the desired office, and then repeats the numerical part of the number, unchanged, to the switches in that office.

The position of the director in the automatic system is shown by Figure 224. The telephone stations at the left, represented by *T* are connected to the usual lineswitches, which may be only primary or may be primary and secondary. The trunks from the lineswitch banks are led to first office selectors, one trunk to its own selector, as is usual. But between the lineswitch bank and its selector a group of relays is interposed, called the trunk relays. Each group of trunk relays is inti-

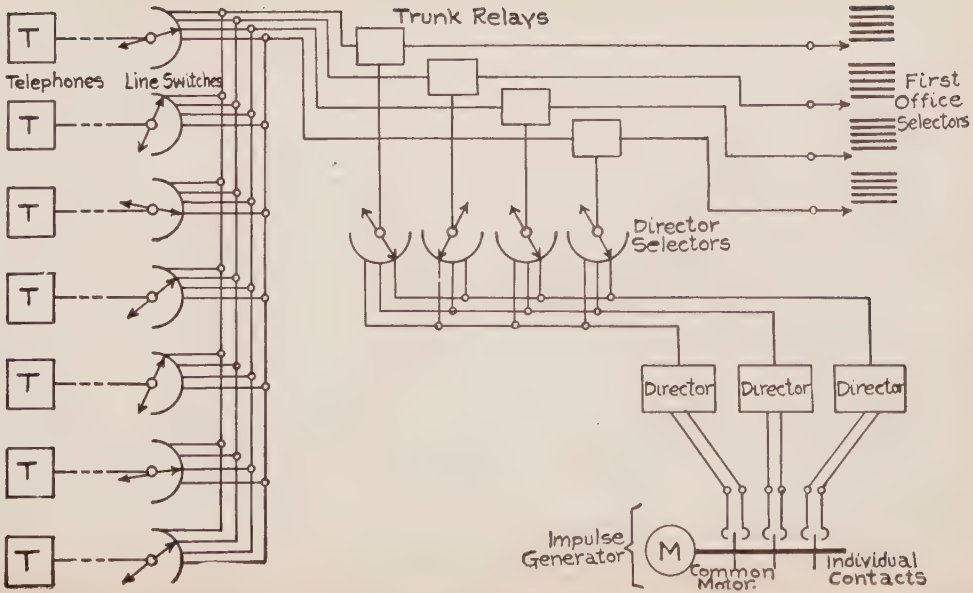


Figure 224.—The Place of the Director in the Automatic System.

mately associated with a director selector, which is a rotary lineswitch adapted to select an idle director. There are fewer directors than trunks, because each director is occupied only long enough to register a call and run it off to the switches.

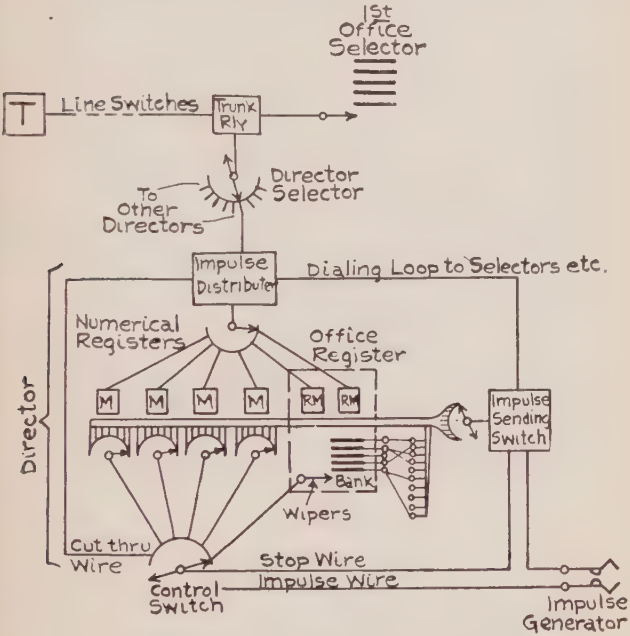


Figure 225.—Director General Plan.

The impulses for the directors are generated by a common impulse generator, consisting of one motor with a shaft and as many pairs of contact springs and cams as there are directors. In reality the impulse generation is individual—the motor alone is common.

The general plan of the director, as to its internal parts and relationships, is given in Figure 225. The impulse distributor is the central organ of the body, for through it pass all wires which connect with the trunk which happens to be in use. But it is only accessory, the registers and the impulse sending switch do the work, and the im-

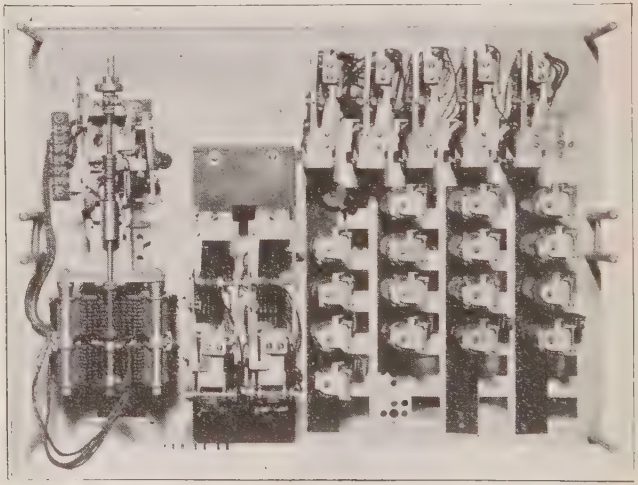


Figure 226.—Director Unit Ready for Mounting.

pulse distributor and the control switch minister to their needs.

This director is shown arranged for a two-digit office name. The two digits of the office name are registered on the "office register," which is a major switch like a connector, with a vertical and a rotary motion. The numerical part of the call number is registered on the four numerical registers, each of which is a minor switch. The control switch is a

rotary lineswitch. The impulse sending switch has a rotary lineswitch for part of its mechanism.

One director unit ready for mounting is shown in Figure 226. At the left is the office register, a major Strowger switch. It has four wipers and two regular line banks, so that the four wipers may be set to any one of 100 positions and give four conductors through the bank.

At the right of the office register is the impulse sending switch, a rotary lineswitch. At its right is another rotary lineswitch, which is the sender control switch.

In the upper right hand corner are five minor switches. One of them is the impulse distributor, the others are the number registers (thousands, hundreds, tens and units).

Figure 227 shows the rear of this unit, with the cross connecting block swung open. On this block are made all the connections between the bank of the office register and the bank of the sending switch, these fix the route along which the apparatus will direct each call to a distant office.

When a subscriber initiates a call, the lineswitches extend his line to an idle trunk. There the subscriber loop terminates in a line relay, which repeats the impulse to the director. The impulse distributor sends these impulses first to the vertical magnet of the office register, then the next digit to the rotary magnet of the same. The remaining digits are sent successively to the numerical registers, one after another. Each of them is a minor switch.

When the last of the two office digits has been registered, the control switch starts the sending switch to feeding impulses to the first office selector. While sending impulses, the wiper of the sending switch is exploring its bank. The wipers of the

Figure 227.—Director, Rear View, Showing Cross Connecting Block Swung Open.

office register are connected through the distributing rack to certain bank contacts on the sending switch. When the wiper of the impulse sending switch strikes the contact to which the first wiper of the office register is connected, a circuit is established which stops the impulses, and moves the control switch to the next contact. The sending switch hurries on to normal again and starts to hunt the bank once more. This time it is stopped by the circuit set up through the second wiper on the office register.

After the office code has been run off, the control switch switches to the first of the numerical registers. Each in turn fixes the number of impulses which the sending switch shall deliver to the switches in the train leading to the called telephone. When all the digits have been run off, the control switch uses the cut through wire to cause the director to be cut off, and the subscriber to be connected directly to the switches leading to the called telephone. He may now hear the ringing induction, indicating that the desired station is being rung, and may converse when the called station answers. The director reverts immediately to common use.

The complete circuits for a simple director are given in Figure 228. It will direct routes to 100 offices (theoretical maximum) and handle four digits in the numerical part of the call number.

A careful notice of the following points will give the reader a clear view of the arrangement of apparatus, and make it easy to follow the action. He will know that at certain points in the process some long wires need not be followed to the end because he knows what they carry or what purpose they serve. These points to be kept in mind are few.

The calling telephone is shown at the left, with the intermediate lineswitches indicated. At the right the first office selector is indicated by its line and release relays. This shows the ultimate direct connection of the line wires and the release trunk straight through from the primary lineswitch to the selectors, and to the repeater, if the call goes out to another office.

The calling subscriber controls registry by way of the line relay immediately associated with the trunk, and an impulse wire. Follow it by relay *2*, the *10-V* springs, relay *L*, to the impulse distributor wiper *Lf*, where it is switched successively from vertical magnet to rotary magnet (office register) and to the various magnets of the number registers. (Thous. Hunds, etc.) Each motor magnet moves the wiper which is below it, *MM-6* moves the thousands wiper, *MM-5* moves the hundreds wiper, etc. There is a series relay and a release magnet *Rlsc* associated with each minor switch (register).

The impulse wire loops through the contacts on the relay *W* only when it is time to permit that relay to release the whole director after the call has been run off.

The director controls the numerical switches in the train (office selectors, M-selector, C-selector, connector) by means of a loop marked *L-1* and *L-2*. Relay *D* is the one which acts as calling device to this train of switches.

All the release magnets of impulse distributer, office register, and the four number registers draw negative current through the 0.3-ohm relay *R*. All are tied to one common release wire which may be grounded by relay *S* and relay *L* (the latter through the off normal springs *ONS* of the office register). But each switch cuts off its own re-

lease magnet by its own *ONS* when it gets back to normal, regardless of the others.

The director selector has no release magnet and remains where used last.

The sending switch and the sender control switch likewise have no release magnets, but are returned to normal by strapped bank contacts and the self-vibrating mechanism of the motor magnet.

The director is as nearly fool-proof as it has been found possible to make it. The displacement of any member of it will not put it out of order. If the director is idle, and a member be displaced, it will return to normal when the disturbing force is removed. If the director is in use when disturbed, it may spoil the call, but when the apparatus is discharged, it automatically erases the effects of the trouble, and serves the next call perfectly. This is a feature common to practically all parts of the Strowger automatic system.

The reader is invited to test the above feature by moving a switch from normal by hand, or by pressing the armature of any relay and then letting it go. This may be tried on the diagram here presented as well as on the actual apparatus.

Let us follow a call through. When the subscriber starts a call, the lineswitches quickly connect him to the line relay of the trunk. This operates, energizes the release relay *RlRy* which grounds the release trunk to hold the lineswitches, removes the chain connection, and connects the test circuit of the director selector. This latter puts the motor magnet *MM-1* and the switching relay *SR-2* in series with each other and battery. But the private wiper is resting on a trunk. If the trunk is busy, the switching relay is short circuited by the ground on *PW* and the motor magnet drives the wipers to the next contact. When no ground

is found, the switching relay pulls up in series with the motor magnet and switches the connection to the director. The director is busied by grounding the private at the switching relay. The impulse wire and the loop to the office selector are extended to the director. The loop, being normally closed in the director, now seizes the selector as usual.

The ground on the private wiper *PW* operates relay *S* in the director. Relay *S* takes the ground off the release wire, opens the chain, opens the windings of relay *J*, and connects the pick-up (which will act if the registration is too long delayed).

Relay *V* is also pulled up by the *PW* ground. It opens certain important contacts.

Relay *S* also connects the dial tone wire to ground, so that dial tone now passes through the vertical magnet *VM*, relay *L*, impulse wire, condenser at trunk line relay and thus into the calling subscriber's loop. The subscriber hears it and knows that the apparatus is ready to receive his call. From the lifting of the receiver to the hearing of the dial tone is rarely more than a fraction of a second, usually before the receiver gets to the ear.

The subscriber now dials a digit. The line relay at the trunk repeats the impulses to the vertical magnet of the office register, lifting the wipers, *W-1*, *W-2*, *W-3*, *W-4*, to a certain level. At the same time relay *L* pulls up and stays up. It operates relay *K*, which connects motor magnet *MM-2* to the back contact of *L*. At the end of the series of impulses, relay *L* falls back and grounds *MM-2*. Then relay *K* releases and *MM-2* falls back. This drives the wipers *Rt* and *Lf* of the impulse distributer to the next point.

The second digit of the call number is now dialed. This time the impulse wire leads to the

rotary magnet of the office register. The relay *K* connects a condenser to the rotary magnet, to absorb the spark. Relays *L* and *K* again co-operate to advance the wipers of the impulse distributer to the next point. The wipers of the office register rest on a set of contacts in the level fixed by the first digit. Thus the first two digits have fixed the number of the desired office. It is possible for the sending switch and the four wipers of the office register to change this into from one to four digits, to set as many selectors.

The wipers of the impulse distributer are now on their third set of contacts.

From here, two separate processes take place at once. The sender sends the digits necessary to trunk to the called office, while the subscriber dials the rest of the call number. It is the arrival of the impulse distributer at its third point that starts the sending switch (by grounding wire *Sw-1*).

The sender may begin its work, or proceed with it, (a) when the office code is completely registered, (b) when each subsequent digit in succession is registered. The complete setting of each number register prepares itself to be used. (It grounds its wire *Sw-Th*, *Sw-H*, etc.) The sender will catch up with the subscriber if he dials slowly, but can not run ahead of him.

We will first follow the registry of the remaining digits. The next set of impulses come over the impulse wire and are delivered by the impulse distributer to the motor magnet *MM-6* of the thousands register. During the time that this magnet is stepping the wiper around, the series relay *E* is energized continuously. The off normal springs are operated with the first step. But the series relay *E* holds the *Sw-Th* open until the end of the impulses. Then relay *E* falls back and the wire *Sw-Th* is

grounded. At this time the single wiper of the thousands register stands on one of its bank contacts, and therefore is in touch with a bank contact on the sending switch (the "stop" bank).

During the registering of the thousands digit, the relays *L* and *K* are energized. At the end of the series they cause the motor magnet *MM-2* to move the wipers of the impulse distributer to the fourth point, where the next series of impulses will be delivered to motor magnet *MM-5* of the hundreds register. Thus this register will be set, and its wire *Sw-H* grounded. This process is followed until all the digits have been registered.

Now follow the sending switch, as it sends the impulses to the numerical switches in the train leading to the called line.

When the first starting wire *Sw-1* was grounded, a circuit was established through wiper *3* of the control switch, impulse generator back contact on relay *B*, back contact on *W*, to relay *D* and battery. The impulse generator is running constantly. Relay *D* will begin to vibrate. This is the starting of the sender.

The first impulse may be partial—not full length. But it may move the wipers, by actuating the motor magnet *MM-7*. But this first impulse which *D* would otherwise give to the loop (*L-1*, *L-2*) is prevented by relay *C*. It is not operated until *MM-7* has moved the wipers onto the second point. Then *C* takes the short circuit off the impulse springs of *D*. This insures perfect impulses from the start.

Relay *C* remains energized during the sending of impulses. It prepares a locking ground for relay *B*. It also pulls up the motor magnet *MM-8* of the control switch, getting ready to move the latter.

Wipers *PW* and *Stop* are moved simultaneously

over their banks. When the Stop wiper strikes ground, relay *B* will pull up and stop *D* from sending impulses. It also releases *MM-8*, which drives the control switch to the next point.

The ground which stopped the sender came from the impulse distributer, wiper *Rt*, over wire *Sw-1*, control switch wiper *2*, office register wiper *1*, cross connecting block, to bank of sender. We have assumed that the digits "542" must be sent to reach the distant office. Hence on this first group, the wipers of the sender have found ground on the bank wire marked *5*, and here the relay *D* stopped sending impulses to the loop.

The operation of relay *B* connects the interrupter contact of the motor magnet *MM-7* to the grounded private bank, so that the sender wipers are quickly brought ahead to the normal position.

The control switch wipers are now on contact two, connecting wiper *W-2* of the office register to the grounded start wire *Sw-1*.

Immediately on arriving at the home position, the sender is started again by the same means as at first. This time it will find ground on the wire marked *4*, put there by *W-2* of the office register. Hence only four impulses will be sent by *D* to the loop.

Likewise the third time around, the sender will cut off at *2*.

In the case being illustrated, there is no fourth digit to be sent. Hence the bank contact for the fourth wiper *W-4* is connected to the fourth cut off lug (*4th. CO*) on the cross connecting block. As relay *B* pulls up at finding ground for the third digit, *MM-8* falls back and drives the control wipers to the fourth point. There wiper *2* connects *W-4* to the grounded *Sw-1* wire, which is thereby extended to the fourth contact in the *1* arc of the

control bank. This makes *MM-8* step the control wipers immediately to the fifth point, before the sending switch has had time to do anything. Thus the fourth digit is omitted.

Wiper *3* of the control switch now switches the impulse generator wire from *Sw-1* to *Sw-Th*. If the thousands digit of the call number has been registered, there will be ground on this wire. This will start the sender again, as has been described. The ground on the "Stop" bank of the sender will this time be fixed by the position of the wiper of the thousands register. All the connections of the number registers to the "Stop" bank of the sender are fixed and are " straight." There is no cross connecting. All digits go through exactly as they were dialed by the subscriber. In fact, the only reason for having these number registers is the almost invariable lag of the sender behind the registering. The subscriber goes ahead dialing, and the sender has to work off the digits as fast as it can. So there must be a temporary storing of these digits. But in straight Strowger trunking, all switches controlled directly by the subscriber's calling device, the switches handle the digits as fast as the subscriber dials them. It is clear to see how the remaining digits in the registers are repeated by the sender.

When the last of the digits has been repeated, the wipers of the control switch are moved to their 9th point. There the wiper *4* finds ground, which it connects to the operating or pull up spring of relay *W*. This relay pulls up and locks itself to the private wiper *PW* of the director selector. Relay *W* cuts off and grounds the impulse wire, which immediately causes the switching relay *SR-1* in the trunk to pull up, extending the subscriber loop to the trunk wires, $+T$ and $-T$, and locking itself to

the release trunk, also closed through. This cuts off all attachments to the trunk, which now passes through as two wires to the connection beyond. The switching relay *SR-1* is legged off the release trunk to hold the circuit.

The release and clearing of the director is as follows. When the trunk was cleared, the line relay *LR* let go and permitted the release relay *RlRy* to fall back. This let the switching relay *SR-2* fall back, cutting off the private wire. The removal of ground from the private wire allows relays *S* and *V* to release at the same time.

The falling back of relay *V* grounds all of bank *1* of the control switch, except the first contact. Hence the motor magnet *MM-8* vibrates itself to normal.

The falling back of relay *S* grounds the release wire of the registers. All of them release their switches, and are cut off, independently, by their off normal springs, when their switches reach normal.

The director is ready for another call.

If the route to the desired number requires only one selector, the 2-digit office code will be sent out as one digit by the sender. In this case, the office register bank contact for the second wiper *W-2* must be connected to the "cut-off" lug on the cross connecting block. Such a connection is shown dotted to a set of bank contacts. It permits the first wiper *W-1* to do its work, but when the control switch is moved to its second point, the ground on its second wiper is extended through *W-2*, *CO* lug, wiper *4* of control switch, to the pull up contact on relay *W*, which immediately switches the connection through and cuts out the director. It is used to direct such undesirable numbers as "11" to a clerk.

If it is desired to permit subscribers to call an assistance operator, such connections are frequently

secured by dialing the one digit "0." The director will then immediately switch through. It is secured by means of a set of springs marked *10-V*, operated by the shaft of the office register when it reaches the tenth level. These springs cut off the impulse wire, and connect together the second and third points on the *Rt* bank of the impulse distributer. When the latter switches to point "two," the *Sw-1* wire is grounded at once. This starts the sending switch, which will send ten impulses, for there is no stopping ground on the bank, until it gets to the permanently grounded tenth point. The *10-V* springs also connected the rotary magnet momentarily in parallel with *MM-2*, so that when relay *L* grounded one it grounded both. This stepped the wipers of the office register onto the first set of contacts. Here the *W-2* wiper gets onto the *CO* lug. When the sender has sent the digit "0" the connection just mentioned will cause the relay *W* to switch the connection through and cut out the director.

