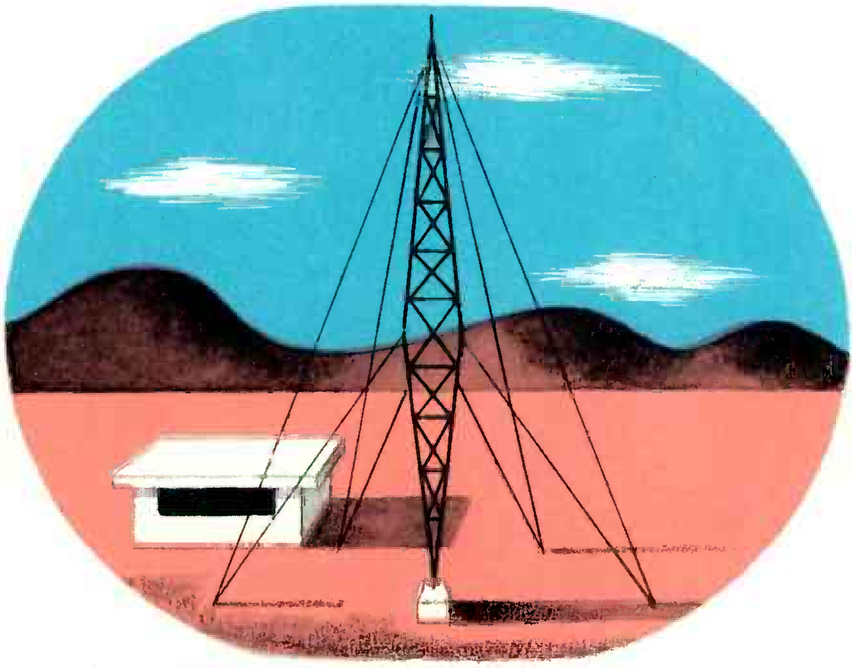
PICTURE BOOK OF RADIO AND TELEVISION

AND HOW THEY WORK



BY JEROME S. MEYER

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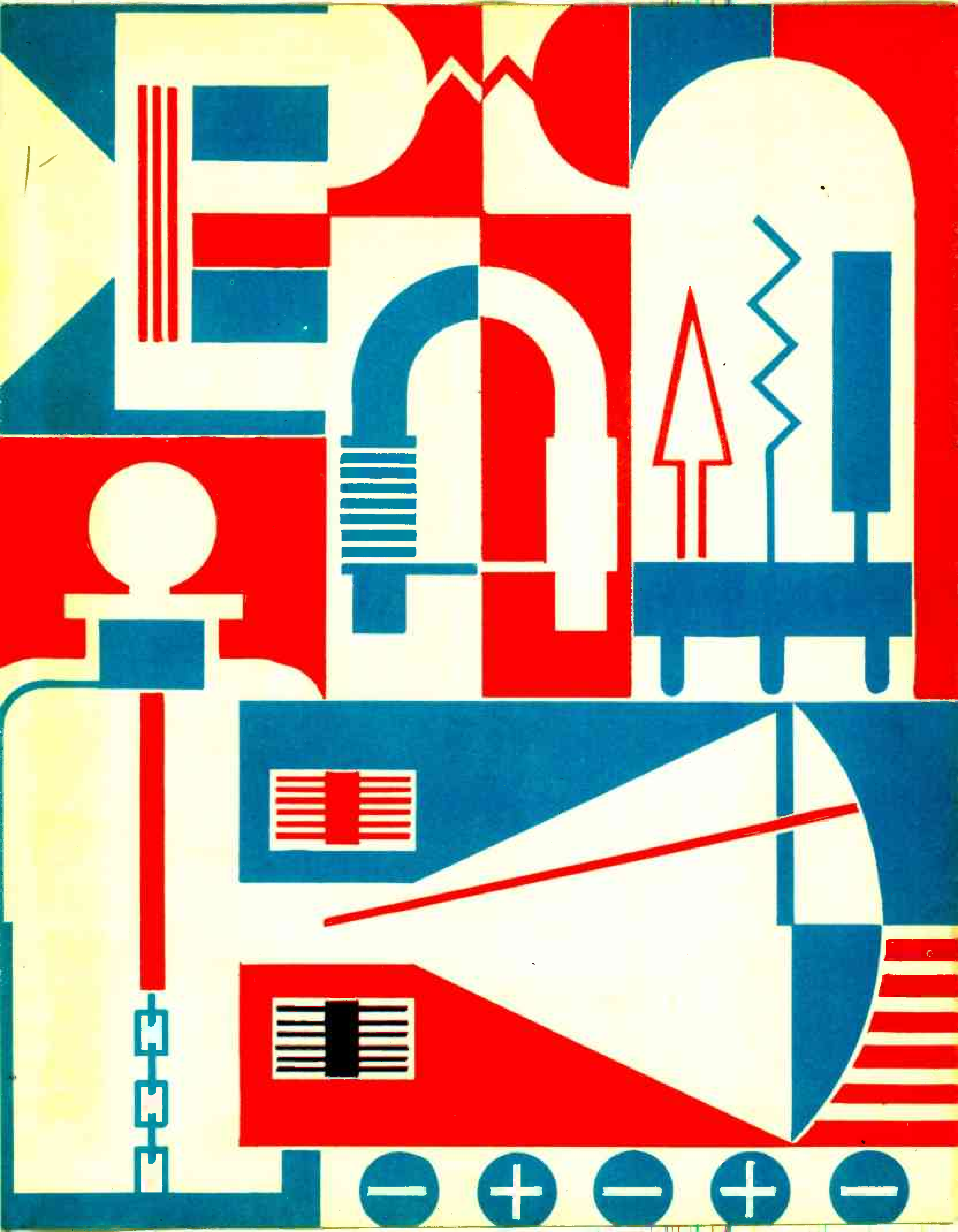


PICTURE BOOK
of
RADIO
and
TELEVISION

To David Emanuel Wartels

MAGIC WAVES IN YOUR LIVING ROOM

SURROUNDING me in this room, as I write this book, are hundreds of strange, invisible complicated waves, all different from one another. They come into my house through the walls and ceilings and floor and, right now, they are doing the same thing in your house. Some are striking this very book, going through it and through you and everything else in the room. They are upstairs and downstairs; they are in the attic and in the cellar and in the garage — even up in the clouds. They travel along with passengers in buses and trains, in steamers and airplanes. They are all over the world, surrounding everything and everyone; yet no one can ever see or hear them or feel them. But we know they are present; all we have to do to prove it is to turn on our radios or television sets. Then we pick them right out of the air and transform them into music and voices that we can hear and moving pictures that we can see.

These magic waves come from everywhere. Turn the knob of your radio just a little and you may hear a news commentator in Australia. Turn it a little more and you may hear a statesman in London or the Governor of California. Or, if you prefer, turn the knobs of your television set and these same waves make it possible for you to see Hopalong Cassidy one minute and the Brooklyn Dodgers in Ebbets Field the next. All you need do to bring the world into that box in your room is turn some little knobs! When you turn the knob of your radio and tune in, you release sound waves and you *hear* the program. When you turn the knobs of your television set, you release sound and light waves and you *see* and *hear* the program. How were these waves brought into your set? The answer, and amazing story behind it, all goes back to

THE LUCKY ACCIDENT THAT CHANGED THE WORLD

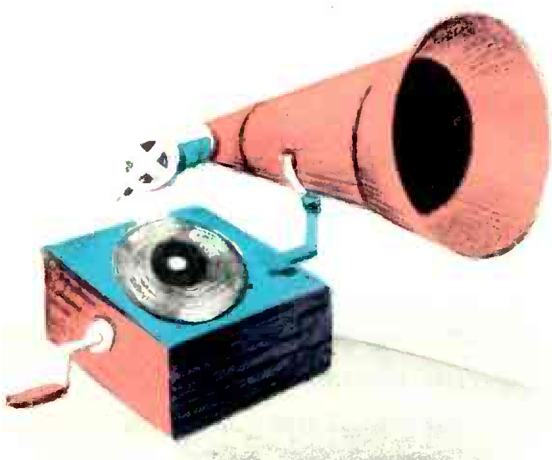
IT happened in Denmark. A professor, while lecturing to his science class glanced down at the table where his compass was resting. He noticed, to his surprise, that the needle of the compass, instead of pointing to the magnetic North, pointed East. Then he noticed that the compass was resting on wires connected to the battery he was using in his lecture.

The professor said: "The electric current in the wires must DO SOMETHING to the needle of the compass to change its position. It must affect it in some way." He reasoned that because the needle of the compass was a small magnet, there must be some connection between an electric current and a magnet. A few years later the electromagnet (electric magnet) was invented, all because of the little professor's important discovery. We shall describe the electromagnet later, but we'll just say here that without this invention there could be no radio, no television, no dynamos or motors or large factories, no telegraph or telephone or electric lights or bells, no electric railroads or elevators, no traffic lights or signals or news tickers, and no electrical machinery of any kind. In fact, everything we see around us today that is run by electricity has one or more electromagnets connected with it. Without the electromagnet we should all be back in the horse-and-buggy days of our great-great grandfathers. And it all hapened because, accidentally, the wires from a battery were under the professor's compass!

