ALL ABOUT TELEVISION

INCLUDING
EXPERIMENTS
BY

H. Winfield Secor & Joseph H. Kraus

EXPERIMENTER [illegible] COMPANY

…NCH HUMOR Arrives in America

FRENCH HUMOR 7

Food for Thought

COLONEL PASTORELLI, who became illustrious during the Italian-Turkish War, belonged to the guard of honor. For this reason he wore an eagle in his cap.

One day he had a violent altercation with a colonel of the infantry about a plan which the former was elaborating.

"The eagle which you wear on your head has eaten your brain," exclaimed the exasperated colonel of the infantry.

Then, Colonel Pastorelli answered very calmly:

"That's lucky for him. If the eagle were on your head, he would have starved to death."

Nothing to Worry About

ONE day a learned doctor told his patient that he had to submit to a very serious operation.

"Is it dangerous?" inquired the patient.

"Not for the patient, as we put him to sleep. But it is a very painful operation for the doctor."

"How's that?"

"We suffer from anxiety. Just think! It succeeds only once out of a hundred times."

THE ONLY OBJECTION

—*Et le mariage? Vous aimez le mariage?*
—*Bien sûr, j'aime le mariage, mais c'est le mari qui me gêne.*

"And what do you think of marriage? Do you like it?"
"Of course, I think it's great! But it's the husband that annoys me."

THE BIG SHOT

—*J'ai vue un lièvre!*
—*Et tu ne l'as pas tué?*
—*Il était trop petit.*
—*Pour le tuer?*
—*Non pour le toucher!*

"I saw a hare!"
"And you didn't kill it?"
"It was too small."
"To kill it?"
"No, to hit it!"

When Modesty is Great

THE great Italian composer, Verdi, was extremely modest. He hated the indiscreet, and fled precipitously from those who wished to interview him.

One day a reporter asked him what were the most important happenings in his life.

Verdi thought it over for a moment, and then answered gently:

"The most notorious event in my life was my birth, in 1813. Since then nothing has happened which deserves to be called important."

Bravery

THE old maid—"Oh! That was a wonderful charity bazaar we had, and I had such a good time. Can you imagine, the Mayor gave me five dollars for one kiss!"

The young maid—"The Mayor is a very courageous man. He does everything for charity."

ISN'T IT THE LI IT?

—*Qu'est-ce que c'est que ce portrait de femme-là?*
—*C'est une femme que j'ai connue autrefois.*
—*Alors, c'est ça, tu me trompais déjà avant de me connaître!*

"What's this woman's picture doing here?"
"That's a girl I used to know."
"So, *that's* it! You were untrue to me even before you met me!"

FRANCE sends its matchless wit and humor to every American Home

FRANCE, the magic land of humor, wit, and keen, knife-edged "parlay," no woffers humor-loving Americans its choicest, finest humor through the new weekly magazine, "FRENCH HUMOR."

Americans (who have never been in France) invariably hold the opinion that anything French in humor or jokes must be smut with a Capital S. This is, of course, all tommyrot. The average far-famed Gallic with is no more smutty than the average Chicago citizen is a Gun-man.

This new magazine will show America what makes the …man laugh—also that humor is international. It will foster a better understanding between Americans and Frenchmen as a whole. Illustrated jokes in "FRENCH HUMOR" are printed first in French—and then in the English translation—this will be of great interest and help to those who are studying or who have a smattering of this important world language.

The first copy of "FRENCH HUMOR" will prove what we say—it's the funniest, wittiest and most entertaining magazine you have ever read.

Copies are sold on all newsstands, large size magazines 9x12 inches, profusely illustrated with genuine French illustrations.

… WEEKLY
…N ALL NEWSSTANDS

EXPERIMENTER PUBLISHING CO., Inc.,
230 Fifth Ave. New York

TELEVISION

Including

Experiments

by

H. Winfield Secor
Managing Editor

and

Joseph H. Kraus
Field Editor

of

Science and Invention

The Most Complete and Historically Accurate Work on the subject of television, giving the step by step developments and including information enabling anyone to build his own television apparatus

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Owners of Broadcast Station WRNY

PREFACE

by Hugo Gernsback

Editor RADIO NEWS
and SCIENCE AND INVENTION
MEMBER AMERICAN PHYSICAL SOCIETY
MEMBER AMERICAN ASSOCIATION ADVANCEMENT OF SCIENCE

FOR the last thirty years inventors all over the world have been working feverishly to invent a means whereby we could see at a distance. Ever since the advent of the telephone, whereby you could talk to your friend thousands of miles away, inventors have asked themselves why it should not be possible, as long as we can hear voices over a distance, to see each other from widely remote points. Seeing at a distance, whether by wire or by radio—it matters not—is true television.

Since the arrival of radio broadcasting, television has assumed an entirely new aspect, because every one realizes that the radio is blind, inasmuch as you can only *hear* the results of any given broadcast. What the public demands is *sight* by radio, that is, an apparatus to be attached to your radio set, whereby it will be possible for you to see what goes on at the radio station in the studio or elsewhere, whatever sight is to be broadcast. Thus, in the future, if the President speaks at Washington, we shall have a television transmitter in Washington also, which will transmit the visual impulses while the President is speaking. Then the entire country, by listening to the President, will also be able to see him. The same will be the case when two prize-fighters meet in the ring; the public will be enabled not only to hear, but actually see what is going on.