If the subscriber dials part of the number and then stops, but does not hang up, the director will be cut out after a reasonable time. This is accomplished by means of a common contact called the "pick-up." It makes a leisurely contact (perhaps one second) at intervals about thirty or forty seconds apart. It takes two of these contacts, with no dialing between, to cause the director to be cut through.

Relay *S* connects the pick-up wire to relay *P*. When the pick-up contact closes, relay *P* closes contact *a*, but can pull no farther. But when the pick-up contact opens, the 1,200-ohm winding assists the 600-ohm winding, and relay *P* pulls clear up and locks to ground at the back contact of relay *L*. If still no dialing is done, the next contact of

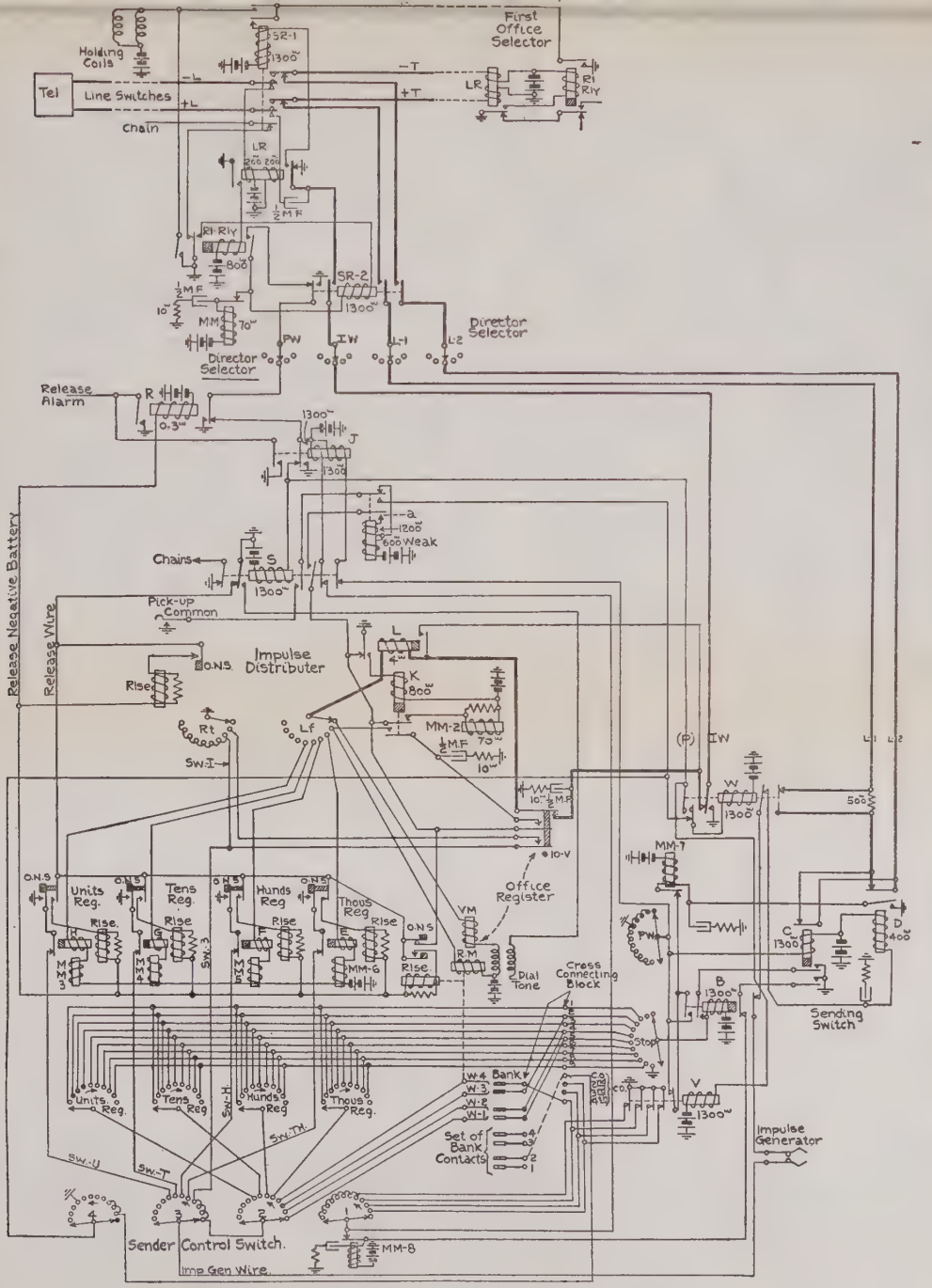


Figure 228.—The Director, Electrical Circuits.

the pick-up will operate relay *W*, which cuts the director out. If the subscriber hangs on, the call will be taken care of by the switchmen.

If the subscriber dials between two impulses of the pick-up, relay *P* will be released by the action of relay *L*.

If the subscriber hangs up at any time before the director has been discharged, the latter will be cut off at once. It happens as follows. Line relay *LR* falls back, followed by release relay *RlRy*. Switch-

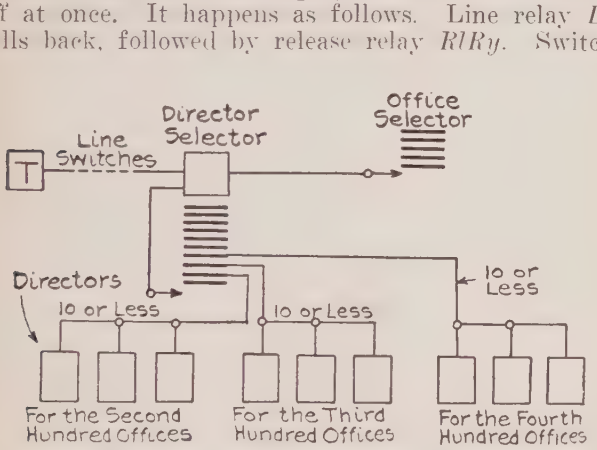


Figure 229.—Plan of Directors for Several Hundred Offices.

ing relay *SR-2* lets go and removes the ground from relay *S*. Relay *S* in falling back grounds the release wire, so that the registers release. Relay *S* also connects the two windings of relay *J* one to the private wiper *PW* of the sender, the other to the first wiper of the control switch. If both of these switches happen to be at normal, *J* will do nothing. But if either is yet away from normal, relay *J* will find ground, will pull up and ground the private contact belonging to this director on the

banks of all the director selectors, so that it will not be seized until both sender and control switch have reached normal. Note that relay *V* was released at the same time as relay *S* and grounded all the contacts in the *1* bank of the control switch, insuring its release.

Directors for Several Hundred Offices.—The director has been arranged for several hundred offices by the plan shown in Figure 229. The director selector is a major switch, having ten levels of bank contacts, with ten sets of contacts per level. The director responds to the first digit of the office code dialed by the subscriber. It then acts as a selector in hunting an idle director in the group chosen by the first digit.

The directors are arranged by groups. Usually the first level is not used. All the directors in the group are arranged to send such digits as will direct the call to offices of a predetermined group. The next group of directors are like the other group, but are set to direct their calls to a different group of offices. As to interior organization, these directors are similar to the one described at length above.

CHAPTER XXI

THE PRIVATE AUTOMATIC EXCHANGE

The private automatic exchange, abbreviated P.A.X., is an automatic exchange which is devoted to the service of one concern or interest. It is primarily for isolated, interior telephone traffic but is easily connected to the public telephone system if conditions warrant. As a carrier of traffic it is far superior to a manual switchboard, for it gives a uniform service, a very quick service, available continuously, day and night, and as good at night as in the day. It binds a business organization together with an efficiency not equalled by other means of intercommunication. It is regarded by many users as an efficiency device.

As to connections with the public system, this has in the past been discouraged for business reasons in some cities, and encouraged (also for other business reasons) in other cities. In either sphere of usefulness, the P.A.X. has unqualifiedly made good.

When isolated, the P.A.X. has relieved the manual P.B.X. of all interior traffic. In so doing it has revealed astonishing facts. One is that the interior traffic has been very seriously interfering with public traffic, between the P.B.X. and the public system. In many cases, the manual P.B.X. operator looked for a great relief from work when the P.A.X. was installed. But her hopes were not realized, for the in and out traffic increased so much after the cut in of the P.A.X. that she had her hands as full

of work as before. In other words, much of the public business had been crowded out by the interior traffic.

The P.A.X. can be trunked to any kind of public exchange, manual or automatic. It lends itself more perfectly to the latter. If trunked to a manual exchange, all calls both in and out must be handled by an operator or clerk, sometimes located in the nearest main office, sometimes on the premises of the subscriber. The operator is called an attendant, and the apparatus with which she works is housed in an attendant's cabinet Much of her duty is to filter and direct the incoming traffic according to the rules of the house. People from outside desire service of the business concern. They know what they want but do not know what department or person should attend to their wants. The attendant directs the call to the proper place. Sometimes she dials it through. In other installations she is given a multiple of the P.A.X. lines, so that she can plug directly into a jack and ring the line manually. Both methods are in successful use. Sometimes there is a partial restriction of outgoing service, some telephones may not call public exchange numbers. A tone is placed on such lines, so that the attendant may refuse to extend the call. The tone has been called "discriminating tone," but lately it has been called "class of service tone," which probably fits the case better.

When the public exchange is automatic, the attendant is still needed for the purpose of guiding calls from the public to the proper department in the organization. She needs not to dial or connect all calls, for many of them can be trunked around her and relieve her of that much unnecessary work. There is usually one general number listed in the directory, which number is dialed by the general

public when calling this concern. In this case there may be some people whose duties require them to call certain departments which are well known to them. They may be permitted to dial directly into the P.A.X. and reach their destination without the help of the attendant. Again, some firms have the general number, and in addition list the call numbers of several departments, so that the general public may dial directly to them without using the

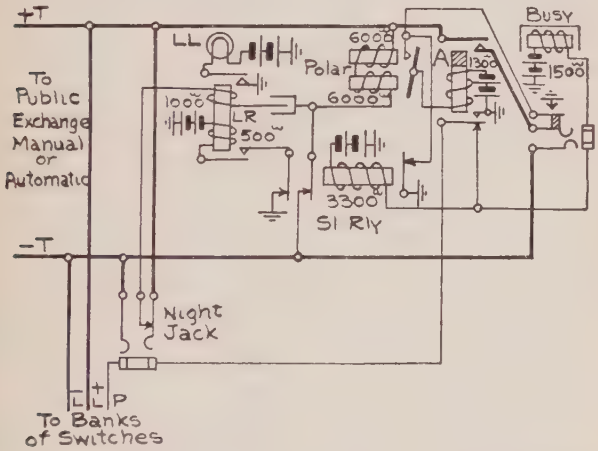


Figure 230.—Trunk Circuit, P. A. X. to Public Exchange.

attendant. This duplicates some features of present manual practice.

It may be best to permit most of the P.A.X. telephones to dial out to the public automatic exchange without bothering the attendant. This is easily arranged. However, if certain stations must be restricted, the apparatus can be arranged so that if such a telephone dials the number used to call the public exchange, the call will be routed to

the attendant, who will handle it according to the rules. Or the call may be given a busy tone, which will discourage further outside calling.

A few circuits will show how the above traffic may be handled. Figure 230 is a trunk between a P.A.X. and a public exchange, either manual or automatic. It is worked by the attendant with cord circuit of Figure 231.

Normally the line voltage which comes from the public exchange holds the polar relay operated against its spring. If the trunk breaks or becomes dead short circuited, the polar relay falls back and makes the trunk busy against calls which come through the automatic switches.

There is a line relay across the trunk, which operates on ringing current and locks up, lighting the line lamp. When the attendant plugs in with the cord of Figure 231, the ground on the sleeve of plug operates the sleeve relay *SlRy* and the busy signal. The sleeve relay unlocks the line relay and clears the trunk of bridges. The polar relay falls back and operates relay *A*, which closes the tip side of the line and grounds the third wire to the night jack and to the private on the banks of switches. Relay *A* gets ground at the auxiliary contact on the jack. The trunk is now a clear pair of wires from the public exchange to the cord in the attendant's cabinet.

The attendant listens like an operator, then plugs into a jack on a P.A.X. telephone line and rings. The sleeve relay *SlRy* of the cord does not pull up on plugging in, but does operate when the ringing key is pulled. It locks to sleeve. Relay *SlRy* closes the tip side of the cord through the supervisory relay.

If the board is large enough to need it, there is a busy test for the attendant. The test circuit is

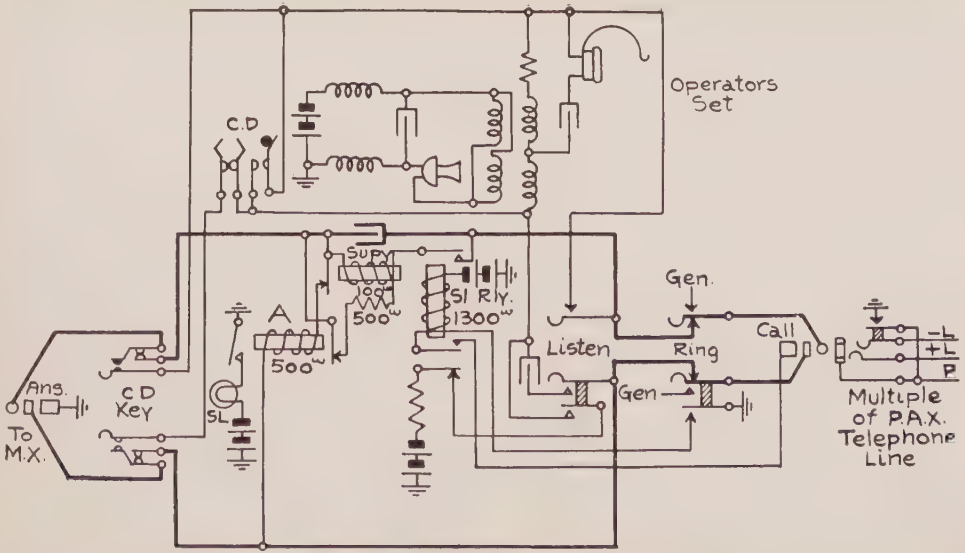


Figure 231.—Attendant's Cord Circuit (P. A. X. to M. X.).

from tip of calling plug through the operator set, the auxiliary contact on the listening key (operated) and a resistance on the back contact of the sleeve relay to negative battery. The test potential is from negative battery instead of ground, for the sleeve of the subscriber's jack is connected to the private normal of the P.A.X. line, which is normally at full 48 volts from earth. If busy, the potential is that of earth, or nearly so. When the sleeve relay operates it cuts off the negative battery connection.

Relay *A* is across the cord. The supervisory lamp *SL* burns until the subscriber answers. The super-

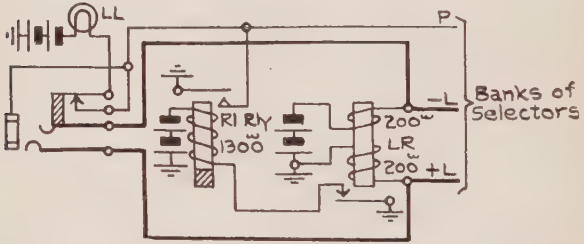


Figure 232.—Information Trunk (P. A. X. to Attendant).

visory relay pulls up, cuts off relay *A* and this puts out the lamp.

Most calls from the P.A.X. are expected to be dialed by the subscribers. They use the same trunks by the route indicated in Figure 230. But if any person desires the help of the attendant, he dials the information number which puts him on the trunk of Figure 232. This trunk is not for through connections—only for information. The attendant asks the caller to hang up. When the connection is ready she calls him. The attendant then uses the cord and the regular trunk, and by throwing her calling device key, dials out through the public

exchange to the called number. Or if the public exchange be manual, she passes the call in the usual way.

P.A.X. stations may be connected up for night service directly by plugging them up into the night jack with a night cord, which is simply a pair of plugs connected by three conductors without attachments.

The regular incoming night service is handled by the circuits of Figure 233. The night cord is used to connect the night bell jack to the night jack of the trunk. Any incoming call during the night

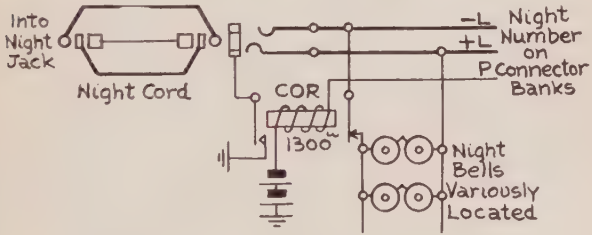


Figure 233.—Night Bell Connection (P. A. X. to M. X.).

will ring all the bells, which are scattered around the plant where they will be most easily heard by the night watchman. He goes to the nearest automatic telephone and dials the night answering number which leads him to the night bell line. His answering stops the ringing. The ground which his connector places on the private wire pulls up a cut off relay *COR* which opens the bell line and grounds the sleeve to the trunk, busying the trunk to others who might call.

Special Services.—The very great flexibility of automatic switches has led to the addition of special services which are not strictly included in ordi-

nary telephone traffic. These services range from blowing fire whistles to opening locked doors. From among them we may mention the following as more important:

1. Code call.
2. Conference line.
3. Watchman's system.
4. Fire alarm.

The code call is used to page certain people whose duties call them to move about from place to place in the mill or factory, but who need frequently to be located. By dialing a certain number, the code apparatus will sound a distinctive signal, known to the person being called, which will sound on many bells, buzzers, or other signals all over the place. The called person will go to the nearest P.A.X. telephone and dial a certain number, which puts him in connection with the calling person, and stops the code. These code calls soon become known to many people, and it is common for one person to tell another that his call is sounding, if the called person happens to be just beyond the reach of the call.

The conference line permits several people to hold a conference by telephone. The person who calls the conference dials each person desired and tells him to meet him on the conference number. Each person hangs up, then comes in on the line again and dials the conference number, which brings them all in on one pair of wires and lets them talk together. Any one may release, make other calls, and rejoin the group on the conference wire. But it should be used not too freely, for it ties up switches as long as the conference lasts.

The watchman's system permits each P.A.X. telephone to be used as a watchman's reporting station, and the routes of the men may be easily changed

from time to time as need requires. To report and record on the clock chart, the watchman needs only to lift the receiver of the telephone which has been attached for service. This records the fact that at the time indicated by the chart, he was at that telephone station. If he needs to talk to the gateman, or whoever is in charge of the night work, he needs only to dial a number and be connected. Many neat devices for emergency services have been worked out and are in use.

Fire alarm systems are defective in that the station pulled is indicated, but not the location of the fire. When the P.A.X. is used to report fire, the person reporting can give the location, which may be considerable distance from the calling station. This saves much costly time. Special outdoor fire calling stations have been made and used, having a P.A.X. telephone, and sometimes a loud signal so as to enable the central office of the plant to call watchmen who may be near. Sometimes the fire number is attached to a central and general fire signal, like a steam whistle. Of the many variations we have not space to write.

Isolated Private Automatic Exchange.—The isolated P.A.X. is practically the same as any small system which has been described. It may be 100 lines, or more than that. But it has all the characteristics of an independent automatic exchange.

The power plant is a vital point in small P.A.X.'s both as to cost and operation. In the very small plant, the power plant seems to occupy a place out of proportion to its function. For this reason, much time and thought have been given to reducing it to the limit of practical size and cost.

CHAPTER XXII

POWER PLANTS

The power plant for a manual central office is not greatly different from one for an automatic office, except the voltage is lower for local connections and is not controlled by counter cells. For toll connections even manual offices use 48 volts, but not regulated.

The former practice of having two batteries of cells, and charging one while using the other has been replaced by the use of one set, which is charged while in use, usually during the day. It is the best practice to run the charging generator during the peak of the traffic load, carrying that load entirely or sharing it with the battery. During light load the battery may be adequately charged.

The power plant consists of the storage battery, charging generators, ringing and tone machines, and a switchboard to carry the switches and fuses for controlling and protecting the apparatus.

