# NATIONAL RADIO INSTITUTE

## Complete Course in PRACTICAL RADIO

NRI

**Radio-Trician**

(REG. U. S. PAT. OFF.)

*Lesson Text No. 46*

# TELEVISION

Originators of Radio Home Study Courses
••• Established 1914 •••
Washington, D. C.

"Nothing is so difficult but that it may be found out by seeking." —*Terence.*



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# Radio-Trician's
(REG. U. S. PAT. OFF.)
# Complete Course in Practical Radio
NATIONAL RADIO INSTITUTE WASHINGTON, D. C.

## TELEVISION

For some years past we have become accustomed to "listening in" by radio to audible sounds produced at some distant point, which may be anywhere up to several thousands of miles away. How long will it be before we are able also to "see in" by radio, and thus witness scenes and events at places similarly distant from us? In view of the vast progress recently made in this direction, it will not now be very long before this comes to pass.

The moving picture has been developed within the last twenty years or so, till today it is a highly efficient and marvelous means of entertainment. Its appeal is to the eye, also the ear. We see and hear on the screen great actors. Many inventors have been working for years to make this possible.

Radio broadcasting as we know it today, is one sided. We can hear a great man speak, but we cannot see his gestures and facial expressions. It is the province of Television to overcome this disability. By combining television with ordinary broadcasting, we shall, in the near future, not only hear the performance of a play, but also see the actors, the scenery, the entire stage.

### REPRODUCTION OF SIGHT

That is the function of television. It must not be confused with telephotography, which is something totally different. Telephotography, or phototelegraphy as it is sometimes called, means the telegraphic transmission of a single "still" picture from one place to another.

In Webster's dictionary, television is confused with phototelegraphy, and if such an authority is in confusion, there is no wonder that the public—even the technical section of it—does not possess clear ideas on the subject. It needs no apology, therefore, to commence an article on television with an attempt to define exactly what television is, and for an authoritative statement, we cannot do better than quote the British patent office, whose business it is to define and catalogue such terms.

In the patent office library, we find classed, under the heading "Television," "Apparatus for transmitting instantaneously to a distance images of views, scenes or objects by telegraphy (either wire or wireless)." In other words, Television means seeing at a distance by telegraphy.

## HISTORY OF DEVELOPMENT

Both phototelegraphy and television are no new ideas. The latter is but a development of the former; and the inspirations for both date back to the year 1873, when May, one of Willoughby Graham's assistants, communicated to the Society of Telegraph Engineers the details of his discovery of the photo-electric properties of selenium.

It was not long before this discovery led to the construction of selenium cells by Siemens, Graham, Bell and others. These, as all the world knows, are devices for transforming light impulses into electrical impulses; and the idea soon occurred to a number of investigators that they might be utilized to give to the eye what telephony had given to the ear, and render it possible to see by telegraph.

Ayrton, Perry, Senlee and several others actually described systems which were to accomplish this; and nearly fifty years ago, it was confidently predicted that in a very short time, it would be possible for us to see one another over the telephone line!

These optimistic inventors had, however, entirely over-rated the capabilities of selenium to respond to the immense speed of signaling involved; and their predictions came to naught, as far as practical results were concerned. Considerable progress was made, however, in phototelegraphy, for time is a secondary consideration in the transmission of a single still picture, and the various other problems in connection with this accomplishment are considerably easier.

At the present time, many investigators in various countries have demonstrated their ability to transmit and receive still pictures, either by wire or radio; among whom may be mentioned C. Francis Jenkins in the United States, Thornton Baker in England, Fournier and Belin in France, and Dr. Korn in Germany. Also worthy of mention is the more recent achievement of Captain Ranger of the R. C. A., who succeeded in sending a photographic copy of a check from London to New York in 25 minutes.

Phototelegraphy, therefore, is not only a definitely accomplished fact; it is also a commercial proposition. Television, however, has not made anything like such progress; for only a few actual demonstrations of "seeing at a distance" have been given.

## SOME PROBLEMS OF TELEVISION

Most of the systems in use for transmitting still pictures make use of the cylinder method; in which the picture to be transmitted is transferred to a film, which is wrapped around a cylinder of glass. As this cylinder is rotated, a spot of light is caused to cover the film from end to end in a series of finely separated lines. The intensity of the light which passes through the film depends upon the latter's density at different points; and the varying light beam, after passing through the film, is focused upon a light-sensitive cell, of one type or another. This cell transforms the light variations into electric-current variations, which are sent over a wire or by radio to the distant receiver.

X 2

At the receiving end, the process is reversed, the incoming current variations being caused to vary a source of light which is focused upon a photographic film wrapped around a rotating cylinder. This film becomes covered with fine lines of varying density, which, when developed in the usual manner, make up the complete picture.

Obviously, this system is inapplicable to television, for a scene, or even the image of it, cannot be wrapped around a cylinder. Some means, therefore, had to be found which would enable a picture to be transmitted directly from a flat surface. This can be done by moving the light beam instead of the picture. By rotating a suitably designed and arranged series of prisms between a fixed light source, and a fixed flat-surface picture, the beam of light is made to traverse the picture from side to side, moving slowly across it as it does so, so that ultimately the entire surface is covered.

This, very roughly, is the operating principle of television apparatus, but only as applied to the transmission of a single picture or image.

From the transmission of a single picture from a flat surface to television is a far cry, however; and, to understand something of the tremendous obstacles to be overcome, let us consider the moving picture. When witnessing a movie performance, we think we see a smoothly flowing animated scene. Actually, we are looking at 16 separate and distinct pictures every second, but, owing to the persistence of human vision, we do not receive this impression from the sense of sight. The one and only similarity between the movies and television is that, in both cases, the scenes are projected upon a screen. In order to make television a success, it is necessary to transmit and receive something like 16 complete pictures per second, in order to give the witness an impression of life-like movement.

## BELL LABORATORIES SYSTEM

Described as one of the greatest triumphs in the history of communication methods, the television process of the American Telephone and Telegraph Company is the product of many minds working together in the Bell laboratories in New York under the guidance of Dr. Herbert E. Ives. Despite the elaborateness of the apparatus, television depends essentially upon the fact that a film of potassium metal in a vacuum tube can be made to give a small electric current when light shines on it. This is in the photo-electric cell. The method of its use in the new process is quite different from previous attempts to attain the same result. In other methods, the subject, whose visage is to be transmitted, is flooded with brilliant light and a lens picks up the illumination and focusses it on a small photo-electric cell. In the new method, by the idea of Dr. Frank Gray, the subject is illuminated with a tiny moving spot of light, which is picked up by a battery of large photo-electric cells—the largest yet made. The result is the most successful transmission of the actual view of the human face that has yet been achieved.

As seen on the small receiving screen, the scene looks like a halftone two inches high, printed in the pink sheet edition of a daily paper, except it has come to life. Most newspapers print photographs in what is known as a halftone—small dots spaced 50 to 60 to the inch and blended by eye into a continuous picture —a process, incidentally, which was the invention many years ago of Frederic E. Ives, the father of Dr. Herbert E. Ives, who is immediately responsible for the new process.