All of this is not a prediction, but may be said to be a fact right now, for already television, experimentally, is with us. Baird in England, and more recently the American Telephone & Telegraph Company, in its demonstrations made before thousands of interested spectators, have shown that visual events can be transmitted, not only by wire, but also by radio. It may be stated that at this moment radio television is in the same position occupied by radio about ten years ago. During the next few years you may rest assured that you will be able to buy, for little more money than your present radio set costs, a television attachment, whereby you will be able to see what is going on wherever there is a broadcast station to transmit the television impulses.

The day will also probably come when television attachments will be placed upon every telephone, and whereby it will be possible to see your friend or your business acquaintance, no matter how far away he is from you. It is significant that the greatest telephone institution in the world, the American Telephone & Telegraph Company, has expended a fortune upon television, because, no doubt, it is realized that a television attachment to the existing telephones will prove a tremendous source of income when finally perfected.

At the present time, most of the television arrangements necessitate revolving discs, or other more or less cumbersome moving devices. This is not the final solution of television. The final device will have no cumbersome moving apparatus, but will be greatly simplified. This is theoretically possible, and a number of experiments made along these lines point the way to the final completion of this phase.

The publishers of this book have been intensely interested in television for the past twenty years, and have contributed perhaps more than any other publishing house to the literature of this new art. Indeed, the writer was probably the first one to use the word "Television" in his article entitled "TELEVISION AND THE TELEPHOT," which appeared in the December, 1909, issue of "MODERN ELECTRICS," the pioneer radio publication issued by this company, in which a number of articles on television appeared. It is believed that these were the first articles on the art of television published in the United States.

Throughout this book a number of reprints of such articles will be found, and it will be astonishing, even to those who have made a study of television, to note how many articles on this subject originally appeared in the publishers' magazines during the last twenty years, and to further observe that there is not any one particular invention directly responsible for modern television. The development was slow and gradual.

In presenting this volume to those interested in the new art, we hope that you will realize that this is the first extensive work on television that has as yet appeared. It will probably become the forerunner of many others, once the art gets under way.

I personally have the greatest faith in television and believe that this new art will far surpass that of radio itself in the immediate future, and, as usual, those who get in on the ground floor will most likely reap a great harvest.

Summer 1927.

CHAPTER I

Television Experiments

NOT so many years ago experimental radio, or wireless, as it was then called, gained a tremendous hold everywhere. But we believe that today we have something not only as interesting as radio in its experimental form, but something far more interesting, that is, *experimental television.*

The suggestions given in the following paragraphs follow closely the television system used in the recent successful demonstrations by the Bell Telephone Laboratories, and while there are other methods of carrying on experiments in successful television, such as that of Mr. Baird, and details of which appear in another chapter prepared by Mr. C. A. Oldroyd, well-known English engineer, we have paid considerable attention here to the Bell system, as it is for one thing very simple in its make-up.

Like all simple machinery, however, we learn from the experts who developed and demonstrated this perfected television apparatus that the parts must be carefully and accurately made. Usually, unless the parts are very poorly made, some results will be obtained, but every effort should be made to have the various details as accurate as possible if a fairly clear image is to be obtained at the receiving end of the television line.

The Simple Television Apparatus

The illustration, Fig. 1, shows the simplest television apparatus that we can build perhaps, and this follows the form of the apparatus used in the Bell Telephone Laboratories in all the preliminary experiments. As will be seen, the receiving apparatus at the left, together with the transmitting apparatus at the right, are connected to the same common shaft, which in turn is driven by a belt or otherwise from an ordinary D. C. or A. C. motor. It does not matter with this apparatus whether the motor speed varies a little now and then, and the speed of the shaft should be approximately 1080 revolutions per minute.

The beauty of this simple set-up of television apparatus lies in the fact that the experimenter can always have recourse to a so-to-speak standard model, by means of which he can try out his photo-electric cells, neon tubes, diaphragms, amplifiers, etc., without having to worry about the fact that the transmitting disk is probably rotating out of synchronism with the receiving disk. Each of these disks are perforated with 50 small holes laid out on a spiral, as described further on in detail. The main thing to note in all television apparatus is that the holes in the rotating disks in any system must be at the same position at any given instant. As soon as we cut the shaft in half that joins the two disks in the apparatus shown in Fig. 1, and have to provide a means for synchronously rotating the transmitting and receiving disks when separated at a distance, then we have another problem on our hands. A special chapter on synchronizing means will help you in this particular problem.