There is a tendency for the charging machine to make the exchange noisy by what may well be called "generation noise." This is the rapid undulations in the charging current caused by the process of generation, and is different and distinct from "generator noise" which is the sound heard in the room containing the generator. Generation noise is reduced by proper design of the generator, and by keeping the resistance of the common part of the battery circuit very low. This requires that the

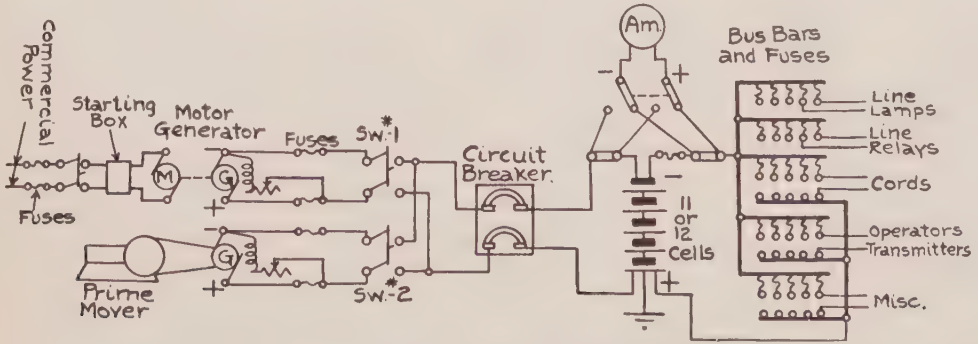


Figure 234. — Power Plant for Manual Switchboard (Elementary).

charging wires shall be kept separate from the discharge wires all the way to the terminal lugs of the battery. The same wire can not be used for charge and for discharge unless it is very large, or the charging current is very weak.

The elements of a power plant, as far as battery is concerned, are shown in Figure 234. The charging apparatus is at the left, the distribution through fuses is at the right. The ammeter is shown with two shunts, one for the charge and the other for the discharge. The voltmeter is not shown. It has a voltmeter switch with taps to each generator, to the battery, and to the bus bars.

Two means for charging are always provided. A motor-generator and a generator connected to a prime mover (like a gas or gasoline engine) are the two shown here. The former is used regularly, the latter is the reserve. But the reserve should be regularly run, so as to know at all times that it is in working condition.

The bus bar is subdivided according to the various classes of apparatus served. Line lamps and line relays form two separate groups. Cords require low-resistance pairs, because they supply the talking current. The fuses are indicating, they sound an alarm when they blow. It is usually done by letting a spring down on a small strip which is connected to a buzzer.

Ringing current is best supplied by motor generator sets, especially if there are no party lines. For the biased bell party line the motor generator is used, but for the harmonic system the harmonic converter (a collection of polechangers) holds sway.

Many small plants use the pole changer for all the ringing. The oldest of them is the Warner, whose circuit is shown in Figure 235. Two contacts, *P-1* and *P-2*, are mounted on the end of an

insulated vibrator, which is kept in motion by a self-interrupting magnet run by a single cell of closed circuit battery. Opposite the contacts *P-1* and *P-2*

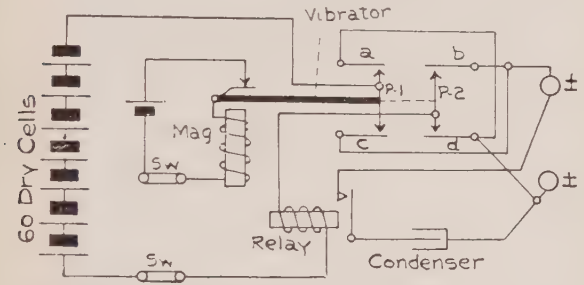


Figure 235.—Principle of Warner Pole Changer.

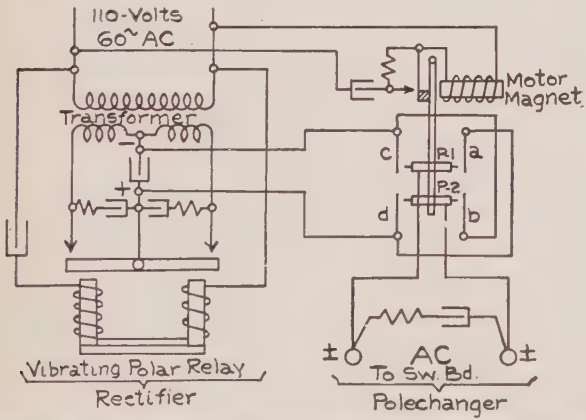


Figure 236.—Polechanger Operating on A. C. (Cacraft Leich).

are four stationary springs, *a*, *b*, *c* and *d*. *P-1* vibrates between *a* and *c*, while *P-2* vibrates between *b* and *d*. Springs *a* and *d* are wired together and carried to the lower binding post. Springs *b* and *c*

go to the upper post. A series relay pulls up each time ringing current is drawn, connecting a condenser across the binding posts. It was capable of producing much noise in a switchboard, but did effective ringing.

A later idea is to run the pole changer on commercial 110 volt alternating current. This requires the rectification of the current before it is put through the polechanger. Figure 236 shows a typical circuit. The rectification is secured by a vibrating polar relay which reverses the connections of the transformer in phase with the alternations in the supply, delivering pulsations of uniform direction. These pulsations are partially smoothed out by the condenser connected across the leads to the polechanger.

The polechanger is almost like the Warner as to circuit. The motor magnet is run directly by the 110 volt supply. In reality the device is a frequency changer.

The busy tone is made by interrupting battery current in the primary of an induction coil, whose secondary is connected to the busy back jack. Figure 237 shows such a circuit with a many-toothed wheel as interrupter. When the operator plugs into the jack the sleeve relay connects the primary to the interrupter wheel. A cam on the shaft of the ringing machine connects the secondary to earth at intervals, producing the customary "buzz-buzz."

A relay interrupted busy tone is shown in Figure 238. The jack connections are as above. The sleeve relay starts the busy back. Relay *IR* at once begins to buzz at high speed, producing the tone. Relays *A* and *B* vibrate each other and send pulsations to relay *C* which connects the tone intermittently to the ring of the jack.

The Automatic Power Plant.—If we should walk

into an automatic central office and begin to look for the power plant, we should be directed to the power board, to a storage battery, and to various charging

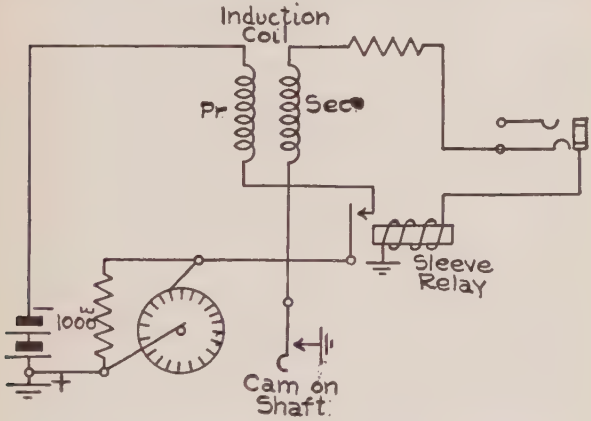


Figure 237.—Busy Back Circuit, Machine Interrupter.

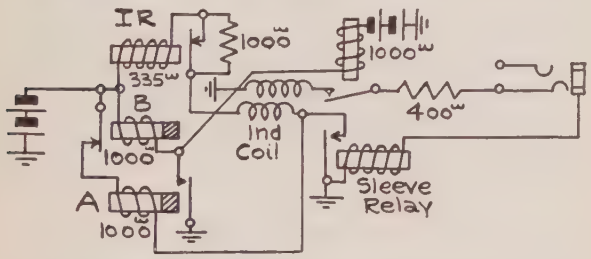


Figure 238.—Busy Back Circuit, Relay Interrupter.

and ringing machines. It has been usual to regard the battery as the heart of the power plant, to which all else is tributary. In a certain sense this is true, for in public exchanges the battery is expected

to carry on the work without recharging for at least twenty-four hours.

But the most conspicuous thing is the power board, of which Figure 239 is typical. Five panels are shown. At the left is the starting panel for the

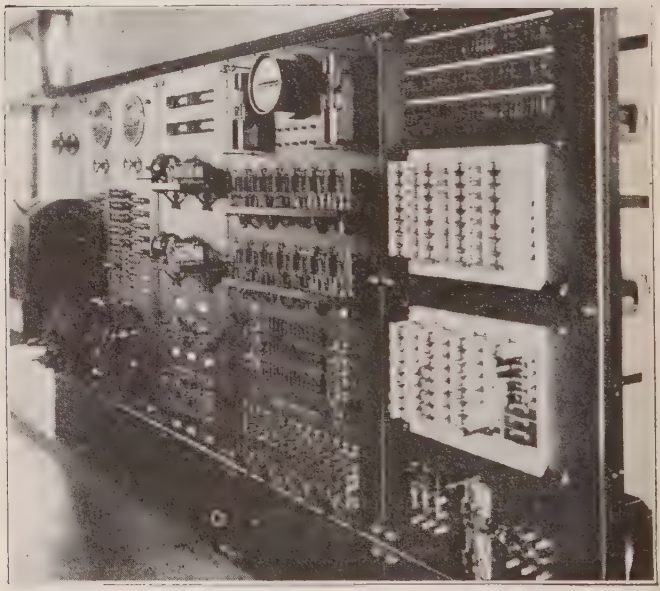


Figure 239.—Power Board (Automatic Exchange).

charging machine. The next panel carries a voltmeter and an ammeter, some fuses, and the counter electromotive force cell switch. The third panel carries interrupter machines and switches. The fourth is the harmonic converter panel, for party line ringing. The fifth panel carries the distribution



Figure 240.—Storage Battery (Automatic Exchange).

fuses and the supervisory relays for the protection of the switches.

The battery charging machines scarcely need to be pictured. They are usually motor-generators, although often the mercury arc rectifier is used with success.

The storage battery is usually in a nearby room, so as to have short leads. Figure 240. There are twenty-five cells, with seven C.E.M.F. cells to control the voltage. These may be seen in the right hand row of cells at the back of the room, with taps coming out between the cells. The voltage limits are 46 to 49 volts.

A typical power circuit for a public automatic central office is shown in Figure 241. It is arranged for manual control of battery voltage on the bus bars, and of the starting and stopping of the charging machine.

The twenty-five cells of the main battery will vary in pressure from about 45 to 55 volts or more. It is better for the uniform operation of switches if the bus bars are held within more narrow limits, such as 46 to 49 volts, the usual range. Formerly end cells were used, because they are more efficient. But the complication of caring for the end cells, with their varying charges, made them more costly than counter electromotive force cells. The latter dissipate some energy from the current being fed to the switchboard but the simplicity of installation and operation more than compensates for the slight waste.

There is a voltage alarm device attached to the bus bars. This gives an audible signal when the pressure falls slightly below 46 volts or slightly above 49 volts. The maintainer then moves the counter cell switch to cut a counter cell in or out.

The charging machine takes many forms. The

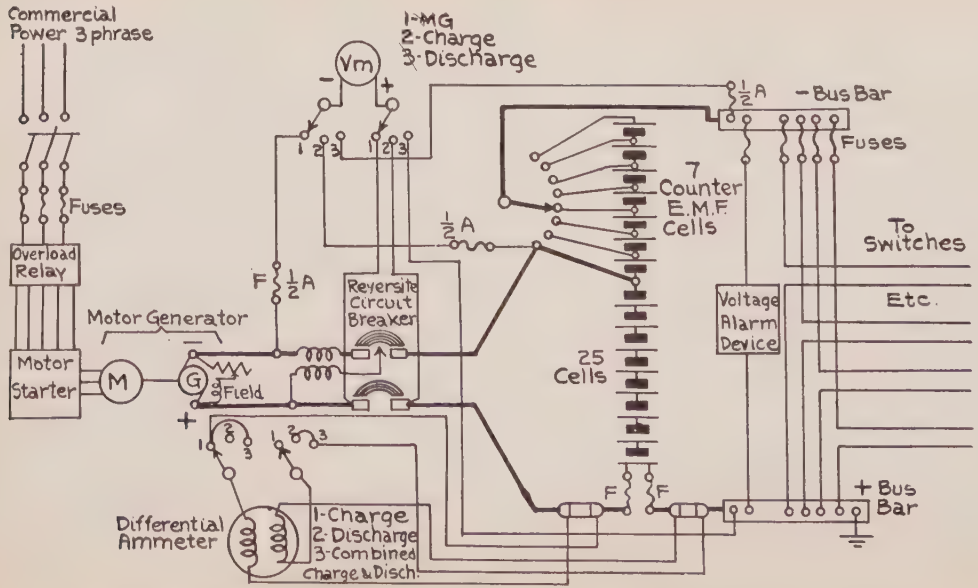


Figure 241.—Power Circuit, Main Office, with Hand Regulation of Voltage.

motor generator is most used, but the mercury arc rectifier has been very successfully used, even up to 50 amperes. The motor is chosen to fit the kind of electrical power available at the central office. It varies from 110 or 220 volts direct current, to the same pressures in alternating single and three phase current. The power illustrated is the last named. When the main power switch is closed an automatic motor starter brings the motor up to speed and cuts it in directly.

A reversite circuit breaker is used as a switch to connect the generator to the battery. There are voltmeter taps on the generator, on the battery, and on the bus bars. The usual methods of cutting the charging machine into service are practiced.

In order to avoid noise on the battery due to the charging machine, the discharge leads are kept separate from the charging leads. The lead to the first stud on the counter cell switch is utilized as one of the charging leads, because it is never used for a discharge conductor at the same time. As soon as charging begins, the rise in pressure forces the cutting in of at least one counter cell.

A differential ammeter is used to secure the value of the current actually going through the battery while charging. It is the difference between the charging current and the discharge current to the bus bars. The moving part of the ammeter is made with two windings. When the ammeter switch is on point *1*, only one winding is connected and that to the charge shunt. Point *2* connects the other winding to the discharge shunt. Point *3* connects both windings, each to its own shunt, so that opposing currents flow in the two windings in the ammeter.

It is most efficient to let the generator carry the switchboard during peak load of traffic. Charge

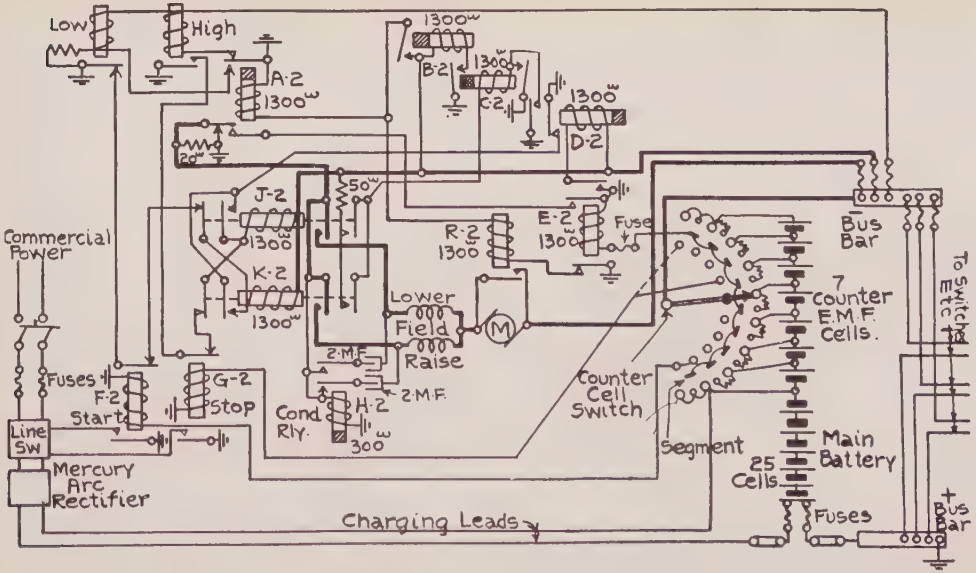


Figure 212.—Power Circuit, Unattended Sub-office, Automatic Regulation and Charging.

current equals discharge current, and the ammeter shows zero. During other parts of the day, when the traffic is lighter, the charging current exceeds the discharge current, and the pointer swings to the side marked "Charge."

The power circuit of an unattended sub-office has considerable automatic apparatus, Figure 242. The counter cell switch is moved by a small motor, and when all the counter cells have been cut out, the charging machine is started automatically, and allowed to charge the battery until a certain number of counter cells have been cut in again. To give the battery an overcharge, which is done periodically, the "stop" wire is moved to the last cell.

The control is placed in charge of two relays, known as the "high" relay and as the "low" relay. The former will pull up if the pressure rises to the upper limit. The latter is normally energized, but will release if the pressure falls to the low limit.

The action of the automatic control can be best understood if we describe what happens when the "high-low" relays act.

When the pressure reaches the low limit, the low relay falls back. This pulls up relay *K-2* (through a back contact on *F-2* and another on *J-2*). Relay *K-2* opens the circuit of *J-2*, gives battery to relay *C-2*, and starts the counter cell switch motor through its "raise" field coil. As soon as the motor has moved the switch arm a little, it touches part of the sector, which it will continue to touch until the arm is nearly centered on the next cell contact. Then it will open. This sector controls the sector relay, *E-2*.

The pulling up of relay *E-2* prevents *R-2* from doing anything, provides a ground for a contact on *A-2*, and pulls up relay *D-2*. The latter provides a locking ground for *K-2*, and also operates *C-2*,

which locks itself and pulls up *B-2*. The latter puts negative battery on relays *A-2* and *R-2*, but only the former can operate. When *A-2* pulls up, it gives direct ground to the "low" relay to pull it up again, and transfers the motor ground from itself to relay *E-2*.

The above condition exists until the motor has moved the switch arm nearly to the next contact, having cut out one counter cell. The sector opens the *E-2* relay, which falls back and quickly does two things, cuts off the motor and applies a dynamic brake by short circuiting the motor armature, by letting relay *R-2* pull up.

The falling back of relay *E-2* lets the other relays fall back in the following order, *D-2*, *K-2*, *C-2*, *B-2*, *A-2*. If the cutting out of one cell is not enough, the above process will be repeated.

The part taken by the condenser relay, *H-2*, is to connect condensers to the motor fields to absorb the arc when the *K-2* relay falls back. When the relay *E-2* fell back, it brought the condenser relay in parallel with the 20-ohm resistance. The condenser relay pulls up and connects the condensers. Being slow releasing, it does not release instantly when relay *K-2* cuts off the circuit, but keeps the condensers on until the spark is gone.

The act of lowering the voltage is very similar. When the bus bar pressure reaches the high limit, the "high" relay pulls up and connects relay *J-2*, which starts the motor in the "lower" direction. The movement of the switch arm produces the same operation of relays as before. But the action of *A-2* this time is to release the "high" relay. These two voltage limit relays ("high" and "low") work on close margins. The "high" relay must be released after each operation, for it would otherwise stay up indefinitely. The "low" relay must be pulled

up after each operation for it can not pull itself up after releasing.

When the last counter cell has been cut out, the start relay *F-2* is energized. This closes the line switch and starts the mercury arc rectifier, which charges the battery. Often it is a motor *generator* which is used to charge the battery. The general principle is the same. During the charging, the pressure of the battery rises. This causes the "high" relay to act and move the counter cell switch up to cut in cell after cell. When a predetermined number have been cut in, the stop relay *G-2* is operated, which opens the line switch and stops the charging. The stop wire is shown connected to cell No. *4*, with a dotted line to cell No. *7*, the latter connection being used to overcharge the battery.

The power plant of a private automatic exchange or P.A.X. is simpler, Figure 243. The main battery has twenty-five cells, but only two counter cells. They are used only during battery charging, which is brought on very frequently. There is only one ammeter, with center zero on its scale, and it is located so as to indicate charge and discharge. There is also only one voltmeter connection for this battery.