In the television receiver, the picture is also made up of 50 eye-blended rows of light and dark, which appear pink because the light in which they are painted comes from glowing neon gas—a rare element found in the atmosphere. Like its relatives —helium, argon, krypton and xenon—the neon used in the receiving lamp is peculiar because it will not combine with any

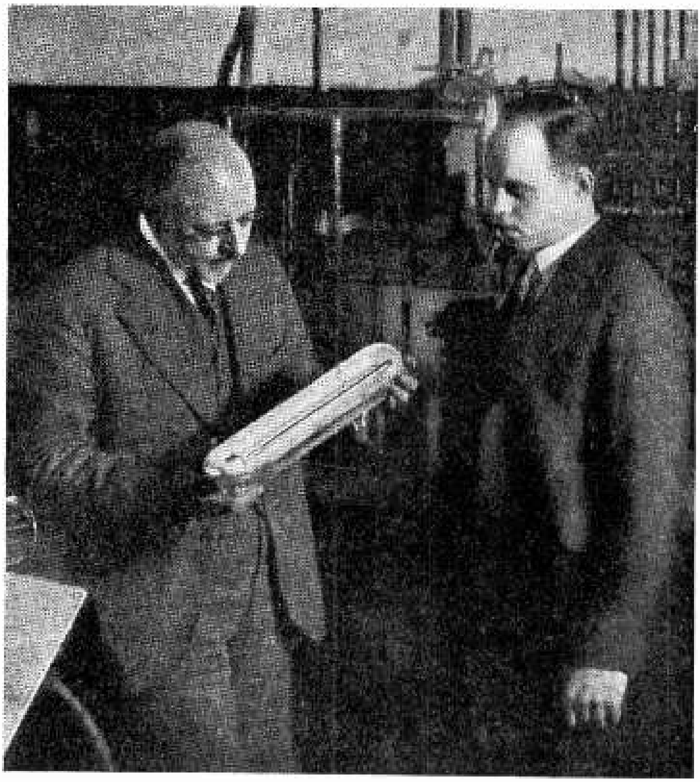

Fig. 1—Examining one of the giant photo-electric cells, which serve as eyes in television.

other chemical substance. When two metallic electrodes are sealed into a glass tube from which all air has been exhausted, but which contains a little neon, and an electric current is passed through the tube, the gas glows with a pinkish light. Unlike the ordinary electric lamp with a filament of tungsten, which continues to glow for an instant after the current has been disconnected, the neon light goes on and off as instantaneously as the current itself.

To television a speaker's face from Washington to New York, for example, the light starts from the carbons of an automatic arc lamp. In front of the lamp is a disc with 50 holes around its edge in a spiral, each hole a little nearer the center than the one before it. A lens projects an image of the holes out into space, just as the lens of a movie machine projects an image of the moving film to the screen, but in the television device, the screen is the subject's face.

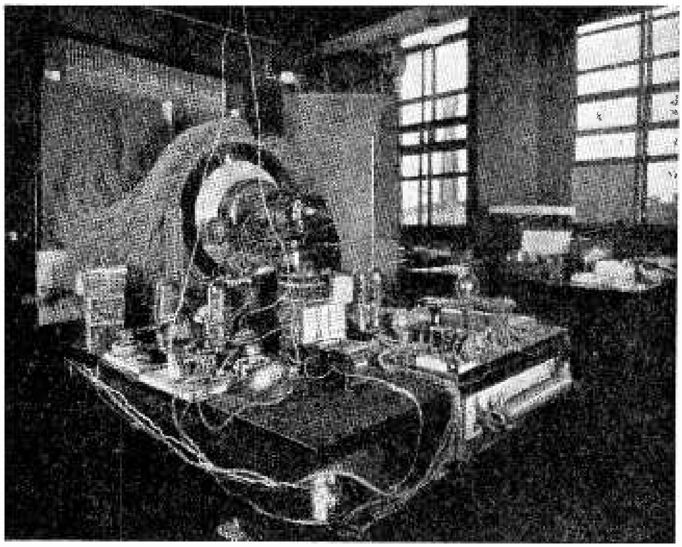

Fig. 2—Rear view of the large grid showing current distributor, its control equipment and preliminary form of the high voltage high-frequency equipment for exciting the successive areas of the neon tube.

And just as the movie film travels through the machine so fast that the single pictures are not seen, but are combined together by the eye into a continuous picture, so does the rapidly moving disc, containing the holes, move so rapidly that the 50 holes, each a little lower than the one before it, sweep across the facial screen in less than a fifteenth of a second. The person being televisioned has this light spot swept over him 17.5 times a second. To a person standing beside the subject, his face seems to be illuminated by a slightly flickering but single area light. The single holes, or even the rows of holes, are not seen separately. Outside of the light from the arc, shining through the holes in the disc, the subject is in semi-darkness. In front of him are three photo-electric cells, the eyes of television. They turn the light into electricity. The production of these cells itself is a triumph accomplished by Dr. Ives. They are the largest that have yet been constructed. When the moving finger of light, a fiftieth of an inch in diameter, sweeps across the face, it encounters the light-colored flesh; light is reflected to the sen-

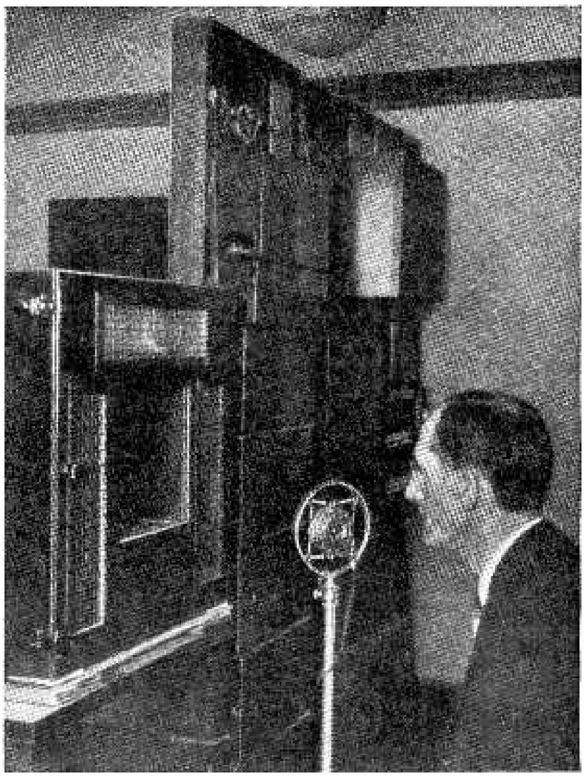

Fig. 3—A close-up of the transmitting apparatus for television at Washington, D. C. When a person talks to the microphone he is viewed by three photo-electric eyes located behind the three screens of the box immediately in front of him.

sitive photo-electric cells. By means of amplifiers like those used in radio stations, the photo-electric cells' tiny current, the electrical counterpart of the light, is magnified thousands of times. And when the spot of light reaches a dark part of the face—the pupil of the eye perhaps—and no light is reflected, no current flows from the cells to the amplifiers.