Referring once more to the illustrations, Fig. 1 and Fig. 2, we see how a motion picture projector of a small home type may be used, as it was by the Bell engineers in some of their early experiments, to flash moving images through the holes in the rotating transmitter disk onto a photo-electric cell. The light fluctuations caused by the motion picture images are translated into fluctuating electric currents by the photo-electric cell, and these minute currents are amplified by three or more stages of resistance coupled amplification. As this vacuum tube amplifier will, in many cases, have to handle frequencies running from ten up to 20,000 per second, resistance coupling is the type of amplifier to use. At least the first three tubes of the vacuum tube amplifier will have to be very carefully mounted in a super-resilient manner, by means of rubber bands, etc., as any slight mechanical vibration will cause a distortion in the amplified current, and in consequence a distortion or blur in the reproduced image at the receiving disk. The Bell engineers placed the first three vacuum tubes inside metal tubes, the audions being packed in mineral wool, and the metal tubes in turn suspended by rubber bands. The number of stages of amplification to be used will depend upon the characteristics of the neon tube behind the disk at the receiver, and also upon the plate voltages and the type of tubes employed in the amplifier. The number of stages required will also be dependent upon the efficiency and electrical characteristics of the photo-electric cell employed. The Case thalofide cell is useful for experiments, but the best is the potassium cell. Experiments may be tried with good quality selenium cells, but these usually have too much lag to be useful for this purpose. There is a new English make of selenium cell which is claimed to have practically no lag, but as photo-electric cells can be purchased in the market, and in view of the fact that they are practically instantaneous in their action, i. e., in the recovery of their electrical resistance after light has ceased to fall on them, it will pay to procure one of these.

The electric motor should be of about 1/8 to 1/4 horse-power if it is to drive two of the small 16-inch disks, as shown in Fig. 4, or it will need to be a motor of about one horse-power possibly to drive two of the large 38-inch diameter disks, shown in Fig. 5. Caution should be observed in driving two of these large disks at 1080 revolutions per minute, as they would be liable to wreck the laboratory if they ever got loose at that speed. At least a 1-inch diameter shaft should be used for the large disks and supported in substantial bearings, while for the small 16-inch disk a 1/2 or 3/4 inch diameter shaft, preferably the latter, will suffice. Three bearings are better than two if the shaft is to be any longer than 2 ft., and take care to place the driving pulley close to one of the bearings to prevent undue

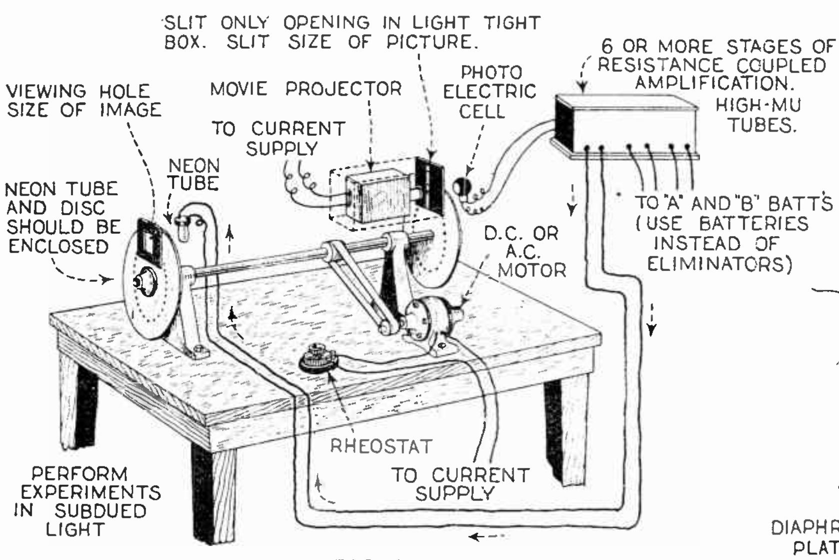


FIG. 1

The simplest experimental television machine which will help to demonstrate the principles of transmitting the living image over a wire, is shown in the picture at Fig. 1 above.

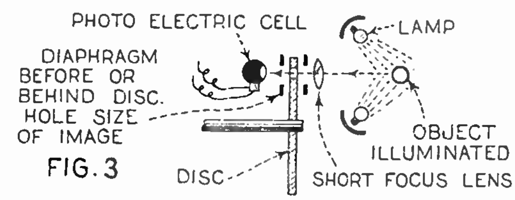


FIG. 3

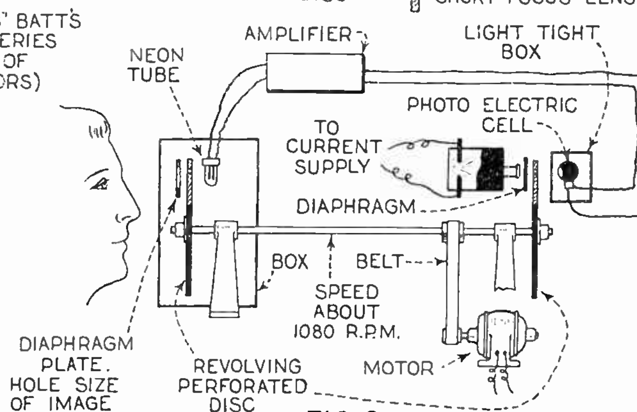


FIG. 2

The diagram above shows how the moving picture images fall upon a photo-electric cell, which causes corresponding current fluctuations in the amplifier and neon tube circuit.

