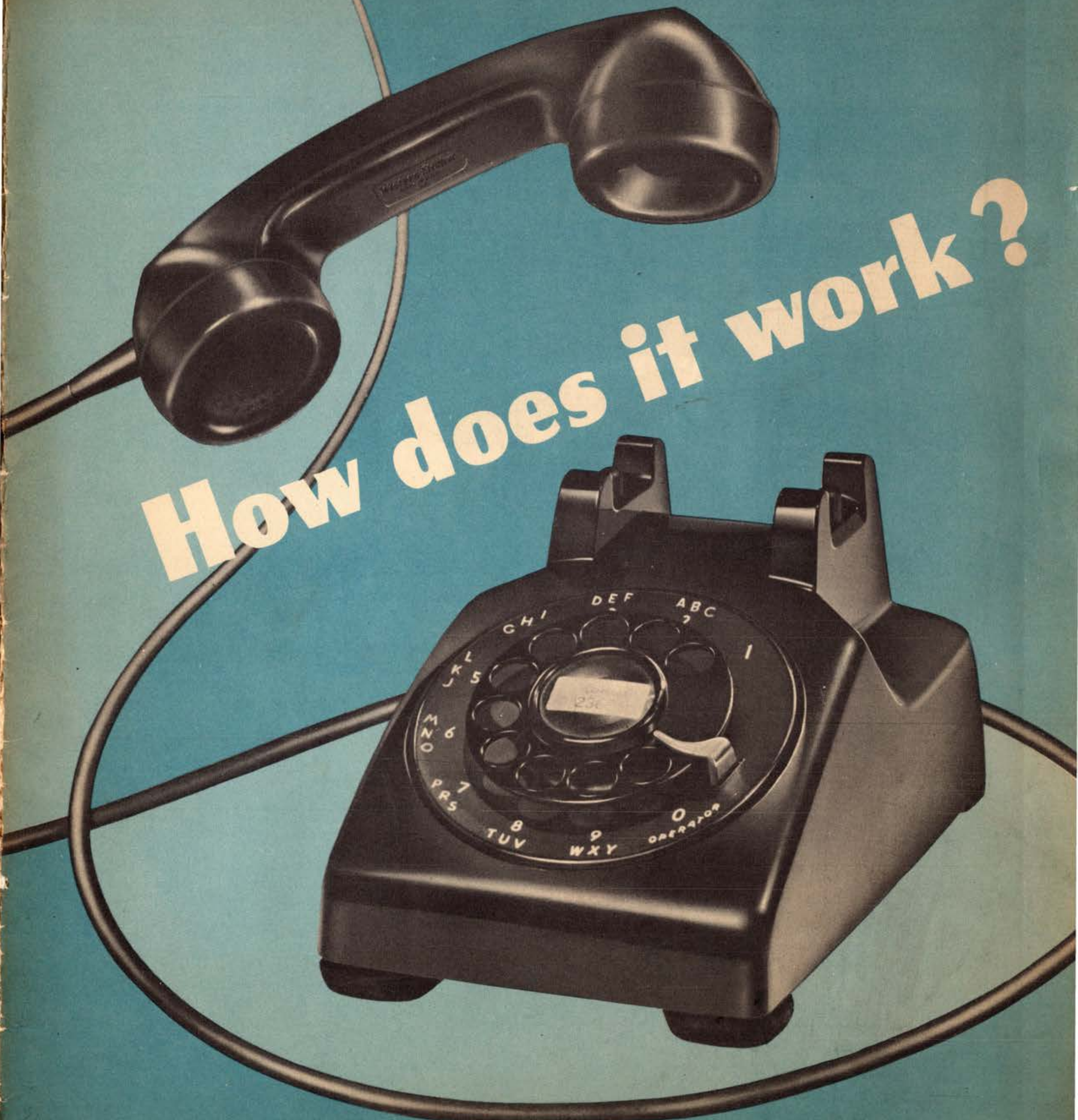
WESTERN ELECTRIC MAKES THE TELEPHONE

How does it work?



This booklet tells you

WESTERN ELECTRIC people began making telephones in 1877, one year after Alexander Graham Bell first succeeded in transmitting speech by wire. Since then, Western Electric has manufactured over 67,000,000 sets—as of 1952—and each year, of course, the Company is producing millions more.

The first telephone was a simple device consisting of only a dozen parts. Mr. Bell's great achievement was not so much the making of the instrument as his discovery—and understanding—of the principles and possibilities of using electricity to carry conversations.

The principles which Mr. Bell discovered still apply today, but the telephone he invented has undergone many changes and improvements. Altogether, through the years, there have been about 25 distinctive types or "models" of the Bell telephone desk set manufactured by Western Electric, and 23 distinctive developments in wall sets. Also, during these years, many other refinements and design changes, important but not so obvious, have been made in the various parts of the set. The result is that the quality and performance of the telephone have constantly improved. The newest Bell telephone, made in our shops, is the "500" set. It consists of 471 parts. It is a complex, precision-made instrument, the result of years of research

how the telephone works

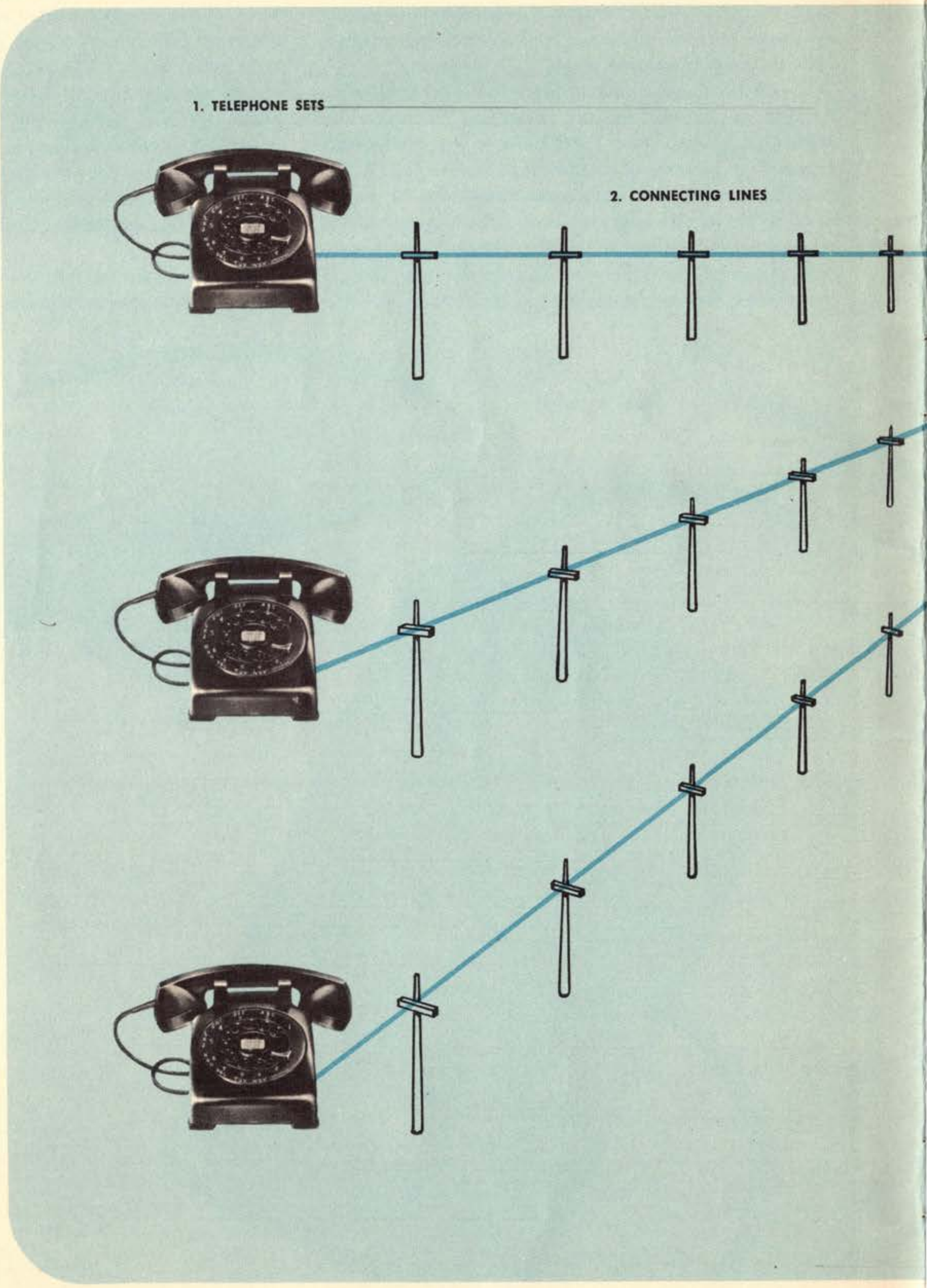
in Bell Telephone Laboratories and years of manufacturing experience in Western Electric. It talks better, listens better, dials and rings better than any of its predecessors.

Over 6,000 Western Electric employees in the Indianapolis plant are engaged directly in making telephones and related apparatus. About 1,000 more in the Distributing House shops repair used telephones so that they can be put back into service by the telephone companies. Thousands of other Western Electric employees, who may not handle telephone parts in their daily work, produce the great quantities of wire, cable and central office equipment required to connect Bell System telephones in a nation-wide network. And still other thousands now work on military projects in which the principles of telephony are very important.