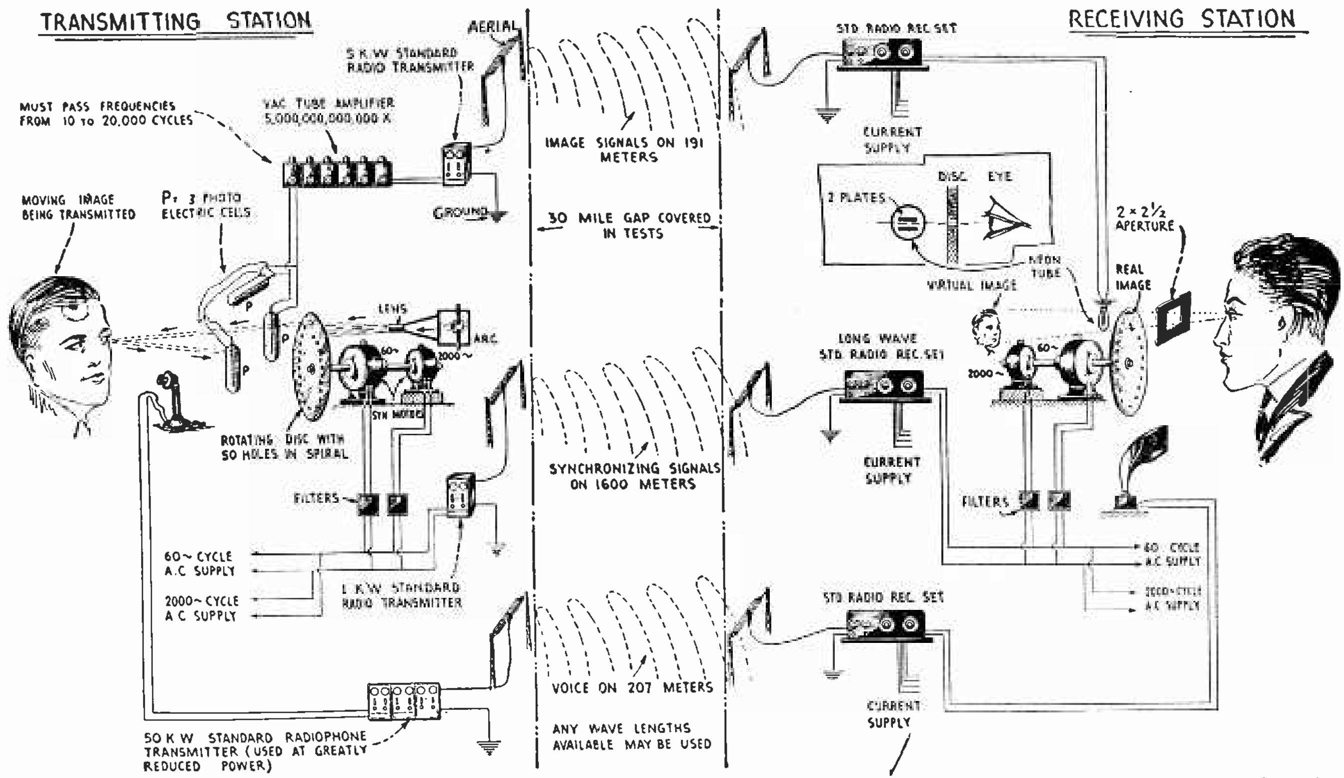


Fig. 4—A comprehensive diagram of the entire Radio television apparatus; the subject, an image of whose face is being transmitted by Radio, appears at the left, while the person observing the transmitted and reproduced image appears at the right. The perforated disc causes rapidly moving targets of light to sweep across the face; the reflections fall on photo-electric cells, P. The light fluctuations are thus transformed into minute electric currents, and these are amplified 5,000,000,000,000 times. The Radio image signals are picked up by a standard receiving set, and after amplification, the image signals pass into a neon glow-tube placed behind a second revolving disc, driven in exact synchronism with that at the transmitter. The observer looking through the small aperture sees the image built up on a plane behind the whirling disc. The voice is transmitted and received in usual manner; while a third radio wave transmits synchronizing signals for the motors.

47

## ESSENTIAL PARTS OF THE APPARATUS FOR SEEING BY TELEPHONE OR RADIO

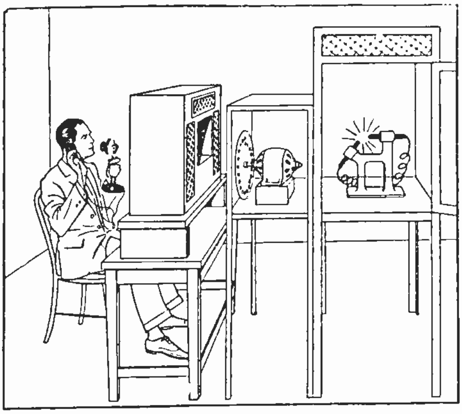

Fig. 5—The Television Transmitter. Light from the arc shines through the holes in the spinning disc, successively lighting different parts of the speaker's face. The reflected light is picked up by three photo-electric cells in the large box in front of the speaker, where it is converted into a pulsating electric current. Greatly amplified by vacuum tubes, this can be transmitted long distances by radio or telephone lines.

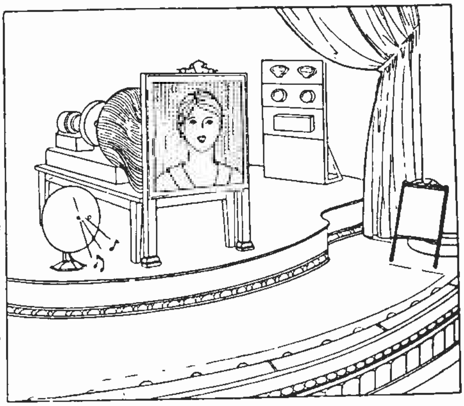

Fig. 6—For exhibition to a large audience the receiver uses a large neon tube of four square feet. This is made up of 2,500 separate elements, each with a separate wire connected with a commutator which runs in step with the revolving disc of the transmitter, so that as the spot of light shines on a particular part of the subject's face, a corresponding part of the neon tube is connected. A loudspeaker reproduces the voice.

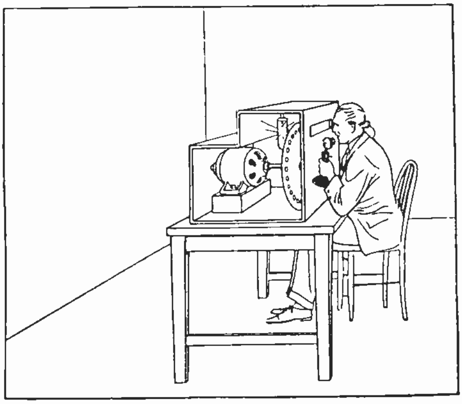

Fig. 7—When one person wishes to talk to and see a friend by telephone, a smaller neon tube is used, which presents a surface of two by two and a half inches. A revolving disc like the one in the transmitter, also in step with it, exposes a part of the glowing surface which corresponds to the part on which the transmitting light is shining at the moment. To keep the two motors at the receiving and sending end running precisely together, was in itself a great achievement.

Thus the lights and shades of the face are transformed into a varying electric current, just as the ordinary telephone transmitter transforms the sounds of the voice into a pulsating current. It travels over the telephone lines for hundreds or thousands of miles, or else on the radio carrier wave for even greater distances. The receiving end picks up the current, amplifies it some more to make up for any losses in transmission, and connects it to the receiver with its neon tube. The variations in current are translated by a neon tube back into variations of light—an inch or more square—with no semblance of a picture of a face or anything else.

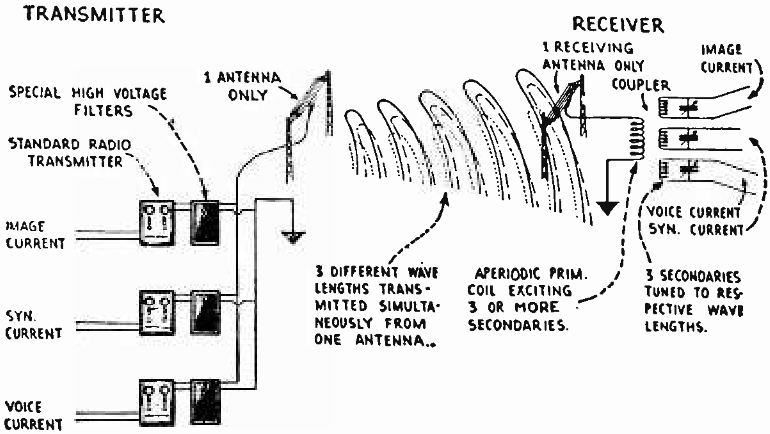


Fig. 8—Simplified system whereby three transmitters, tuned to different wave lengths, are joined to a common antenna through suitable filters.

Here the revolving disc again plays a part. A disc, the exact duplicate of the one at the sending end, revolves in front of the neon tube. Another ingenious invention, made by H. M. Stoller and E. R. Morton, permits the motor running the receiving disc to keep exactly in step with the one at the sending end. If the spot of light in the sending apparatus is shining on the bright flesh, the receiving screen shows a corresponding bright area through the hole. And then as the sending light spot moves to the dark pupil of the eye of the subject, the neon ceases glowing and the screen shows a dark spot. As the spot moves to another white portion, such as the bridge of the nose, the neon again shines through the hole, which has also moved. The receiving disc, like the transmitting one, moves so rapidly that the light appears to the person observing as a continuous surface, blended into a motion picture of the sending scene. The individual changes from light to darkness and back to light again may be over in a twenty-five thousandth of a second.