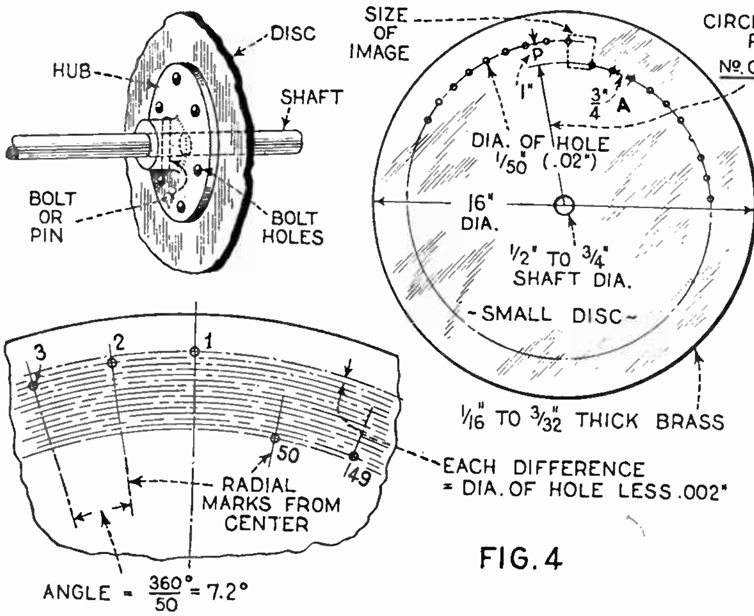


FIG. 4

The method of laying out the holes in the disc used in the Bell television apparatus is shown in the drawing above.

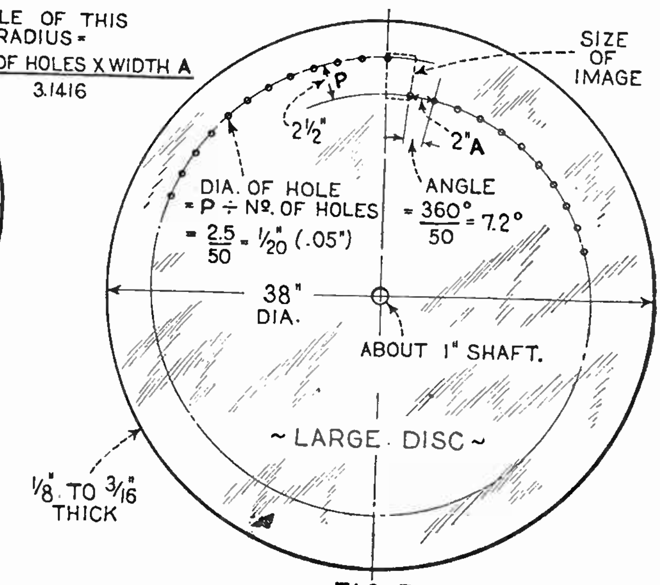


FIG. 5

The holes in the disc used in the Bell television apparatus are laid out on a spiral in the manner illustrated.

bending strain on the shaft. The neon tube used in the Bell system is a specially exhausted and carefully filled tube, and each tube is tested out in the laboratory and a characteristic curve plotted for it.

It was pointed out by the engineers who carried on this work that a great deal depended upon the operating characteristics of the neon tube used. As these tubes were specially made at their laboratory, it is necessary for the experimenter to try out whatever neon tubes he can get hold of. One of the simplest and cheapest types possibly is the Westinghouse spark "C" (neon tube) many of which have been sold for testing the spark plugs on automobile engines. If one tube is not sufficient to cover the height of the picture, then several can be placed side by side, as shown at Fig. 7. As shown in the diagram Fig. 8, about 140 to 160 volts is usually employed in the photo-electric cell circuit, and from 200 to 300 volts or more is used in the final stage amplifier circuit leading to the neon tube. Use "B" batteries and not eliminators of any kind, as a steady current is very essential.

As the diagram, Fig. 8, shows, the neon tube at the receiving end of the television system should be connected directly in the plate circuit of the last amplifier tube. *The grid bias or "C" battery potential on the last vacuum tube in the amplifier must be carefully adjusted and made high enough, so that normally when there is no illumination on the screen or object at the transmitter, the neon tube is dark.* In other words, *the bias voltage on the last amplifier tube must be adjusted, so that the neon tube glows only whenever an incoming signal or current from the transmitter arrives and impresses itself upon the grid of the last vacuum tube.*

As is explained elsewhere in this book regarding details of the Baird system of television, the light rays issuing from the neon tube and passing through the perforations in the revolving disk at the receiver, may be passed through a lens, or a series of small tubes, and these allowed to strike onto a screen, such as one made of ground glass. It is to be pointed out however, that as the image at the receiver is enlarged by placing either a lens in front of the revolving disk, or else by allowing the image to pass through a lens, or perhaps a series of tubes (as Baird does it), and the image in turn enlarging and falling upon a suitable screen, the illumination factor reduces also, thus making the image or picture a great deal dimmer.

A small detail drawing, Fig. 3, shows how instead of using a motion picture projector, a regular object, such as a doll, or else a human face, may be lighted by powerful lamps and reflectors, the reflected light image from the face passing first through a lens, then through a diaphragm placed either close before or just behind the revolving disk; thence through the perforations in the disk, as it revolves, and eventually falling on the photo-electric cell. The average photo-electric cell is sensitive to infra-red rays, and as Baird has demonstrated recently, the object may be lighted by invisible infra-red rays, as explained further on in this chapter, thus eliminating the intense heat on the face caused by the use of powerful unshielded incandescent or arc lamps.