When the pressure of the battery falls to the low limit, 46 volts, the low relay falls back. This pulls up the start relay, which locks itself and energizes the closing coil on the remote control switch to start the motor generator. When the speed of the latter is reached, and its voltage built up, the high winding of the self-closing reverse current circuit breaker pulls down the core of the breaker and closes the switch. This connects the generator to the battery and also cuts in two counter cells. The current in the low coil helps to hold the switch

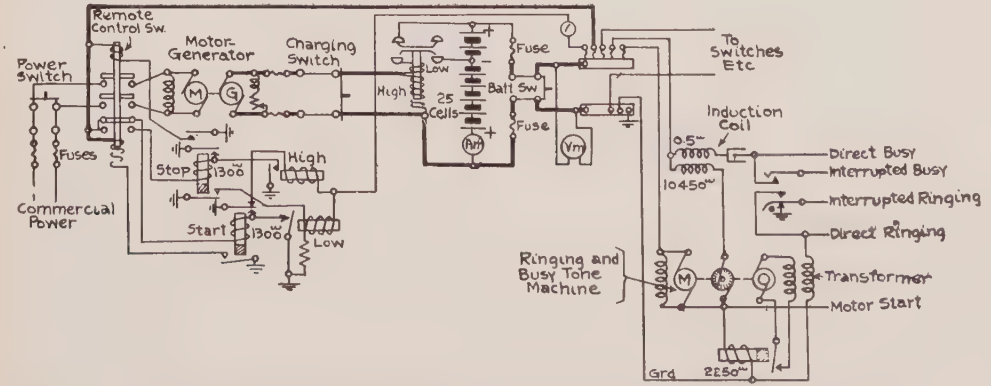


Figure 243.—Power Circuit for Private Automatic Exchange (P. A. X.).

down. The closing of the remote control switch cut off the start relay.

When the bus bar voltage reaches the upper limit (usually 52 volts for a P.A.X.) the high relay pulls up, operating the stop relay, which energizes the opening coil of the remote control switch. Thus the motor generator is stopped. As the pressure of the generator dies down, it becomes less than that of the battery. The reverse current through the low coil of the circuit breaker opposes the high winding, and the switch is released and opened. The pulling up of the stop relay also put a direct ground on the "low" relay and pulled it up. It had remained de-energized during charging. In a similar manner the start relay cares for the "high" relay by releasing it whenever low voltage causes charging to be started.

The ringing current and busy tone are supplied by a little generator which runs by current from the battery. It is started whenever there is need for it, and stopped when the called station answers. The motor part is shunt connected. Normally there is a 2,250-ohm relay in series, so that it can not run, and the loss of current is trifling. The motor start wire which goes to the connectors is connected directly to ground by the latter when seized by a subscriber. This shunts out the relay and starts the machine. The relay also closes the primary of the ringing transformer, which is normally open to permit easier starting. There is a single lug on a slow moving geared wheel which interrupts the ringing.

There is a high speed interrupter which furnishes the tone by interrupting the current in the 10,450-ohm winding of an induction coil. The low resistance winding delivers the tone current. It is interrupted by means of a contact operated by a

number of lugs on the same slow moving wheel which interrupts the ringing.

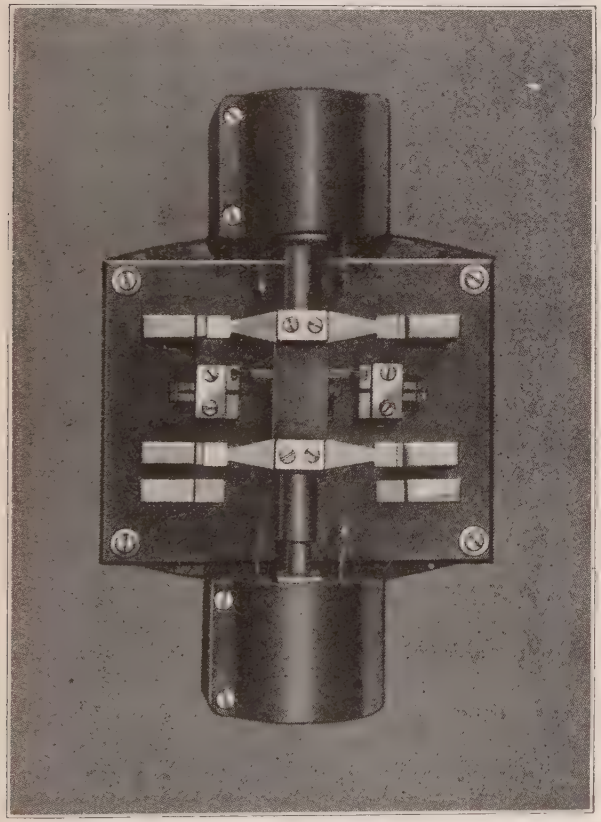


Figure 244.—Remote Control Motor Starting Switch.

Figure 244 shows the appearance of the remote control switch used for starting motor generators. It is shown closed. The two open contacts at the

right are dead—they guide the contact springs and keep them aligned. The little springs in the center are those which operate the start and stop relays.



Figure 244.—Self Closing Reverse Current Circuit Breaker

Figure 245 shows the self closing reverse current circuit breaker. Its magnet is a solenoid, which pulls an iron rod. The adjustments of spring

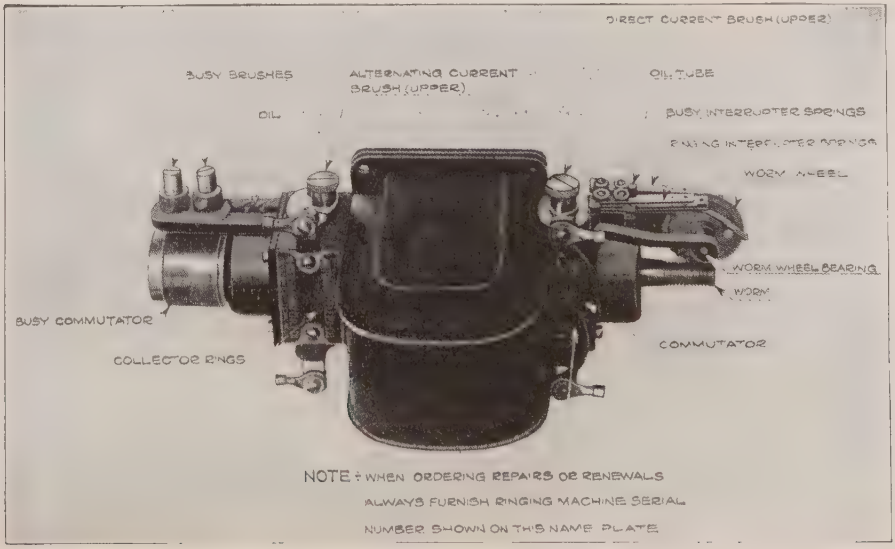


Figure 246.—Ringing Machine.

tension and stroke are made at the bottom.

Figure 246 shows the small ringing machine for P.A.X. The high speed busy interrupter is at the left. The ringing current is delivered by slip rings and brushes at the left of the body of the machine. The motor terminals are at the right. The right end of the shaft is threaded, to run the slow wheel to operate the two interrupters, busy tone and ringing current.

The power circuit of a community automatic exchange, Figure 247, has some features which differ from those just described. Since the C.A.X. may be as large as several hundred lines or even more, closer voltage regulation is used than in the case of the P.A.X. unless the latter is larger than usual. The C.A.X. is therefore equipped with seven counter cells, with automatic control of the counter cell switch to maintain bus bar voltage.

The centering device consists of a slow relay *C* and a set of springs operated by notches in the edge of a disc. These co-operate to cut off the current momentarily from relay *A* or relay *B* to unlock it and enable it to cut off the motor. There is also a set of springs operated by the two pins, *7-C* and *0-C*, which prevent the switch from being driven beyond the limits if for any reason the voltage can not be stopped at either limit.

When the bus bar pressure reaches the low limit, the "low" relay falls back and pulls up relay *A* which locks to ground, pulls up the low relay, and starts the switch motor to "raise" by cutting out one cell. Between points, the notched wheel operates relay *C* and yet insures negative battery for the *A* relay by means of another contact. As the switch arm approaches the center of the next contact, the centering springs open. But relay *C* remains energized for a moment, so that the battery

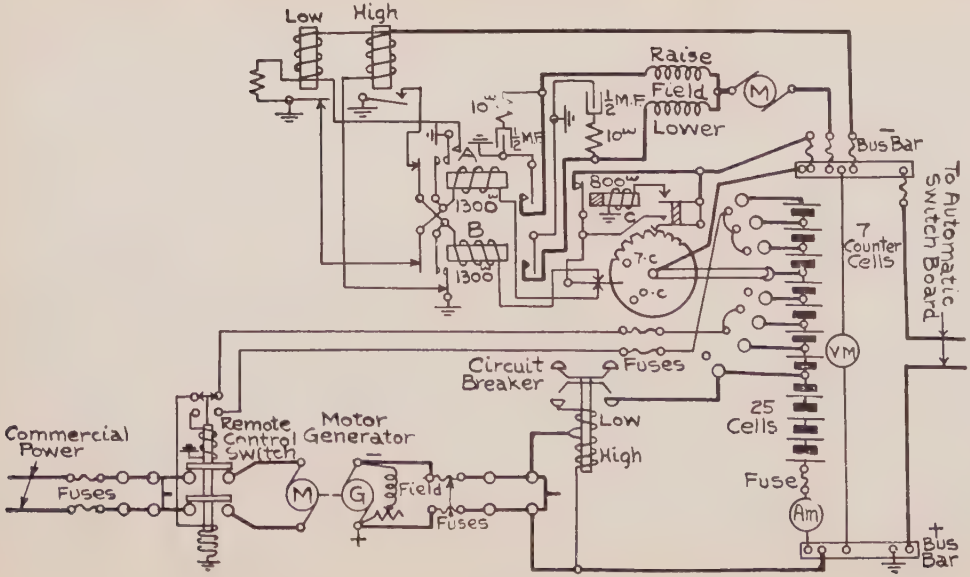


Figure 247.—Power Circuit, Community Automatic Exchange. Automatic Voltage Control and Charging.

connection for *A* is open. This releases relay *A* and thus stops the motor.

If the voltage gets too high, the high relay pulls up and operates relay *B*, which locks to ground and opens the high relay to reset it. Relay *B* also starts the motor by the other field, moving the switch arm to cut in another counter cell. The action of the centering and stopping device is as before described.

When the next to the last cell has been cut out, the charging motor generator is started. The remote control switch coil is given current directly without the use of any intermediate relays. The switch itself changes the connection from its start coil to its stop coil, so that when the charging has raised the battery voltage enough to cause the high relay to cut in five or six cells, the remote control switch will be opened. For overcharge, the tie between the auxiliary studs for the sixth and the seventh cells is opened, so that seven cells must be cut in before the charging stops. Also, if the commercial power in a rural region runs on an intermittent schedule, it may be left this way all the time to insure keeping the battery sufficiently charged.

The power plant of an isolated private automatic exchange has called for perhaps more thought than that of a large central office. The cost of the former has always seemed to be unduly large, and much effort has been put forth to reduce it.

Formerly the battery was large, and could run the exchange all day and perhaps for several days without being recharged. But in recent years the battery has been made as small as possible, and the charging done frequently. It is most customary now to start the charging apparatus automatically when the pressure at the bus bars reaches a low

limit, usually 46 volts. The charge is cut off when it reaches the high limit, 52 volts. This automatic charging has given very good results. The proposal was made to float the battery with a small continuous charge. But it has the tendency either to build up an abnormally high voltage, or to permit the battery gradually to run down.

There is a large choice of charging devices, some of which are very dependent on the character of commercial power available. If direct current is supplied, the rheostat is undoubtedly the cheapest and most satisfactory. But its use is forbidden by the fire underwriters, on the ground that no high voltage may be connected to telephone apparatus. This leaves us with the motor generator, which is very reliable and satisfactory.

For alternating current, we may choose the motor generator or one of a number of kinds of rectifiers. Four classes of the latter are in use, electrolytic, mercury vapor, vacuum tube, and the vibrator. The first named has practically died out. It was too fussy and sloppy, and the aluminum electrodes endured or corroded with no regularity. It was not sufficiently dependable.

The mercury vapor rectifier requires starting apparatus to rock or tilt the tube until the arc is established. This is against it. It is used for unattended public exchanges, but does not find much favor for the small P.A.X.

The vacuum tube rectifier has been much exploited for battery charging, but the difficulty has been to make it satisfactory for the relatively high voltage of the automatic exchange. The generator must generate about 65 volts in order to care for the 25 cells. As far as we know, it is not much used for the P.A.X.

Vibrating rectifiers have likewise failed to make

good for the high voltage of the P.A.X. and the current which must be delivered. Some vibrators have been made and used with success, but their delivery was limited to a fraction of an ampere. But the P.A.X. battery takes from one or two amperes to five or six amperes. In spite of all that inventors have done, the contact points give too much trouble.

The motor generator still stands the best for both direct and for alternating current commercial supply. It costs more than other devices, but it is believed that at least up to date, the service rendered is worth the cost. There is another advantage. The generator may be the same no matter what is the commercial power. This permits the designer of the P.A.X. power plant to standardize everything from the motor generator shaft to the connectors, leaving only the motor to be chosen to fit the commercial power.

CHAPTER XXIII

TESTING AND ADJUSTMENT OF AUTOMATIC APPARATUS

During the thirty-four years in which automatic telephony has been developing, much study has been given to the proper adjustment of the switches and other apparatus. After a long period during which each exchange and each switchman had different methods, the best experience of all was brought together in order to find out which ways of doing things are best. Out of the comparisons came the present standards of adjustments, which are flexible enough to meet any working condition, yet are uniform and sufficiently comprehensive to permit any standard adjusted apparatus to work with any other standard apparatus. There is very little special adjustment left.

We can only illustrate a few of the standard adjustments, and will choose the subjects so as to touch the more important functions.

The Telephone.—In the automatic telephone, the only apparatus which is materially affected by automatic adjustments are the calling device and the hookswitch.

The calling device must give impulses of the correct ratio, at the right speed, and must shunt the talking apparatus during the impulse period.

The impulse ratio is illustrated by Figure 248. It is the ratio between the break in the current to

the total period of the impulse. Current starts to flow some time, as *A*. The first break is at the time *B*, and begins to flow again at the time *1* to be broken again at *C*. Thus from *B* to *C* is the period of impulse, and from *B* to *1* is the break. Fifty per cent and 60 per cent impulses are indicated. Formerly the calling device was set to give a 50 per cent impulse, approximately. But later experiments showed that 60 per cent or 65 per cent break gave better operation of switches, so that now all are made near these values.

The normal speed of impulses is ten per second, giving a period of 0.1 second per impulse. Notice that the total period of the last impulse of any series

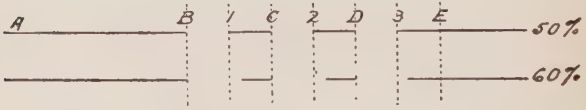


Figure 248.—Impulse Ratios.

ends at the point of time *E*, Figure 248, although the last break ended at *3*. The actual speed of any calling device may vary between nine and eleven impulses per second. But the switches are adjusted to operate at 14 per second—a large margin for safety.

The shunt spring should place a shunt on the talking apparatus during the entire time of impulsing. If care is not taken the shunt may be removed a little before the last closing of the circuit. This produces an extra click, which ought to be avoided.

The above adjustments of the springs of the calling device are secured by bending them to cer-

tain distances. For instance, the space between the tips of the impulse springs is held between 0.022 and 0.032 inch (0.56 to 0.81 mm) apart. They are given a tension such that when one of them is pulled away from the other, the latter will follow until its tip is about 0.020 inch (0.51 mm) past the plane of the opposite surface of the cam. The angular cut of the cam and the tapering of its edges are the chief factors in securing a given impulse ratio, though the bending of the springs has some effect.

The hookswitch must not easily produce a preliminary impulse when a call is being initiated. If the stroke is too short, the rebound may easily open the line circuit after it has been closed, and this has been known to produce an extra impulse, which steps the first selector up to the first level. This may add a digit to the call number, or it may add an impulse to the first digit. By making the stroke long, and closing the line contact early, the preliminary impulse is greatly reduced, and the result is an elimination of the danger of changing the first selector or of affecting the call number.

Central Office.—The central office apparatus consists chiefly of relays and switch mechanisms, with magnets and ratchets. Though there are many kinds of relays, and numerous magnets, there are many common features, so that the matter is relatively simple. It is mostly a matter of multiplication of similar devices, all of which are described and their actions explained throughout various preceding portions of this work. While the numerous pieces of apparatus may give an appearance of complication and intricate connections, an analysis of the circuits will show their real simplicity.

Relays.—The automatic relay is of three kinds, the quick-acting, the slow-acting, and the ordinary.

The first must operate and release as quickly as possible. The second must hold on and not release during a series of impulses. The third has no particular speed requirement—it may act like the ordinary manual relay. The copper collar makes the slow relay. If placed at the armature end, the relay will be slow to operate as well as slow to release. If the copper is at the heel end of the core (away from the armature) the relay will operate much more quickly, but will release slowly. This differential is used in design of circuits. The quick relay may have very few short circuited turns in its winding, for they tend to make the relay act slowly. Also, if a quick relay is cut out of circuit by a dead short circuit, it tends to release slowly. The cause of the slow action is the eddy currents in the copper collar, or the short circuited turns, or the entire short circuited winding. These eddy currents always tend to oppose any change which is going on.

The two main adjustments for a relay are movement of armature and springs and the tension of the springs.

First of all, most relays have a residual airgap of about 0.0015 to 0.009 inch (0.04 to 0.23 mm) in order to prevent the armature from sticking to the pole after the current has been cut off. The line relay has the highest value, because it must not be delayed in releasing at each impulse. The series relay has the least above given, because it must pull up and stay energized during a series of pulsations. The release relay has no residual gap, because it has two rather strong springs and must hold its armature under trying conditions. The residual is given by a small brass screw on the armature. Figure 249.

The movement of the armature and springs is measured by the distance between the armature and

the pole, or between the tip of the residual screw and pole. A thickness gauge is slipped between the two parts and the armature pressed down hard. For instance, the line relay must just begin to break its back contact when there is 0.006 inch (0.15 mm) between pole and armature, and its front contact must begin to touch when the space is 0.004 inch

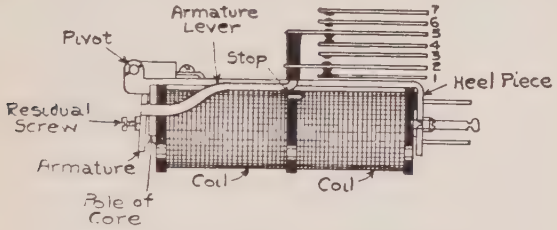


Figure 249.—Typical Automatic Relay.

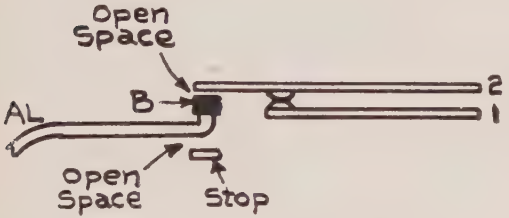


Figure 250.—Back Stop Adjustment.

(0.12 mm). The measurement is made at the pole instead of at the spring contacts because the former is easier and gets the results just as well.

The backstop is adjusted so that there is just an appreciable play of the armature lever, so that the armature spring is known to be free to bear against its back contact with full force. Figure 250.

The armature lever *AL* carries an insulating buffer *B* on its end to move the springs. If there is no back contact, Figure 251, the armature spring bears against the lever until the latter is stopped by the back stop. The position of this back stop is usually given, as for instance, for the rotary interrupter relay of a selector it is fixed at 0.010 inch (0.25 mm), while the two front contacts touch simultaneously at 0.006 inch (0.15 mm). The make-before-break spring combination, Figure 252, has a back contact,



Figure 251.—Springs Without Back Contact.

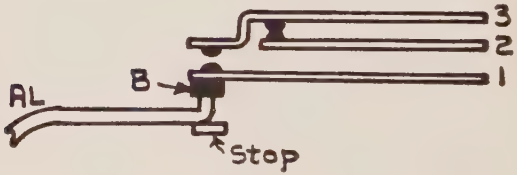


Figure 252.—Make-before-break Springs.