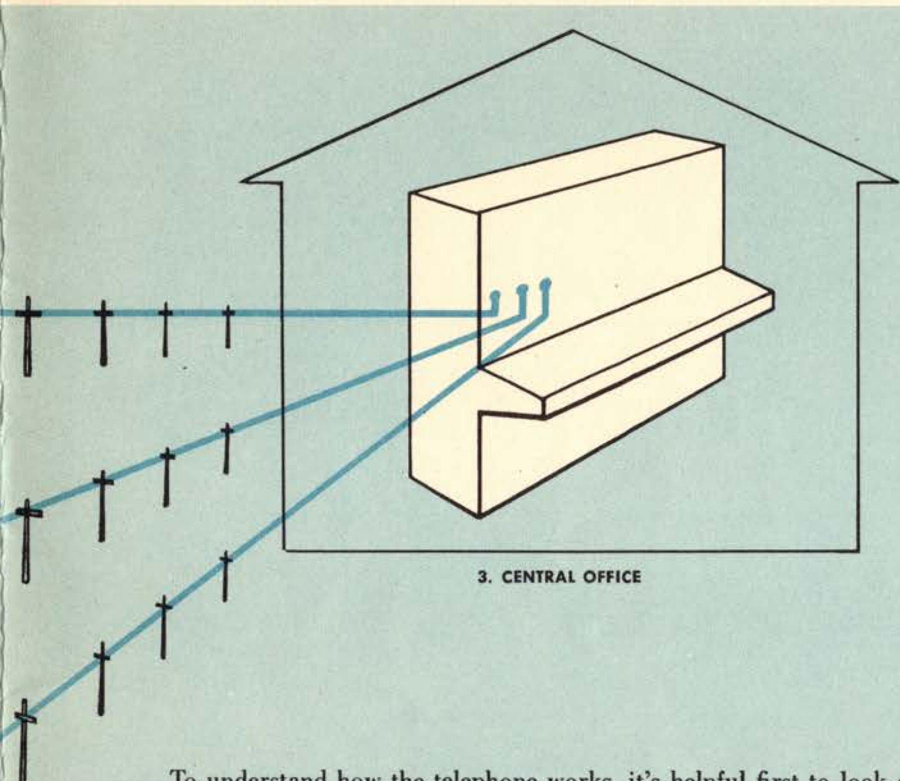
So most Western Electric people have special reason, and special opportunity, for understanding how the telephone operates. Perhaps you are the sort of person who is curious about how things work. Or perhaps you want to know how your job—the particular part you make—fits into the telephone. Or perhaps you want to know about the latest scientific and engineering improvements in the telephone set.

Whatever your interest, you'll find that how the telephone works makes a fascinating story.

TO BEGIN WITH: A simple telephone



system has three main parts.



3. CENTRAL OFFICE

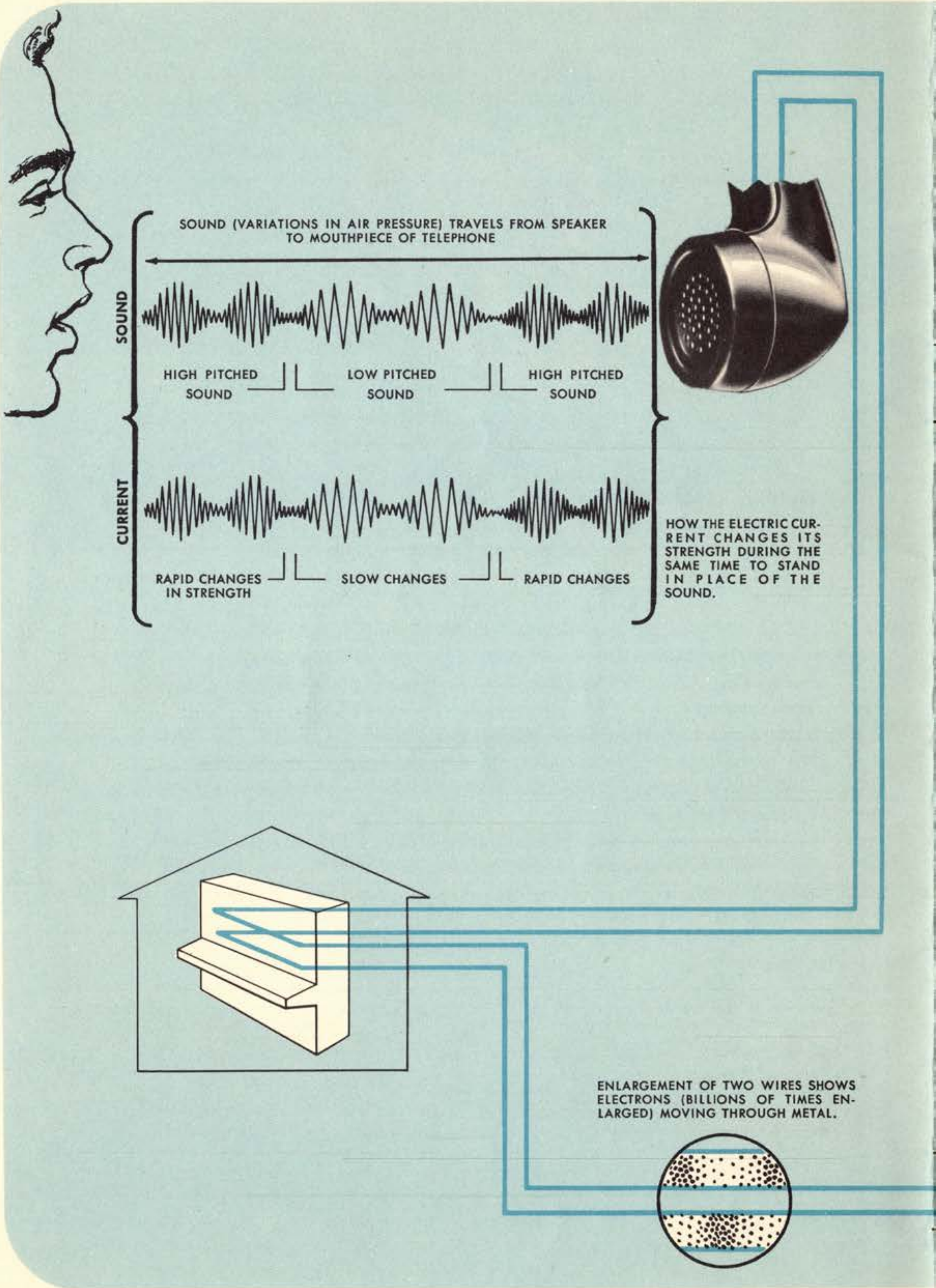
To understand how the telephone works, it's helpful first to look at the telephone system as a whole, and to divide it into its basic parts. This way we get a simple framework within which we can talk about any kind of telephone apparatus.

Pictured on these pages is an elementary telephone system. The three basic parts of this system are in *every* telephone system, whether there are three telephones or three thousand, and whether they reach around the block or across the country.

The three parts are: (1) the telephone set, (2) the connecting lines, and (3) the central hook-up, or switching, point. Of course, when a telephone system becomes larger, reaching thousands of subscribers and providing long-distance service, there must be other connecting facilities between central offices, such as toll lines, cable and radio relay. But, no matter how complex a telephone system becomes, every piece of apparatus fits into one of these three basic parts of the system.

Using our elementary system as illustration, we see that the three telephone sets in the system are connected, each by its own wire line, to the switching center. At the center, the wires from any two of the sets can be connected together. When this connection has been made, words spoken near the transmitter (mouthpiece) of either one of the connected instruments will be reproduced in the receiver (earpiece) of the other.

THE SCIENCE OF TELEPHONY: How electricity carries the



pattern of a sound from one telephone instrument to another.

When you talk over the telephone, something travels over the wire. But what? Probably everyone knows that the voice sounds themselves do *not* travel over the wire. Sound is a vibration of the air next to one's ears. Sound travels at a fairly slow speed and can be heard only at relatively short distances. It can be made to follow a wire, but not very efficiently.

Electricity, on the other hand, is very happy with wire travel, moves at a high speed, and can be strengthened along the way. Electrical currents sent from one telephone to another *represent* the sounds of the voice.

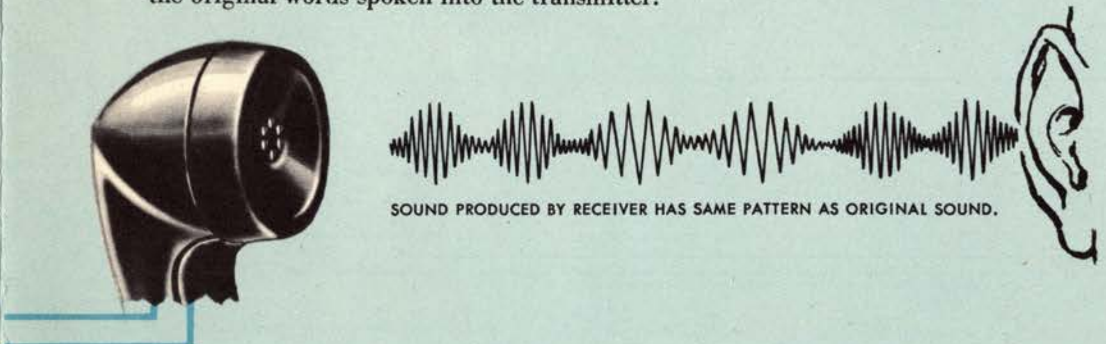
Just how can electrical currents be made to represent sounds? It's true that electricity and sound are very different. Electricity is the motion of infinitesimal particles of matter—electrons—while sound is a vibration of the air particles as detected by the ear.

An example of what we call a high-pitched sound is an air vibration that repeats itself 4,000 times a second. A representative low-pitched sound is one that repeats about 100 times a second. The whole range of sounds normally heard by human beings consists of air vibrations at rates varying from 30 to 15,000 times a second.

But electrons can "vibrate" too—their flow along a wire can vary repeatedly. So if we have an instrument that produces electrical currents that vibrate at the same rates as a particular set of sound vibrations, then we have set up a relationship between sounds and electrical currents.

This is what the telephone instrument does. The transmitter sends out electrical currents that vibrate whenever sounds strike the transmitter, and these electrical currents have the same rates of vibration as the sounds. The receiver does exactly the opposite. It produces *sound waves* that vibrate the same number of times per second as the electrical currents that it receives. By linking transmitter to receiver, we have a change from sound to electricity and back to sound. The diagram at the left illustrates this relationship of sound and electricity.

It is important to remember that the sound you hear over the telephone is *not* the sound spoken at the transmitter. It's an entirely new sound recreated in the receiver by electricity. This new sound is a replica or imitation of the original words spoken into the transmitter.