ANOTHER LUCKY ACCIDENT

ANOTHER lucky accident happened in France in 1839. Two Frenchmen, by the names Daguerre and Niepce, while experimenting with a peculiar kind of salt, noticed that it turned black when exposed to light. The brighter the light that struck this salt, the blacker it got. Mr. Daguerre, like the professor, said: "light waves must DO SOMETHING to this salt. They must affect it in some way." He then made a wooden box, blackened on the inside, and placed a lens at one end of it. At the opposite end he placed a sheet of gelatin coated with this salt. Then he pointed the lens at an object, uncovered the lens for a second, covered it again and found that the light waves recorded that image forever on the very sensitive gelatin. And so was born photography, and from it, later on, movies and television were developed. If Mr. Daguerre hadn't said, "light waves do something to this salt, let us record what they do," you might not be going to the movies or looking at your television tonight.

Years later, in his home in New Jersey, Thomas Edison did with sound what Mr. Daguerre did with light. Knowing that sound waves actually produced tiny invisible vibrations — as we shall see — he recorded these vibrations on wax with a needle, and when the wax hardened he ran the needle over the recording and brought back those sound waves. He called the device for playing back these tiny markings a PHONOGRAPH, and the hardened wax recordings he called a RECORD. We shall discuss this later on when we understand more about sound.



Just about this time Mr. Edison got thinking about how to make a picture move. Being the genius that he was, Edison reasoned: If I take a few hundred pictures of a horse as he trots along, each picture will be a tiny bit different from the one before it, because the horse will be in a slightly different position each time. If I now move this strip of pictures before my eyes very quickly, I won't see anything but a blur. But if I can, in some way, separate each picture from the next one so that I see each picture in turn flash up and go out, flash up and go out many times every second, and keep that up, my eyes won't be able to distinguish one picture from another because they can't see that fast. "What I will have," said Edison, "is a continuous MOVING picture of the horse as he trots along." And so Edison invented the first moving picture.

The movies and the pictures that appear on your television screen are moving pictures that work on that principle. They flash up and go out on the television screen as much as thirty times in a single second and are really no different from the movies you see in any movie theatre, though they are produced in a different way, as we shall see.

Another genius, very important in our story, was Dr. Alexander Graham Bell. He discovered how to change sound waves into electric current and how to change that electric current back into the same sound waves. You know how far sound waves can travel. Not very far. But the electric current can be sent along wires for hundreds, even thousands of miles. And you know how important Dr. Bell's invention, the telephone, is. You speak into the mouthpiece and the sounds you make are transformed into electric current which goes along wires to your friend's house. There, in the receiver, the electric current is transformed back to the original sound waves and your friend hears the same sounds you made.

Light waves also can be converted into electric current, but the way to do it was not discovered until many years after Dr. Bell's invention.

HOW IS SOUND SENT OVER WIRES?

IN order to answer this we must know a little about the nature of sound. Sound is the rapid disturbance of air which affects our ear drums and enables us to hear. It is the air that makes sound possible and if there were no air or atmosphere on the earth you wouldn't be able to hear a thing. You could hear no music or noise or talking because there would be nothing to carry the sound to your ears. These rapid disturbances in the air are called VIBRATIONS. Whenever a thing vibrates it moves to and fro very rapidly, often as much as 600 or 700 times every second. In doing this it pushes the air around it and sends out little air waves very much like the tiny ripples on the surface of a pond when you throw a small pebble into the pond. The waves travel in all directions and they travel very fast.

Vibrations, the very rapid to and fro motion of a wire or a metal or paper or anything else, send out tiny air waves that gently beat against our ear drums and make it possible for us to hear. Now it is impossible to see vibrations that are so rapid or the air waves that are so tiny and delicate, and you can't possibly feel them against your skin. You know they are present because you hear them. And you can feel the object that vibrates and gives off sound.

TRY THIS SIMPLE EXPERIMENT WITH SOUND

JUST hold a large empty cardboard box such as a hat box lightly in both hands and bring it close to your radio when it is turned on as loud as it can play. You will feel the sides of the box vibrate and tickle your fingers. There will be tiny quivers all over the box as long as it is near the loud music. This is because the air inside and outside the box is responding to the vibrations of your radio and the thousands of tiny air waves sent out from the loud speaker actually affect the sides of the box and cause it to vibrate in the same way.

But more important than that: If it were possible to turn off the radio and keep the box vibrating, the box itself would play music. True, it would be extremely faint but it would be music nevertheless. If the box were made of strong paper and it vibrated violently, it would play the music much louder.

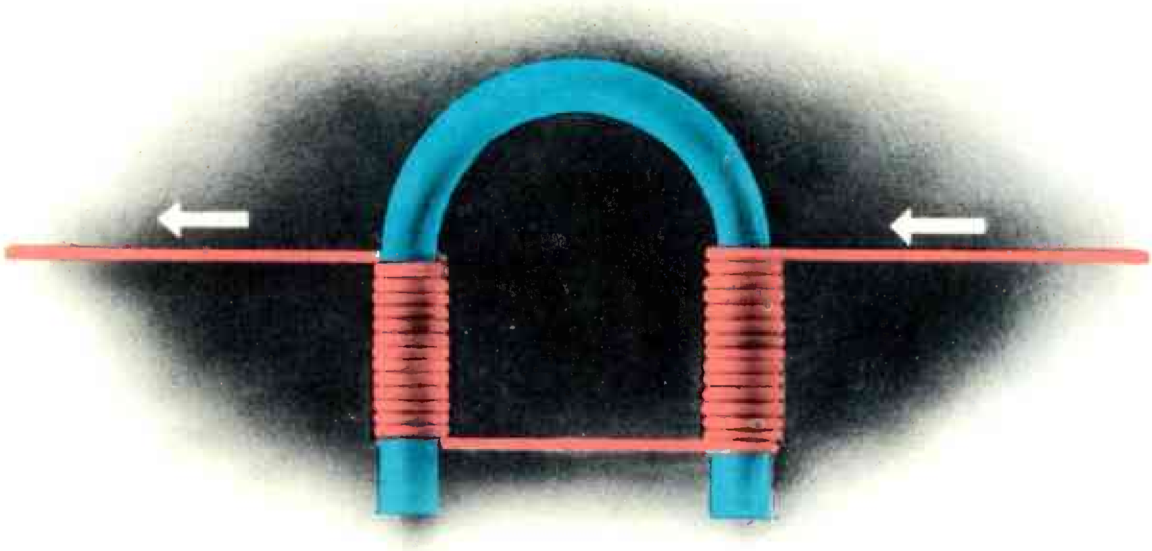
If you perform this experiment you will see that any sound, no matter what it is, will make the sides of the box vibrate. If you talk close to the box you will feel it quiver and, again, if that very slight quiver could be repeated after you stopped talking, you would actually hear that box speak the words you spoke in your own tone of voice. Edison, as we have seen, made this important discovery years ago when he invented the phonograph. He took a thin disc, supported around the edge and attached a needle to it. He then talked into the disc and made it vibrate just as your empty box did. But he recorded the vibrations by having the needle scratch them on a record. After he finished talking he made the needle go over those same grooves and cause the disc to vibrate just as it did when he talked into it. And lo and behold, the disc talked back at him in his very words and voice. By putting a horn or megaphone around the disc he could make the sound so loud you could hear it in the next room.

But how is it possible to send sound hundreds or thousands of miles away? The answer is found in

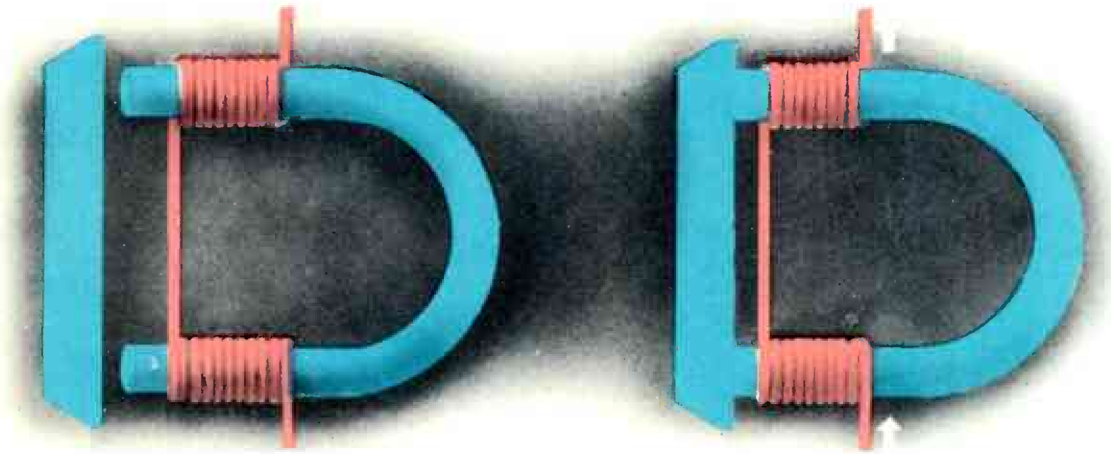
THE AMAZING ELECTROMAGNET

YOU know that sound is sent over wires by means of the electric current but it may surprise you to hear that sound could never be sent over wires without the aid of two magnets. One of the magnets is the kind that attracts tacks and needles and never loses its magnetism. The other magnet is a little different. It is simply a piece of iron with many coils of wire wound around it, the way it is shown in the picture. The very instant that a current is sent through these coils of wire the iron becomes a magnet and the instant the current stops the iron loses all of its magnetism. This piece of iron with coils wound around it is the **ELECTROMAGNET** we already spoke of and which many scientists say is the most important invention in all modern civilization!