2, but it can not relieve the lever. The front contact *1* presses the lever against the stop. Here again there is a back stop adjustment given. Such a combination is found on the series relay of a selector, for which the back stop must hold the armature 0.012 inch (0.30 mm) away from the pole. The front contact *1* must just touch the main spring *3* at 0.007 inch (0.18 mm) and the main spring must just break away from the back contact *2* at 0.003 inch (0.08 mm).

The force or tension of the springs is measured in terms of the current which is required to operate the relay. It is the direct way to do it, for operating on a given current is what relays are to do. In practice it has been found easier to express the current in terms of standard battery voltage and resistances, than in terms of milliamperes. Also, the tension of the springs is held within limits by making them weak enough to permit the relay to pull up through one resistance, but strong enough so that the relay will not operate through a little higher resistance. For instance, the line relay of a major switch (selector or connector) is made to pull up on 46 volts through 3,000 ohms but not to pull up through 3,200 ohms. The release relay has limits of 5,000 ohms and 5,500 ohms. The series relay of a selector, tested in series with the vertical magnet, has the limits 350 ohms and 450 ohms. These currents are also sometimes expressed in amperes or milliamperes. This kind of adjustment (for spring tension) is called "margining" because it secures a margin or factor of safety in operation.

Switch Mechanism.—The vertical and rotary magnet ratchet actions are fundamentally alike, though the one is linear, the other rotary. For the sake of speed there is a residual cap of brass on each pole, about 0.005 inch (0.13 mm) thick.

When the armature is attracted, the lever moves so that the tip of the pawl strikes directly on the root of the tooth which is to be moved. If it strikes to one side or the other there will be a sliding movement which will unduly wear the pawl and ratchet cylinder.

The armature must be stopped by striking on the poles of the magnet. The force is so great near the end of the stroke, perhaps 20 or 30 pounds (9

to 14 kg), that if the pawl be permitted to take the force of the blow, the ratchet parts will be speedily worn out. The magnets can take it safely. They must be evenly adjusted, so that the armature hits both with equal force. Figure 253 shows the vertical magnet attracted. In this position there must be a little play in the shaft, to insure that the pawl is not wedged between shaft and lug (*pawl stop*). Yet the pawl stop prevents the shaft from being tossed up more than one step at a time.

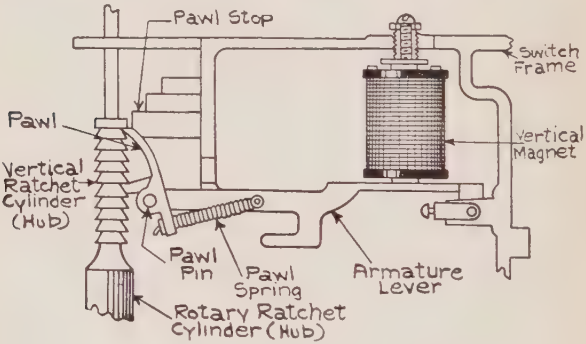


Figure 253.—Vertical Magnet Ratchet.

The rotary magnet and its ratchet are similar in principle.

The wipers must have a certain shape, Figure 254, in order to make good contact with the bank contacts and yet wear a long time. The line wipers (shown here) must clear each other at the tips by about 0.015 inch (0.38 mm) because they carry the full battery voltage. But private wipers, which have both springs electrically connected together, may have the tips in contact. The pressure of the wipers is regulated by the thickness and mat-

terial of which they are made, and by the bending. It is tested by pulling one wiper away from the other and noticing how far the latter follows. It should follow about 0.118 inch (3 mm).

The final test of a switch is its ability to perform at a higher speed (14 per second) than is used in exchanges (9 to 11 per second), and under line conditions more severe than exchanges impose. The two extremes of line conditions have been found to

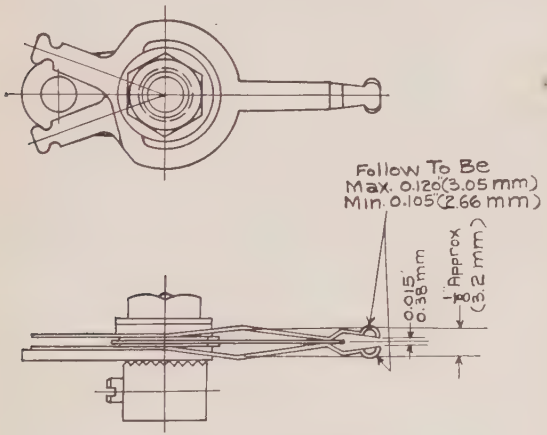


Figure 254.—Line Wipers.

be a high resistance line with no leakage, and a line of zero resistance with heavy leakage. The former causes the line relay to be de-energized very much of the time—it is quick to fall back and slow to pull up. This gives heavy impulses to the magnet and series relay, but short impulses to the release relay. It is a severe test on the latter. The zero line with a low resistance leak causes the line relay to remain energized very much of the time, giving

light impulses to the magnet and series relay and heavy impulses to the release relay. This tests the magnet and series relay, for if the impulses be too short, the series relay will usually let go between pulsations and switch to the next function.

All numerical switches should stand the test if the loop is 1,200 ohms with no leak, and zero loop with 20,000 ohms leak. Another adjustment can be given so as to make it meet 750 ohms loop and 15,000 ohms leak.

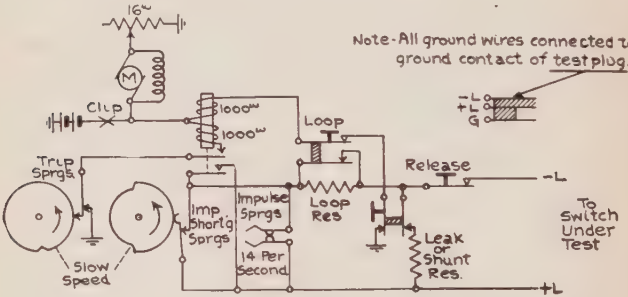


Figure 255.—Impulse Machine for Testing Switches.

The complete switch is tested conveniently by means of an interrupter machine, often called the "varying machine" because it varied the line conditions while testing. It consists of a motor-driven contact maker, arranged to run at 14 impulses per second, and give nine impulses followed by a period of rest with the impulse springs short circuited. A set of push buttons permit the tester to give the high resistance loop test, or the leakage test, or release the switch. The circuit is arranged to plug into the test jack of the switch under test, while negative battery is obtained by one wire which is

clipped onto any convenient terminal carrying battery.

The circuit of an impulse machine for testing switches is given in Figure 255. The motor is adjusted to the standard test speed (14 impulses per second $\pm 1/3$ impulse) by means of a small resistance. The impulse springs are operated directly by the motor shaft. The large cams are geared down to a very much lower speed. One of them is cut so as to keep the impulse springs short circuited except for time enough to deliver nine full impulses. The other has a notch placed so as to permit its spring contact to open at the beginning of the nine impulses. The relay exists for the purpose of insuring that even the first impulse will be a perfect one.

The tester clips the set onto battery. He then plugs into the test jack of the switch to be tested. The motor starts at once. The switch is seized at once, but no impulses given to it because the relay in the test set keeps the impulse springs short circuited.

When the tester presses the "Loop" key, it takes the short circuit off the loop or line resistance and opens the pull down winding of the relay. When the notch in the cam comes around, the trip springs open and releases the relay. This takes the short circuit off the impulse springs, which deliver nine impulses before cut off by the impulse shorting springs. The tester can release the switch by pressing the release key, opening the line.

Nine impulses are used instead of ten because sometimes switches toss the shaft up more than one step at a time. This is true if the pulsation delivered to the vertical magnet is not strong enough to carry the pawl firmly against the pawl stop to lock it, or if the adjustments are not perfect. Thus

the tester can observe both a shortage and an excess of steps.

If the tester presses the "Shunt" key, it places a leak across the line, and likewise prepares to release the relay.

The switch can be tested with high resistance line and low resistance leak at the same time, but it is not done, because these two conditions tend to offset each other and no information is gained.

If the relays and magnets have been properly adjusted, the complete switch almost always meets the impulse test with no other change than a little strengthening or weakening of the magnet spring (to draw the lever back each time).

CHAPTER XXIV

TOLL

Toll connections may be defined as those for which people pay. But it really includes the factor of distance, being regarded as those connections made between different cities of towns. The division between "local toll" and "long distance toll" is often made, the former being connections between nearby places, perhaps 100 miles apart, and the latter connections involving the use of a system of toll lines connecting the more important cities of the country.

The old basis of toll calls was the conversation between two specified persons. This today is called "particular party" calling. A reduced rate is charged for "station-to-station" calls, in case any person at the called station will do. Night rates are lower than day rates. A messenger fee is added if necessary and authorized by the calling party.

Good toll service requires low transmission loss in lines and apparatus, and quiet talking condition. The former is secured by using low resistance wire (No. 10 B&S copper and larger for open wire lines), low capacitance between wires, high insulation resistance, and few bridges across the line, and these of high impedance. When the conductor resistance must be high and the mutual capacitance large, as in cables, Pupin or other loading is used, also repeaters made of vacuum tubes. The subscriber's telephone instrument must also be good, not only strong but accurate in handling speech. There is much room for improvement in clearness.

Quiet talking conditions are secured by carefully balancing the lines, in the offices and outside, so

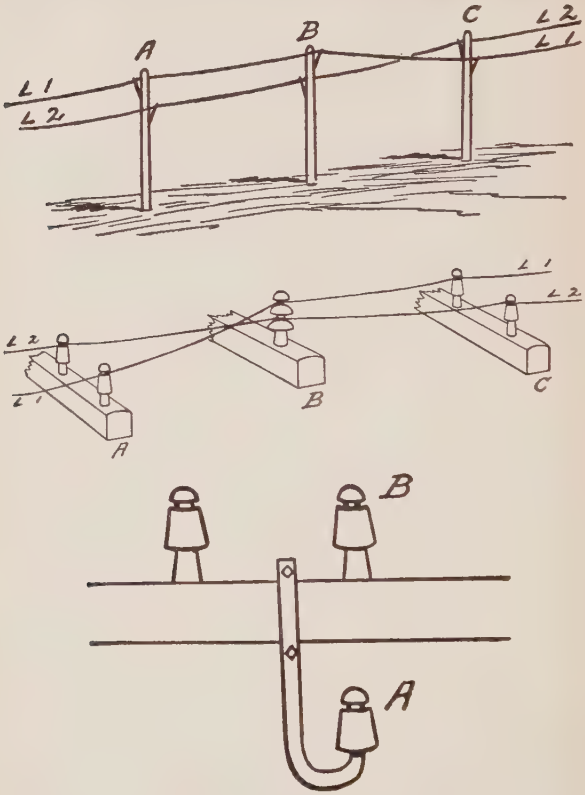


Figure 256.—Running Transposition, Three Methods.

that no disturbance comes onto them. This means careful transpositions, and equal insulation from ground for both wires.

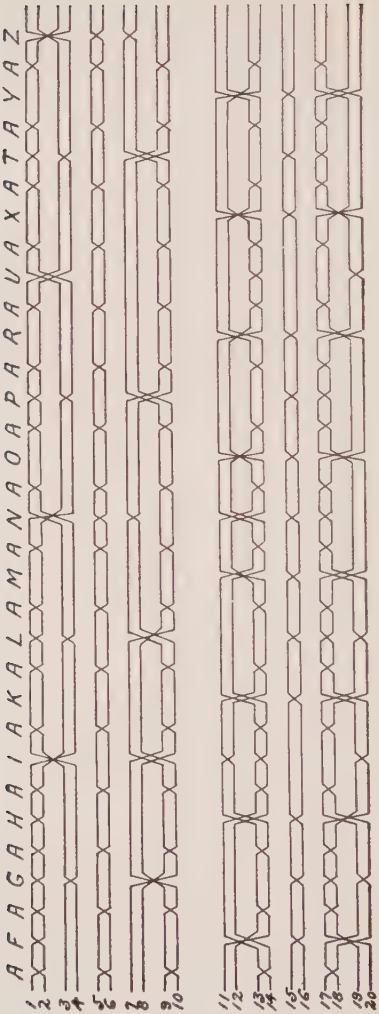
Toll lines require much more careful transposition than subscriber lines, because they are longer and more exposed to inductive influences. Both the scheme of transpositions and the means used for getting one wire over the other must be carefully chosen. The running transposition has shown itself to be the best for simplicity, strength and insulation. It is shown in three forms in Figure 256. The running transposition for a single circuit bracket line is shown at the top. Pole *A* is the same as the rest of the line, with the top bracket on the back side of the pole. Pole *B* is reversed so that the top wire *L-1* is brought to the front and *L-2* to the back side. Between poles *B* and *C* the vertical transposition takes place.

The running transposition for a line on cross arms requires only one insulator, as shown. Care must be taken to pull up the wire *L-1* rather tightly between arms *A* and *B* so that it will not sag onto the other wire. The same is true between the other two arms.

If it is desired to keep the line wires on separate insulators, the underhang bracket should be used. It gives an excellent insulation between the two wires of a circuit and is now used almost exclusively by the larger companies.

A scheme of transposition for four cross arms and eight phantom circuits is shown in Figure 257. The letters at the top and bottom of the figure represent pole marks. A common distance between marked poles is 1,300 feet, about a quarter of a mile (about 0.4 km). The top arm is numbered from *1* to *10* and the other arms follow in order. It will be noticed that the longest run between transpositions is two miles (3.25 km).

In rural and small town regions the toll lines are usually run into the local board as if they were


A F A G A H A I A K A L A M A N A O A P A R A U A X A T A Y A Z
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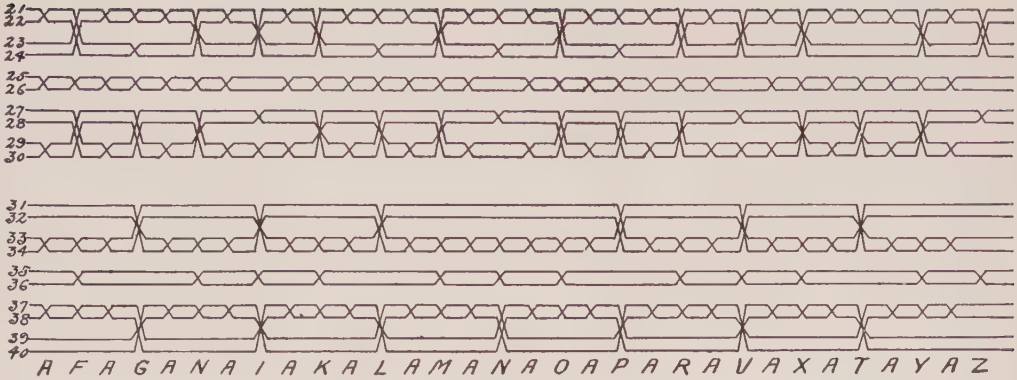


Figure 257.—Transposition Scheme, Forty Wires.

magneto subscriber lines except that they are metallic, seldom earth return. When they are connected to a grounded line, a repeating coil must be used to keep the connection quiet. Way stations at small places along the line are bridged across the line permanently or are fitted with cut-in jacks like those shown in Figure 258. If the agent plugs into the center jack, the bell will be cut off and the telephone bridged without opening the line. If he plugs into the right hand jack, the agent's telephone will talk east, leaving the bell to receive

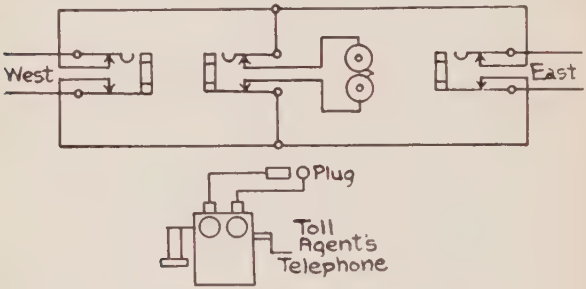


Figure 258.—Toll Station with Cut-in Jacks.

signals from the west. Code rings are used, as on a rural or farmer's line.

If the exchange is larger and the toll business sufficient, a separate toll board is used. This board handles the toll lines on a magneto basis, though line lamps are often used (with locking line relay). The toll to local trunks depends on the character of the local exchange. Most of them are common battery, with the current supply for the subscriber furnished by the toll board, or in large exchanges by the local office. The trunks run from the toll board to the *B* board in each office, and give direct

supervision to the toll operator. It is best to keep the trunk free from ground connections while talking. Such a circuit as is outlined in Figure 259 serves the purpose. Normally the relay across the toll cord is de-energized and the lamp dark. When the operator plugs into the trunk to the local office, battery current from the battery in the latter passes over the trunk and pulls up the cord relay, lighting the lamp. When the local subscriber an-

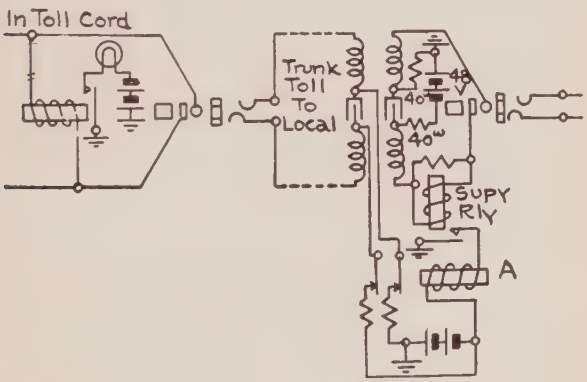


Figure 259.—Toll to Local Trunk (Skeleton).

swers, the supervisory relay energizes relay A, which cuts off the battery from the trunk. The toll cord relay falls back and puts out the lamp. During conversation the trunk is clear of grounds.

More detailed study of toll to local connections is given under automatic switching.

TOLL CONNECTIONS (AUTOMATIC)

Toll connections, with regard to switching, may be considered in three divisions, recording toll, service toll, and the switching of toll lines. These will

be treated briefly, giving only examples of how these connections are handled, without giving the many modifications which are possible and are sometimes used.

Recording Toll.—When a subscriber desires to talk to some person in a distant city, it is necessary for him to call a clerk who can record his desires, give information about the services available, and pass the record of his call to the line operators who actually do the connecting. Such a clerk is usually called a "recording operator," although she seldom connects or operates, but serves only as a clerk.

In the telephone directory is a number which is assigned to the recording toll operator. Formerly it was the single digit "O." Frequently the "O" digit on the calling device dial had the words "Long Distance" around the figure, and it was not necessary to use the directory. In that case, the top level of the first of the office selectors had trunks which led to the recording desk. The present practice is to use three or four digits to call the toll recorder, which permits a greater number of miscellaneous numbers and clerks.

The call for recording toll passes through the usual selectors and a repeater until it arrives at the toll recording desk or board by means of a group of relays. Figure 260. In the repeater the connection is held by means of a line relay *LR* and a release relay *RlRy* in the usual way. In addition to grounding the release trunk *RT* the release relay puts a weak interrupted ringing generator current on the negative line —*L* so that the subscriber hears it and thinks that a bell is being rung. Though a bell is not ringing, the recording operator is being signalled in the following way.

The action of the line relay *LR* closes the negative winding of the back bridge relay *BBR* to the

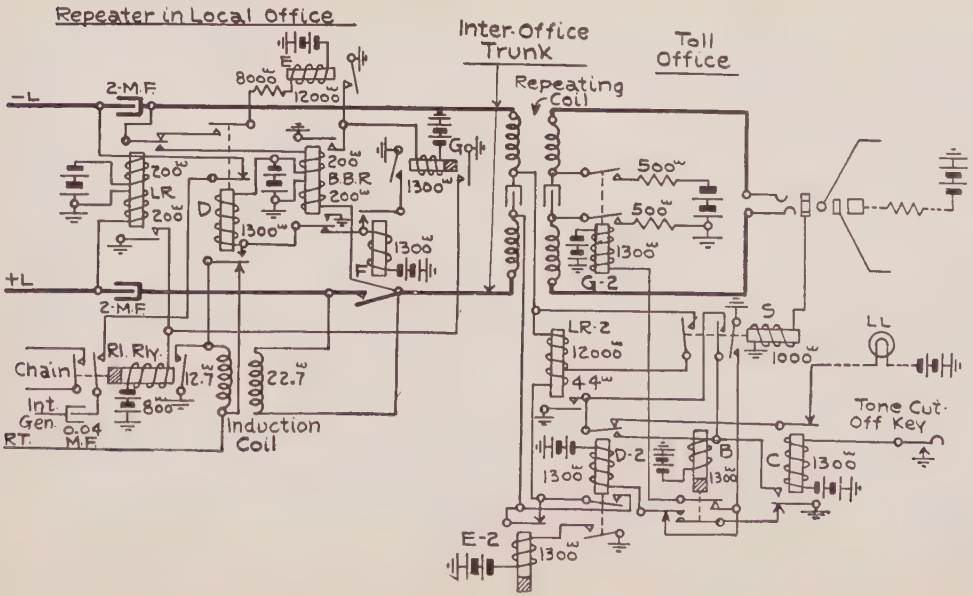


Figure 260.—Recording Toll Circuits.

negative wire, so that the latter sends current through line relay No. 2 (*LR-2*). The latter is high resistance and will not permit the back bridge relay to operate.