Laying Out and Drilling the Disk Holes

In the diagrams, Figs. 4, 5, and 6, some details are given which will enable you to lay out the spiral of small holes on the disks, which are to be revolved at the transmitting and receiving ends of the television apparatus, as shown in Figs. 1 and 2. In the first place, care should be taken to purchase sheet brass big enough to cut the disks from, which has been kept on a shelf and not left standing on edge in the stock rooms of the company supplying the brass. The disk may be 1/16 inch or preferably 3/32 inch thick. The reason why care should be taken to obtain brass, if at all possible, that has been stored flatwise on a shelf, is because of the fact that sheet brass which has been stacked on end will tend to have a slight bulge in it, and experience has shown that it is nearly impossible to hammer or otherwise treat the sheet brass so as to make it perfectly flat and straight.

The disk is best turned from a square sheet a little larger than the diameter of the disk by mounting a piece of sheet brass on a piece of wood, placing small clamping strips all around the edge to hold it in place, while a lathe tool is run into the brass so as to cut a disk of, say, 16-inch diameter. There are numerous other ways in which the brass can be cut out, but it should be done with some form of tool in a lathe, or else with a radial arm cutter, such as those used for cutting holes out of radio panels and sheet metal boxes.

Fig. 5 contains data for laying out the fifty holes on a large 38-inch disk, but few experimenters will probably want to try to

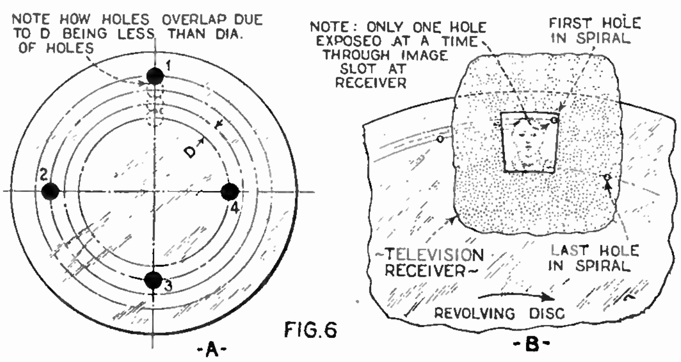


FIG. 6

-A- -B-

The proper neon tube to use behind the perforated receiving disc in the television apparatus, is one large enough to cover the size of the image. As shown at the right several small tubes may be utilized in an experimental apparatus, placing the tubes close together.

Diagram at left shows in simplified form at Fig. 6A, how the holes are to be laid out on the discs, so that they slightly overlap as they move into position before the diaphragm.

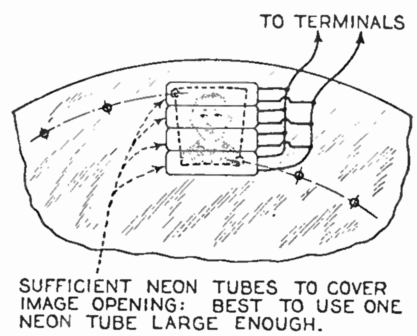
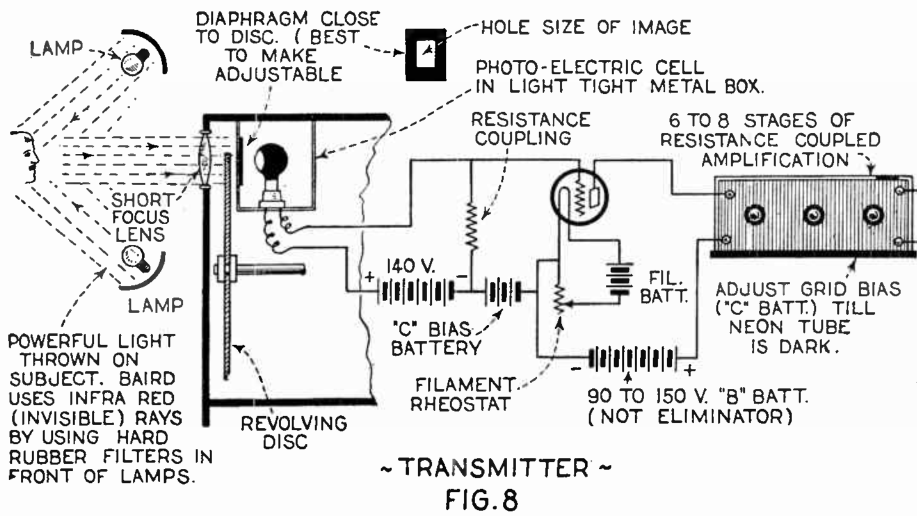
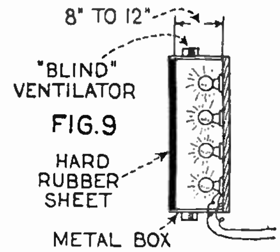
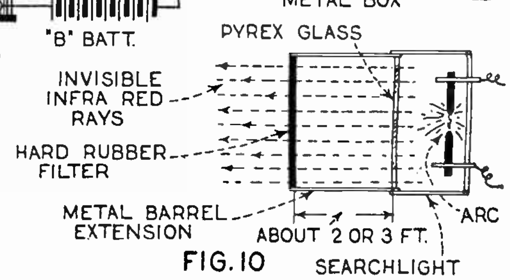


FIG. 7







Here the subject is illuminated by powerful lights, the reflected light rays acting on a photo-electric cell.