The 2 by 2½-inch picture produced by the small neon lamp is intended for individual reception. It is the first form of the apparatus that may in future years be attached to the individual desk telephone. But sometimes a large audience may also wish

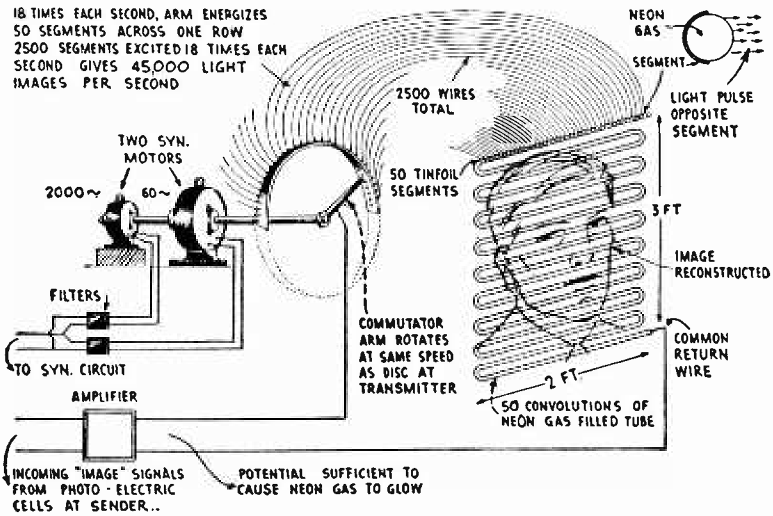


Fig. 9—The large exhibition screen built up of a continuous length of glass tubing along the rear walls on which are cemented 2,500 tin-foil segments. The tube is filled with neon gas; light spots appear opposite each segment when electrically energized.

to receive television, as when Mr. Hoover, in Washington, spoke to the audience in New York and was seen by them more than life-size. This is accomplished with glowing neon also. But a much larger tube is used; in fact, the whole screen, four square feet in area, is made up of a lengthy continuous tube, covering its surface much as lines of type on this page cover the area of this paper. This system is used instead of the revolving disc of the smaller receiver, because a revolving disc so large would not be practicable. The tube is a multiple one, really 2,500 separate lamps in one. A commutator, a disc which makes contact successively with each of the 2,500 separate glowers, is the substitute for the disc with the holes. It also revolves in step with the disc at the transmitter. A spot of light travels in rows across the surface of the large tube, reproducing as it goes, the variations of light "seen" by the photo-electric cells at

5

the sending station. But the big tube is expensive and complicated, as a separate wire must go to each of the 2,500 separate electrodes.

## THE BAIRD SYSTEM

At the transmitting end, a battery of powerful lights shine upon the scene to be transmitted. Light reflected from this scene is collected by means of a lens, in much the same fashion as a camera lens collects the light reflected from a scene to be photographed. In the television transmitter, however, instead of a sensitive photographic plate, as in a camera, the reflected light is focused upon a light-sensitive cell.

Between the focusing lens and the cell, however, there are interposed two rapidly revolving discs. One of these discs has a number of lenses mounted upon its face in spiral fashion, as shown in Figure 10. The function of these lenses is to cause the image of the transmitted scene to sweep across the light-sensitive cell in such a manner that the image is divided into fine parallel lines. The rotation of the disc gives the horizontal motion (i. e., draws the lines), while the movement into focus of the next lens (set a trifle nearer the center of the discs) gives the necessary vertical motion to insure that the lines do not overlap. Reference to Figure 10 will assist the reader to understand the action. In this manner, the entire image is flashed across the light-sensitive cell in the space of one-tenth of a second. The light reflected from the high lights of the scene to be transmitted is, of course, very bright, while that reflected from the dim shadows of the scene is very dim. The light-sensitive cell transforms these light variations into electric-current variations, which are then amplified and transmitted over the circuit to the distant receiver.

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## SPEEDING UP THE TRANSMITTER

The second disc referred to above is a serrated one, and its purpose is simply to interrupt the light at high frequency. By this means Mr. Baird found it possible to eliminate the inertia of selenium, and cause it to respond at a speed great enough to enable him to transmit a sufficiently large number of complete pictures per second, to give to the observer at the receiving station the effect of a smoothly animated scene.

Another advantage of interrupting the source of light is that the output of the light-sensitive cell takes the form of a uni-directional current, interrupted at high frequency, instead of a fluctuating D. C. as would otherwise be the case. A steady D. C. cannot be amplified by ordinary vacuum-tube amplifiers, whereas interrupted D. C. can. As the output current of a light-sensitive cell is extremely feeble, such amplification is necessary before transmission over a wire or wireless circuit can be accomplished successfully.

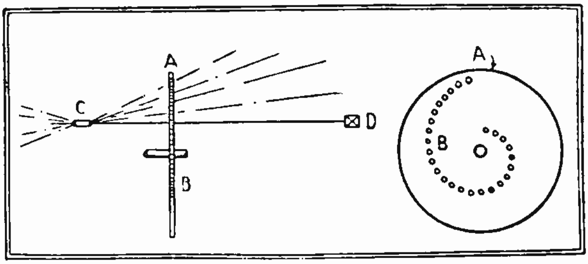



Fig. 10—The action of the Baird television transmitter: A is a rotating disc carrying spirally-arranged lenses, B, through which shines light reflected from scene, and collection by lens C. Movement of disc causes light beam to traverse light-sensitive cell D in two directions, horizontal and vertical.

At the receiving end of the circuit Mr. Baird uses apparatus which, though similar in essentials to that used at the transmitting end, has been reduced to the simplest possible form. There is a source of light and a ground glass screen, and between the two rotate discs similar to those used at the sending station. The incoming current impulses are caused to vary the intensity, or brilliancy, of the light source, in accordance with the strong and weak currents delivered by the light-sensitive cell at the transmitter.

The rotating-lens disc then breaks up the beam of light and throws it on the screen as a complete moving picture. The discs at the transmitting and receiving stations are in each case driven by electric motors, and in order to achieve success, it is necessary that the motors at all receiving stations shall be in exact synchronism with the transmitting motor. This is accomplished in the Baird system by transmitting, in addition to the picture impulses, a low-frequency alternating current, by means of which all motors are kept in step.

In Baird's first public demonstration tremendously powerful lights were necessary to illuminate the sitter whose image was to be transmitted to distant points. So powerful were these lights, in fact, that the "victim" was well-nigh blinded and burned by their intensity.

Obviously, the first necessity was to increase the sensitivity of the light-sensitive cell, in order that the intensity of the light required might be decreased. Within a few months, this was successfully accomplished so that the lighting required was no more brilliant than that used in a photographic studio.

## CONCERNING THE SPECTRUM

Not entirely satisfied with these results, however, Baird began experimenting to see if he could not make use of invisible rays, and these experiments led to most important results. In order to understand clearly exactly what has been done, let us consider briefly the spectrum.

Beneath the range of the shortest radio waves are other wave lengths extending in length down to infinitesimally small fractions of an inch. The frequency of these waves is enormously high, and the entire range of known frequencies, from the lowest to the highest, is known as the spectrum.

An illustration of these appears at the left of Fig. 11, showing the wavelengths to which we assign colors, and the range of normal sight.

The composition of the spectrum may be outlined as follows: Starting at the highest known frequencies, the spectrum is divided up into sections in which fall first the gamma rays given off by radium, X-rays, ultra-violet rays, the visible spectrum (light), infra-red rays, and finally, radio waves.