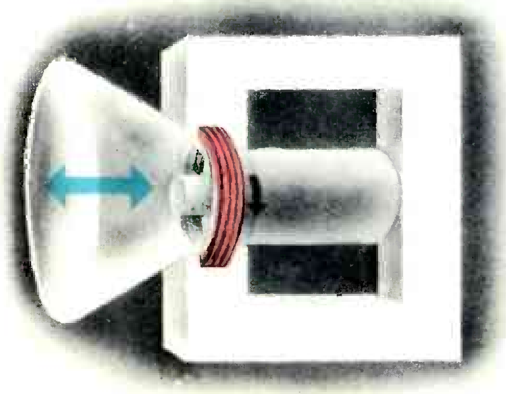
The electromagnet is a magnet when current flows through the coils and is NOT a magnet when the current stops. It is so accurate and so extremely sensitive that it will record the very slightest change in current in the coils of the wire. It is impossible to realize how fast this magnet reacts. If, for example, you could turn the current on



and off a thousand times every second, the iron would be a magnet and lose its magnetism a thousand times in that second! A thin iron disc, as thin as this page, placed very close to this magnet will be pulled ever so slightly toward the magnet and released again, just exactly as often as the current in the coils of the magnet is turned on or off. And not only that, — the amount of pull on this thin disc will be exactly in accord with the slightest change of strength of the current. No matter how fast the current in the coils changes and how many times every second it goes from strong to weak, that disc will move, ever so slightly, just that many times — no more nor no less. The disc, then, will vibrate with each tiny change in current in the coils and can be made to produce sound.



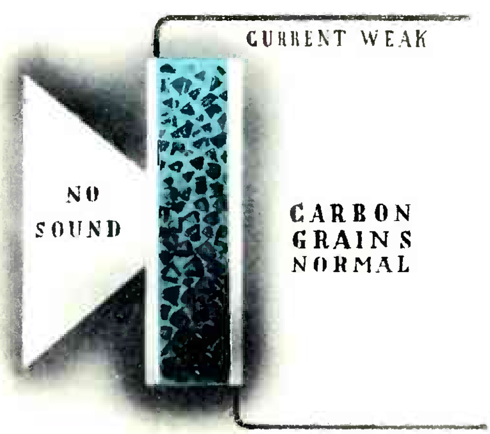
THE LOUD SPEAKER

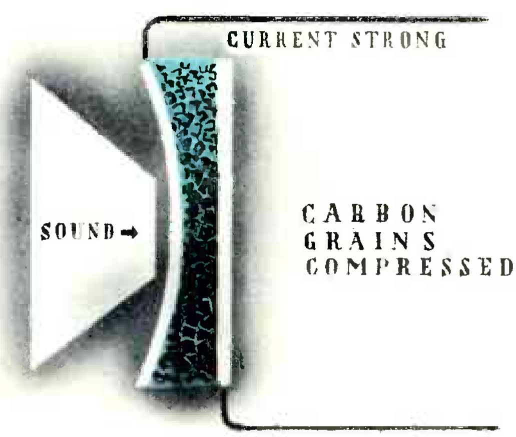


THIS thin iron disc close to an electromagnet is the principle on which the receiver of your telephone or the loud speaker of your radio set works. You might have seen this disc and electromagnet if you have ever unscrewed the receiver end of your phone. In your loud speaker the metal disc is attached to a large cone made of strong paper, and the vibrating paper cone gives you the sound.

THE MICROPHONE

TWO thin metal plates are held at their edges so they are free to vibrate just the way the sides of the cardboard box did when you held it near the radio or talked close to it. Between these thin metal plates, and enclosed in a box, are a number of small grains of carbon, something like very tiny pieces of coal. When an electric current enters the front plate, flows through the grains of carbon and out through the rear plate it flows steadily. There is no change in its strength or weakness. But as soon as you talk or make a noise near the front plate, it vibrates and changes the pressure on the carbon grains. When it presses on the carbon the current flow is strong; when the pressure lets up the current flow is weak. The strength and weakness of the current in





the wires depend entirely upon the vibrations of this metal plate. This device makes the telephone transmitter or the radio microphone work. You might have seen the little compartment if you have ever unscrewed the transmitter end of your phone.

Now you can see that the sounds that vibrate the plate in the microphone cause hundreds of different tiny electrical changes in the current flowing through the wires (called fluctuations). These fluctuations, when sent into the electromagnet of the loud speaker cause the thin iron disc in front of that magnet to vibrate in *exactly the same way* as the plates in the microphone do. The loud speaker then reproduces every sound that was sent into the microphone. And that is the way sound is sent over wires electrically. But how is sound sent long distances without wires? The answer is by means of

RADIO WAVES

RADIO waves travel about one million times as fast as sound waves. Unlike sound waves they do not need air or any other medium to carry them. They travel through space in all directions, and go through walls and ceilings and floors at the amazing speed of 186,000 miles per second. They could go from here to the moon and back in less than three seconds. They cannot be seen or heard or felt, yet they are everywhere.

And there are all kinds of radio waves. Some are vibrating 700,000 times per second and others are vibrating more than a million times per second. The number of vibrations per second is called the FREQUENCY. The different broadcasting stations all over the country are constantly sending out these radio waves, each station having a different wave FREQUENCY. The numbers on your radio dial tell you the FREQUENCY and so identify the different stations.

A SPARK MAKES RADIO WAVES

WHEN you scrape your feet along the carpet on a cold day and touch a metal door knob or some other metal, you may get a shock. An electric spark may jump from your finger to the knob, and sometimes you can actually see it do this. If you could see just what that spark really is you would be surprised. AS FAR AS YOU ARE CONCERNED, it only takes a split second for the spark to leap from your finger to the metal — after that it is all over. But as far as the spark is concerned,

it travels from your finger to the metal, back again to your finger and back again to the metal — to and fro, perhaps a thousand times in that split second! It goes so fast that no eye can see it vibrate.

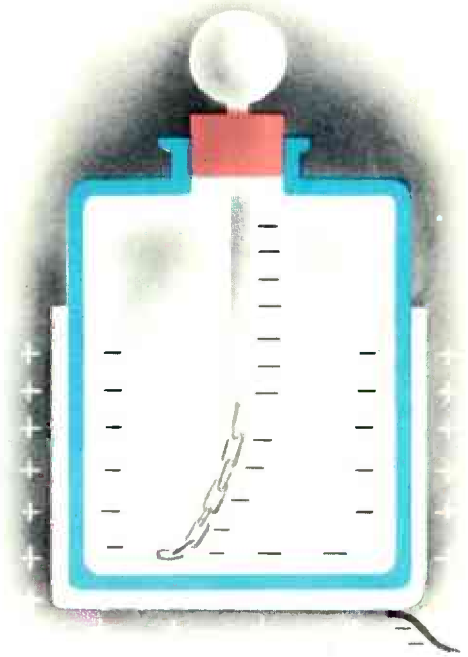
Now, the most important thing is not the spark, but the disturbance that the spark causes in space. In hopping back and forth so fast, it sends out tiny waves similar to radio waves. Of course, the whole thing is over in a fiftieth of a hundredth of a second, but in that small time thousands of little waves actually do travel from your finger and fill the whole room, tiny as they are.

THE LEYDEN JAR

YEARS ago someone coated a glass jar with tin foil, the kind used to wrap up candy and chewing gum. This jar was coated inside and outside with this tin foil and had a metal knob and rod down the center from which a loose chain hung and rested on the bottom, as shown in the picture.

Now the peculiar thing about this jar — called a Leyden jar because it was first made in Leyden, Holland — is that it stores up electricity in just the same way that a water tank stores up water. When you want to tap the water tank, you either put a hole in the bottom or put a faucet on it and turn the faucet on and out comes the water. And the water will pour out of the faucet as long as there is water in the tank.

The Leyden jar is charged with electricity from batteries or a generator. When you want to get electricity from the Leyden jar, you bring another metal knob very near the metal knob of the jar, and a spark leaps from one knob to the other and back, just as the tiny spark did between your finger and the door knob. But the spark here keeps leaping to and fro and will do so as long as there is electricity stored up in the jar. The waves that are sent out from it continue, too. If there is a great deal of electricity in this jar, the sparks will be very strong, but they will not vibrate or jump back and forth so rapidly. If the amount of electricity in the jar is little, the sparks will be weak, but they will jump very quickly to and fro. The waves sent out will depend upon how much electricity is stored up in this jar. You must remember that these waves — the same as radio waves—are actually alternating positive and negative disturbances in space, traveling at almost instantaneous speed and going through everything — walls, doors, closed windows.