Figs. 9 and 10 show method of arranging invisible infra-ray illuminants for use at the television transmitter.

build a set of true running disks of this size, not to mention the larger motor required to drive them. Figuring on an image approximately 1-inch high by ¾-inch wide and referring to the disk lay-out diagram at Fig. 4, we see that the first step is to divide the circumference of the disk by means of a protractor or otherwise into 50 equal divisions, each measuring 7.2 degrees. These disks are laid out by drawing 50 circumference marks on the face of the disks with a pair of dividers. Dividing the height of the picture P by 50, gives us the difference in radius for each circumference mark between the top and the bottom of the image to be formed by the disk. However, instead of taking this division as thus found, which would be 1/50 of an inch (.020″) for a 1-inch high image, we take this value, less .001 to .002 inch, which will cause the disk holes to overlap slightly as they pass by the image opening in the diaphragm. (Thus the radius difference would be .020″ less .002″ or .018″.) This will tend to give a more perfect reproduction. The diameter of the holes to be drilled along the spiral is found by dividing the height of the picture P by the number of holes 50, which gives us for the 1-inch high image, 1/50 or .02 inch. as the hole diameter. As becomes evident when you have drawn the 50 radius marks from the center out to the edge of the disk, and then drawn or scribed on the disk surface the 50 circumference marks properly spaced, you can then easily lay out the 50 holes on a spiral, dropping down one space or division each time you lay out a new hole, and at the same time working around from right to left. A less number of large holes can be tried, of course, for your experiments.

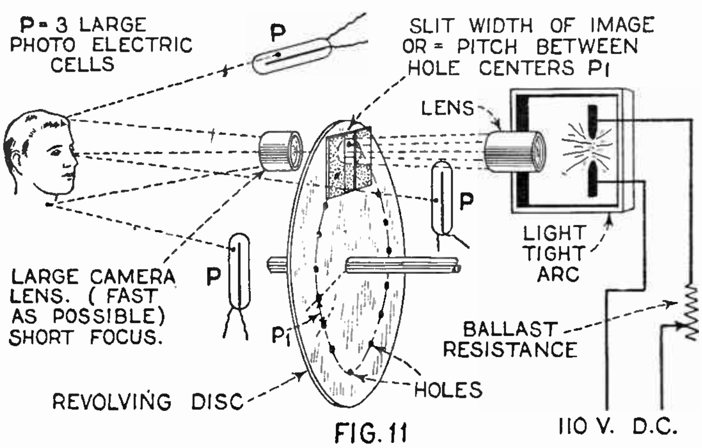
Reference to Fig. 6-A for the moment will make this a little clearer; here let us suppose that only four holes have to be drilled through the disk on a spiral path; the dotted circles at the top show how the holes line up in the course of one revolution of the disk so as to completely cover the image.

A very important point to remember is that the diaphragm opening, placed close before or just behind the revolving disk at the transmitter and receiver, is to be made the size of the image, i. e., its height must be sufficient to come even with the top of the outer hole on the disk, and also with the bottom of the innermost hole on the disk; while the width of this diaphragm opening is equal to the pitch or distance between the centers of two holes. The distance is approximately ¾ inch for the small disk, as shown in Fig. 4, where the dotted lines at the top of the disk indicate the size of the image.

For the large 38-inch disk shown in Fig. 5, used for producing a larger image 2½-inches high by 2-inches wide say the diameter of each hole would be 2½ divided by 50, or .05 inch. The circumferential pitch of the holes would be 360 degrees divided by 50 or 7.2 degrees. Other metal than brass can be used for the disk, but care must be taken to see that the metal is perfectly flat, so as to run true.

The disk holes should be drilled carefully at medium speed and a small reamer should be passed through the holes to smooth them up as well as true them. This is a very important part of the work and great care must be taken to see that the holes are accurately drilled in the positions laid out on the disks, and it will probably be advisable in many cases, unless you are an expert mechanic, to have your local machinist do this for you.

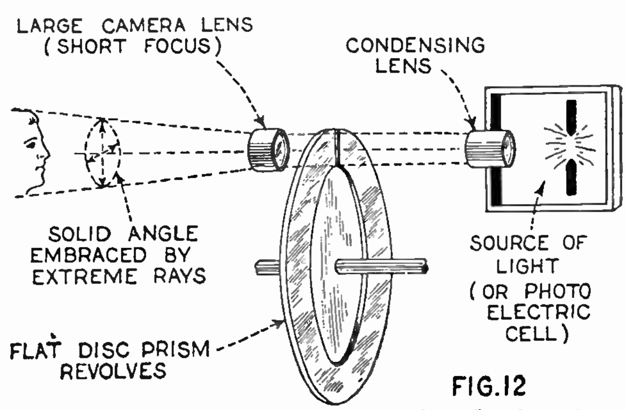
Probably one of the best ways to mount the disks rigidly on the shaft, is to purchase or have made a pair of steel or brass flanges of fairly large diameter, and then to drill a ring of holes through the disk and the flange, securing the disk to the flange face by means of machine screws of about No. 14-20 size at least, using 12 to 16 of these screws on each flange, equally spaced. The flange can be secured to the shaft by drilling a hole through the hub of the flange and through the shaft also, and then passing a steel pin or bolt through the two, making sure that it is securely fastened and will not release when rotated at 1080 revolutions per minute.