The most familiar of these sections is the visible spectrum, which contains the colors extending from violet to red. It is more familiar to us because it is the only band of frequencies within the entire spectrum to which the unaided human senses are capable of responding. To detect the other frequencies, special instruments are necessary; such as, for example, a radio receiver, when it is desired to detect radio waves.

Light-sensitive cells, such as are used in a television transmitter, are capable of responding to not only visible light, but also to a narrow range of frequencies beyond the upper and lower limits of the visible spectrum; and it is this fact which has made possible one of the latest developments in television.

In his first attempt to make use of invisible rays, Baird used ultra-violet rays; but these proved to be far too dangerous, for they had a bad effect upon the eyes of the sitters.

Turning to the other end of the visible spectrum, Baird next tried infra-red rays, and immediately discovered that his light sensitive cell was capable of responding equally well to these rays, which are invisible to the human eye.

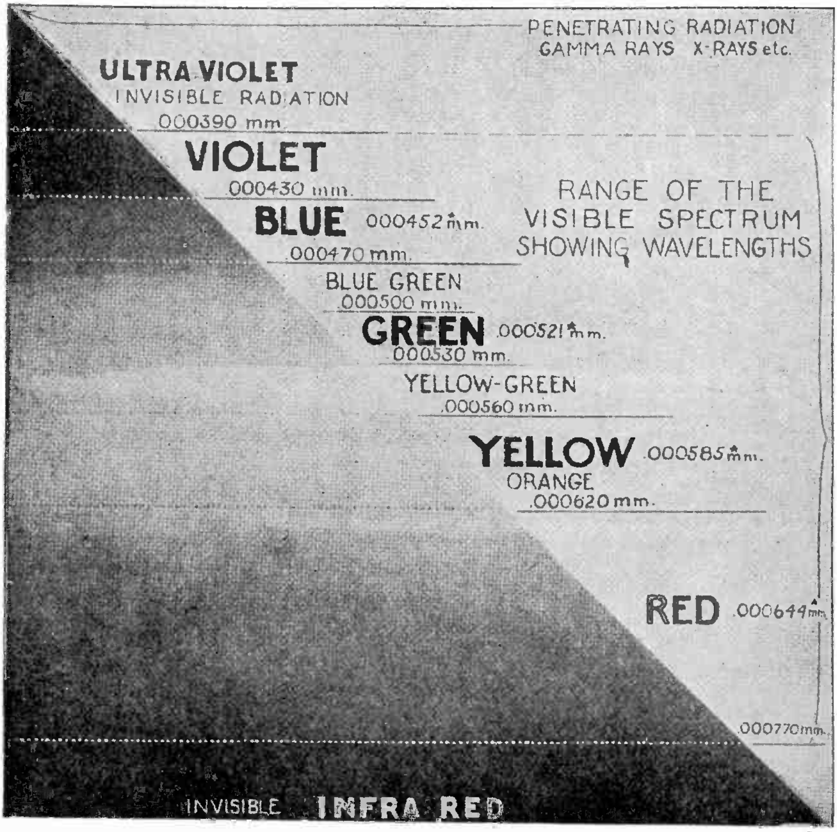



Fig. 11—The electromagnetic rays of the "visible spectrum," one billionth as long as those used in broadcasting, produce on the eye the effect of color (the stars indicate the wavelengths of the primary colors). Beyond its limits, at either end, no sensation of sight is caused. However, photo-electric cells register the impact of both ultra-violet and infra-red rays. The latter are used for "lighting" at the receiver of the Baird Televisor; and at the transmitter are reproduced as visible light, giving a normal effect.

## SEEING IN TOTAL DARKNESS!

Within a short space of time the inventor was able to dispense entirely with visible light, with the very startling result that it was possible to "see in total darkness!"

This is, perhaps, the most spectacular development of all in connection with television, and it has an uncanny and impressive effect upon visitors to a demonstration; a vivid description is given in the following words of a visitor who witnessed a demonstration of "seeing by dark light."

"First of all, I was shown into the transmitting studio, the windows and doors of which were heavily draped to exclude all daylight. The place was in complete darkness. Even after having become accustomed to the stygian gloom it was literally impossible to see my hand in front of my face; and yet those watching the receiving screen were able to see me put my hand up in an effort to see it!

Leaving a friend of mine there, I wended my way down stairs to the receiving theatre, where I conversed with my friend over the telephone and simultaneously watched his face on the televisor screen. He assured me that he was "still in total darkness," and yet there was his image on the screen before me, an image which, incidentally, showed considerable improvement over that which I first saw over a year ago!"

Thus have the Powers of Darkness been dispelled—those mythical powers which, right down through the ages of Man's history, have struck terror into the hearts of the ignorant and the superstitious.

It is difficult to estimate the full extent of the importance of this achievement in warfare, for it renders it possible to follow the movement of the enemy when he believes himself to be under cover of darkness.

Attacking aircraft, approaching under cover of the night, will be disclosed to the defending headquarters by the electric eye of television apparatus. They will be followed by searchlights emitting not visible light but infra-red rays, and as these rays will be invisible to them, they will continue to approach until, without warning, they are brought down by the guns of the defense.

Darkness, the great cloak for military operations, will no longer give security. The attacking party, creeping forward for a surprise attack on a pitch-black night, will be swept by an invisible searchlight and watched on the television receiving screen of the defenders. They will be permitted to come well within range and then find themselves, in spite of the apparent protection of darkness and the absence of visible searchlights, overwhelmed and decimated by well-directed gun-fire. It is to be hoped, however, that other uses may be found in peace time for this latest development of television. The fact that infra-red rays possess great fog-penetrating powers opens up possibilities in connection with the navigation of ships during foggy weather.

## SEEING THROUGH FOG

To understand the possibilities in this direction, it is only necessary to consider the behavior of ordinary visible light during foggy weather. The most intense white lights, it will be noticed, show through fog as a dull red color. The thicker the fog the duller the red which shines through.

This phenomenon is not due to any change in the characteristics of the original source of light. The fact is that any given light-source emits not one single color of light, but several, which combine to give the effect of a single color. By means of filters which will allow only certain component colors to pass, all other colors can be eliminated. Fog acts as a filter which will pass only red light.

The penetrating power of light varies as the fourth power of the wavelength; so that red light penetrates some 16 times more effectively than blue light, and infra-red light 200 to 300 times.

Red light has already come widely into use in aerodromes and for other purposes where fog-penetration properties are of importance. This new application of television renders possible the use of infra-red rays with their still greater penetrative powers.

They will not, of course, be visible to the naked eye, even through fog. It will be necessary at the receiving end (e. g., a ship at sea) to make use of a television apparatus in order actually to "see" through fog.

In order to generate infra-red rays, any form of lamp may be used which will provide the necessary intensity of illumination, although certain types of lamps are richer in infra-red rays than others. Having selected a suitable light-source all that is required to obtain infra-red rays from it is a filter which will cut off all the frequencies but those belonging to the invisible rays. Several substances may be used as filters, such as, for example, hard rubber.

Thus, in order to transform an ordinary searchlight (which is already very rich in infra-red rays) into an infra-red ray search-light, it is necessary only to cover the front of it with a suitable filter substance.

The infra-red rays are used by Baird in exactly the same way as ordinary visible light. That is to say, the rays are directed upon the sitter, and the "dark light" reflected from his face is passed on to the television transmitter.

## IMPROVEMENTS IN IMAGE-EXPLORING MECHANISM

Quite recently, Mr. Baird has made some improvements in his image-exploring mechanism. He has discarded his rotating disc of lenses, retaining only the two rotating slotted discs. To understand his reasons for doing this, let us consider briefly the rotating lens disc and its function in the apparatus.