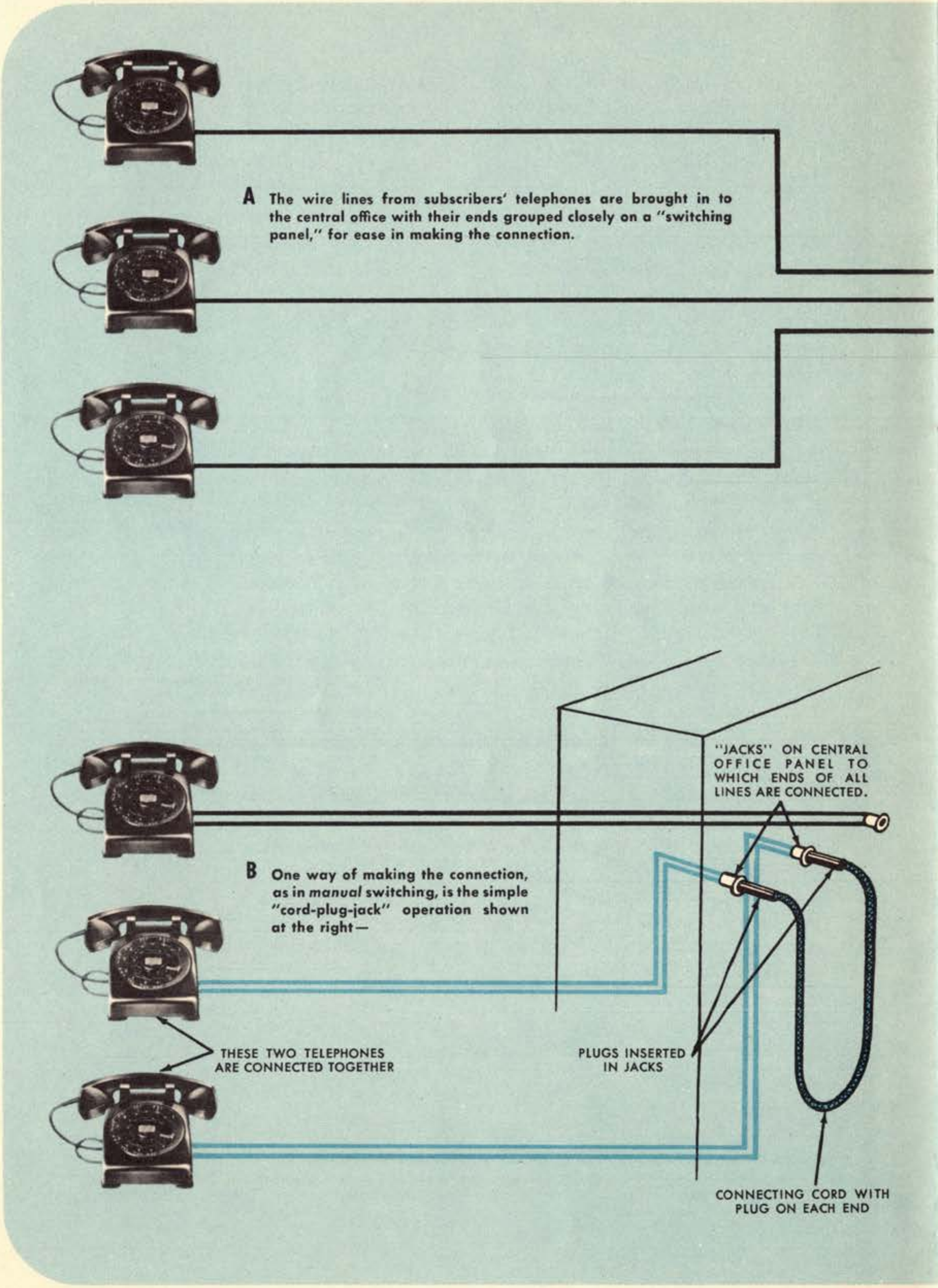
SOUND PRODUCED BY RECEIVER HAS SAME PATTERN AS ORIGINAL SOUND.

technically speaking

"Transducers" like the transmitter and receiver of the telephone are inherently complex in design because of the wide range of frequencies that must be handled. In telephony, which simulates the conditions of conversational speech, the frequency range is from below 200 cycles per second to over 4,000, or a high-low ratio of better than 20 to 1. Mechanically vibrating structures just don't like to operate over such a wide range of speeds. They will develop any number of quirks when forced to do so. The designer's problem is to know about the quirks that will develop in his structure, preferably in advance, so that he can eliminate them.

The descriptions of the transmitter and receiver of the new "500" set, on Pages 10 and 12, show the large number of elements that the designers of these instruments had to handle from the very inception of the design. The circuit elements in the equivalent circuits of the two instruments include all of the features of the acoustic and mechanical structures that would materially affect their performance as transducers. The designers, by "solving" these complex electrical networks, could closely predict and control the performance of their instruments in advance of building the first model. This high development of "network theory," and expertness in its use in actual design, are significant contributions of the Bell Telephone Laboratories.

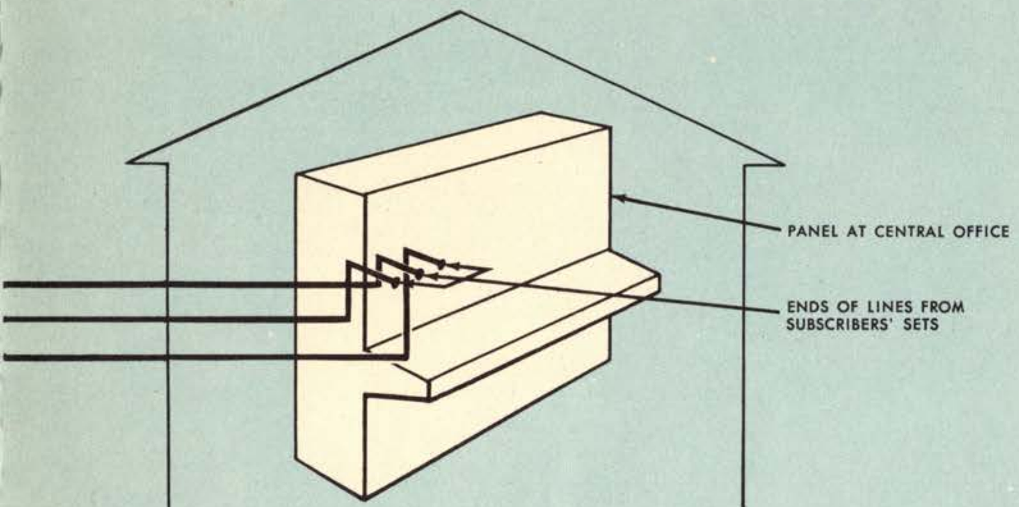
THE CENTRAL OFFICE: Its main job is to



A The wire lines from subscribers' telephones are brought in to the central office with their ends grouped closely on a "switching panel," for ease in making the connection.

B One way of making the connection, as in *manual* switching, is the simple "cord-plug-jack" operation shown at the right—

connect the end of one telephone line to another.



Now let's consider the operation of the central switching point shown in the simplified telephone system on Page 4. The lines from the three telephones are brought in to this point so that any two sets can be connected together for the duration of a conversation, and then disconnected.

Above is a diagram showing the switching panel of our elementary system. The function of this switching point is to provide an electrical connection between the ends of any two of the lines. This *could* be done with a number of different sorts of switching devices. In fact, if the wire ends were loose, the telephone operator could simply twist together the ends of the lines from the two telephones, and *untwist* them when the call was finished. But this would be much too slow, and there would be considerable wear and tear on the wire ends—and on the operator's fingers.

A highly satisfactory *manual* method for making the connection is the familiar cord-plug-jack arrangement. This is illustrated in its simplest form in the diagram at the left. The lines from the telephones are connected to receptacles, or "jacks," on panels in front of the operator. The operator has a short flexible piece of insulated electrical conductor—a "cord"—with a metallic "plug" on each end. By putting the plug at one end of the cord into one jack, and the plug at the other end into another jack, the operator provides an unbroken path for electrical currents to travel between the two lines.

The basic operation of *automatic* switching, which uses relays and other automatic devices, can not be described so simply as that of the manual switchboard. Its purpose, though, is the same as that of manual switching—to provide a path that will link together the lines from two telephones for passage of electrical currents.

technically speaking

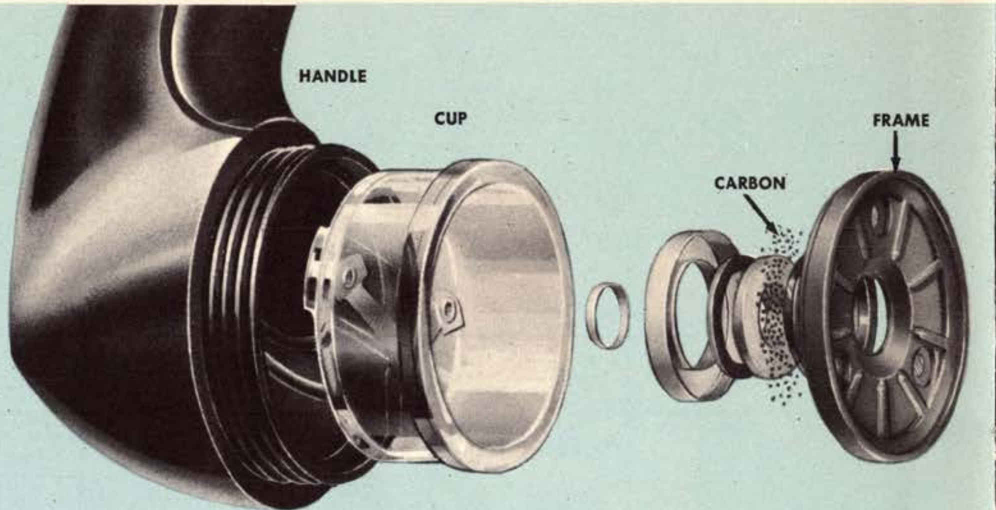
The switching problem in telephony is put in a clear light with the aid of a little simple mathematics. The switching equipment must be capable of making prompt connection from the end of any subscriber's line to the end of any other subscriber's line. The number of different connections that must be made obviously goes up very rapidly with an increase in the number of telephones served: it can be expressed by the formula $\frac{x(x-1)}{2}$, where "x" is the number of telephones served by the central office. According to this formula, a central office serving 5,000 telephones must be prepared to make any of 12,497,-500 different connections. With 10,000 telephones, the number rises to 49,995,000!