The interesting thing about the Leyden jar is that its ability to hold electricity (this is called *capacity*) depends entirely upon the tin foil that it contains; the more tin foil, the greater the capacity or the ability of the jar to hold electricity. If it were possible to roll the tin foil of the jar up and down, like a window shade, the capacity of the jar to hold electricity would vary accordingly. And the sparks given out by the jar would vary in strength and vibration too. By this imaginary moving of the tin foil up and down the sides of the jar and varying the sparks, what you really do is VARY THE VIBRATION OR THE FREQUENCY OF THE RADIO WAVES that the sparks create.

WHY ELEPHANTS ARE NOT ALLOWED TO CROSS THE BROOKLYN BRIDGE

THIS heading may surprise you, for what have elephants to do with what we are discussing? They have a lot to do with radio waves and frequency as we shall see presently. As long as the elephants are *not* marching in step, the bridge would be safe, but if they all came down on the bridge with their *left* feet at the same time and the next second came down on the bridge with their *right* feet, all at the same time, and kept that up, all being in step, the bridge would begin to respond and it would actually vibrate, big as it is, with the up and down, up and down, up and down steps of the elephants. As this vibration would get stronger and stronger, it could

eventually cause damage to the bridge. For the same reason soldiers have to "break step" when marching across a bridge. When your little brother is swinging in a swing and you give him a push every time he comes near you, you know very well he will go higher and higher, provided you push him each time when he is in the same position.

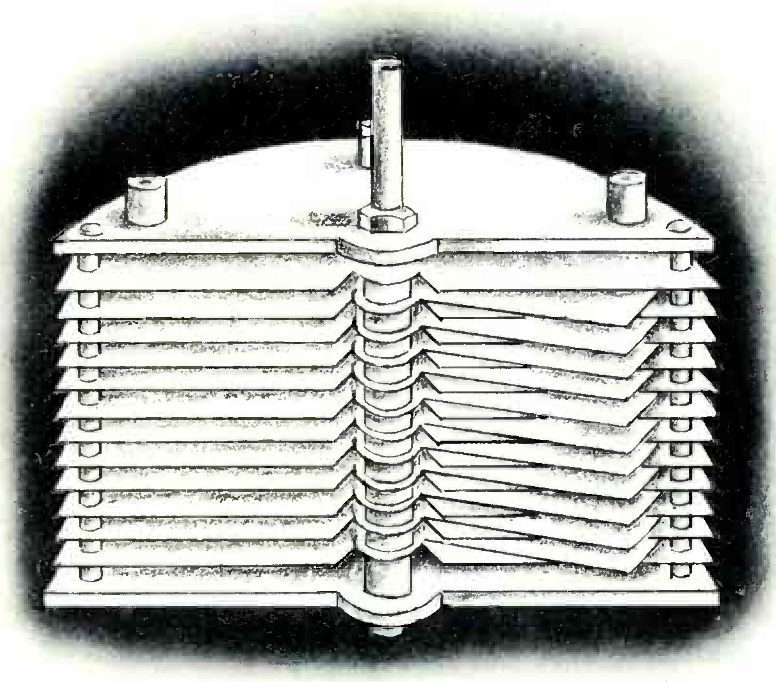
In the same way one tuning fork can make another tuning fork vibrate even if the second tuning fork is a distance away. But the two forks must be tuned to the *same* note. The waves sent out by the distant tuning fork strike this nearby tuning fork and make it vibrate. If the nearby fork were not the same note as the distant fork – if one were C and the other F, they would never vibrate together. This is because the vibrations of one are not the same as the vibrations of the other and the two forks are "not in step" like the elephants crossing Brooklyn Bridge.

Now, let's go back to our jar that sends out waves at different frequencies.

HOW DO WE TUNE IN?

SUPPOSE you and six of your friends stationed at different rooms in your house, all had Leyden jars with different amounts of tin foil in each one. Then each jar would have a different vibration or WAVE FREQUENCY because the amount of tin foil in each is different. Merely by turning your imaginary knob and making the tin foil in your jar go up or down like a shade roller, you could, at six different times, make your tin foil equal to the tin foil in each of the six jars. You could then get "in step" or in tune with each jar separately and vibrate to it like the tuning fork vibrates to a particular note and no other note. If you didn't like Fred's jar you could just turn your imaginary knob to "tune him out" and get Peter's or Mary's or Bills.

These friends of yours, instead of being boys and girls with Leyden jars, could be radio stations with different wave frequencies all sparking together and filling space with radio waves of different frequencies. And the imaginary knob is no longer imaginary, for you actually turn it in your radio set and, in doing so, you vary the amount of metal that comes near a fixed amount of metal inside the radio as shown here. It is very much like rolling the tin foil in your Leyden jar up and down only this is a fixed gadget called a CONDENSER instead of a Leyden jar. By turning the knob you vary the capacity of this condenser and are able to get any wave frequency you want.



THE SOUND WAVES RIDE ON THE CARRIER WAVE

WE must remember that the radio waves that come from the broadcasting stations are enormously rapid in their vibrations. They alternate between positive and negative charges anywhere from 1,000,000 to 10,000,000 times per second, and that is much too fast for our radio set. Our radio loud speaker could never receive waves that vibrate as fast as that. The radio waves that enter our sets are produced in the broadcasting stations by alternating current like the spark between your finger and the metal door knob. Alternating current is current that changes from positive to negative hundreds of thousands of times per second. First it has a positive charge and then it has a negative charge and it keeps on alternating from positive to negative so rapidly you can't possibly notice the changes anymore than you can detect each individual picture in a movie. This alternating current is sent up a tall shaft and out into space. Before this current is sent out, it is made very strong by means of big vacuum tubes. As soon as it leaves the shaft it sets up these alternating radio waves.

The alternating current that is sent up the tall shaft and out into space usually carries the sound wave which, at this point, is nothing more than much slower electric vibrations, just like those that we send through the telephone wires. Because it actually carries this wave it is called a CARRIER wave. Sometimes it carries nothing at all but most of the time the sound wave is "riding" right on it. It is like a continuous moving stairway which keeps on going up whether there are people riding on it or not.

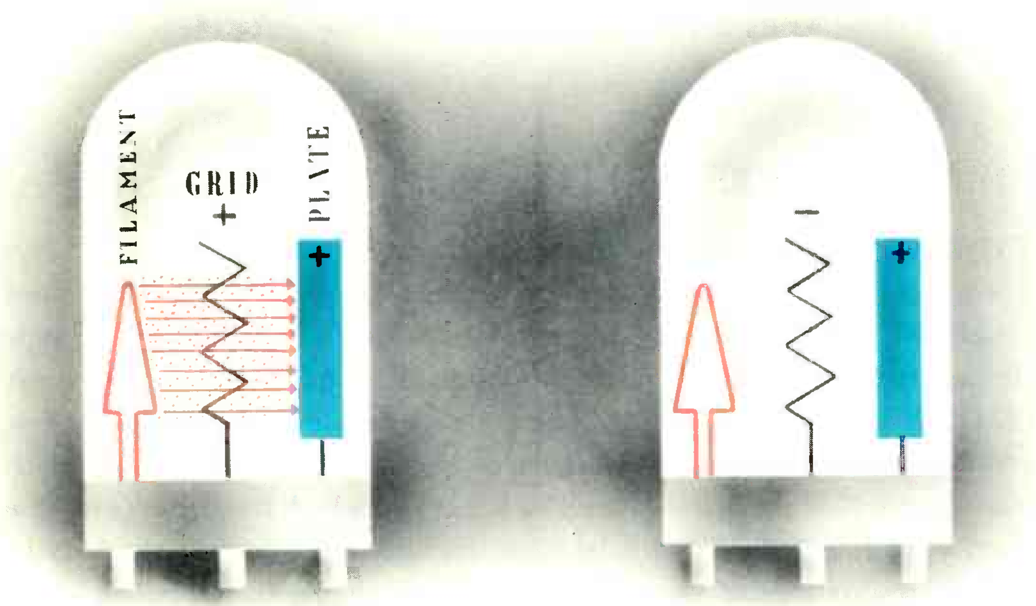
By the time the hundreds of different carrier waves, all mixed up together, reach your radio they are much too weak to be of any use. If they were sent into the electromagnet in the loud speaker they would have no effect on it whatever and there wouldn't be any sound. They have traveled so far they begin to disappear, like the ripples on a large pond when they reach the edge of the pond. But that is not the only thing the matter with these waves. Even when they are separated from one another and made much stronger, they still won't produce any sound in the loud speaker because they vibrate much too rapidly — hundreds of thousand times per second. Our ears are not able to hear vibrations that fast and when a thing vibrates more than 20,000 times per second it doesn't make any sound.