The lens-disc, it may be remembered, consisted of a large disc upon which were mounted 16 lenses, in two groups of 8, each lens in each group being set a little nearer the center of the disc, or staggered. As the disc revolved each lens took a small portion, or narrow strip of the image and swept it across the light-sensitive cell, so that the entire image was so swept across once for every revolution. The image was thus divided into 16 vertical strips. They were further sub-divided into minute horizontal portions, or flashes, by the two other rotating discs, and each flash was, in turn, thrown upon the light-sensitive cell and signalled to the distant receiver.

From the foregoing, it will be obvious that the fineness of the "grain" of the image as seen on the televisor screen was limited to sixteen vertical strips, or lines. This is all right for a small reproduced image; but when it is desired to enlarge the size of the televisor screen it becomes necessary to retain the fineness of grain during the magnification process. Sixteen image strips are scarcely discernible as such, on a screen only about six inches square; but on a screen six feet square, the effect can well be imagined.

The obvious solution to the problem seems to lie in an increase in the number of lenses mounted upon the rotating lens-disc, but when an attempt was made to do this, mechanical difficulties were immediately encountered. In the first place, in order to accommodate the desired number of lenses, the diameter of the disc had to be increased to such an extent that it became unwieldy. Secondly, the weight of the lenses increased the centrifugal force of the rotating disc to such a great extent that it burst.

Baird, therefore, cast about for some other means of projecting an image in small sections across his light-sensitive cell. Besides lenses, prisms and vibrating mirrors can be, and have been used for this purpose; but they have their own peculiar disadvantages. Finally, the idea of the pin-hole camera occurred to Baird one day, and he devised an apparatus based on this principle.

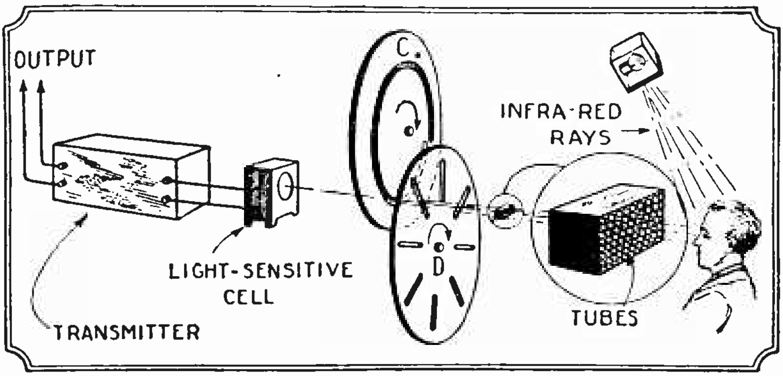



Fig. 12—The infra-red rays are reflected from the object through the tubes, and the revolving slotted discs C and D, where they are broken up, as explained in the text. They are then transformed into electrical energy by the cell, and are fed to the transmitter. At the receiving station they may be recorded on a phonograph, and reproduced at any future time.

## PROJECTION TUBES A SOLUTION

This apparatus is illustrated in Figure 12. It consists of a block, or cellular structure, of tubes of tiny diameter which is arranged between the sitter and the two rotating slotted discs. The cellular structure can be seen in the illustration of this block.

Each tube in the block casts an image of a small part of the scene before it, so that the total effect of the block is to split up the entire image into scores of tiny round sections, or dots, and it only remains to impress the light values represented by each individual dot upon the light-sensitive cell in proper sequence. Baird does this by retaining two revolving discs of his original system. One of these discs has a long spiral slot in it, while the other has a series of radial slots. These discs revolve immediately behind the cellular structure, as shown in Figure 12, in such a manner that the discs overlap, the overlapping portions moving past each other in opposite directions as the discs revolve.

The spirally-slotted disc, C, revolving comparatively slowly, exposes layer after layer of the tubes to the light-sensitive cell, shifting in a vertical direction. The slots in disc D, which revolves at a high rate of speed, are so arranged, however, that the light ray of only one tube at a time is exposed to the light-sensitive cell.

Thus, while, say, the lower layer of tubes is open to the cell through the spiral slot, the slots in the disc D swing rapidly along the line and flash the light of each tube in turn upon the cell. Then the next row of tubes is dealt with, and so on, until the entire image has been flashed over the cell.

At the receiving end, apparatus exactly similar is installed, except that the light-sensitive cell is replaced by a source of light which is varied by the incoming electrical impulses, which are strong for high-lights, medium for halftones, and zero for dark parts of the picture. Immediately in front of the cellular structure, at the end remote from the spinning discs, there is a ground glass screen, upon which the picture appears, a faithful reproduction of the original, complete with even gradations of light and shade, and showing the movements of the sitter exactly as would a movie film.

## THE NEXT STEP

Whereas the older method used by Baird, employing a spinning disc of lenses to project the image upon the light-sensitive cell, tended to produce at the receiver end a picture made up of closely-fitting narrow strips, the new method gives a picture made up of tiny dots, like a newspaper reproduction.

The grain can be made very much finer by this new method, and the picture enlarged considerably; but, even so, the ultimate degree of fineness obtainable, when enlarging the screen, is limited by mechanical imperfections. Obviously, there is a limit to the number and thinness of the tubes which can be employed, as also there is a limit to the speed at which discs can be revolved.

Recognizing this, Baird continued his research until he has now developed what he calls an "Optical Lever" to replace all his present image-exploring mechanism. It is impossible to describe this latest development, owing to the patent situation, but it can be stated that by means of it any degree of fineness of grain can be optically obtained, and there is no mechanical limit to the speed of operation.

## PERMANENT RECORDS OF SCENES

An interesting phenomenon in connection with television is that, if the output currents of the light-sensitive cell are listened to in a telephone receiver, they can be heard as sounds and every object or scene has its own peculiar characteristic sound.

For example, the fingers of a hand held in front of the transmitter will give rise to a sound similar to the grating of a very coarse file, while the human face will cause a high-pitched whistle which will vary in pitch as the head is turned or even when the features are moved.

For experimental purposes, Mr. Baird had some phonograph records made of the sounds made by different persons' faces, and by listening carefully to the reproduction of these records, it is possible to distinguish between one face and another by the sounds they make! With practice, faces may even be recognized by the sounds produced.

A further interesting point of far-reaching importance is that these records can be turned back into images. This is done by replacing the ordinary sound box by an electrical reproducer and causing the output currents from it to vary the intensity of the light source of a televisor. Thus, we can now store a living scene in the form of a phonograph record as well as in the form of a moving picture film! Baird calls this invention a "Phonoscope."

There is room here for the imaginative to indulge in speculation on the scope for future development along these lines.

## THE BELIN APPARATUS

The schematic wiring diagram, Figure 13, illustrates the mechanism used in the Edouard Belin system of television. The interior of the projecting lantern contains an electric arc, A, a convex lens, and a slide carrier, O, into which an ordinary positive photograph upon glass is inserted, as if for projecting the image or picture upon a screen in the usual manner.

The rays from the arc pass through the positive slide and project its image through a second or objective lens upon a plane mirror, B, which is attached to a drum completely surrounded by such mirrors, those at the ends of each diameter being parallel. The drum is connected by gears to a motor, by which it may be rapidly revolved. When it is in a state of rest, the image from the lantern slide may be projected by reflection from the mirror B to a diaphragm or screen, C, on which it is reproduced with all its graduations of light and shadow.