Manual switching, as it has developed in the Bell System, handles this problem by grouping the ends of a large number of subscribers' lines closely in the familiar rows of jacks, any one of which can be reached by a number of different switching operations in the central office. Automatic switching uses the many different *combinations of positions* that are available when a series of automatic switching elements are hooked together.

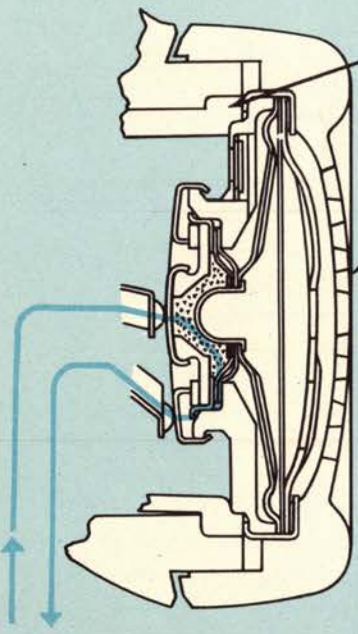
THE TRANSMITTER: It varies electric current to

In this operation in the Company's Indianapolis plant, a machine is used to place carbon granules in the transmitter of the new "500" set. Hundreds of granules are needed to fill one assembly.

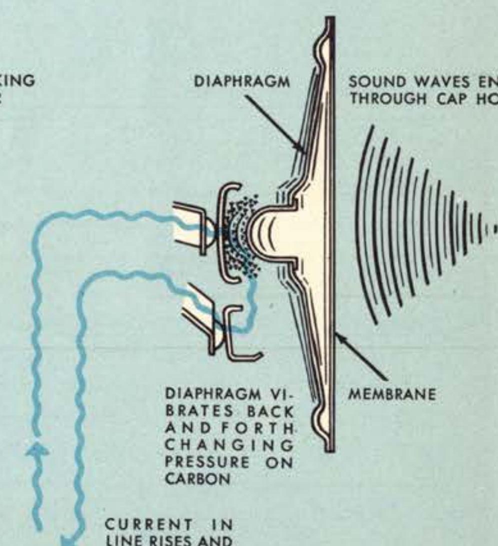
Performing an assembly operation in the manufacture of the transmitter for the "500" set. The operator is fastening a gold-plated electrode to the transmitter diaphragm. The operation is a precise one, because the parts must nest together in order to meet the close tolerances required.



A Here are the parts of the transmitter

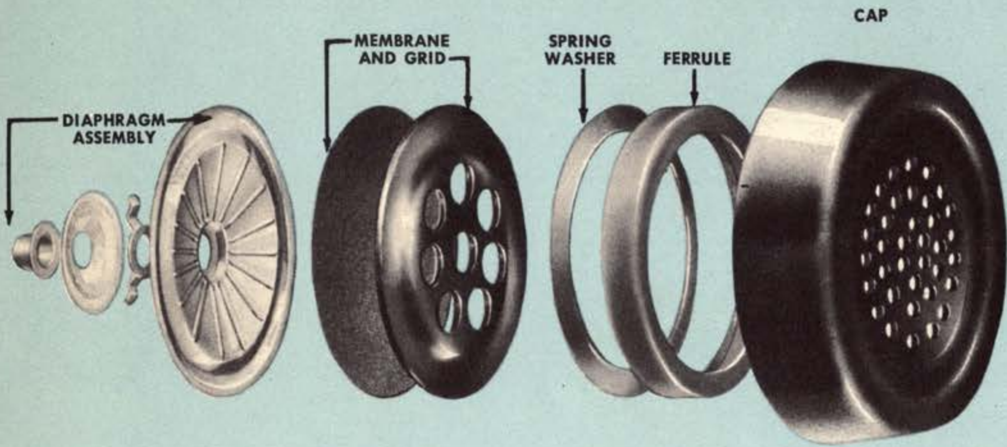


B When the handset is lifted, but before sound strikes the transmitter, steady current from the central office flows through the transmitter like this—



C When sound strikes the diaphragm, here's what happens to the current—

resemble the sound pattern imposed on its diaphragm.



Did you ever think of a telephone call as one of the world's most ingenious tricks of imitation? We pointed out on Page 7 that the voice you hear in the receiver of your telephone is *not* the voice at the talking end, but a similar sound produced electrically in the receiver next to your ear. Let's begin to look at the main parts of the telephone instrument to see how they work together in creating this wonderful illusion.

We already know (Page 7) that the transmitter produces variations in electrical currents that rise and fall at the same rate per second as the vibrations of the voice. Above, in Illustration "A," we have laid open the transmitter and labeled its parts.

Now look at Illustration "B," which shows the parts in place, with current from the central office power supply flowing through the transmitter—as though you had lifted the receiver but had not begun to talk. The steady flow of current through the transmitter conveys no conversation. It has no *change* or *vibration*. It's something like a blank ticker tape coming out of a machine. But it must be flowing over the line so that the instrument will be ready when you begin to talk.

Now look at "C" to observe what happens when you talk. Sound enters the holes in the outer cap. The membrane moves in step with the sound, passing the vibration on inside to the diaphragm; the diaphragm then moves back and forth the same number of times per second as the sound vibrations, squeezing the carbon grains a little tighter each time it moves in, and relieving the pressure a little each time it moves out. Remember that the current coming over the line passes through these same carbon grains. When the grains are a little more tightly packed together by the inward moving diaphragm, more current can flow; when the diaphragm moves out and the carbon grains loosen a bit, less current flows. Thus the variation in the flow of the current is closely in step with the sound of your voice. And this current variation is carried through the line at tremendous speed—at nearly the speed of light, or about 186,000 miles per second!

technically speaking

An objective in the design of the transmitter in the new "500" set was to produce an instrument with ruggedness and reasonable manufacturing cost that would (1) provide an improvement in frequency characteristic over previous designs, and (2) produce about 5 db more output than previous designs.

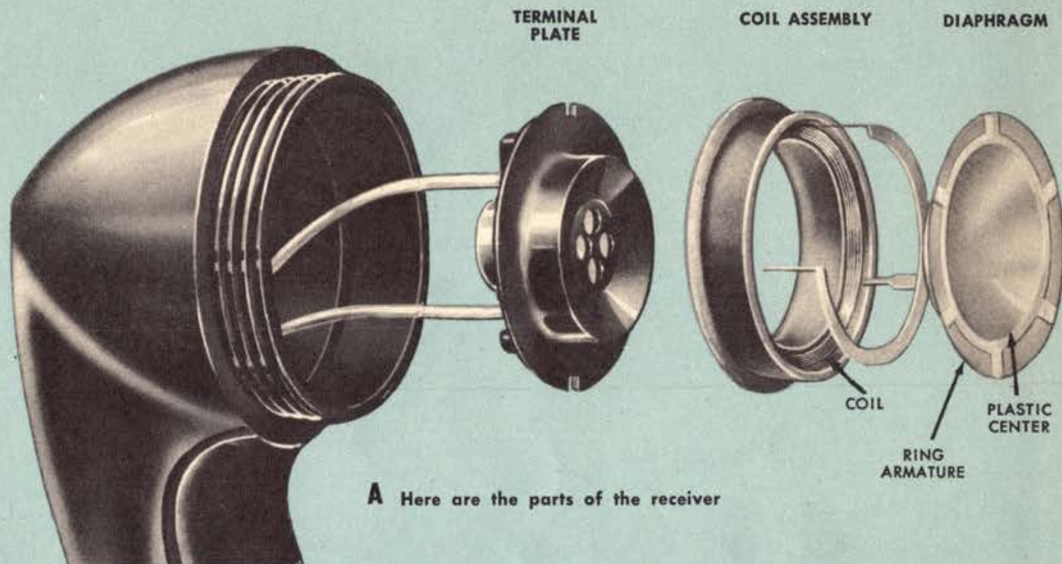
In the design of the transmitter, an actual electrical network was built with circuit elements that "corresponded," by the "equivalent circuit" technique, to all of the mechanical and acoustical parts of the proposed transmitter and its housing. Computations on this equivalent electrical circuit indicated the constants required to obtain the desired response frequency characteristic. This procedure materially shortened the time needed to determine the constants of those mechanical parts involved in the transmitter performance.

The desired 5 db increase in output was obtained by clamping the diaphragm rigidly at its periphery; by improving the modulation of the carbon granules; and by putting the transmitter closer to the speaker's mouth with a shorter handset.

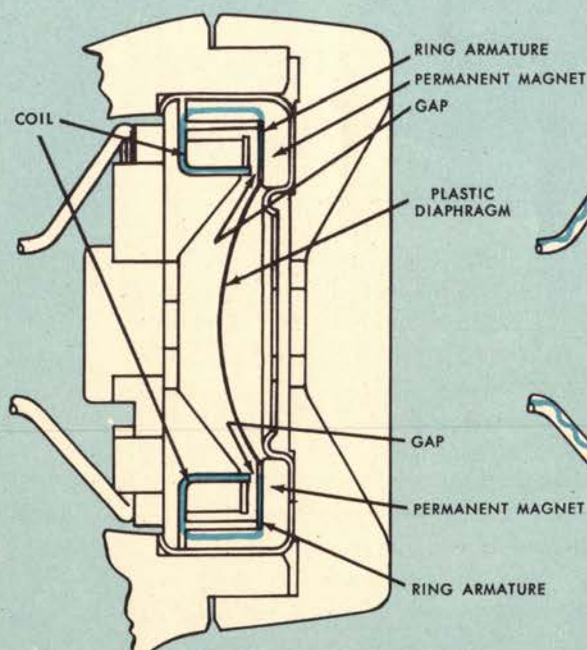
THE RECEIVER: How the receiver

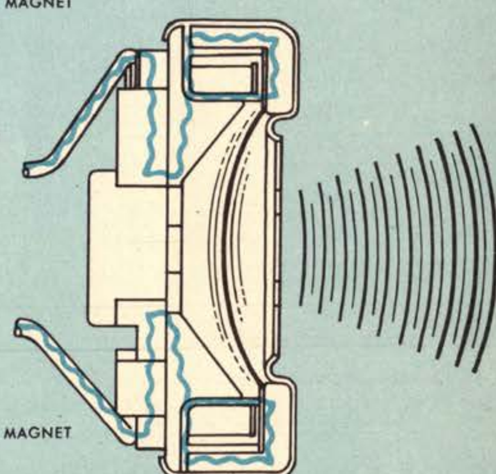
This Indianapolis employee is operating an automatic screw machine, making the pole piece for the receiver. Four other Indianapolis people have similar jobs in manufacturing the receiver.