Before we can make these radio waves produce sound in the loud speaker we have three big problems to solve. First, we must separate them and select one particular wave frequency from all the rest. (We found out about this when we talked about the Leyden jars and the tuning in by turning a knob.) Second, we have to strengthen greatly these tiny, weak ineffective waves or else they will be totally useless. Finally, we must separate the sound wave from the carrier wave (the sound wave is called the audio frequency wave from AUDIO meaning "to hear"). Only after we do all this can we hope to get the same sounds in our loud speaker that were sent into the microphone in the studio.

THE MYSTERY OF THE VACUUM TUBE

OF course you know that no radio set today would work without two or more vacuum tubes. But what does the vacuum tube do and how does it work and why is it so important?

The main purpose of the vacuum tube is to strengthen the weak radio waves that come into your set from the antenna. The tube is like a very peculiar electric light bulb. It contains a glowing wire filament like the electric light bulb, but much less brilliant, and a small metal plate which is always charged with positive electricity. Between this hot glowing filament and the positively charged plate there is a little wire grid, something like a straight sieve. This grid is connected directly with the antenna and receives the incoming alternating current radio waves. So, inside this little



vacuum tube we have three things: a hot glowing filament, a tiny wire grid that is charged with the alternating current of the incoming radio waves, and a small metal plate that is always charged positively.

Now, see what happens: the heated filament sends out billions of inconceivably small, invisible negative charges called ELECTRONS, and keeps on doing this as long as the filament is hot and glowing. We'll say more about these electrons later on. These billions and trillions of negative electrons are attracted over to the plate which has a positive charge. Unlike charges always attract each other and like charges always repel one another.

So far so good. The electrons flow in a steady stream from the filament over to the metal plate. But in doing this they have to pass through the wire grid which changes from positive to negative hundreds of thousands of times per second. When the grid is negative the electrons are repelled and they can't possibly reach the plate, but when the grid is positive (in the next one hundred thousandth of a second) the electrons not only go over to the plate but they are actually given an additional "shove," something like the extra shove you give your little brother in a swing to make him swing higher. They therefore "pound more forcefully" on the metal plate and so they become stronger. By sending this stronger pulsating current into more tubes we can strengthen it more and more and we don't interfere with the frequency at all. We make the waves stronger but do not increase the frequency. So, by sending the very weak little waves that come from the broadcasting station through vacuum tubes we make them much stronger.

...AND THE LOUD SPEAKER SPEAKS

NOW that the carrier wave, with the sound wave riding on it, is made very much stronger by means of the vacuum tubes, all we have to do is "pick the sound wave right off" the carrier wave and send it into the loud speaker where it will be transformed from electrical vibrations to sound vibrations. This is done by means of a DETECTOR which is just another vacuum tube similar to those we have described only without the wire grid between the glowing filament and the metal plate. The alternating current of the carrier wave which is at a very high frequency (a few hundred thousand vibrations per second) is transformed into direct current at a very low frequency. The vibrations of the wave, instead of changing from positive to negative hundreds of thousands of times every second, all become positive and vibrate only a few hundred times per second. This leaves the sound wave to go along about its business without the help of the carrier wave. It is the exact same wave that was sent up that tall shaft and out into space "on top of" the carrier wave. It is, in fact, just like the wave of vibrations in the telephone wires that that we spoke of at the beginning of this book. And it is strong, too, and ready to enter the electromagnet in the loud speaker. As soon as it does this, it vibrates the metal disc with the paper cone attached to it and out come the very same sounds that entered the microphone in the studio.

And so ends the story of radio. The story of how, by turning a little knob in a box in your room, you can hear things going on thousands of miles away. Now, before we tell the story of television, let us collect all the different things that happen in radio and list them in order.

EASY SUMMARY OF THE IMPORTANT STEPS IN RADIO

WE have learned a great many different things and it is only natural that we may become a little confused about what happens, when, and other details. So here is a summary which will help to refresh your memory.

FIRST: The artist or commentator in the studio steps up to the microphone and starts to vibrate the thin metal disc in it by speaking, singing or playing. This is the disc that has the tiny carbon grains in back of it and when it vibrates it changes the pressure on the carbon grains and varies the electric current in the wires.

SECOND: The vibrating electric current is sent through the wires to the sending station many miles away. This vibrating current is otherwise known as the sound wave or audio-wave.

THIRD: The sound wave, which is vibrating electric current, is now made very much stronger by means of vacuum tubes (we have seen how they make these waves stronger) and is sent up a tall shaft together with the very high frequency CARRIER wave. This carrier wave is the wave that carries the sound wave over hundreds of miles of space. It has a definite frequency for that particular station and is like the sparking from the Leyden jar that was described on page 16. It is always going up the shaft like a moving staircase. It is there as long as the station is "on the air" and regardless of whether or not there are any sound waves on it. The carrier wave is always alternating current, varying from positive to negative hundreds of thousands of times per second which is called its frequency.

FOURTH: After leaving the tall shaft the carrier wave with the sound wave riding on it travels hundreds of miles through space in all directions along with many other carrier waves of different frequencies. They all hit the antenna of your radio set and by the time they arrive they are very weak and ineffective.

FIFTH: Now, remember how you varied the capacity of your Leyden jar by the imaginary knob that rolled up and rolled down the tin foil? Refer back to page 16 and review it and you'll see how you can select any one of the hundreds of different stations by turning the knob of your radio set.

SIXTH: The carrier wave that you have selected by turning the knob now comes into your radio in the form of a very weak alternating high frequency wave with the sound wave on it. It is far too weak to send into the loud speaker so it is made very much stronger by sending it into the vacuum tubes we described on page 21. By going through these tubes the alternating current is given a series of "lifts" and the tiny pulsations are made stronger and stronger and are finally ready to send into the loud speaker.

SEVENTH: But the strong pulsating wave is still much too rapid in its frequency to affect the loud speaker. It would vibrate the disc all right and cause it to move several hundred thousands times per second but no sound would come out of it because our ears can't hear vibrations that rapid. The wave must be brought down to "hearing" or AUDIO frequency.

EIGHTH: The carrier wave is now sent into a detector which is a vacuum tube that changes the alternating current into direct current and slows down the frequency to bring it within the range of "hearing." This does away with the carrier wave and leaves the strong sound wave, in the form of electrical pulsations, ready to be sent into the loud speaker.

NINTH: The sound wave enters the electromagnet in the loud speaker and vibrates a metal disc that is attached to a cone of paper to make the sound loud. The metal disc and the cone vibrate exactly the way the microphone did in the studio and the sound in the studio is exactly reproduced in your radio.

TELEVISION

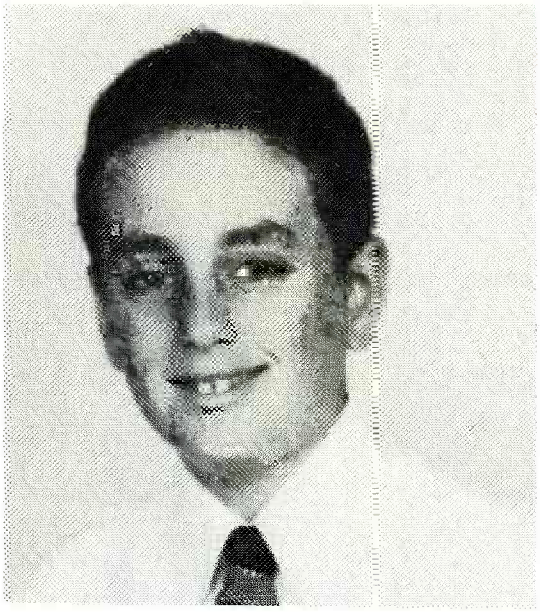
THE MIRACLE OF TELEVISION

IN radio we saw how the carrier wave carried the sound wave on it in the form of electrical vibrations. When this audio-frequency wave was sent into the loud speaker it was turned back into a sound. Now we shall see how another kind of carrier wave carries a "moving picture wave" in the form of electrical vibrations. When this wave is sent into your television receiving set, it is transformed into moving pictures.

It is easier to understand how this is done if we know something about how photographs are printed in our newspapers and magazines.