If we make a hole, 1/25 of an inch in diameter, in this screen, a luminous ray will pass through it, and fall upon the fixed mirror, D. The point of light it forms will have a diameter larger than the perforation in the screen, because of the spreading of the rays; and the mirror itself will accentuate this effect. Accordingly, we place another lens, E, in the path of the reflected ray, which is thus caused to converge. From this it passes to the mirror F, which again reflects it to the drum of mirrors. Here it impinges on the mirror G, which is diametrically opposite to B, and thence finally to a screen H, where it appears as a luminous point, corresponding to that which fell originally on the spot on C through which we made the opening. Now we start our motor and set the mirror-encased drum revolving; with what results? So long as the first mirror B remains stationary, the image which it projects upon the screen H is motionless; but when we set it in motion, in the direction indicated by the arrow, the image reflected by it will be deflected downward upon the diaphragm C. Over the hole in C all the points constituting a vertical line in this image will pass, and be projected in succession upon the mirror B. Through the reflecting system which has been set up, these will be reproduced in succession upon the receiving screen H. Each mirror which succeeds B in position on the revolving drum will receive the image in the same manner and make it pass through the opening in the diaphragm C.

## THE IMAGE REPRODUCED

We now are able to transmit a luminous vertical line, traversing the image from top to bottom, and always composed of the same succession of points. They will not be of equal intensity; because the ray will be very luminous when it represents a transparent portion of the slide on O, and more obscure when it passes through a part representing a darker portion of the image.

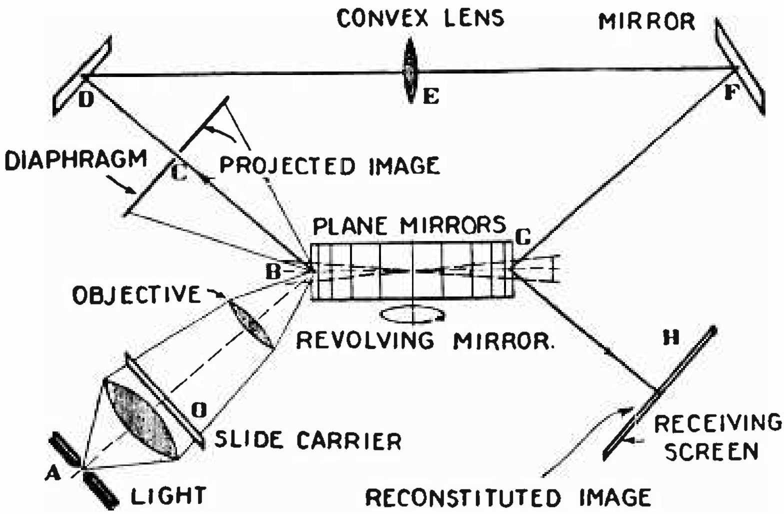


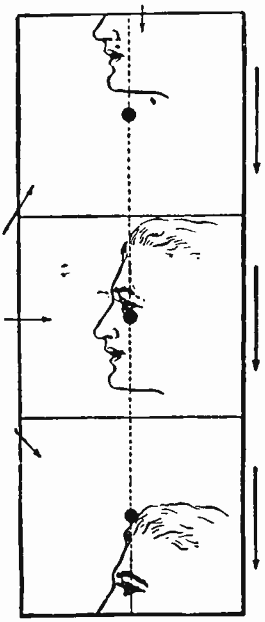

Fig. 13—This diagram is fully explained in the text. The cylinder is covered with plane mirrors, revolving downward on the side toward the lantern. One ray at a time, from 1/25,000 of the area of the image, passes through the opening in C. The fixed mirrors D and F send it back to the mirror G, opposite B on the cylinder, and it is finally reflected against H in a position corresponding exactly to the portion of the image from which it was first taken. The effect of continuous vision is produced.

Now the problem is to cover the whole area of the image on the slide, by causing the luminous line to be displaced at each movement over the screen, taking a course very close and perfectly parallel to the preceding stroke. This is accomplished by giving the mirror-drum a horizontal movement, alternating from right to left; which is accomplished by the use of a double spiral cam attached to its base, which gives it the necessary reciprocal action from right to left and back. Those movements, communicated to the revolving mirrors, deflect the image from side to side upon the diaphragm C. In this manner, the image is made to cover the opening in this screen with every successive point of which it is composed. The revolving mirrors thus transmit to D and its train of reflecting all the points of the projected image, in vertical lines, which by means of the oscillation of the drum, are delineated so close together that each practically touches the preceding one; and no perceptible portion of the image fails to be projected through the opening in C. As the mirror G and those which succeed it reproduce, in reverse direction, the motions of B, the reflected ray at H reconstitutes one by one, in the same order, all the points of the image on C which pass over the opening in that screen. As the entire screen is covered in a tenth of a second, or less, the image will appear clearly upon the receiving screen, as if reflected over its whole surface at once. This ingenious experiment has proved that every luminous emission of sufficient intensity which lasts for 1/250,000 of a second is perfectly registered by the retina, the impression on which persists for 1/10 of a second. This brings out clearly the curious property of the eye, "the persistence of vision," by which the sight of an image is preserved for a period of 25,000 times longer than the duration of the impression.

## APPLICATION TO RADIO

To transmit the image by radio waves, we have only to replace the mirror D by a photo-electric tube, such as has already been described. All luminous points in the image will be projected upon the tube, creating impulses which will be transmitted by means of ethereal (Hertzian) waves through space. By means of a properly synchronized corresponding mechanism attached to a receiver, they will be reproduced and projected in the same order upon a screen corresponding to H, producing the phenomenon of television.

It must be pointed out that the luminous ray is not displaced upon the mirror D of our diagram any more than it will be upon the photo-electric tube. If it passed through transparent glass, instead of through the picture on the lantern slide, it would have an unvarying intensity, and the current transmitted would be a continuous one. It is necessary to move the mirrors in order to cause the displacement of the entire image which they reflect over the aperture in the diaphragm. The slide remains fixed in the projecting lantern, and the magnified movements of its image are obtained by the rotation and oscillation of the drum. It would be theoretically possible to move the image in the lantern, or the screen C, to obtain the same result, but not practicable.



The moving image on the fixed diaphragm (C).

Fig. 14—At the left are shown the successive positions of the reflected image upon the diaphragm C. The portion of the image indicated by the (greatly magnified) dot in the center passes through this to the train of succeeding mirrors. In the upper illustrations is shown the effect of the downward rotation of the mirror B. The image passes vertically from top to bottom of the screen, every point in the vertical line shown being successively transmitted to the final screen H. By reason, however, of the upward rotation of the mirror G, these points, instead of remaining in the center of the field, are reproduced in a similar vertical line from the top to the bottom of H. For when B reflects the point at the bottom of the image (as in the top view) down to the center of the screen C, G reverses the motion and throws it up again from the center to the top of the screen H; and vice versa. The position of the ray in the apparatus from B to G is always the same, no matter to what portion of the image it corresponds.

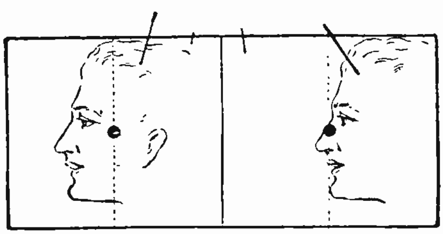


Fig. 15—This shows, in a similar manner, the effect on the image of the oscillation from side to side of the mirrors. It is swung from side to side on the perforated screen or diaghragm, until every part of it has been covered by the vertical lines traced by its movement over the central opening. These motions, also, are reversed by the opposite motions of the parallel mirrors so that the entire image is reproduced in its proper form on H.

Dr. E. F. W. Alexanderson, one of the foremost radio engineers in the world, has been working for the past few months on improvements in telephotography. He has succeeded in transmitting, by radio, photographs in one-tenth of the time that it previously took; and the copies, taken from the air at the receiving end, are excellent reproductions of the originals. Dr. Alexanderson, however, is looking beyond the transmission of photographs; his goal at the present time is "television."