The receiver coil is fastened in place by pressing a coil stop into position. This particular operation is performed at two stations, one on each of the two receiver assembly lines now being operated at Indianapolis.



A Here are the parts of the receiver

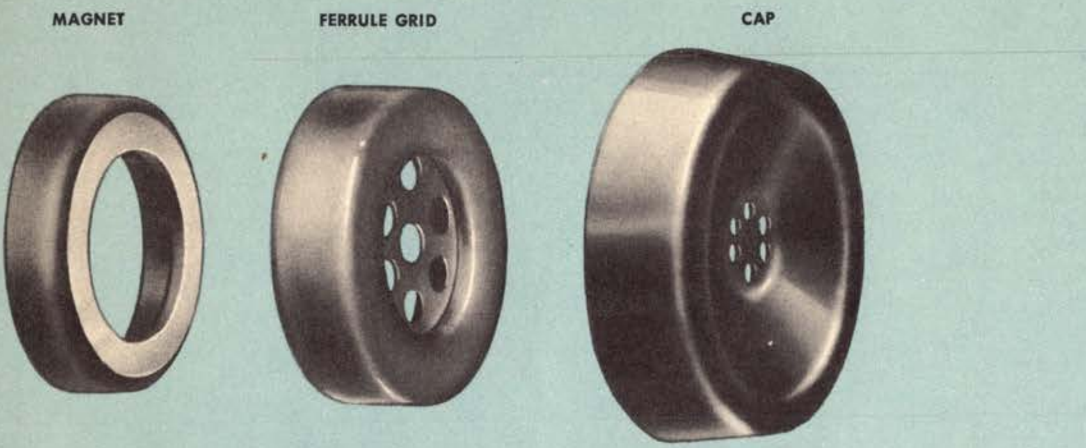




B With the parts assembled, but with no current reaching receiver, magnetism flows through as shown here—

C When a varying electric current flows in the coil, here is what happens to the magnetic force, the diaphragm, and the air next to the receiver—

of the "500" set produces sound.



When the lines from two telephones are connected in the central office, the current flows into the receiver of the called telephone, and there sound is created for the listener. Pictured above are the receiver parts involved in this ingenious "trick."

Now let's put the parts into working position. In Diagram "B" at the left the receiver is at rest—no sound being produced. Note the lines representing magnetic force flowing from the permanent magnet. And note that the outer edge of the ring (the armature) rests on a supporting lip, held there by magnetic attraction. All around the inner edge of the circular armature is a small space between it and the pole piece of the magnet. Magnetic force flows across this gap, pulling on the inner edge of the armature.

Diagram "C" shows what happens when the varying electrical currents from the transmitter of the calling telephone flow into the coil of the receiver. The coil lies inside the permanent magnet, forming an *electro magnet* that aids or opposes the *permanent* magnet. Magnetic force in the receiver is alternately increased and decreased, depending on the direction in which the alternating current is flowing. This variation in magnetic pull causes the flexible armature to move in and out all around its inner edge. The plastic diaphragm moves in and out with the ring at the same rate and, in turn, pushes against the air, setting the air into vibration at the same rate.

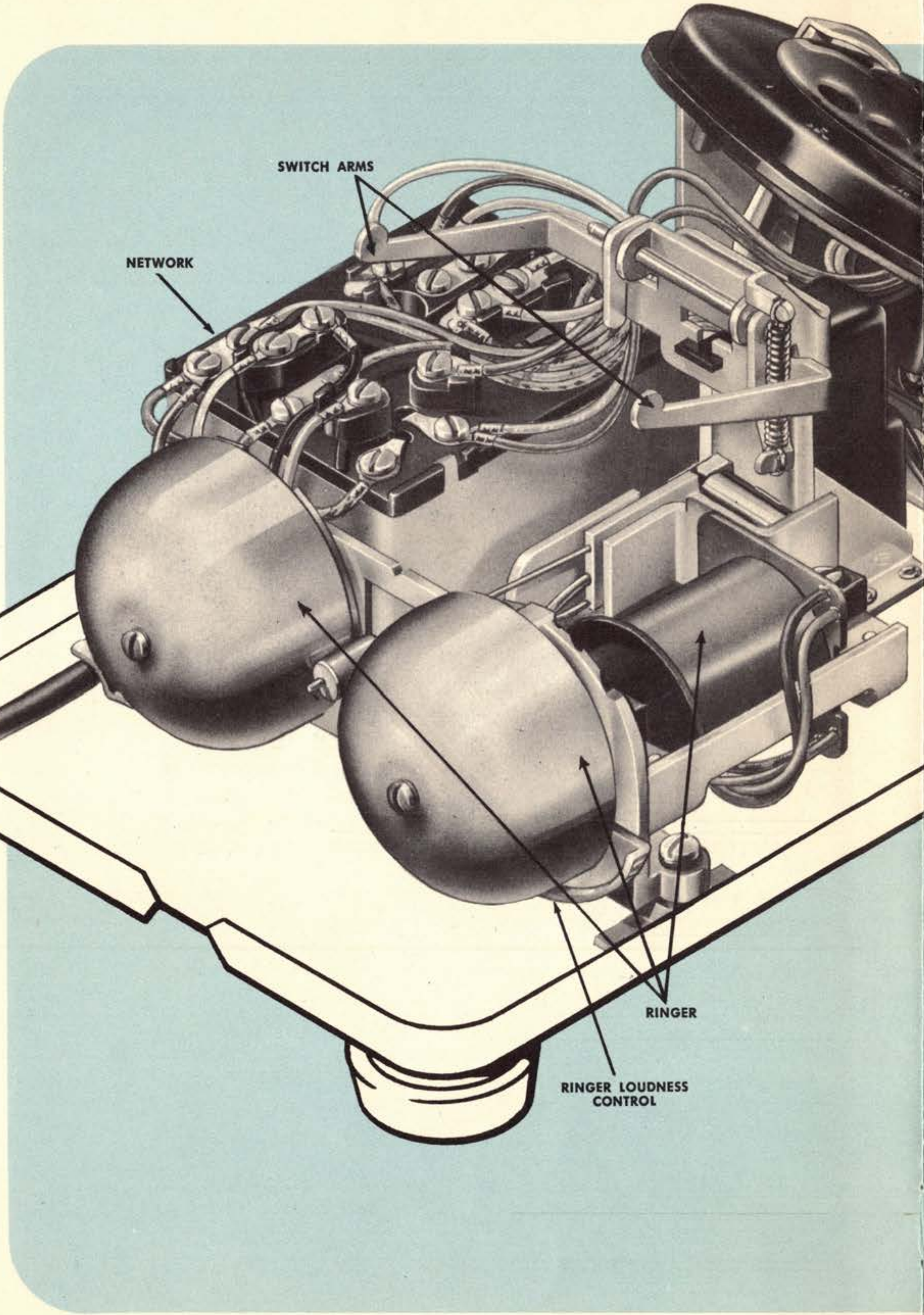
This air vibration is the "voice" you hear in your telephone receiver. It is an excellent imitation of the voice at the other end of the line because every part in the system has been designed to pass along substantially unchanged the *essential element* of the original sound—*its vibration*. Beginning with the motion of the transmitter diaphragm, this vibration is handed on through a succession of variations linked in a chain: the varying pressure on the carbon grains; the varying electrical currents on the line; the varying magnetic force in the receiver; the varying motion of the "ring" and diaphragm; and finally the varying air pressure next to the ear of the listener. It's a neat "trick," isn't it?—one of the most useful that science has so far devised.

technically speaking

The "ring armature" receiver in the new "500" set is a sharp departure from earlier designs. The moving system is divided into two parts: (1) a central dome of lightweight plastic material, which is used to recreate sound waves, and (2) a ring of metal attached around the outer edge of this dome, which is the part acted on by the electromagnetic force produced by the "talking current" and the magnetic circuit. An advantage of this arrangement, as contrasted with the earlier designs in which the whole diaphragm was of metal, is that the central dome moves almost entirely like a piston, that is, in one piece, with consequent improvement in frequency response. Also the moving system is much lighter, and with the larger effective area this gives the receiver much lower acoustic impedance, with better performance when the receiver is held off the ear (as may occur in service), and wider frequency response.

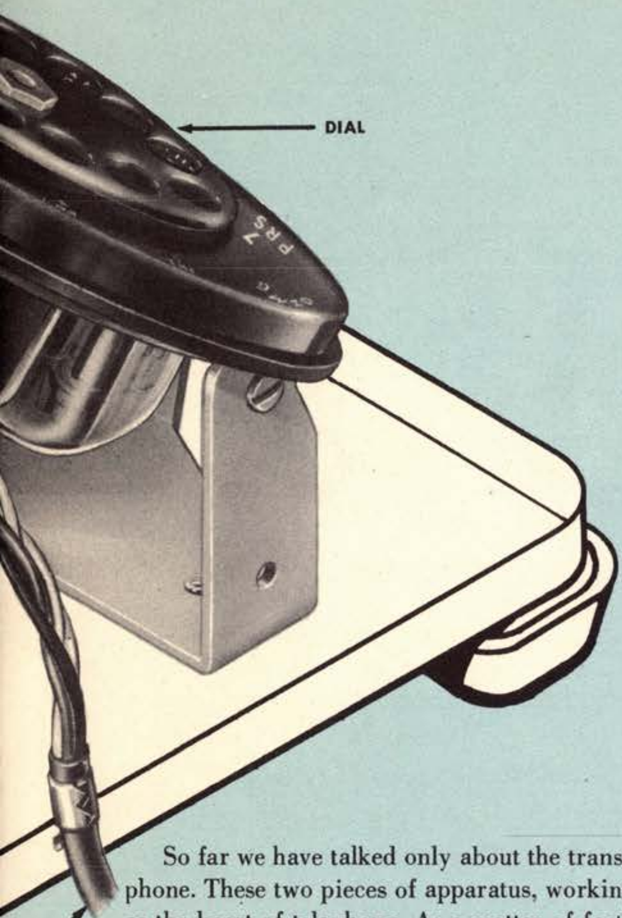
IN THE BASE OF THE SET: Before the housing or plastic cover

A "500" set housing is placed on the conveyor after finishing operations have been completed. These housings are injection molded in one piece in a 600-ton injection molding press.