When the second line relay *LR-2* pulls up, it lights the line lamp *LL* and attracts the attention of the operator. She inserts the plug of a cord which she has. The sleeve of this cord carries negative battery and operates the sleeve relay *S*.

The sleeve relay, on operating, energizes relay *B*, which switches relay *D-2* over to a ground on the back contact of relay *C*. Relay *D-2* then pulls up and cuts off the line lamp *LL*. Relay *D-2* also safeguards the circuit of *LR-2* while operating relay *E-2*.

The sleeve relay also shunted out 12,000 ohms of *LR-2* which causes the back bridge relay *BBk* to operate. This gives the operator control over the release in case the subscriber should hang up, and opens the way to her to hear a discriminating tone, if such should be present on the release trunk.

The control of the release is secured by relay *G*, which grounds the wire from the release relay. The discriminating tone is uncovered by relay *D*, which takes the short circuit from the induction coil in the release trunk. The secondary winding is in series with the positive line to the repeating coil. Relay *D* also cuts off the ringing tone and prepares the circuit of relay *E*.

The discriminating tone is put on the release trunk if the subscriber is not to be given toll service. The conditions are applied at the line-switch and are repeated to the incoming trunk at the recording board. When the operator has satisfied herself as to the tone, she erases it by operating the tone cut off key for a moment.

This pulls up relay *C* which holds relay *B* but permits relay *D-2* to fall back. Relay *D-2* opens the line and let relay *E-2* fall back. The latter closes the line again. During this brief opening of the line, the back bridge relay *BBR* released and operated relay *F*, which closes a shunt around the secondary of the induction coil and locks itself to ground at relay *G*. When the operator hears the tone disappear, she releases the key, whereupon relay *C* lets go, relay *D-2* operates again, and all is as before except that relay *F* is locked.

Conversation takes place through the repeating coil. The cord has the usual current supply and supervisory signal used for common battery manual boards.

If the subscriber hangs up before the operator pulls out the plug, *LR* falls back, but *RlRy* does not, being held by relay *G*. Relay *D* is also locked to ground at the release relay and holds relay *E* to the back contact of the line relay *LR*.

The releasing of *LR* cuts out the 200-ohm negative winding of the back bridge relay *BBR* and puts in place relay *E* with a total of 20,000 ohms. Relay *E* responds and holds relay *G* energized. Relay *LR-2* falls back, which causes relay *B* to release. In falling back, relay *B* transfers the circuit of relay *D-2* from ground at *C*, to ground at *S*, so that relay *D-2* does not release. The releasing of relay *B* operates relay *G-2*, which puts battery on the tip and ring of the cord circuit, and operates the supervisory signal. The operator can then pull down the cord.

Service Toll Connection.—The toll ticket which has been made out by the recording toll operator is passed by some means to the toll line operator who operates the line or lines necessary to reach the distant city. She calls the distant exchange,

takes care of all the necessary preliminaries, and when all is ready, calls the subscriber who placed the call and informs him that his connection is ready. The connection from the toll line to the calling subscriber will now be discussed. The operator in the distant city is using the same connection if it has an automatic exchange and it is of the same kind.

A general idea of the train of switches used may be obtained from Figure 261. The toll line is connected to a toll service trunk by means of a cord circuit. The toll service trunk runs to an office selector of the usual type. There are as many office selectors as needed to handle the call number and reach the desired office. From the banks of the last order of office selectors there are direct trunks to the called office, where they terminate in *M*-selectors. These thousands selectors are of the ordinary type. But the hundreds or C-selectors are different, for they supply battery current for talking, and also perform other functions. This kind of selector has been called a "transmission selector." Beyond this selector is the connector, which also is unusual. When used for toll purposes, it furnishes a clear pair of wires, but when used for local calls, it is a current supply of the usual kind. Usually there is a reduced number of combined toll and local connectors for each 100-line board, perhaps two, or three, or four of them. They are the last choice for the local C-selectors, but the first and only choice for the toll selectors.

The circuits used from the toll line to the subscriber's telephone are shown or outlined in Figure 262. The selectors in the toll office are omitted, for they are like other selectors which have been given. The same is true of the thousands or *M*

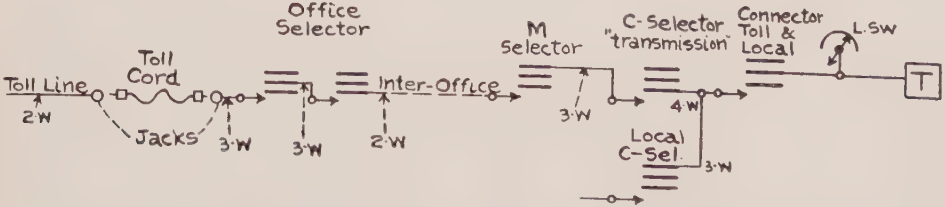


Figure 261.—Toll Service Train of Switches.

selector in the called office. The lineswitch of the called line is also omitted.

The toll line circuit is simple, consisting of a lock-up line relay, a line lamp, a visual busy signal, and a cut off relay which mechanically unlocks the line relay, and clears the line.

The toll to local cord circuit is not as simple, but yet is made up of elements which are easily understood. Normally the tip and ring lines pass through from plug to plug, with a relay and high impedance bridged across for toll (ringing current) supervision, and another relay and impedance bridged for the local (direct current) supervision. Each sleeve circuit has a grounded relay which furnishes current for the cut off relay of each trunk, the latter being connected to negative battery. There are keys to connect a calling device so as to dial either to the local switches or out onto the toll line.

The operator's set is like the regular anti-sidetone circuit used for local boards, except that there is provision for a calling device and a relay for giving a monitoring circuit.

The service toll trunk has a visual busy signal, being multipled to more than one position (like the toll lines). The ring side is normally open at the holding relay. The sleeve relay *SlRy* controls the busy signal and the release relay *RlRy*, and draws its current through the marginal winding (100 ohms) of the holding relay. Attached to the busy signal wire is the release trunk leading to the first office selector.

The toll hundreds selector (toll C-selector, or "transmission selector") has a number of added functions over those of an ordinary selector. It feeds battery current to the called telephone, relays supervisory conditions back from the telephone

to the toll board, relays the ringing current to the called telephone, etc. It has so many relays, that part of them are mounted on a separate base. No distinction is made as to location in the diagram, for we are showing principles of action.

The combined toll and local connector, which may be used by local hundreds selectors (C-selectors) as well as toll selectors, has two incoming trunks, one from each of the above named paths. The regular path is from the local selectors, and leads through the connector just as if it were one of the ordinary kind which has been described. The trunk from the toll selectors arrives at the toll switching relay *TSR*. There are four wires in this trunk. If the toll switching relay be energized, it converts the switch into the kind which operates with the toll selector.

In handling connections from the toll board to the subscriber, it is desirable to meet a number of conditions which have been discovered by experience.

Toll supervision, a distant operator can signal separately from local signals.

Operator must be able to connect to the subscriber line without ringing, and hold the line until the connection is ready.

The operator must control the connection at all times.

The called line must be held and seized as soon as a busy condition ceases ("camp on busy").

The operator must be able to start the ringing when desired.

Periodic ringing is best for toll as well as local connections.

If the subscriber has answered and thereby stopped the ringing, the operator must be able to start it again if the subscriber hangs up.

Local supervision must be positive (lamp lighted means receiver on hook).

Current supply for the subscriber station must be from his own central office, to make it as strong as possible.

The circuits which are shown here accomplish all the above.

The operation of the toll to local connection is as follows:

Suppose that the call comes from a distant city. We do this to get the action of the line relay and lamp. The ringing current operates the line relay *LR*, which pulls up and locks mechanically. The line lamp *LL* lights and the visual busy displays. There is the usual pilot relay operated by a pilot relay. When the toll operator plugs into the jack, the sleeve current pulls up the cut off relay *COR*, which clears the line, holds the visual busy signal, and unlocks the line relay armature. The latter falls back and puts out the lamp.

The sleeve current operates the sleeve relay *SlRy-1* of the cord. It provides battery and ground for the relay *R-1*, but it will not act, because it is short circuited.

The operator uses the listening key, which bridges her set across the cord as usual. The springs of the calling device *CD* and of the monitoring relay *MRy* do not have any effect just now. The operators talk to each other and pass information.

The toll operator in this office now plugs into an idle trunk. The sleeve current from *SlRy-2* operates the sleeve relay *SlRy-3* of the trunk, but not holding relay, for the resistance of the cord sleeve relay *SlRy-2* is too high. The trunk sleeve relay operates the visual busy signal and prepares a ground for the release trunk to the selector when it shall be needed. It also opens the circuit

of the release relay of the trunk *RlRy*, to prevent premature release.

The operator now operates the local calling device key, *CD* local, having restored the listening key to normal, or not, as it makes no difference This action cuts the cord circuit in two, and connects the operator's set to the local trunk without any condenser between. It also short circuits the local cord sleeve relay *SlRy-2* which permits the holding relay of the trunk to pull up. The latter closes the trunk line to the first office selector. It locks itself to a ground at the release relay of the trunk. Current now flows from the line relay of the office selector through the operator's induction coil secondary and the impulse springs of her calling device.

The operator now dials the number of the desired telephone. This sets up the connection, switch by switch. We will go at once to the toll hundreds selector, the first point of interest.

The toll hundreds selector supplies battery to the toll cord through the negative winding of its line relay *LR* and a ground connection at the rotary cam spring *11-R* and a back contact of relay *R-4*. Upon seizure by the toll operator, the line relay of the selector pulls up, closes the negative line (to −W) and operates the release relay *RlRy*. The latter grounds the release trunk *RT* to hold the other selectors, provides a ground for the switching relay *SR* and the rotary magnet (later), and prepares the impulse circuit for the vertical magnet by way of line relay back contact, release relay front contact, switching relay *SR* back contact, series relay *Se* winding, and vertical magnet.

When the toll operator dials the digit which operates this selector, the line relay of this selector vibrates according to the impulses. The release re-

lay holds on as usual. The impulses from the line relay back contact operate the vertical magnet and lift the wiper shaft. The first step up operates the off normal springs, one pair of which connects the rotary interrupter relay *RIR* to the front contact of the series relay.

The first impulse to the vertical magnet operates the series relay also, and it remains operated during the series. In pulling up, it operates the rotary interrupter relay, which locks itself through *ONS*, rotary magnet contact, *RIR* front contact to ground at the back contact of relay *R-7*.

At the end of the series of impulse, the line relay comes to rest energized, holding the release relay. After a moment, the series relay falls back and gives the first impulse to the rotary magnet. The latter rotates the wipers onto the first trunk of the level chosen. Near the end of the stroke, it opens the circuit of the interrupter relay *RIR*, letting it fall back. When *RIR* falls back it opens the circuit of the rotary magnet, which also releases. Now, if the private wiper *P-2* is resting on a busy trunk, grounded, there will be ground on the back contact of the rotary magnet, by way of a back contact on the switching relay *SR*. So, when the rotary magnet closes the circuit of the interrupter relay, the latter will pull up again. This action is seen more clearly in the small diagram at the left, where only the parts concerned are shown. In this way the magnet and the relay vibrate each other until an idle trunk is found. The failure to find ground on the private wiper *P-2* permits the switching relay *SR* to pull up in series with the interrupter relay *RIR* (the latter does not act). The switching relay extends the release relay ground to the private wiper *P-2*, cuts off the vertical magnet circuit, and closes the lines

to the wipers —*W* and +*W*. Wiper *P-1* is also connected as shown to a front contact of relay *R-6*, and ground on the back contact of the ringing relay *RiRy*.

This selector now acts as an impulse repeater for the rest of the digits which the toll operator dials. Relay *R-4* at the repeating coil is electropolarized by its 2,700-ohm winding, which was energized by the off normal springs *ONS* when the shaft made its first step up. The current through the 100-ohm winding of *R-4* comes from the connector and opposes the polarizing current. Hence the imulsing of the connector is done through this 100 ohms and the repeating coil.

Pass now to the connector. When the selector cut through onto the connector, there is ground on both private wires *P-1* and *P-2*. In the connector, this ground is extended through the off normal springs *ONS* to the private contacts of local selector banks, making this connector busy to those switches.

The selector has its line wires closed by the repeating coil and relay *R-4*, which causes the line relay of the connector to pull up, also relay *J*. The path is as follows: Positive battery, positive winding of line relay, back contact of back bridge relay *BBR*, back contact of toll switching relay *TSR*, +*L*, to selector, through repeating coil and *R-4* onto —*L*, to connector, back contact of toll switching relay, 200 ohm winding of relay *J*, back contact of back bridge relay, negative winding of line relay *LR*.

When the line relay pulls up it operates the release relay *RlRy* as in any switch, which in turn prepares the magnet impulse circuit. Relay *J* pulls up and locks itself to ground at the line relay. Relay *J* grounds the 1,300-ohm winding of

the ring cut off relay *RiCOR,* which operates it and forestalls any ringing. It locks to *P-1.*

The impulses dialed by the toll operator and repeated by the toll hundreds selector operate the connector just as any connector is operated. The first group of impulses go to the vertical magnet, the second group go to the rotary magnet. The busy relay makes the busy test.

If the called line is busy, the connector will "camp on busy," that is, it will give the busy signal to the toll operator, but will not lock—it will seize the line as soon as it becomes free. At the time of making the test, the ring cut off relay is energized. Hence, the busy relay, on finding ground on the private wiper *PW* will lock itself as follows, back contact on wiper closing relay, back contact of rotary interrupter relay, front contact of busy relay, front contact of ring cut off relay, ground on private wiper. The toll cord local supervisory lamp is dark, its relay (polar) gets current opposed to operation. When the called line becomes free, the removal of ground on the private wiper lets the busy relay fall back. This takes off the busy tone, and puts release trunk ground on the private wiper, through the 125 ohm winding of the wiper closing relay. The latter pulls up and locks itself to the release relay ground *RlRyGrd.*

The operation of the wiper closing relay puts ground on the negative winding of the back bridge relay by way of a front contact on relay *J.* The back bridge relay operates and reverses the current fed to the repeating coil and relay *R-4.* The latter now pulls up and locks. It connects the current supply relay *R-6* in its place. But now *R-6* and *LR* (of connector) meet each other with like battery polarities, so that *R-6* does not operate and *LR* falls back. In falling back, the line relay of the connector

momentarily grounds the toll switching relay *TSR* as follows, ground at *TSR*, back contact *LR*, front contact of *RlRy*, *ONS* (operated), front contact on relay *J*, front contact on *BBR*, to winding of toll switching relay. The latter pulls up and locks to the release trunk *P-2* which is held grounded by the selector. Relay *R-4* reverses the polarity of current to the toll cord, operates the local supervisory relay (polar) and lights its lamp.

Now the connection is ready for the next move by the toll operator. Take a look at the conditions. The line from the called telephone reaches battery through *R-6*, for *R-4* is energized. But *R-6* is normal, the current from the line relay of the selector to the toll cord is reversed so that the supervisory lamp is lighted. Relay *R-4* has connected relay *R-5* across the operating wires leading to the line relay of the selector.

Now the operator may start the periodic ringing by ringing on the trunk with her local ringing key. This sends alternating current over the trunk and through relay *R-5*. It operates and pulls up the ringing relay *RiRy*, which takes ground off the private *P-1* and thereby releases the ring cut off relay of the connector (*RiCOR*). The latter falls back and connects the ringing current to the called line. It is interrupted as usual.

When the called station answers, the ring cut off relay is pulled up and locks to *P-1*, the operator having restored her ringing key to normal and the ringing relay of the selector being normal. Immediately the called telephone begins to draw current from the relay *R-6*, which pulls up and cuts off the current from the trunk, but holds the line relay of the selector by a 1,000-ohm resistance. The cutting off of trunk current lets the local supervisory relay fall back and put out the lamp.

During conversation, there is no battery on the trunk.

If the subscriber hangs up, relay *R-6* will fall back, restore current to the trunk, operate the supervisory relay on the cord, and light the supervisory lamp.

If the operator needs to ring the subscriber who has hung up, one pull on the ringing key starts the periodic ringing again.

If the subscriber hangs up first, the toll operator releases the entire connection by pulling out the local plug. The sleeve relay *SlRy-3*, of the trunk, falls back and closes the winding of the release relay *RlRy* to the trunk. It operates and opens the locking circuit of the holding relay. The latter falls back, opening the trunk wires and takes the ground off the release trunk. The removal of a complete circuit on the trunk causes the line relay *LR* of the toll hundreds selector to release, opening the lines to the connector, and taking ground off *P-1* and *P-2*. This releases all the switches.

Conditions for Pay Stations.—Some of the later pay stations used with automatic exchanges require the collection or return of the money by 110 volts direct current placed on the lines, which sends current through a polarized magnet in the coin box, tilting the scoop one way or the other according to the polarity of the current. The current returns by way of earth. The toll operator has a key on key cord circuit which applies the strong current to one wire of the trunk. It is relayed onto both wires in the toll hundreds selector (transmission selector) whose circuit is given in Figure 263. The chief difference in this circuit is the introduction of relays *PS-1* and *PS-2*. In the regular operations they do not function. But when

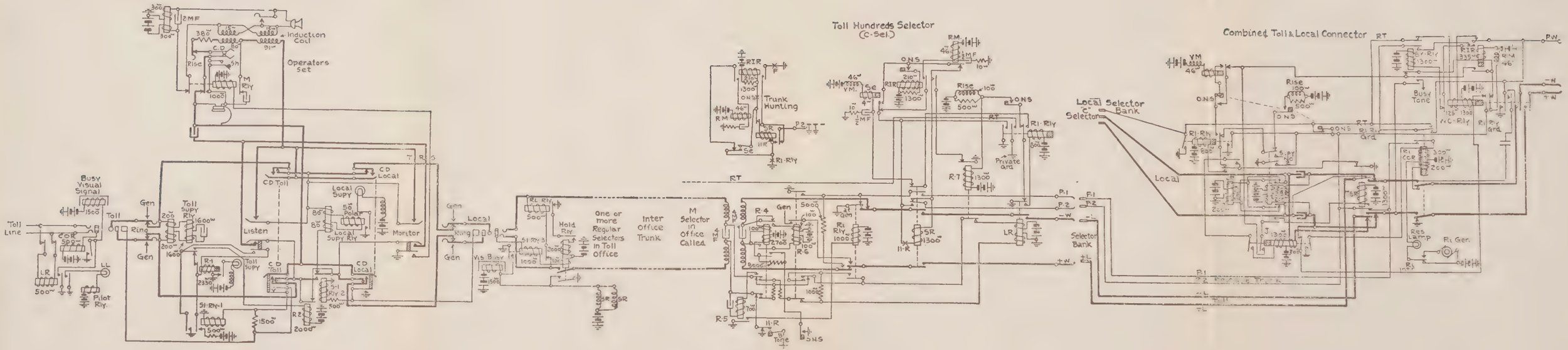


Figure 262.—Service Toll Circuits.