## THE TELEVISION SYSTEM OF DR. E. F. W. ALEXANDERSON

Figure 16 shows a mode of a television projector, consisting of a source of light, a lens and a drum carrying a number of mirrors. When the drum is stationary, a spot of light is focused on the screen. This spot of light is the brush that paints the picture. When the drum revolves the spot of light passes across the screen. Then, as a new mirror, which is set at a slightly different angle, comes into line, the light spot passes over the screen again, on a track adjacent to the first; and so on until the whole screen is covered. If we expect to paint a light-picture of fair quality, the least that we can be satisfied with is ten thousand separate strokes of the brush. This may mean that the spot of light should pass over the screen in one hundred separate impressions of light and darkness in each path. If we now repeat this process of painting the picture, over and over again, sixteen times in a second, it means that we require 160,000 independent strokes of the brush of light in one second. To work at such a speed seems at first inconceivable; moreover, a good picture requires really an elemental basis of more than 100 lines. This brings the speed required up to something like 300,000 picture-units (dots) per second.

Besides having the theoretical possibility of employing waves capable of high-speed signaling, we must have a light of such brilliancy that it will illuminate the screen effectively, although it stays in one spot only 1/300,000 of a second. This was one of the serious difficulties; because, even if we take the most brilliant arc-light we know of, and no matter how we design the optical system, we cannot figure out sufficient brilliancy to illuminate a large screen with a single spot of light. The model television projector was built in order to allow us to study the problem and to demonstrate the practicability of a new system, which promises to give a solution of this difficulty.

Briefly, the result of this study is that, if we employ seven spots of light instead of one, we will get 49 times as much useful illumination. Off-hand, it is not so easy to see why we gain in light by the square of the number of light-spots used, but this can be explained with reference to the model. The drum has twenty-four mirrors and, in one revolution of the drum, one

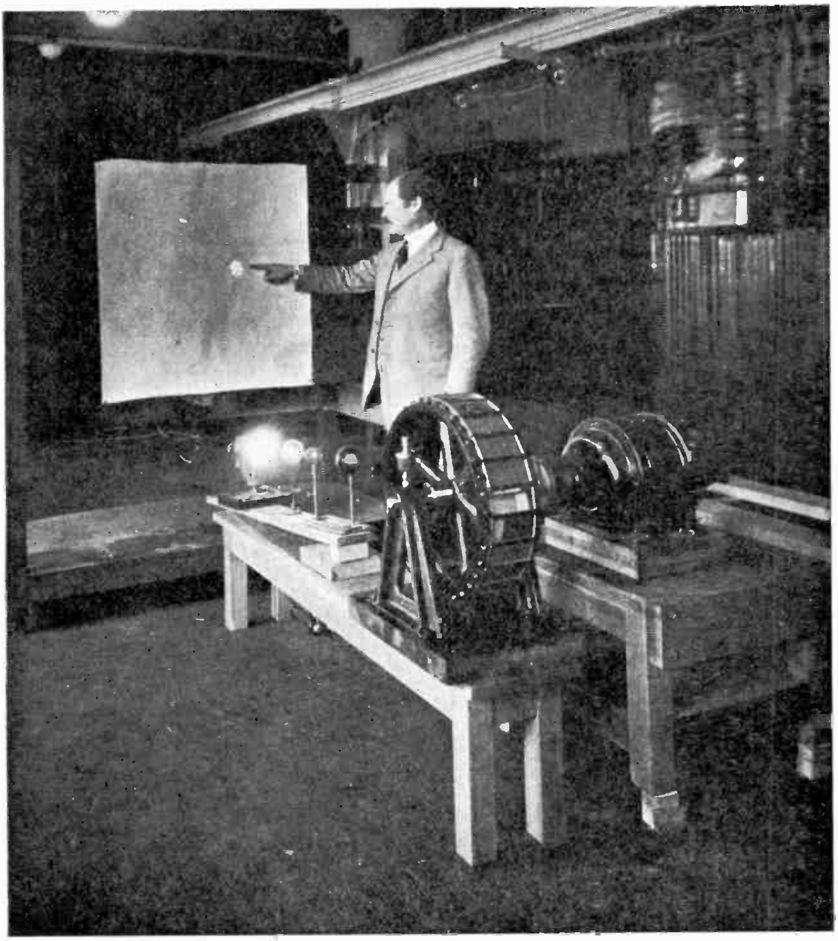


Fig. 16—Dr. Alexanderson in his laboratory indicating the seven light-spots which are used in the method proposed by him for television. In the foreground is the drum on which are mounted the mirrors, with the motor for rotating it. A system of lenses may be seen, together with an arc light.

light-spot passes over the screen twenty-four times; and when we use seven sources of light and seven light-spots, we have a total of 170 light-spot passages over the screen during one revolution of the drum.

## ADVANTAGE OF MULTIPLE LIGHT-RAYS

The gain in using seven beams of light in multiple is twofold. In the first place, we get the direct increase of illumination of 7 to 1; but we have the further advantage that the speed, at which each light beam must travel on the screen, has been reduced at a rate of approximately 7 to 1, because each light-spot has only 24 tracks to cover instead of 170. While the light itself may travel at any conceivable speed, there are limitations of the speed at which we can operate a mirror-drum or any other optical device; and the drum with 24 mirrors has already been designed for the maximum permissible speed. A higher speed of the light-spot can, therefore, be attained only by making the mirrors correspondingly smaller; and mirrors one-seventh as large will reflect only one-seventh as much light. The brilliancy of the light-spot would, therefore, be only one-seventh of what we realize by the multiple beam system, which gives seven light-spots seven times as bright, or 49 times as much total light.

There is another advantage in the use of the multiple light-beam; each light-beam needs to move only one-seventh as fast and therefore needs to give only 43,000 instead of 300,000 independent impressions per second. A modulation speed of 43,000 per second is high with our present radio practice; but yet it is within reason, being only ten times as high as the speed we use in broadcasting.

The significance of the use of multiple light beams may be explained from another point of view.

It is easy enough to design a television system with something like 40,000 picture units per second, but the images so obtained would be so crude that they would have very little practical value. Our work on radio photography has shown us that an operating speed of 300,000 picture units per second will be needed to give pleasing results in television. This speeding up of the process is, unfortunately, one of those cases in which the difficulties increase by the square of the speed. At the root of this difficulty is the fact that we have to depend upon moving mechanical parts.

## SEVENFOLD TELEVISION APPARATUS

Our solution to this difficulty is, not to attempt to speed up the mechanical process, but to paint seven crude pictures simultaneously on the screen and interlace them optically so that the combination effect is that of a good picture.

Tests have been made with this model television projector, to demonstrate the method of covering the screen with seven beams of light working simultaneously in parallel. The seven spots of light may be seen on the screen as a cluster. When the drum is revolved, these light-spots trace seven lines on the screen simultaneously, and then pass over another adjacent track of seven lines until the whole screen is covered. A complete television system requires an independent control of the seven light-spots. For this purpose, seven photo-electric cells are located in a cluster at the transmitting machine and control a multiplex radio system with seven channels.

Seven television carrier waves may be spaced 100 kilocycles apart, and a complete television wave band should be 700 kilocycles wide. Such a radio channel might occupy the waves between 20 and 21 meters. If such use of this wave band will enable us to see across the ocean, I think all will agree that this space in the ether is assigned for a good and worthy purpose.

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## TEST QUESTIONS

Number your answers 46 and add your **student number.**

No. 1. What is television?

No. 2. What is a light-sensitive cell?

No. 3. What furnishes the light in the television receiver of the Bell system?

No. 4. How many times are the minute electric currents from the photo-electric cells amplified in the Bell system?

No. 5. How large is the neon lamp used in the Bell system when it is desired to receive television for a large audience?

No. 6. What is the function of the lenses mounted on the revolving disc used in the Baird system?

No. 7. Name the kind of rays which were used by Baird in his experiments of "seeing in total darkness."

No. 8. What changes should be made in Figure 13 if it is to be used to transmit images by Radio?

No. 9. What is the big difficulty encountered in the Alexanderson system?

No. 10. How many photo-electric cells are used in the Alexanderson system?

RADIO BY MAIL

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