The arrangement of the transmitting apparatus in the Bell television scheme. Here a powerful arc light is focussed through a lens on to the rear of a perforated revolving disc. The constantly changing pencils of light flash on to the man's face, for instance, and when reflected they fall on one of the three large photo-electric cells marked P in the picture. The photo-electric cells cause variations in the electric current sent over the line, and which corresponds with the lights and shadows of the image.

Circuit Details

Referring for the moment to diagram Fig. 8, we may take a close look at the television transmitting apparatus. Here we see the revolving disk at the transmitter



The Jenkin's television scheme utilizes a revolving flat glass prism, which causes a light beam to travel over the whole face, progressively, many times a second.

with a diaphragm placed close behind it for instance. This diaphragm has a hole the size of the image, as explained previously. Behind it is placed the photo-electric cell, and this is connected with a resistance coupled amplifier. Note that the photo-electric cell is connected through a coupling resistance to the first stage of vacuum tube amplification. It was pointed out by the engineers who successfully demonstrated the Bell apparatus recently, that the common method of connecting the photo-electric cell to the first stage of amplification without any coupling resistance or other medium, proves very unstable and is undesirable. Proper C battery bias is to be used on each stage of the V. T. amplifier.

In Fig. 8 we see how the object at the transmitter is illuminated by two or more powerful incandescent or other lamps, the reflected light from the object, such as the face, being reflected through the revolving disk holes and diaphragm onto the photo-electric cell. Figs. 9 and 10 show how Baird caused a subject sitting in total darkness to have the image of his face transmitted by television through the agency of invisible infra-red rays. If a bank of incandescent lamps are used in a metal box properly ventilated with blinds or shields over the ventilating holes, it will have to be fitted at the front with a sheet of hard rubber or a dark glass filter, now available on the market, which passes infra-red rays but cuts off the visible light rays. If a searchlight is to be used for carrying on experiments in *noctovision* or seeing in the dark, as demonstrated by Baird recently, then the diagram Fig. 10 shows the position of the hard rubber sheet at the end of the metal barrel fitted on the front of a searchlight, so as to keep it several feet away from the pyrex or other glass front on the usual searchlight housing. No doubt air would have to be circulated in and out of the extended casing on the front of the searchlight, in order to keep the heat down, and a water cell would also help. Another way to cut off the heat from the visible and radiant light rays striking the hard rubber sheet, will be to extend the length of the steel tube or barrel carrying the infra-red filter, and mounted on the front of the searchlight.

Bell Telephone Laboratory Television Transmitter

In the diagram Fig. 11, we see how the Bell Telephone Laboratory television transmitter is arranged. Here an arc lamp in a light-tight but ventilated metal box passes a powerful beam of light through a condensing lens of large size, the condensed beam of light being focussed on the rear of the revolving disk and the diaphragm just ahead of it. The diameter of the focus spot is equal to the diagonal of the image opening. This diaphragm may be a sliding metal plate affair, the distance between the plates being made equal to the distance between hole centers on the disk. The diaphragm in any case, will be evident, is used to permit but one hole at a time to pass a ray of light, either out to the object or inward onto a photo-electric cell, depending of course upon which type of transmitter is used. A suitable lens is placed after the disk, i. e., between the disks and the object.

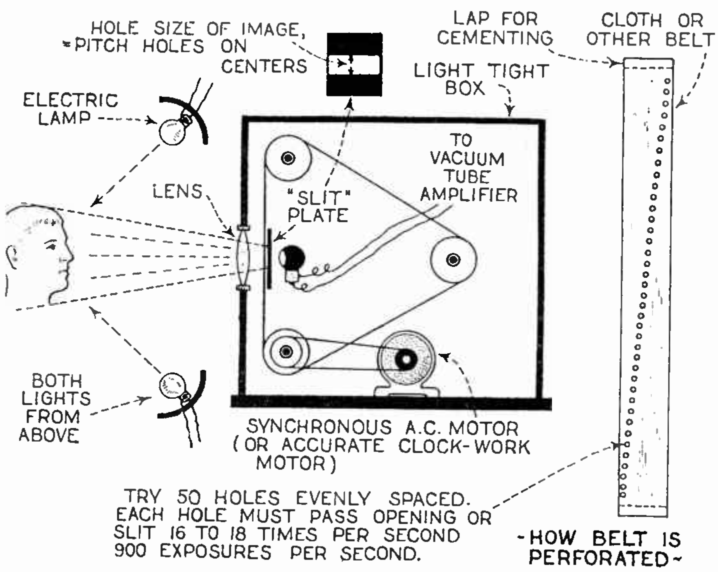
As was explained in the detailed article written by Mr. Secor, and which appeared in the June, 1927, *Science & Invention* Magazine, and also the June, 1927, RADIO NEWS, and reprinted in chapter VII herewith describing the radio and electrical features of the Bell television apparatus as actually demonstrated, use is made in the Bell transmitter of three new and extremely large photo-electric cells, P. These large photo-electric cells devised by Dr. Herbert Ives, of the Bell Telephone Laboratory staff, are similar in principle to the usual type, but measure 4-inches in diameter by 14-inches long. One cell is placed at either side of the transmitter disk cabinet, and one cell at the top. The consequence is that the rapidly changing reflected light beams coming from the face of the subject are bound to fall on one of the three photo-electric cells; these are connected in parallel to the two wires leading to the vacuum tube transmitter. The experimenter who does not have access to these special large photo-electric cells, can try out a scheme whereby several banks of photo-electric cells, or selenium cells of the new quick-acting type, are used instead. These banks of cells should be placed at either side of the disk cabinet, and also one bank across the top.