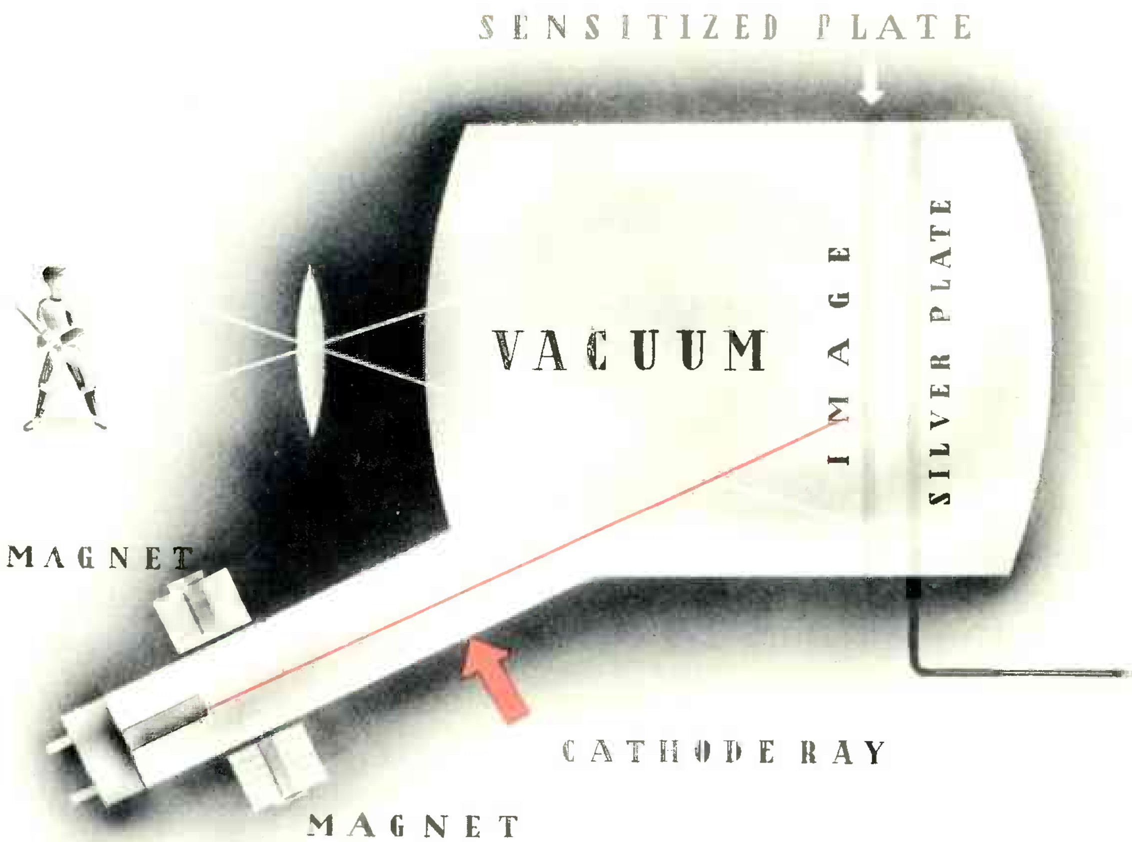
LET'S EXAMINE A NEWSPAPER PHOTOGRAPH

IN order to reproduce a photograph in a newspaper or magazine we must put it on a flat piece of metal, ink the metal and print from it just as we print from type. But as long as the metal is smooth all over it will not print the picture — it will be a black smudge and nothing more. So we have to break the photograph up into thousands of tiny dots by rephotographing it through a fine wire screen. Then we must put it into a bath of strong acid that eats the metal in between each dot so each little dot will be raised slightly and won't be touching the dot next to it. If the plate is now inked, each particular dot will give up just that tiny particle of ink to the paper and all these thousands of inked dots together will reproduce the picture.



Now take a magnifying glass and carefully examine any photograph in any newspaper. You will see the dots very clearly. In the dark parts of the picture the dots are close together, in the light parts they are far apart. Look carefully and see if this is not so. Now hold the picture about a foot away and you won't be able to see any dots at all. All you will see is the picture itself.

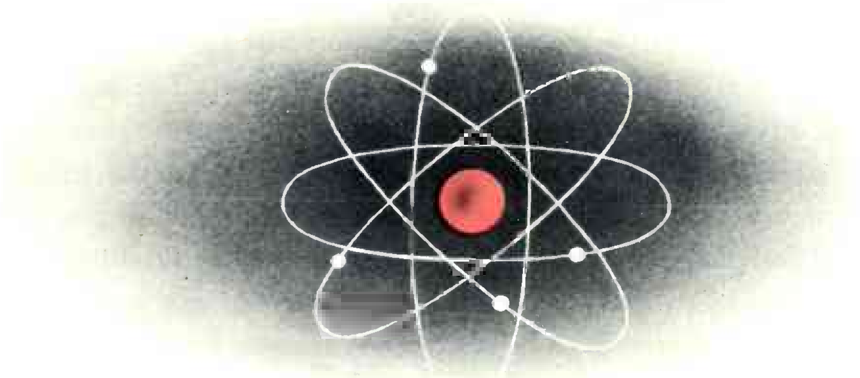
The television camera works like the metal plate that prints the newspaper photograph, only instead of producing the picture altogether, it produces it in hundreds of sections but does it so fast you think it is a whole picture. It contains a mica plate, with a metal backing, composed of millions of microscopic specks of silver each separated from the next one and each coated with a metal called CAESIUM. When you stand in front of the television camera the lens focuses your picture right on this plate, which is inside of a large vacuum tube called an ICONOSCOPE. (This is shown in the illustration.) As the light from your face reaches the plate it strikes each of the microscopic specks of caesium-coated silver the way the ink strikes each particular dot or speck in the newspaper-plate. We shall see presently how each of these caesium-coated specks in the iconoscope gives off a tiny electric current or impulse just as each dot in the newspaper plate gives up a tiny speck of ink. We shall also see how the current or impulse given off by each speck depends upon the intensity of the light that falls on it and how these tiny electric currents or impulses which are very very weak, have to be strengthened a million or more times before they can be sent through miles of space to your television set.



HOW LIGHT MAKES ELECTRICITY

LET use leave this screen in the iconoscope for a moment and find out how light makes electricity. We know that electricity makes light — we see this every time we turn on the lights in our house. But how does light make electricity? Well, imagine yourself with a garden hose, watering a roadway in front of your home. Suppose you played the steady stream of water that comes out of the hose on a pile of tiny stones on the road. What do you think would happen to the little stones? They would be scattered all over the road from the force of the water. The stronger the stream the more these little stones would be scattered. And right now it would be well to know a little more about electrons in vacuum tubes.

WHAT ARE ELECTRONS?



ELECTRONS are unbelievably tiny invisible particles having a negative electric charge. Small as atoms are (one hundred million atoms will fit comfortably on the head of a pin) electrons are very much smaller, for they go shooting around and around inside of the atoms with lots of room to spare! There are more electrons in a large drop of water than there are drops of water in the Atlantic Ocean, so you can imagine, if you have a good imagination, how tiny they really are. All atoms contain electrons and everything, everywhere is made up of atoms. You and I are made up of atoms, so we are made up of trillions of quadrillions of electrons. The same is true for everything else in the world — paper, wood, metals, air, water and all other forms of matter — they all contain these invisible negative electric charges. Now a very important thing to remember is that an ELECTRIC CURRENT IS NOTHING MORE THAN THE FLOW OF ELECTRONS FROM ONE PLACE TO ANOTHER, just as the current in a stream is nothing more than the flow of water from one place to another. The faster the water in a stream flows, the stronger is the current of the stream. And so it is with the electric current: the faster the flow of electrons the stronger is the current.

THE ELECTRICAL PICTURE WAVE

THE metal caesium that we spoke about a little while ago is different from most other metals. It gives off electrons when light strikes it. The brighter the light that strikes this caesium, the more electrons it will give off. So the caesium is like the pile of tiny stones and the stream of light that hits it is like the stream of water from the garden hose. But billions and trillions of electrons are given off by the caesium and it is extremely sensitive to the slightest change in brightness of the light that strikes it. Changes in brightness that you or I could not possibly detect will change the number of electrons given off by the caesium. Remembering that

AN ELECTRIC CURRENT IS NOTHING MORE THAN THE FLOW OF ELECTRONS FROM ONE POINT TO ANOTHER: THE MORE ELECTRONS THAT PASS A GIVEN POINT THE STRONGER WILL BE THE CURRENT

we can understand how each independent microscopic speck of caesium-coated silver on the screen in the iconoscope, in giving off electrons, gives off its own independent tiny current. When the light is very bright, more electrons leave the tiny specks and more current is given off. When the light is weak (in the dark places of the picture) less electrons are given off and the current is much weaker. So the entire iconoscope screen is made to give off millions of different tiny electrical impulses or currents according to the lights and shadows in the picture. The image of your face then is transferred from a picture to a collection of millions of varying electrical impulses or an electric picture wave which will be sent through space after being strengthened more than a million times.

You have undoubtedly seen a moving picture film and noticed how many small pictures there are to a running foot. Each picture is flashed on the screen. It appears and disappears in a jiffy, and the next picture, only slightly different from the previous one, appears and disappears. Thirty such pictures, each one a little different from the one before it, appear and disappear every second, and what you see is a moving picture. You can't possbly see each separate picture because it appears and disappears much too fast. What you do see is the whole effect of all these hundreds of pictures moving together.

Just as thirty slightly different pictures per second are flashed on the movie screen, so thirty slightly different electrical pulsating pictures, greatly strengthened by vacuum tubes, are flashed through space and caught in your television set every second. But, unlike a movie film, each electrical picture has to be "built up" in hundreds of sections before it leaves the iconoscope screen. Before we explain how this "building up" is done, look at the maze of black spots on this page. It doesn't look like anything at all, does it? Close up to you it is nothing more than a lot of meaningless black specks, but if you put this book on the floor and look down at this page, you'll see a human eye staring right back at you! Try it and see. All the specks seem to blend into one another from that distance and a picture of an eye appears as if by magic.