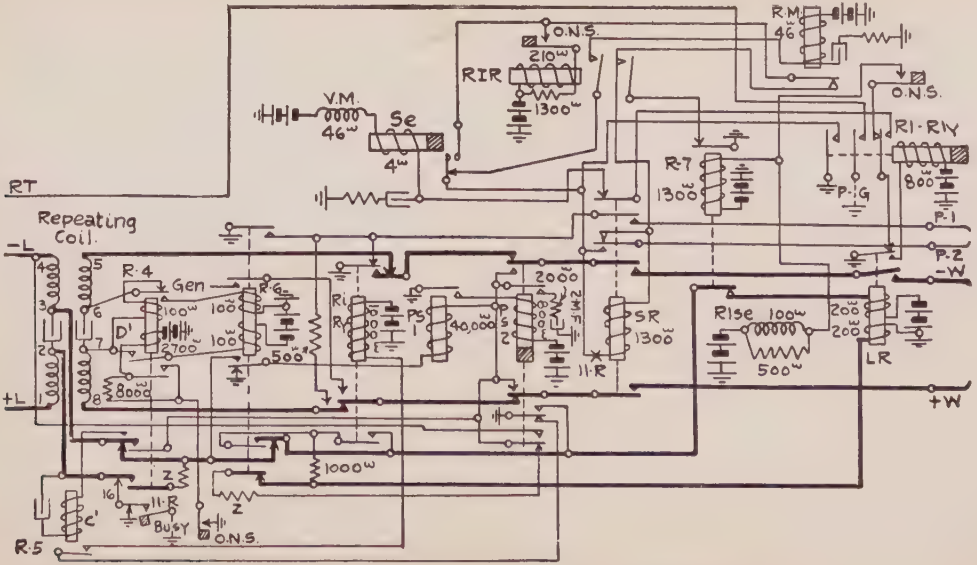


Figure 263.—Toll Hundreds Selector for Pay Stations.

the operator puts 110 volts on ^{-}L, the 40,000 ohm *PS-1* pulls up and operates *PS-2*. The latter connects both lines beyond this point onto the one line which is carrying 110 volts. Since the two wires are clear of all attachments from here to the telephone station, the pay station magnet will receive the full effect of the current. When the operator lets her key back to normal, relay *PS-1* falls back, letting *PS-2* release, disconnecting the multiple and restoring the talking condition.

CHAPTER XXV

THE PHANTOM CIRCUIT

General Principle.—The use of simplex and phantom circuits depends upon the principle of the Wheatstone bridge. By its application we are able to telegraph on a toll line over which conversation is being carried and have no interference between the two forms of communication.

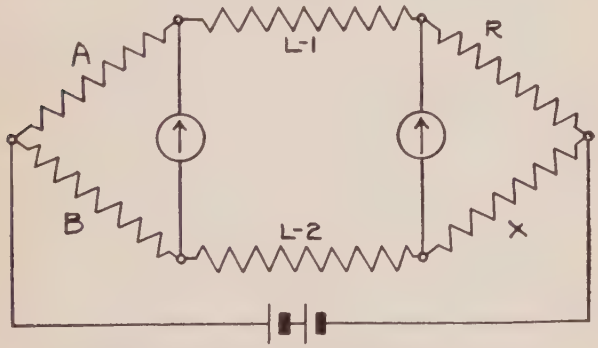


Figure 264.—Extended Wheatstone Bridge.

An extended form of bridge is shown in Figure 264. The only difference which it possesses from the ordinary form is that the arms *A* and *B* are separated from *R* and *X* by two additional resistances, *L-1* and *L-2*. If the proportion between the two sides of the circuit is maintained, there will still be no current in the two galvanometers. This

extended form of bridge is like a telephone circuit with two coils bridged across it. The resistance, *L-1* and *L-2* correspond to the two line wires.

We may set up a circuit like that shown in Figure 265 and have two conversations which do not interfere with each other. Consider main circuit to be between telephones *A* and *B*. Bridge across it the two impedance coils, *M* and *N*. Then conversation held between *A* and *B* will suffer very little loss, since the inductance of the coils permits very little of the talking current to leak. If we tap the two coils at their center points and carry a wire from each to the telephones *C* and *D*, we have another

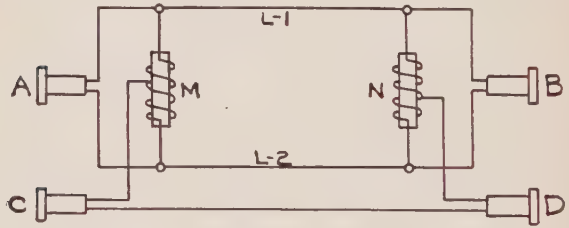


Figure 265.—Simplexed Telephone Circuit.

circuit which takes the place of the battery of Figure 264. The talking current from *C* to *D* will divide equally between the two lines *L-1* and *L-2* and not pass through the telephones *A* and *B*. Moerover, the current entering the center of each impedance coil will, in flowing outward, magnetize the core in opposite directions in the lower and upper parts of the winding. The result is that the core is magnetized very little, and the coil acts nearly as if non-inductive to the current from *C* or *D*. The circuit *A-B* is said to be the "physical" circuit and that over which *C* and *D* talk is called a "phantom." The return between *C* and *D* may

be the earth, if there is no external induction to make it noisy.

Practical Phantom Circuits.—In practice it is rare that the earth return phantom will serve. Metallic circuits are necessary on account of induction. Hence the arrangement of Figure 266 is used. From *A* to *B* is one physical and from *C* to *D* the

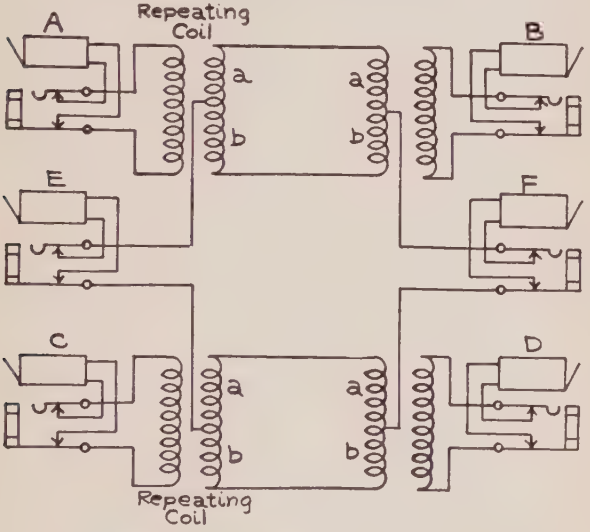


Figure 266.—Phantom Circuit.

other physical circuit which are to be "phantomed." Four repeating coils are cut into the lines as shown. It is of the greatest importance that the two halves of each coil shall be exactly balanced.

Each metallic circuit or "physical" acts as one wire of the phantom. Hence we must transpose the physical circuits bodily so as to make the phan-

tom circuit quiet. This is in addition to the transpositions of the metallic circuits on their own account.

The reason for employing repeating coils instead of simple bridged impedances is that in some cases the latter course would make one side of the phantom circuit longer than the other and expose it to more induction than its mate. This condition is illustrated by Figure 267. The lower metallic is longer than the upper one. Hence, any induction picked up by the lower metallic circuit has noth-

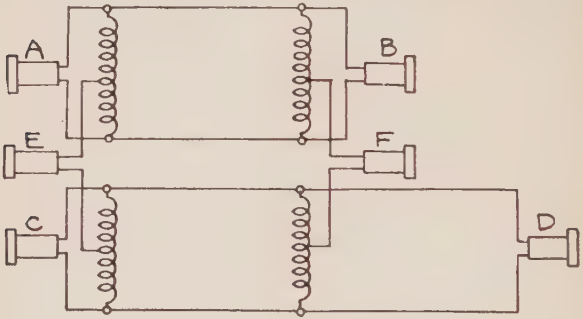


Figure 267.—Unbalanced Side Circuits.

ing to neutralize it, and a noisy phantom is the result. It is exactly like having a metallic circuit with one wire longer than the other.

The repeating coil must be able to repeat ringing current as well as talking current. The transmission on the physical circuits will not be as good as if the phantom had not been applied. The phantom will talk much better than either physical, because it has less resistance, and does not have as much loss in the repeating coils.

In order to give good service, the metallic cir-

cuits which compose the phantom should be well insulated. All joints must be the very best. A short circuit on one of the physicals will not hurt the phantom, though it stops traffic on the faulty wires. A cross between one wire of a physical and a wire of the other physical will stop traffic on the phantom and make the two physicals cross talk with each other. A ground on one of the physicals will make that physical and the phantom both noisy, but will not make the other metallic noisy. A high resistance joint or an open break in one line wire will make the faulty physical noisy and give cross talk with the phantom. It will not affect the other physical.

CHAPTER XXVI

LOADING OF TELEPHONE LINES

Properties of Telephone Lines.—Telephone lines possess several properties which materially affect both the clearness and the loudness of the speech which is transmitted. These may be named as follows: Conductor resistance, leakage between conductors and to the earth, inductance, and capacity. The losses to the voice current are due to the leakage and the conductor resistance. Well built and cared for lines have the leakage reduced to a very low point. Dry core cable has at least 500 megohms insulation resistance per mile when new, and must show at least 100 megohms per mile when laid and connected for service. If we neglect the losses due to leakage, the chief factor which causes attenuation or weakening is the resistance of the wire. If this were a simple weakening, affecting all the frequencies alike, the total result would be bearable. The received speech would be weak, but clear. It would be simply a matter of making transmitters and receivers sufficiently powerful in order to talk any distance.

However, telephone lines, especially cables, are much more affected by the capacity than leakage. The effect of the capacity is to cause an unequal attenuation or weakening of the different frequencies found in articulate speech. The loss is due to the resistance, but is controlled by the capacity. A full discussion of this interesting matter can not

be given here, but those who are interested enough to pursue it further should read U. S. patent No. 652,230 issued to M. I. Pupin*, together with papers which he has read before the American Institute of Electrical Engineers and before the American Mathematical Society.

Telephone transmission employs electrical current in the form of waves, which differ in an important respect from those used in ordinary lighting and power. In discussing the latter, it is usually correct to assume that at any given instant the current is of the same value at all points in a series circuit.

In telephone transmission the current is not the same at all points at the same time. If at the sending end the current at this instant is at its maximum value, fifteen miles away it may be zero, and fifteen miles further it may be flowing in the reverse direction. Hence the ordinary methods of calculating current flow which are used for most power work will not do for the telephone. The mathematics of telephone current are too complicated for discussion here, but the results will be of interest to the reader.

The predominating effect of capacity is to cause the telephone current to weaken as the wave progresses along the line. Figure 268. *A* is the sending end at which the current is full strength as indicated by the long wavy line beginning at *a*. As the electrical wave progresses farther to the right, it decreases in amplitude, until at *B*, the receiving end, it has the strength indicated by the wavy line at *b*.

Inductance possesses the power to correct the

*M. I. Pupin, Propagation of Long Electrical Waves, Transactions A. I. E. E. Vol. 16, pp. 93-142, 1899. Wave Transmission over Non-uniform Cables and Long Distance Air Lines, Trans. A. I. E. E. Vol. 17, pp. 445-512, 1900. Propagation of Long Electrical Waves, Trans. American Math. Soc. July, 1900, p. 259.

loss due to capacity. Dr. M. I. Pupin found that by inserting inductive coils at regular and closely spaced intervals along the line, he could very much improve the transmission of speech. The method of insertion is shown in Figure 269, L, L, L, being the coils. From A to B the capacity of the line is represented by a series of small condensers, though

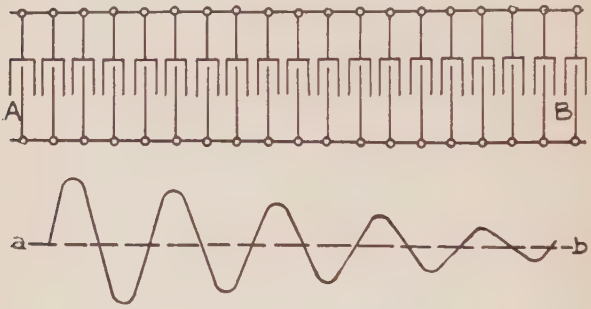


Figure 268.—Attenuation Due to Capacitance of a Line.

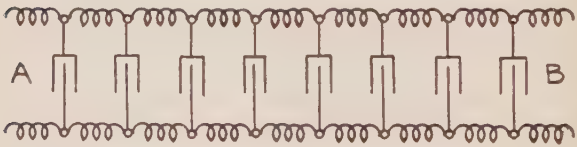


Figure 269.—Loading Coils Applied to Correct the Effect of Line Capacitance.

in real lines the capacity is evenly distributed. The distance between the coils varies according to the characteristics of the circuit. In cable they may be a mile or two apart. In overhead open wire lines the distance is much greater.

Theory indicates that the inductance should be evenly distributed along the line. One of the

chief points of value in the invention of Dr. Pupin is his discovery that practical commercial results can be obtained by lumping the inductance. He found that if the coils were evenly distributed so as to have not less than sixteen per wave length, the effect is so nearly the same as that of distributed inductance as to be practically the same.

The addition of loading coils greatly increases the current received at the far end of the line. A specific case will make this clear. In a certain length of cable, only two per cent of the sending current was received at the far end. By loading the cable, this percentage has been increased to twelve per cent. This means that the received current with loading was six times as great as without loading. If the two per cent is loud enough for commercial conversation, the loaded cable could be used to talk more than three times as far as the unloaded cable.

CHAPTER XXVII

THE PRIVATE BRANCH EXCHANGE

The private branch exchange has grown out of the need of business houses for more ample connection to the public exchange than is afforded by individual lines. The growing traffic which can not be handled by a single line is sometimes cared for by two lines, usually adjacent in the multiple of the public exchange, so that if either is busy the other can be used. The multiple is marked so that the operators will know that either will serve.

It soon becomes apparent that more telephone instruments are needed, in order to put many people into easy touch with the outside world. The need outgrows the possibility of being met by extension stations on a few lines. Inevitably a switching device must be installed to handle incoming and outgoing calls.

Thus the private branch exchange is the expansion of the single subscriber station, having in view traffic to and from the public exchange. Local traffic, intercommunication, is incidental. It exists, because the switchboard can give it. But local traffic usually interferes more or less with the in and out business, and tends to clog it. This clogging has been discovered in many cases only after the intsallation of a private automatic exchange for local traffic only—the manual P.B.X. operator, relieved of all local traffic, still had more

than she could handle. The in and out traffic grew when relieved of the clogging effects of the local traffic.

The private branch exchange is mechanically a little central office, with switchboard, operators, subscriber lines, and substations. Both local battery and common battery systems are used, but the latter is much preferred. It is simpler, has more automatic features, and gives better satisfaction. There is also better efficiency of trunks to the public exchange, because of automatic supervision.

Local battery circuits for the P.B.X. will not be shown, for they are the same as the simple magneto board which was shown.

There are many makes of P.B.X.'s and to show them all would take more space than we have at our disposal. Therefore we will discuss a set of circuits which are very fairly typical, and will open the way for the reader to understand other circuits.

The three most used circuits, line, cord, and operator's set, are shown in Figure 270. The line circuit at the left has only a line jack, a line relay *LR*, and a line lamp *LL*. When the subscriber removes his receiver from the hook, the current from the battery through the telephone energizes the line relay, which lights the line lamp. When the operator answers the call, the insertion of the plug opens the inside contacts and clears the line of line relay and ground.

The cord circuit has two supervisory relays, which serve to feed battery current to the telephones. No repeating coil is used, as this is the condenser-impedance system, which has been described. There is a ringing key on the calling cord only. If the board is a small one, there may

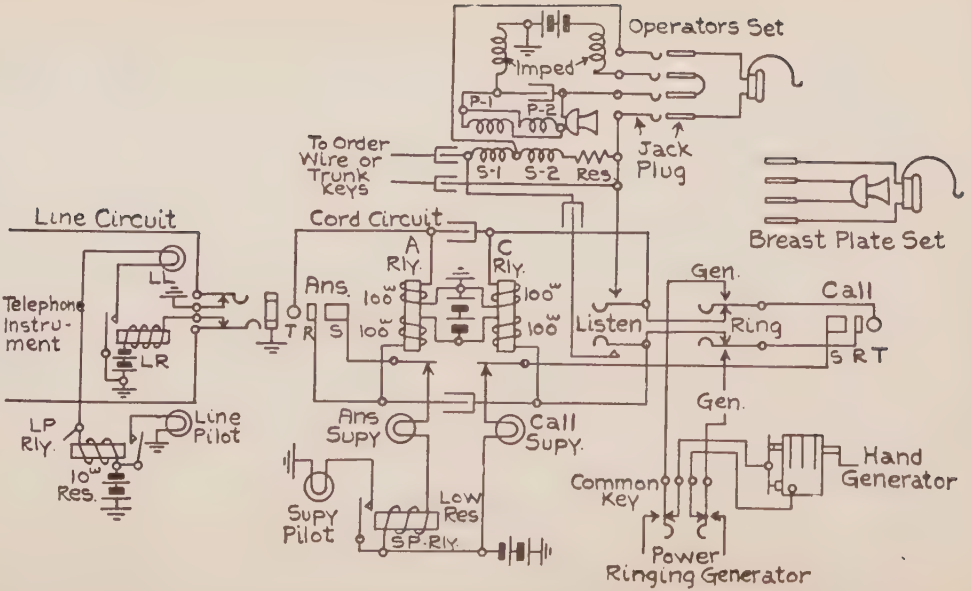


Figure 270.—Private Branch Exchange Circuits, Common Battery, Non-multiple.

be only a hand generator, which the operator must turn while holding the ringing key. But if there is a supply of generator current, the common key is turned to the power supply, and the work is that much easier. Often this ringing current is supplied from the nearest office of the public system over a pair of cable wires.

The operator's telephone set is usually of the anti-sidetone type. There are two induction coils, each having a primary and a secondary winding. The primaries, *P-1* and *P-2*, are usually placed in parellel. The transmitter is supplied with current through one or two impedance coils. A condenser permits the alternating portion of the primary current to flow in a low impedance path, not through the impedance coils.

The two secondaries, *S-1* and *S-2*, are in series with each other and with a resistance. Sometimes the resistance is combined with *S-2*, but retains with *S-2* the desired impedance to reduce the side tone to a satisfactory point.

The set illustrated in the diagram is shown arranged for a hanging transmitter. The circuit for it is closed by the operator's plug, which may be inserted in either way. But if the breastplate set is used, the transmitter terminals in the board are short circuited.

When the operator answers a call, the sleeve current through the answering supervisory lamp is broken because the subscriber is on the line. After the plug is in the jack, the telephone gets battery current through the *A* relay. When the number or name of the desired station is secured, she plugs into the called jack. The calling supervisory lamp lights through the sleeve circuit. Ringing is as usual. When the called station answers, the battery current drawn by the telephone operates the

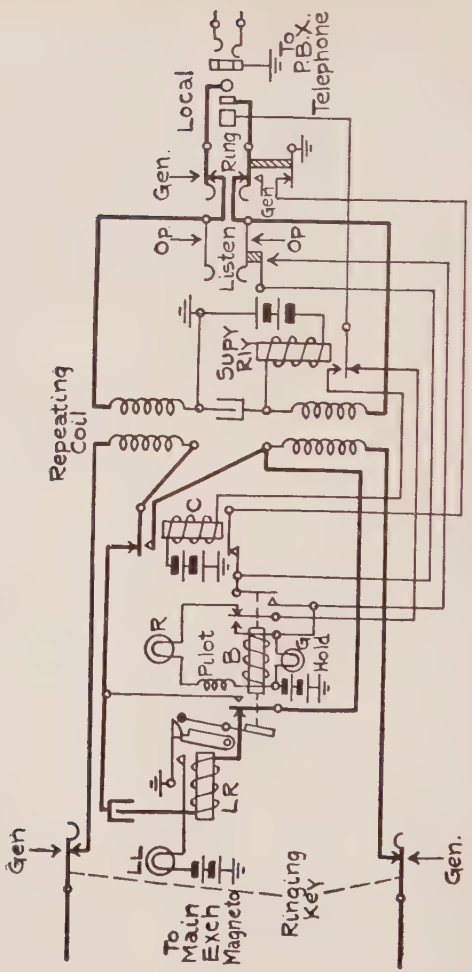


Figure 271.—Trunk Circuit, P. B. X. and M. X. (Magneto).