This operator is fastening the completed calling dial into position during final assembly operations on the "500" set.

is placed over it, the base of the "500" set looks like this:



So far we have talked only about the transmitter and receiver of the telephone. These two pieces of apparatus, working together, might be described as the heart of telephony. As a matter of fact, Bell's original telephone was actually just a receiver—it served not only as a receiver but also as a transmitter.

But in the telephone of today—the "500" set—the molded handset containing the transmitter and receiver accounts for only 78 of the total of 471 parts in the set. The base, including dial and housing, contains 393 parts, and all of these parts are important. They perform a number of auxiliary functions that are essential in making a telephone call.

The main components of the base are the *switch* that goes into operation when you lift the handset; the *ringer* that summons you to the telephone; a *network* that couples the instrument to the line so that your own voice currents, reaching your receiver, are reduced to a point at which they are not bothersome; and, on sets connected to an automatic central office, the *dial* mechanism.

These components are shown, left, in a view of the combined set with the housing removed. Let's assume that you have lifted the handset from its cradle—the telephone is ready for operation. Now for a short explanation of how the principal components of the base help you make your call.

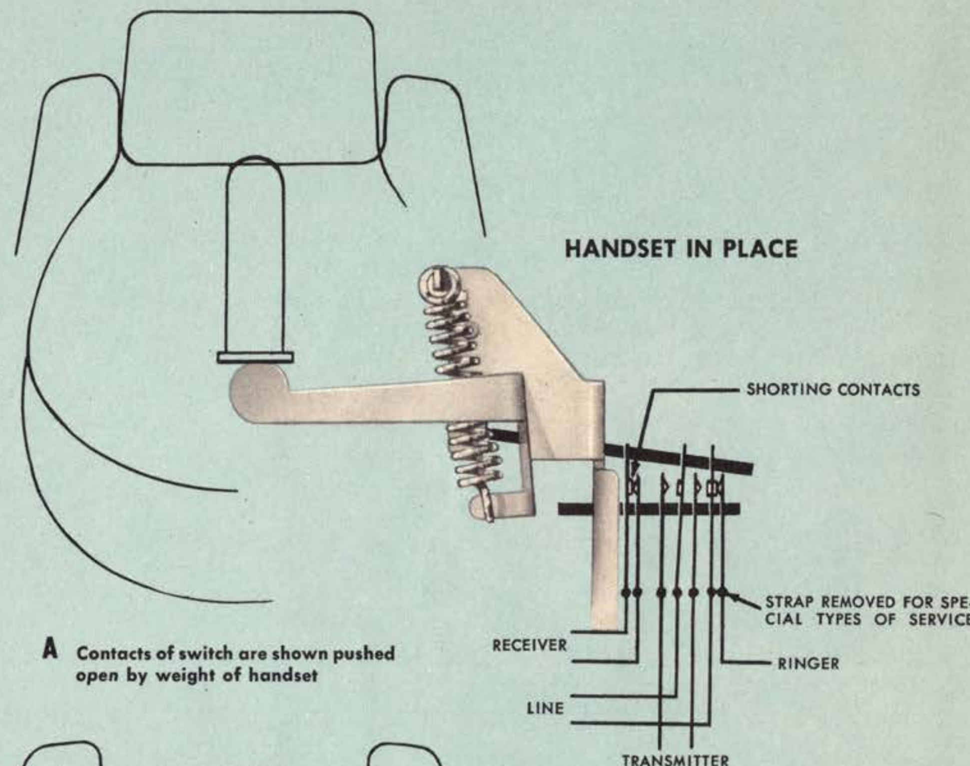
technically speaking

The circuit of the "500" set (See Page 21) is a variation of one of the standard anti-sidetone circuits developed by the Bell System, but with the addition of a more refined balancing network that automatically matches the set to the individual subscriber's line conditions. Because of the increase in efficiency of the new transmitter and receiver combination, sidetone would have risen to objectionable levels without the more complex balancing network which more nearly "balances out" the sidetone. Also, because of the new instrument's efficiency, the loudness level would have been excessive on short loops. The network contains an element that reduces the transmission level for short loop connections but permits the maximum transmission performance for long loop connections where full efficiency is desired.

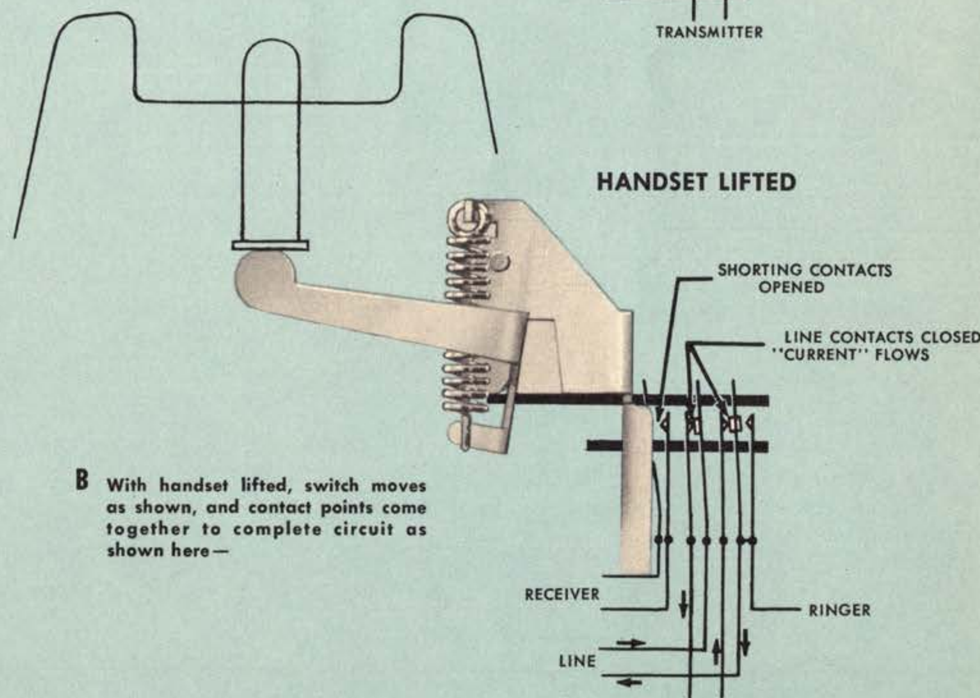
THE SWITCH: When you lift your handset, the

In performing initial stages of operations on switch assembly line, this operator selects switch parts from stock and puts them in the proper order on an assembly fixture. Then other operators add other parts until the pile-up of each switch assembly is complete.

This Indianapolis plant operator is performing final assembly operations on a switch for the "500" set. She is one of nine Indianapolis employees who do similar work on switch assemblies.



A **Contacts of switch are shown pushed *open* by weight of handset**



B **With handset lifted, switch moves as shown, and contact points come together to complete circuit as shown here—**

switch connects your transmitter to the line.

What happens when you lift up your handset? Within the plastic cover of the base, a spring immediately throws a *switch* from one position to another.

If your telephone is connected to a manual switchboard, current from the central office flows immediately through your transmitter and back to the central office, where a switchboard lamp signals the operator that you wish to make a call. Next you hear the operator's voice, carried by the talking current:

"Number, please?"

Substantially the same thing occurs if your telephone is connected to a dial central office. The lifting of your handset throws the switch, and the current flowing through your instrument has the effect of "signaling" the automatic central office that you wish to make a call. This equipment responds by releasing a flow of current known to telephone users as the "dial tone." This tone says, in effect:

"Number, please?"

At the left are diagrams that show how the switch in the base operates. Note that the switch has three sets of contacts. Diagram "A" shows how these contacts are arranged when the handset is in its cradle:—Each side of the telephone line from the central office is broken by gaps in two sets of contacts; the third set of contacts is closed, "shorting out" or eliminating the receiver. It's because the receiver is "shorted out" that you don't hear a loud click in your ear when you "flash" the operator.

Diagram "B" shows you what happens when you lift your handset. The switch has snapped over, and now both sides of the line are connected, and the short circuit across the receiver has been opened. Now current from the central office is flowing through your set.

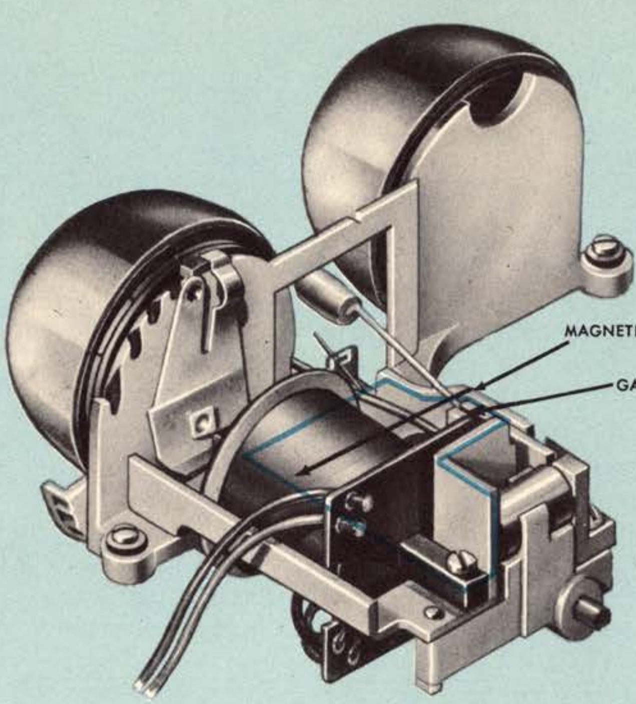
In a moment you'll hear the "Number, please?" of the operator or the dial tone of an automatic switching system.

technically speaking

In previous designs, the weight of the handset was sufficient to operate the switch through a direct linkage operating against the force of the contact springs. Because of the lighter handset of the new set, it was impractical to utilize such an arrangement. In the new switch, the activating force is furnished by a coil spring, and the contact springs are biased to oppose this force, thus acting as a counterbalance. The handset weight, through lever arms, is thus required to overcome only the force differential between the coil spring and the contact springs. At the point where the contact springs reach the end of their stroke and the activating card disengages, the full force of the coil spring comes into play. At this point, however, the coil spring mechanism is approaching dead center, and very little buildup in operating force is encountered. This assures correct seating of the lightweight handset on the mounting.