A MAGIC PAINT BRUSH

SUPPOSE we had a magic paint brush that moved from left to right the way you read this page only hundreds of thousands of times faster and, as it did this, it painted the first row of black specks in this picture like this:

and then it instantly painted the next row of specks under that row like this:

and it kept this up for row after row, until all the specks in the picture were painted in in less time than it would take to say "Boo," do you suppose you could SEE this magic paint brush move and do all this in that tiny fraction of a split second? Of course you couldn't. You would see a picture of an eye suddenly appear, and you would probably wonder how it got there. And if, in the same way, the magic paint brush painted another picture slightly different from this one, and another and another, and painted thirty such pictures every second, you would see a movie of the eye, perhaps winking at you just as you see a movie in the theatre. You would never know that each one of these pictures is made up of millions of specks and put together, row by row, in a flash. Your eyes couldn't possibly see that fast.

A MAGIC BEAM OF LIGHT

WE have already seen how the television camera lens focuses the image on the iconoscope screen, and how millions of tiny caesium-coated silver specks each give off tiny electrical impulses according to the brightness of the light that strikes them. This we have called an "electrical pulsating picture" and it is produced in the same way that our magic paint brush produced the painted picture of the eye, dot by dot and row by row. Instead of our magic paint brush, however, we use a very thin beam of electrons called a CATHODE-RAY BEAM. This amazing beam sweeps along every row of the caesium-coated silver specks on the iconoscope screen with a speed that would make a flash of lightning seem slower than a snail. As it does this, it supplies each one of the 5,000,000 specks with the electrons that it gave off previously so it is constantly "filling up" the gaps left by the electrons and, in doing this, it makes the entire iconoscope screen come alive with millions of tiny electrical vibrations. Engineers have found that, for best results, the beam should move on a slightly downward slope from left to right, but instead of covering each row of specks in turn, it should cover the odd numbered rows (the first, third, fifth, seventh, etc. rows) first, and then go back and cover the even numbered rows (the second, fourth, sixth and eighth rows), and do the entire job in a thirtieth of a second! This means that the cathode-ray beam goes back and forth in the iconoscope tube more than 15,750 times in a single second, traveling at the rate of over 5,000 miles per hour.

So, every second that the television camera in the studio is in use, thirty electrical picture waves leave the iconoscope and each one of them is built up row by row, faster than lightning, and in the way we just described! These electrical pictures are not pictures at all. They are complicated electrical waves composed of millions of tiny weak pulsating currents. They are so very weak they would vanish if sent over the air and would never have any effect on your receiving set. So they are strengthened thousands of times by means of vacuum tubes, and by the time they are ready to leave the enormously high television tower, they are more than a million times as strong as they were when they left the iconoscope in the television camera.

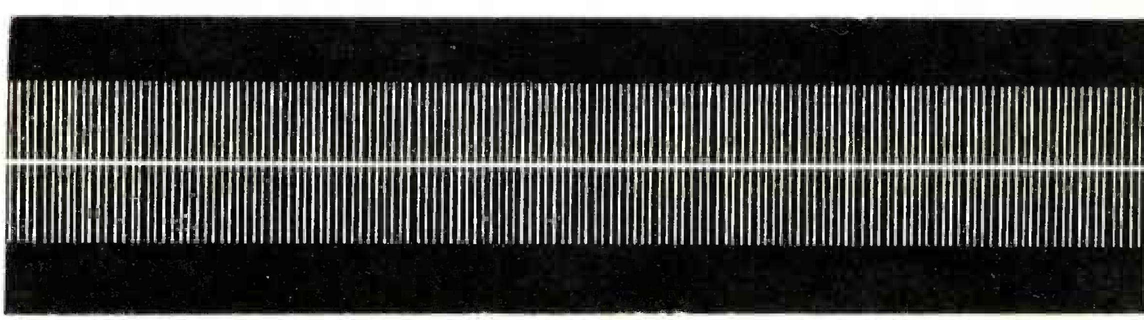
The amazing cathode-ray beam, that remarkable needle point stream of electrons, is played like a hose over the iconoscope plate, traveling at the rate of over 5,000 miles per hour and covering every speck on the screen in less than one five-millionth of a second. It is guided with unbelievable precision and accuracy over the plate by means of two electromagnets because, oddly enough, the beam is attracted to a magnet just the way iron and steel are. The very slightest change in the strength of the magnets will affect the movement of this beam. One of the magnets controls the vertical movement and the other controls the horizontal movement. The electromagnets are so placed, and the current that is sent into them is so carefully calculated, that they are able to make the cathode-ray beam perform just the way our imaginary magic paint brush performed.

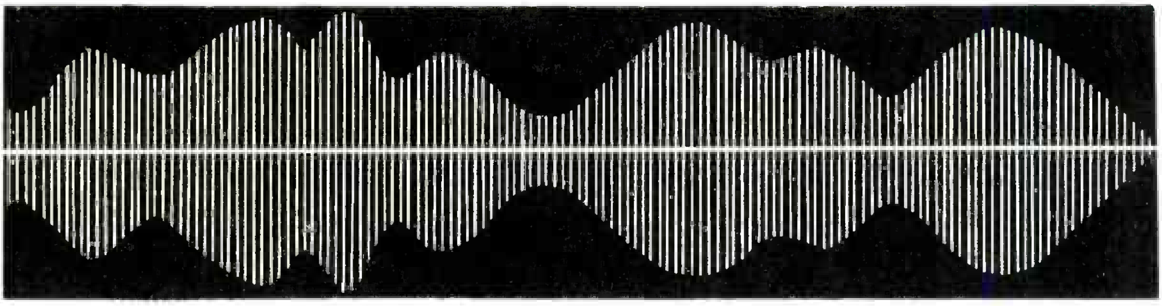
But there is something more to this. The current that controls these magnets is also sent out over the air along with the electrical picture waves and radio sound waves, and enters your set just as the other waves do and are made to work two electromagnets in your set in exactly the same way that they work the electromagnets in the studio. We shall see how this is done presently.

THE TELEVISION CARRIER WAVE

THIS TV carrier wave is somewhat like the carrier wave in radio only it vibrates about 150 or more times as fast. Where the radio carrier wave vibrates about 560,000 times per second, this television carrier wave vibrates about 100,000,000 times per second. The same thing is true for the picture wave that rides on it. It, too, vibrates very much faster than the sound wave that rides on the radio carrier wave.

Because of these extremely high frequencies, the television wave lengths are very very short. By wave length we mean the distance from the crest of one wave to the crest of the next one, like the ripples on a pool. The distance from the top of one ripple to the top of the next ripple is one wave length. The wave lengths of radio waves are very





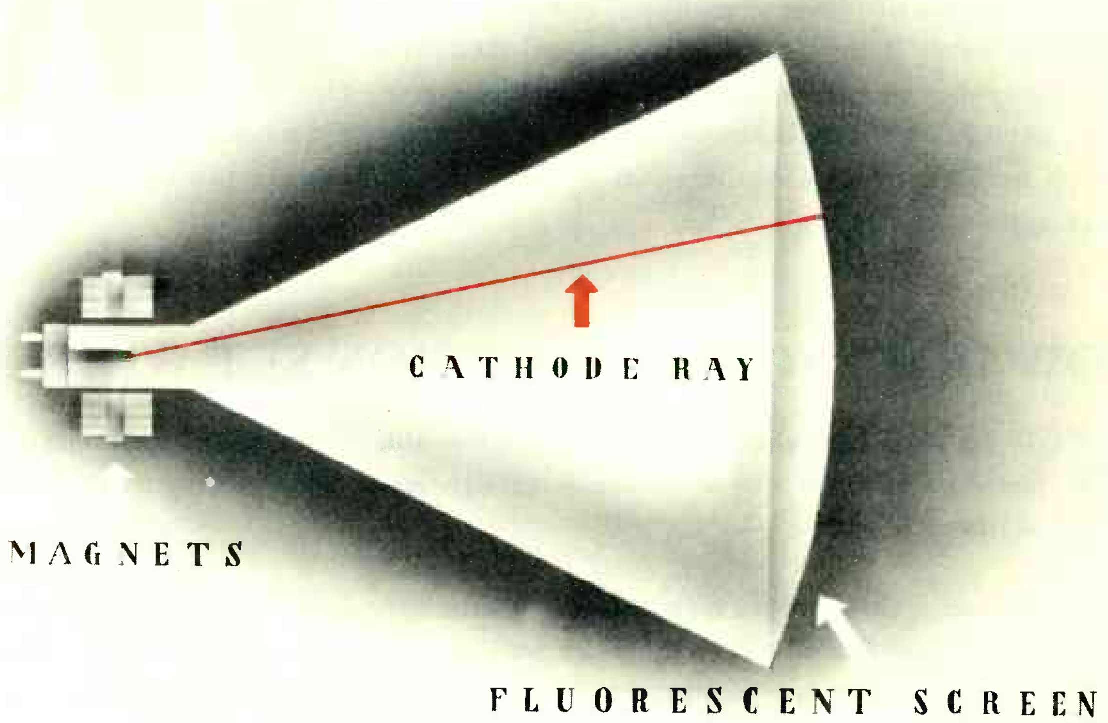
long — sometimes as long as a hundred yards; the wave lengths of television are very short — only a fraction of an inch. These short TV waves can't travel as far as the long radio waves. They can travel out beyond the horizon but not too much further. That is why they are broadcast from such very high towers. They are literally sprinkled down, like invisible snow flakes, on the buildings and houses far below them and, due to high buildings, they sometimes cast a television "shadow." In this case a double image appears on the TV screen.