C relay, which puts out the calling supervisory lamp.

There are two pilot lamps, one for the line lamps and one for the answering supervisory lamps. They are operated by a low resistance relay in the common lead to all the lamps.

The connection from the operator's set to trunks to the public exchange has two condensers, in order to prevent any possibility of crossing the trunk with a local cord, if the operator should happen to have the two keys operated at once.

Trunk to Magneto Public Exchange.—It sometimes happens that there is a common battery P.B.X. in a city which has one or more manual public offices. A trunk to such an office is shown in Figure 271. It is plug-ended, for these have shown themselves to be better than jack-ended trunks.

There is a key to enable the P.B.X. operator to ring the public exchange, for the P.B.X. trunk terminates on the board like a regular subscriber line. Also the public exchange operator rings the P.B.X. as she would ring any other subscriber line. In this case it pulls up a line relay *LR* which is locked mechanically while it lights the line lamp *LL*.

When the operator answers the call by throwing the listening key, an auxiliary contact on the key operates relay *B* and lights the hold lamp (green) which is in parallel with it. Relay *B* also locks to ground on an auxiliary contact at the ringing key (local), cuts out the line relay coil, and mechanically restores the line relay armature, putting out the line lamp. The operator talks through the repeating coil.

The P.B.X. operator extends the call to the local subscriber by plugging into his line jack. Ring-

ing is done as usual. When the called station answers, the supervisory relay *SupyRly* pulls up and operates relay *C*. The latter cuts off relay *B* and closes the trunk circuit directly through the reeating coil. Thus the green holding lamp goes out when the subscriber answers.

It will be noted that if the operator should answer the call and restore the listening key without doing anything else, the green lamp will burn to indicate that the call was answered but not completed.

When the conversation is completed, the P.B.X. subscriber hangs up. The supervisory relay falls back, releases *C*, and lights the red lamp *R*. This is the disconnect signal. Strictly speaking, the P. B. X. operator should ring off to the main exchange, for there is no automatic disconnect signal on the trunk. Pulling down the plug restores all to normal.

Trunk to Common Battery Public Exchange.— This trunk circuit, Figure 272, has all supervisory signals automatic. There is a line relay like that shown for the other trunk, for the public exchange operator treats a P.B.X. trunk like other subscriber lines as to ringing and passing calls. Only in the case of large private branch exchanges are order wires or call circuits used.

It is to be noted also that the subscriber is switched directly onto the main exchange board, and gets his battery current from a cord circuit there. Supervision is taken off for the P.B.X. operator by means of a series relay *SupyRly* of low resistance, shunted by a condenser.

The operator in the main exchange rings, and the line relay operates and locks. The line lamp burns. The P.B.X. operator answers with the listening key, which also pulls up relay *B*. The

latter locks. The holding lamp (green) lights in parallel with relay *B*. Relay *B* also switches the ringing bridge from the line relay to a holding coil, a high impedance of moderate resistance (500 ohms more or less).

The P.B.X. operator plugs into the local jack and rings. Although the ringing key takes ground off the locking circuit of relay *B*, the latter still holds on by the sleeve ground. The hold lamp still burns.

When the subscriber answers, the current drawn by the telephone gives supervision to the public exchange, and also to the P.B.X. The series relay *SupplRly* operates and pulls up relay *A*. This cuts off relay *B* and the hold lamp. Relay *A* cuts the signal bridge off the trunk. This is the condition during conversation.

When the conversation is completed, both subscribers hang up. Both operators get the disconnect signal at the same time. The P.B.X. operator gets it by the falling back of the supervisory relay. It lights the supervisory lamp *R* by its back contact and the sleeve ground. Relay *A* falls back, but there is now no path for direct current through the bridge.

If the P.B.X. operator should need to signal the public exchange operator, she may use the flashing key, which opens the trunk and operates the supervisory relay and lamp. The click is reduced by connecting the line relay condenser across the trunk before opening the trunk, the flashing key having make-before-break springs.

To initiate a call, from the P.B.X. to the public exchange, the P.B.X. operator merely throws her listening key. The auxiliary contacts operate the *B* relay, which locks to the ground on the ringing key (local). Relay *B* connects the holding

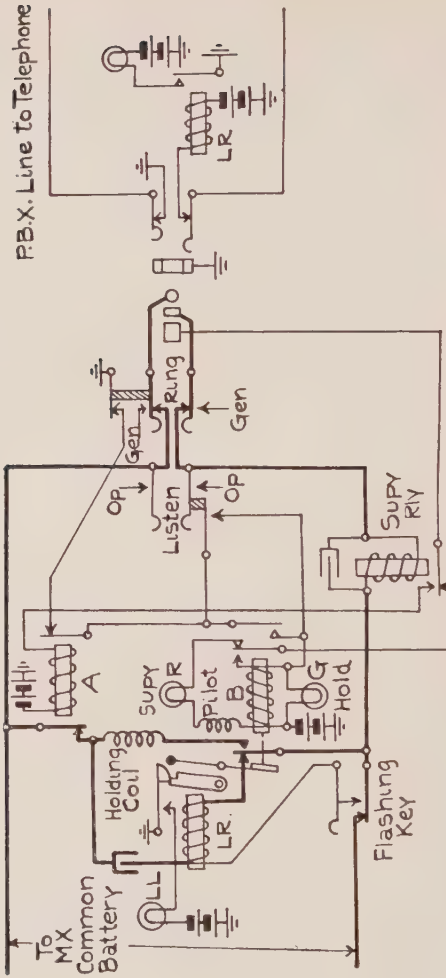


Figure 272.—Trunk Circuit, P. B. X. to M. X. (Common Battery).

coil to the trunk, which signals the central office operator. The rest of the operation is evident.

Night service can be given to as many telephones as there are trunks, if desired. Trunk circuit of Figure 272 is merely plugged into the line which is to be left connected. This will light the supervisory lamp on the trunk, though it can be cut off by a key, which removes the battery from all lamps and relay coils. When the central office calls, it will ring through the supervisory relay to the extension telephone. When the station answers, the current drawn by it from the central office will operate the supervisory relay and pull up relay *A* on the trunk, cutting off the bridge. The line relay *LR* will operate on the central office ringing current, but it does no harm as the lamp will not light. The P.B.X. station can call out directly, the supervisory relay causing relay *A* to clear the trunk.

Trunk to Automatic Public Exchange.—A typical trunk to a public automatic exchange is shown in Figure 273. These trunks are connected to the banks of P. B. X. connectors in the public office. These connectors are equipped to test a number of trunks and to take the first idle trunk. Otherwise they act as ordinary connectors, and ring on the trunk as if it were an ordinary subscriber line. The lines are also connected to lineswitches, for calls from the P.B.X. to the public.

The chief change required to adapt the common battery trunk above described to automatic use is to insert the calling device key in each trunk and provide one common calling device for the operator. This calling device is usually of the dial type, the same as is used by subscribers. The calling device key has an auxiliary contact which is in parallel with a similar contact on the listening key. It oper-

Figure 273.—Trunk Circuit, P. B. X. and Automatic Public Exchange.

ates relay *B* so as to guard against the call being forgotten.

Suppose that a call comes in from the automatic system. The ringing current will operate the line relay *LR*, which lights the line lamp *LL* and locks mechanically. The operator answers by the listening key, which pulls up relay *B*. The latter locks to ground at the ringing key. The holding lamp lights in parallel.

When the person desired is known, the P. B. X. operator plugs into the local jack and rings. The hold lamp still burns. When the called subscriber answers, he draws current from the connector switch in the public office, but pulls up a series supervisory relay *SupyRly* in the P.B.X. The latter operates relay *A*, which releases relay *B* and puts out the hold lamp.

If the local station desires the attention of the P. B. X. operator, as, for instance, to transfer the call to another local station, moving the hook up and down will do it. It makes the supervisory relay vibrate, flashing the red supervisory lamp. The operator can pull out the plug and insert it in another jack, ring, and call another.

The calling subscriber in the public system controls the connection. The P.B.X. subscriber can signal the P.B.X. operator who can pull down the trunk, but it will leave the switches up until the calling subscriber releases. This is standard in all automatic exchanges.

If the call originates in the P.B.X. for an automatic subscriber the operator throws both the listening key and the calling device key. The former locks up the hold signal lamp (green). She then operates the calling device according to the desired number. Restoring the *C. D.* key leaves her in a

position to hear when the ringing begins, when the called subscriber answers, or if the busy signal is given. But even if she did not have her listening key thrown, relay *B* holds the holding coil across the trunk and the connection will be held.

If the calling subscriber is on the line, the operator may restore her listening key to normal, and let the subscriber talk when the called subscriber answers. If this is the case, the subscriber in the P.B.X. will draw current through the supervisory relay and will operate relay *A*, which cuts off the holding coil and leaves the substation to get all the battery current. The P.B.X. subscriber controls the conection after the operator gets off the trunk. If he hangs up his receiver, the switches will be released. But the red lamp will light to notify the operator to pull down the connection.

Night service can be given to as many P.B.X. stations as there are trunk lines and as have calling devices. All that the operator needs to do is to plug up the trunks to the lines. The red lamp will show on each such night connection unless a call is being made. When a station calls the automatic, the supervisory relay operates and puts out the red lamp. It also operates relay *A*, but it does nothing. The station can dial, talk, and release as if it were an individual line. It can also receive calls. But the order in which night stations get calls depends on the order in which they appear on the P.B.X. connector banks.

CHAPTER XXVIII

MEASURED SERVICE

Measured service is given in a variety of ways, both manual and automatic. The substation equipment is practically alike for both, for similar control conditions have been worked out which either manual or automatic central office apparatus can furnish.

Measured service is either credit or cash. The former involves meters of some kind, either in the central office or at the substation. So far the only successful unit is the call, although promising attempts have been made to introduce the time element. If, as in the case of long distance connections, the call is manually supervised, the user can be made to deposit additional coins periodically, and thus in a timed call obtain cash service.

Automatic service lends itself most readily to flat rate service while manual operation favors measured service. It is because the cost of service manually is more closely bound up with the call, while in automatic switching there is less connection. Also, for the cost of meters and metering equipment more than enough switching apparatus can be bought to take care of the additional traffic which flat rates bring. It is known that measured service lowers the usefulness of the telephone to the community, for it very greatly reduces the calling. The telephone ought to serve the people as fully as possible.

Credit metered service is given automatically by the trunk and meter arrangement which was shown and described by Figure 207. The reader will find on page 276 a complete description of how the automatic exchange records all answered calls, and

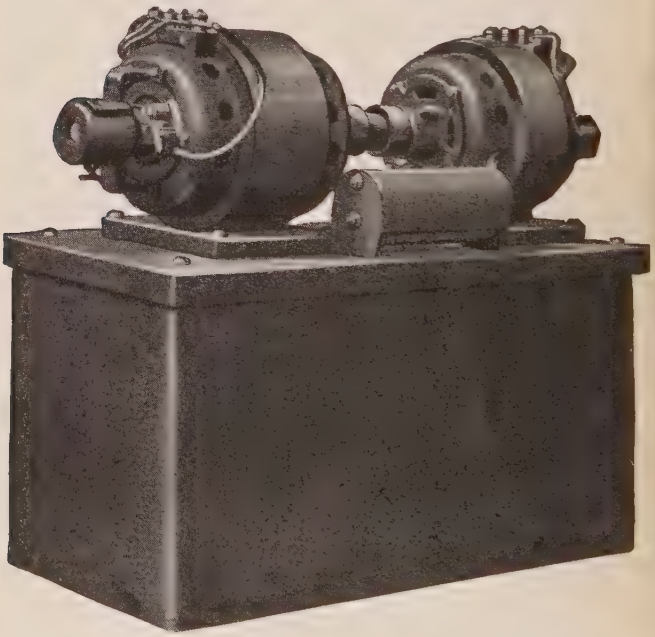


Figure 274.—Automatic Meter or Register.

gives free service where necessary. Figure 274 shows the meter or register.

An automatic coin collector much used in connection with automatic telephones is shown in Figure 275. The coin slot being at the top, right side. It

curves downward to the left and delivers the coin into the locked compartment below. Near the center is a polarized magnet, on whose lever is carried a light trigger. If the magnet be operated, it will close the springs which may be seen in front of the

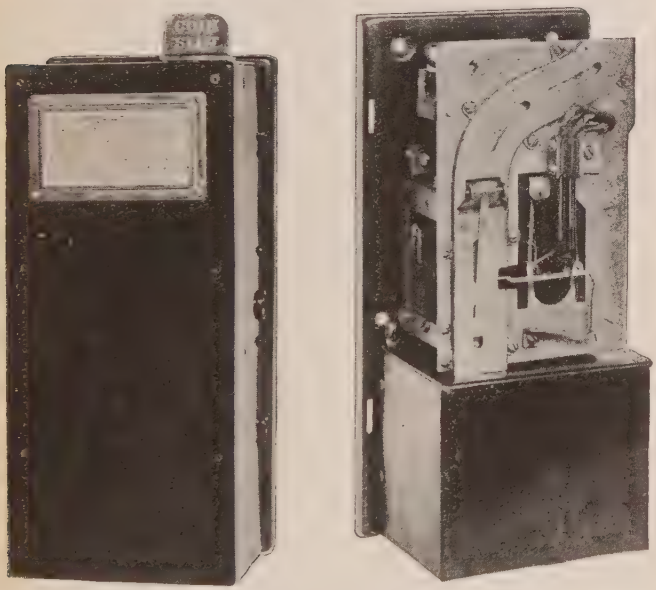


Figure 275.—Automatic Coin Collector.

magnet. Now if a coin be dropped into the chute, the coin will strike the end of the trigger and release the springs, although the magnet remains operated.

The circuits of the coin collector and the telephone are given in Figure 276. The polar relay-magnet has two windings, a low resistance one in

series with the line, a high resistance one for bridging. The trigger is indicated by *P*.

The subscriber takes the receiver from the hook and dials the call. The current holds the polar key relay as shown. When the called station answers, the connector reverses the current, operating the polar relay. This dead shorts the transmitter and puts 30 ohms around the receiver. The user can hear the called station answer, but can not hold conversation. Then he drops the coin, which strikes *P*

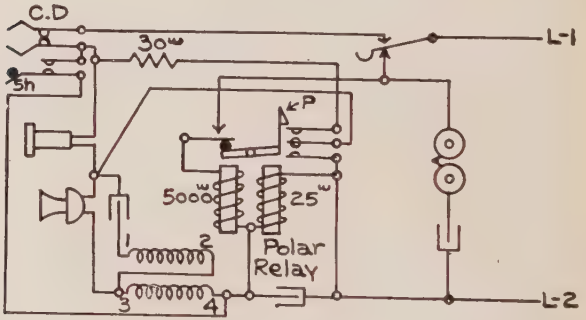


Figure 276.—Coin Collecting Telephone Circuit.

and releases the springs, so that conversation is as usual.

If the called station hangs up and then comes in again, the polar relay will not lock the calling subscriber out. The trigger ratchet is so shaped that when the battery current in the line reverses, the 25-ohm winding is too weak to pull the armature lever back over the projection, hence the shunting springs remain open and the 5,000-ohm winding remains connected to the hookswitch. When the subscriber hangs up, the 5,000-ohm wind-



Figure 277.—Multi-coin Pay Station.

ing, being strong, pulls the lever back over the catch.

It is often necessary to use the same pay station for local and for long distance service. When the local service is automatic, it is better to let the users dial all calls, and require them to pay cash for the service. For this purpose the multi-coin pay station shown in Figure 277 is very useful. It is of the pre-payment type, in that the user must deposit a coin before he can use it. There are three slots, taking a five-cent piece, a ten-cent piece and a twenty-five-cent piece. The chutes through which the coins fall lead past bells of different pitches, into a scoop. There the weight of the coin operates a set of springs which take a short circuit from the impulse springs of the calling device, making it possible for the user to dial. The coin is collected or returned when the subscriber hangs up.

The circuits of this coin box and its repeater are given by Figure 278. There is a polar relay which ing and the positive line $+L$. This contact is operated by the coin.

The repeater, located between the lineswitches of the pay station board and the selectors, is arranged to prevent any effective impulsing unless the polar relay at the pay station is connected to positive line and earth. It also sends out positive or negative 110-volt current at the time of release to collect or refund the coin.

There is a balanced differential relay DR in the battery feed of the repeater. This relay controls a relay F which short circuits the impulsing contacts of the line relay LR by means of which the line relay would repeat the impulses to the selectors. If the subscriber tries to dial without depositing a coin, or works the hook to send impulses, the dif-

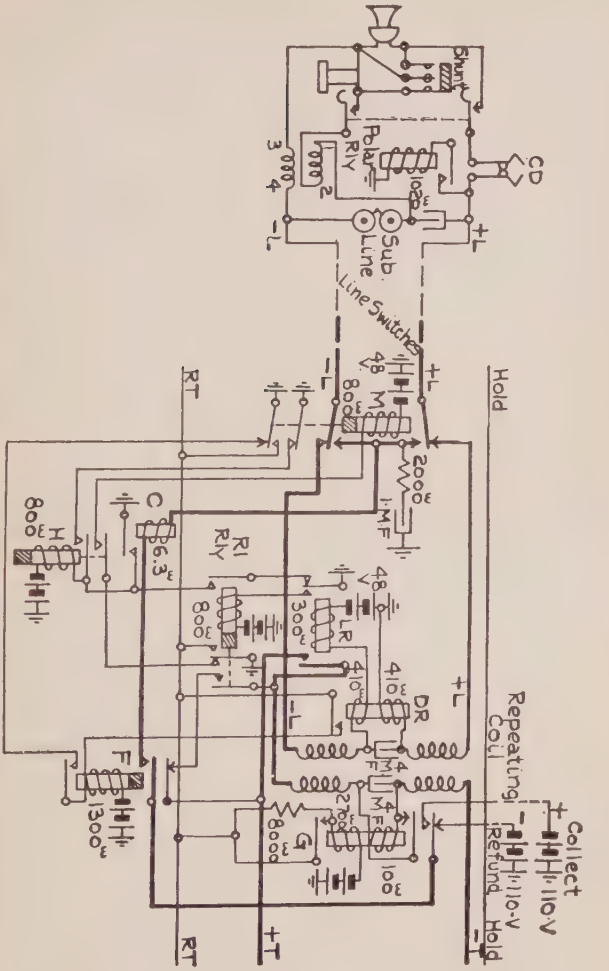


Figure 278.—Multi-coin Pay Station Circuit and Repeater.

ferential relay, being balanced, remains inert, and relay *F* leaves the impulse springs of the line relay short circuited. But when the coin is deposited, it connects the 1,020-ohm relay to earth on the positive line, which unbalances the differential relay. This operates relay *F*, which locks itself and removes the short circuit from the line relay springs.

The collection or return of the coin depends upon whether or not the called station has answered. This is indicated by reversal or non-reversal of the line current, as has been described before. This reversal operates and locks the electro-polarized relay *G*, which controls the polarity of the 110 volts applied on release.

When the calling station releases, the line relay *LR* falls back together with the differential relay *DR*. *F* remains locked. The release of the line relay operates relay *H*, which locks itself and prepares the circuit for relay *M*. Then the release relay falls back, operating relay *M*, which swings both lines away from the battery feed to the 110-volt supply. This operates the polar relay in the pay station. If positive current is applied, the relay tilts the scoop so as to slide the coin into the cash box. If negative current is applied, the scoop is tilted in the opposite direction, so that the coin falls into the return chute, where the user can recover it. Relay *M* unlocks relays *H* and *F*, restoring all to normal.

If the user of the pay station desires long distance, he will deposit a coin, dial the recording toll number, and give the call to the operator as usual. Her trunk does not reverse battery, so when he hangs up, he gets the coin back. When the call is ready, the operator calls the pay station by way of a trunk which includes the toll hundreds selector

of Figure 263, which enables the toll operator, after calling for the toll fee and listening to the sounds of the bells, to collect or refund, according to the final conditions of the connections.

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