THE RINGER: It produces the familiar

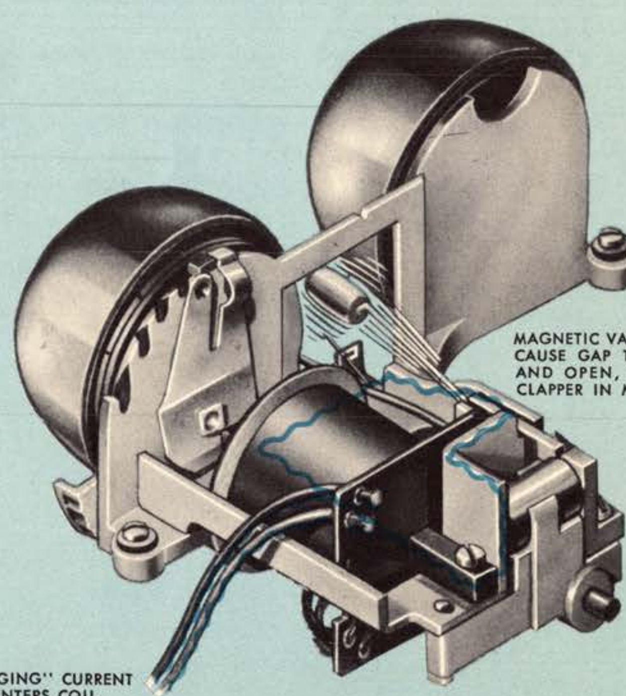
This operator is performing a preliminary adjusting operation on the ringer assembly line. She is one of 26 Indianapolis employees engaged in similar work.



A When no "ringing current" is coming over the line, the ringer in the 500-type set looks like this—note path of magnetic force.

This Indianapolis plant employee is operating an automatic ringer adjuster (see "Technically Speaking" on Page 19). She is one of four people assigned to automatic adjusting machines.

B To make your telephone ring, an alternating ("ringing") current is sent over the line, and through coil on ringer, causing clapper to move as shown—



sound that summons you to your telephone.

The telephone's ring is one of the most familiar sounds in modern life—and even in the make-believe life of the stage, movies, radio and television, it has become a commonplace part of the action portrayed.

At the left are diagrams of the device that produces the ring. The action of the *ringer* is based, like that of the receiver, on the effect made by a varying electrical current flowing in a coil wound around the coil's magnetic structure. In Diagram "A" are shown:

The permanent magnet, which, because of the magnetism in the air gap, produces a constant magnetic force on the armature to which the clapper is attached.

The magnetic force flowing through the structure.

A spring that holds the clapper against the right hand bell. This spring is just strong enough to hold the clapper assembly away from the magnet when no electric current is present.

In Diagram "B," an alternating current is flowing through the coil and the magnetic force across the gap is alternately increased and decreased. The result is that the clapper is alternately pulled sharply first against the left-hand bell, and then against the right-hand bell.

The ringer is always connected to your telephone line and is put in action by an alternating current supplied by the central office just for this purpose. "Ringing" current is sent from the central office over the line into your telephone whenever your number is called.

A new feature of the ringer in the "500" set is the tone relationship of the two bells, carefully adjusted to produce together a pleasing, harmonious sound. The "500" set also has a control knob on the under side of the base plate by which you can adjust the volume of the ring. Turning the knob in the direction of "soft" or "loud" adjusts the distance the clapper moves in its stroke.

technically speaking

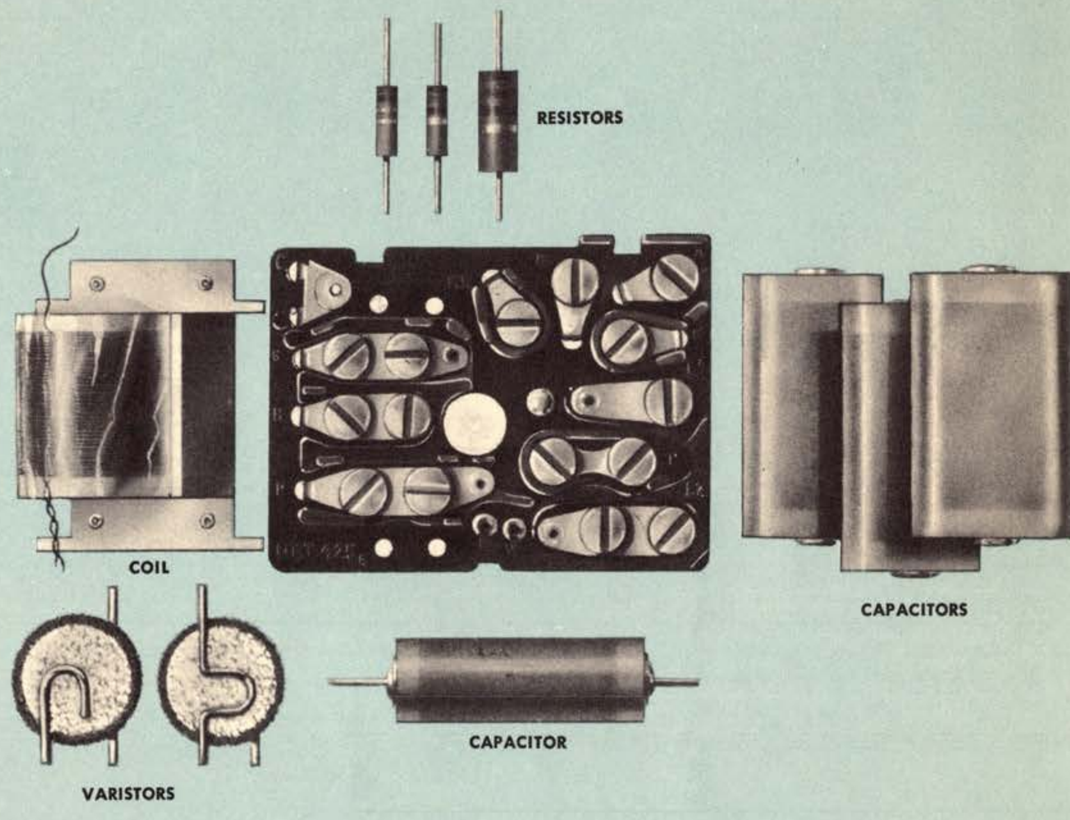
The ringer coil and magnet designs in the "500" set produce a higher impedance than in earlier designs so that five bridged ringers can be used per line instead of the previous four, with resulting low bridging loss. The sound output can be adjusted over a total volume range of about 14 db. The fundamental tones of the bells are lower in the musical scale than previous bells. The two gongs are a musical third apart, producing together a harmonious sound.

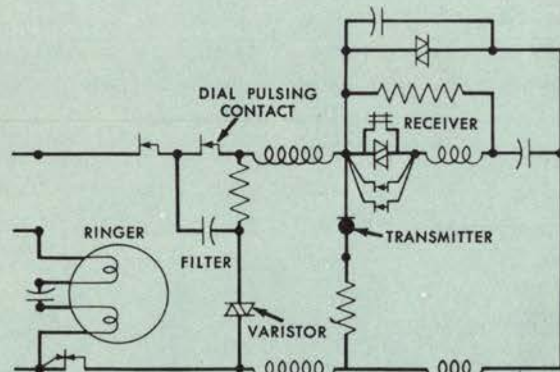
In the manufacture of the ringer, the principal adjustment problem is the balancing of the permanent magnetic pull against the spring that holds the clapper assembly away from the magnet when no ringing current is applied. The two forces—magnetic and spring—are interdependent in their effect on performance, and adjustment by hand would be very slow and costly. To overcome this, an automatic adjusting machine was developed for the ringer, with a demagnetizing circuit, which can demagnetize the permanent magnet in the ringer in controlled steps, and a servo mechanism for tensioning the spring. The ringer is placed in the machine and the adjusting machine automatically brings the two forces to the proper balance by a series of rapidly repeated small changes. Concurrently, the machine tests the ringer to make sure that operating requirements are met.

THE NETWORK: It couples the instrument to the line in such

This member of the network assembly group in the Indianapolis plant performs two operations: she rivets the capacitor bracket and clinches the induction coil to the terminal plate. Over 60 Indianapolis employees work in the network assembly group.

This operator in the network assembly group is shown soldering a resistor to the capacitor on the network assembly. There are 21 Indianapolis employees engaged in similar work.





CIRCUIT OF THE "500" SET

a way that your own voice currents don't become bothersome.

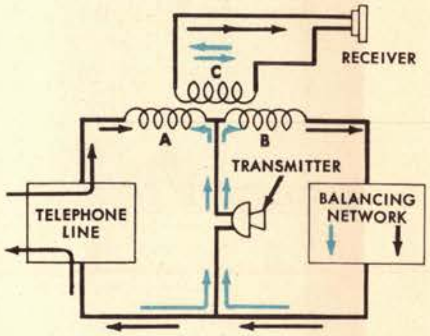
Have you ever wondered why the sound of your own voice doesn't come back to you through the receiver as you talk over the telephone? The square housing next to the right-hand bell of the ringer contains an array of electrical parts that prevent this from happening. At the same time these parts effeciently transmit the voice currents to and from the line.

This unit in the base, known as the *network*, contains the induction coil, resistors, and metalized paper capacitors. All these parts are shown and sparately identified on the left.