HOW DOES YOUR TELEVISION SET WORK?

NOW let's see how your own receiving set is able to transform these electric picture vibrations that are hurled through space, into moving and talking pictures.

Your set is principally a large picture vacuum tube, entirely different from the radio vacuum tube. It is coated on the inside with a chemical that glows instantly when light strikes it and goes out instantly when the light stops — the brighter the light the brighter the chemical will glow. When you watch television you are really watching the top of this large glass vacuum tube called a KINESCOPE, somewhat like the iconoscope in the studio camera. Just as the iconoscope in the studio transforms the light from the actual scene into electrical vibrations, so the kinescope in your TV set turns these electric vibrations back into moving pictures.

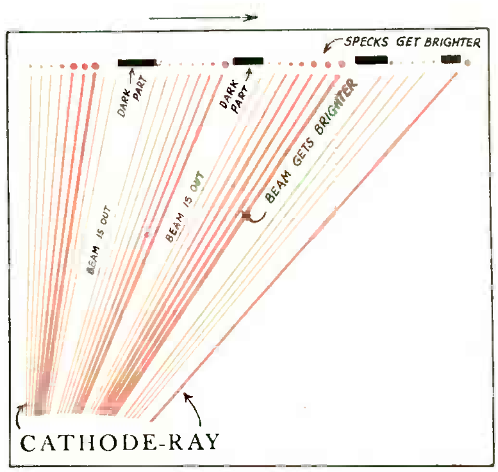
At the far end of the kinescope there are two electromagnets exactly like those in the iconoscope in the studio camera. We now know that the current that works those electromagnets guides the cathode-ray beam over its screen 30 times every second. This very same current is sent over the carrier wave and enters your set through the antenna. It is then sent into the electromagnets in your set and makes them behave exactly as they do in the iconoscope in the studio. The magnets in your set, then, are completely "in step" with the magnets in the iconoscope in the studio.



The electromagnets in your set also control a cathode-ray beam. This beam moves inside the kinescope and covers your television screen in the same way that the cathode-ray beam in the studio covers the iconoscope screen. The cathode-ray beam in your set and the cathode-ray beam in the studio move in exactly the same way because the electromagnets that control them behave in exactly the same way. You can understand this if you wave your arm above your head back and forth in front of a mirror. The reflection of your arm in the mirror moves exactly the same way as your arm does — they move together just the way the two cathode-ray beams do, and no matter how quickly you move your arms back and forth, the reflection of your arm in the mirror moves just as quickly.

BUT HOW DOES YOUR CATHODE-RAY BEAM PRODUCE A MOVING PICTURE ON THE TELEVISION SCREEN?

IT produces it because it is constantly receiving the millions of incoming vibrations from the electric picture wave sent out by the iconoscope. To understand this, suppose we could take a magnifying glass and examine a very small section of the iconoscope screen as the light from the actors or studio scenery falls on it. Suppose we consider two tiny specks where the light is bright for the first speck and the second speck is in the shadow where there is little or no light. That small section might look like this:



From what we have already learned, that caesium-coated speck on the iconoscope screen, having a bright light on it gives off a large quantity of electrons which sends a sizable current by means of the carrier wave right into the cathode-ray beam in your receiving set. This current, being strong, makes the cathode-ray beam strong and so that speck glows brightly on your television screen. But the next speck is in deep shadow where there is little or no light. Very few electrons are then given off in the iconoscope screen so very little current flows into the cathode-ray beam in your set and it remains weak. The next speck on your screen, then, glows very little or perhaps not at all. So the light and shadow that fall on the two specks on the iconoscope screen in the studio are exactly reproduced on the television screen in your home. In the same way all other lights and shades, no matter how slight they are, are reproduced faithfully on your television screen the instant they strike the iconoscope screen in the studio camera. The cathode-ray beam in your television set is the same as the magic paint brush that painted that picture of the eye, row by row in 1/30 second, although it "paints in" the odd rows first and then goes back and "paints in" the even rows just as the cathode-ray beam in the studio camera did. You see all this at one time and the result is a picture.

Now we have our cathode-ray beam completely covering our home television screen 30 times per second just exactly as the cathode-ray beam in the studio iconoscope scans its screen. And we have the millions of variations in light intensity of our cathode-ray beam being exactly the same as the millions of variations of current intensity in the iconoscope screen. We then have a moving picture of the scene in the studio reproduced on your television screen.

We already know how slow our eyes are. They can't even distinguish separate pictures moving only 10 or 12 every second. As these millions of specks that glow and go out in a millionth of a second cover the TV screen in 1/30 of a second, you can realize how our eyes see them all together as one picture flashed up 30 times every second. It follows, then, that whatever takes place in front of the studio iconoscope camera is faithfully reproduced in moving pictures on our television screen. You can then see the entire action and scenery of a studio program or a ball game outdoors or anything else that takes place.

The sound and talking part of the pictures come into your set just the way they come into a radio. The sound wave, in the form of electric vibrations, rides along on the carrier wave with the other electric vibrating waves and is sent into the loud speaker just as it is in radio.

EASY SUMMARY OF THE IMPORTANT STEPS IN TELEVISION

FIRST: The television camera focuses on the actor or artist in the studio just the way a regular camera focuses on you when your picture is taken. Just as the image is formed on the photographic plate or film in a camera so the image of the actor or artist in the studio is formed on the plate inside of the iconoscope.

SECOND: Each of the million microscopic specks of caesium-coated silver on that plate in the iconoscope receives a tiny speck of light from the image and the image is therefore broken up into a million tiny dots much smaller than this i dot. Some of the dots receive a lot of light while others receive very little light. Some have no light at all on them. It all depends upon the nature of the image. So the image now may be compared with a printed photograph in any newspaper when you examine it through a magnifying glass.

THIRD: Since caesium has the unusual ability of giving off electrons when light strikes it, the stronger the light the more electrons are given off, and since the electric current is really the flow of electrons, it follows that each tiny speck gives off its own little current or electric pulsation. The strength of this current or pulsation depends upon the brightness of the light that strikes the caesium. The image is then transformed into an electrical pulsating picture, a huge collection of tiny electrical impulses all varying in intensity. This "electric picture" is transferred over to a metal plate very close to the plate we have been talking about and from there it is intensified thousands of times and sent over the air to your set.

FOURTH: But the electrical picture that is sent over the air is only ONE of many thousands. We know that in order to have a moving picture we must flash twenty-five or thirty slightly different pictures every second on the screen. Our eyes are not fast enough to see each picture so we see the result which is a movie. So thirty "electric pictures," just like the one we just described, must be sent over the air every second and to do this we have to make use of the cathode-ray beam.

FIFTH: The cathode-ray beam is a very thin stream of electrons which is played on the iconoscope screen the way you might play a hose with a very thin stream of water on your garden. The beam is carefully guided by electromagnets which attract it just the way an ordinary magnet attracts needles and nails. The beam is made to pass over every one of the millions of tiny specks of caesium-coated silver on the screen in the amazing time of one-thirtieth of a second. By covering the screen in that short time it "fills in" the specks that have given up electrons with new electrons just as you might fill up a number of tiny holes in the ground by playing the hose on them.

SIXTH: Thanks to the cathode-ray beam thirty different "electric pictures" per second are sent over the air, each one a little different from the next just as each motion of the actor or artist is a little different from the next. The result is a moving picture electric wave which enters your television set.

SEVENTH: The screen in your set is the top of a very large vacuum tube. It is coated with a substance that glows when light strikes it and is dark when no light strikes it. Inside the tube is a cathode-ray beam exactly the same as the one in the TV studio. This beam is made to move *in exactly the same way* that the beam in the studio does. It covers the screen in a thirtieth of a second and as it does so it becomes stronger and weaker depending on the current it receives. If a tiny speck of caesium in the iconoscope received a bright light from the image of the actor or artist, its current will be strong and the beam in your set will immediately receive this strong current and it will be bright. It will then make a tiny bright spot on your television screen in exactly the same place as the spot from the image was made on the screen in the iconoscope. In the next millionth of a second the ray will change and a new speck on your screen, so close to the first speck you can't measure it, will be dim or dark. All this takes place in a thirtieth of a second for each picture and in a way we described in the "magic paint brush." The result is a perfect movie of what goes on in the television studio reproduced on your television screen hundreds of miles away.