The coil and two of the capacitors make up the "anti-sidetone" circuit. "Sidetone" is the technical name for the sound that travels from the transmitter to the receiver of the same instrument. Since both the transmitter and receiver are connected to the line, a person talking into the transmitter would naturally send sound currents into his own receiver as well as into the one at the other end of the line. To prevent the talker from blasting his own ears, "sidetone" is reduced below bothersome levels by including in the circuit a clever arrangement of the coil, varistors and capacitor. This is how it works:

When varying electrical currents come in from the *line*, that is, from a distant telephone, they flow freely through the *receiver*. When such currents start at the *transmitter* in the same set, they go through the coil in such a way that any currents from the transmitter flow readily to the line—but the windings are arranged to buck or cancel out the current through the receiver.

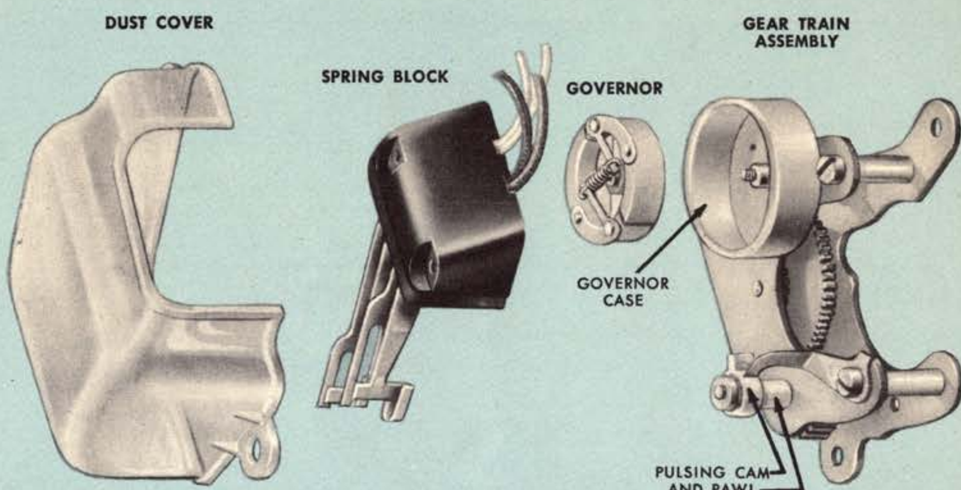
That, in brief, explains why your own voice currents don't come back to your ear to a bothersome degree when you make a telephone call.



technically speaking

The basic principle of the anti-sidetone circuit is shown, simplified, in the schematic above. Coil labeled "A" induces a voltage in Coil "C" that cancels that induced by Coil "B" on current from transmitter, but not on current from line. Arrows indicating path of current through transmitter and out to line show that this current can not pass through receiver because it passes through the two coils "A" and "B" in opposite directions. But current coming in from the distant telephone passes through "A" and "B" in the same direction.

THE DIAL: With this familiar device you help



A Exploded view of dial

By means of this machine in the Indianapolis plant, the center post or bearing is pushed into the dial frame. The operation is performed by hydraulic pressure.

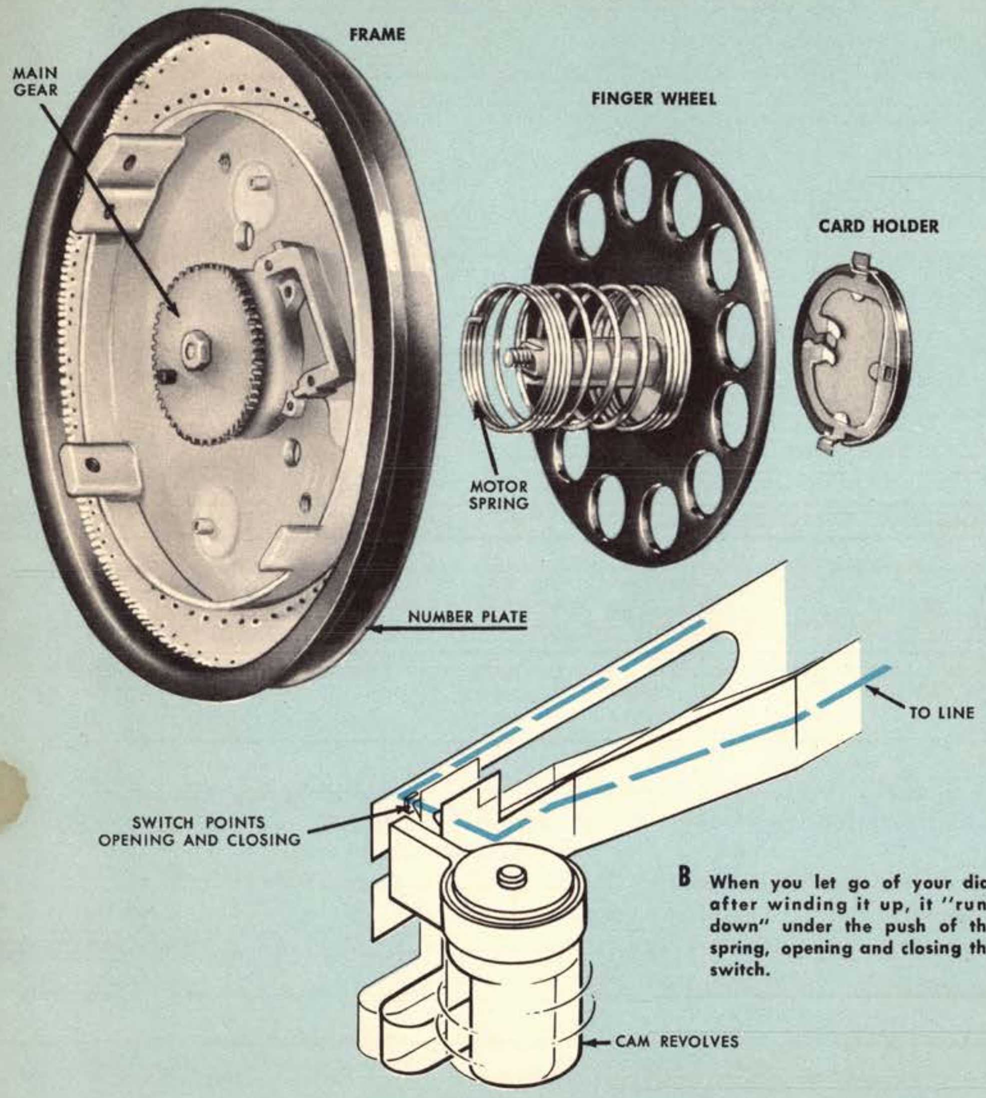
This Indianapolis plant employee is shown adjusting a dial to insure proper pulsing. This adjustment operation is performed at six other stations in the dial assembly group.

Your telephone may or may not include a dial, depending on whether it is connected to a manual or to an automatic central office. Above is an "exploded" drawing of the new dial mechanism, the operation of which is very simple. Remember, first, that when you lift your handset, and before you talk or dial, a steady electrical current, called a "talking current," flows from the central office to your set. It is the *variation* in this talking current, caused by variation in pressure on the carbon granules in the transmitter, that "carries" your voice.

The dial uses "talking current" in another way. The dial is really a switch to turn the current on and off. If the path for flow of current is broken *in your set*, current from the central office will stop flowing. This is a form of signaling, because whenever the current stops flowing through your set, that fact is immediately evident in the central office. If the flow is broken in a series of "opens" and "shuts," relays in the central office can "count" each set of these interruptions of talking current.

Now let's look at the dial mechanism to see how it produces these breaks, or "pulses," in the current on the line. The break is made at the switch points shown in Diagram "B." When you release the dial, the clock-like gears revolve, and this revolves the plastic "cam." Each time the cam turns around, it pushes the switch open and allows it to close again, thus producing one of those "breaks" in the current that are counted in the central office.

to perform complicated switching operations.



B When you let go of your dial after winding it up, it "runs down" under the push of the spring, opening and closing the switch.

When you dial "7," for instance, the cam revolves on the "run down" just enough to open and close the switch seven times. In the central office, a set of relays records the interruptions of current as a "7-series."

Each letter and number you dial actuates the relays in the central office. Then the equipment automatically connects you to the called telephone. (Just how this automatic switching is accomplished is another big story.) So when you wind up your dial and release it you are actually controlling the action of the switching equipment in the central office—you are your own operator. A wonderful machine, the dial central office!

technically speaking

Among the differences between the dial in the 500 set and the dial in previous designs is the single-lobed cam. Instead of a cam with a series of lobes, which open and close the contacts when the cam turns through the necessary fraction of a revolution, the cam in the new dial is connected to the shaft through a gear train, so that it revolves the required number of times, opening the contacts once per revolution. Thus the same cam action is obtained for each pulse, resulting in greater uniformity of pulses than was obtained with the multi-lobed cam. The speed governor is an improved type. It is connected to the dial by a clutch so that the governor is driven only on the run-down of the dial. Centrifugal force presses the friction studs against the case and regulates the run-down speed of the dial closely.

THAT'S THE STORY...

. . . the story of how one of our main products—the telephone—works. We have taken as our example the newest telephone set Western Electric makes—the "500." Because it is still new, it may be unfamiliar to many readers, but the basic principles of its operation are similar to those of other telephones that we have all used.

As in the case of earlier telephones, many people had a part in producing the new "500" set. First of all, there are the engineers at the Bell Telephone Laboratories who designed into one set the refinements suggested by laboratory research and operating experience in the Bell telephone companies. Then there are the Western Electric engineers who cooperated with the Laboratories designers and worked out the problems of large-scale manufacture. And there are the thousands of production workers in our Indianapolis plant who are turning out millions of telephones each year.

The fact that the "500" set does an excellent job has no trace of accident in it. It doesn't just *happen* to work. Its quality is the result of hard work and teamwork among thousands of people—designers, manufacturing engineers, machine operators, assemblers, testers and others. Backed by the skillful operation of other Bell System facilities by Bell telephone people, the "500" set will contribute to still better telephone service. Again, advancement has come through teamwork of Western Electric people with one another and with other workers in the Bell System.

The same sort of developmental and manufacturing effort that produced this improved telephone set is constantly being applied to the two other main parts of the telephone system—the switching equipment and the connecting lines. The stories of how these other Western Electric products work may be told in future Booklet Rack publications.

This Booklet was prepared for distribution to
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