Fig. 12 shows how C. Francis Jenkins, the well-known Washington, D. C., investigator of television and radio picture transmission problems, does away with a perforated disk at both the transmitter and the receiver. Mr. Jenkins causes a pencil of light to travel over the object by means of a flat glass prism, revolved by a motor in the usual way. This flat glass prism corresponds to the rotation of a regular prism, and it has been very carefully and mathematically worked out. Suitable lenses are employed with the transmitting prism as shown. One of the latest applications of this revolving flat glass prism of Jenkins, is the projection of motion pictures without the use of a shutter or intermittent mechanism the film traveling through the projector continuously.

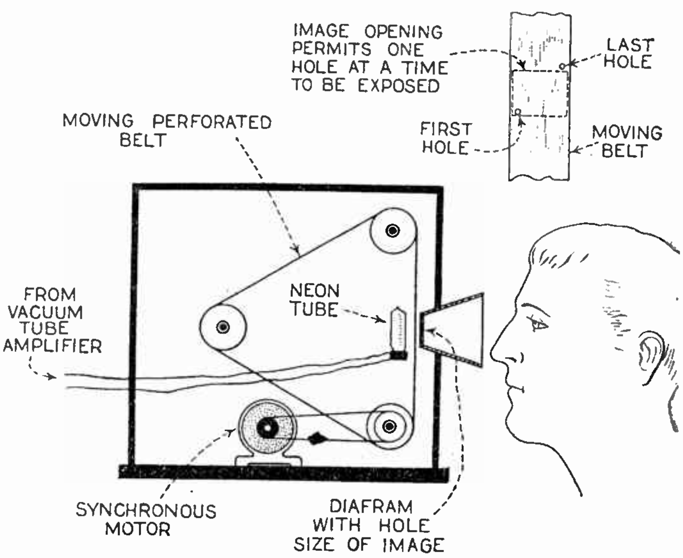
Perforated Belts Instead of Disks

In the illustrations, Figs. 13 and 14, a different idea than that previously described is suggested. One investigator, whom the authors have been in touch with, Mr. L. J. Schramek by name, stated that he had obtained some very interesting results with a perforated belt machine, of the general pattern shown in the illustrations. Here we have a rapidly moving perforated belt, instead of the revolving perforated disk. When the transmitting and receiving mechanisms are separated, synchronous motors will have to be used to keep the two belts revolving in perfect step with each other.

As the diagram Fig. 13 shows, the holes may be laid out by drawing a diagonal line along the entire length of the revolving belt, allowing space at each end for lapping and cementing. The 50 holes are laid out along this diagonal line, the diameter of the hole being found by dividing the width of the picture by 50, as previously explained for the disk. The spacing of the holes will determine the height of the picture, and the longer the belt, the greater the height of the picture and vice versa. The belt should be made of some stiff cloth material, or painted photo film may be tried for elementary experiments. The belt must be



~"BELT" TRANSMITTER~
FIG. 13



~"BELT" RECEIVER~
FIG. 14

The experimental television machine shown at Fig. 13 and 14 above, has been tried out successfully by its inventor, Mr. L. J. Shramek. The perforated belt represents one way of causing the light ray to progressively traverse the image at the transmitter, and also to build up the image from the successive light pulses in the neon tube at the receiver.

opaque. The holes may be spots where the paint is scraped away. The trouble with the belt machine as a regular proposition, is that the belt may break at any time, and is liable to become frayed and worn. A diaphragm or "slit" plate having an opening the size of the image, is placed just behind or just ahead of the rapidly moving perforated belt; a suitable (camera) lens is placed before the moving belt at the transmitter.

Fig. 14 shows the receiving television apparatus embodying the moving perforated belt, a neon tube being placed behind the eye piece, and also a diaphragm having a hole the size of the image or picture, placed just behind or just before the belt. It is understood, of course, that the television signals coming from the photo-electric cell of the transmitter will have to be amplified, as previously described, by several stages of resistance coupled amplification, before being passed into the neon tube at the receiver.

With regard to the number of holes in the moving belt or disk in the previously described machines, it may be wondered why 50 is invariably recommended. This is due to the fact that the less the number of holes or perforations used in the disk, belt or other light interrupting device, the coarser the "grain" of the picture. Likewise the more holes you use, the finer the grain of the picture, but 50 has been found to be a happy medium. As aforementioned, the main purpose of the diaphragm is to frame the picture and prevent more than one hole at a time passing light, either to the eye from the neon tube or again from the illuminated face or other object onto the photo-electric cell of the transmitter.

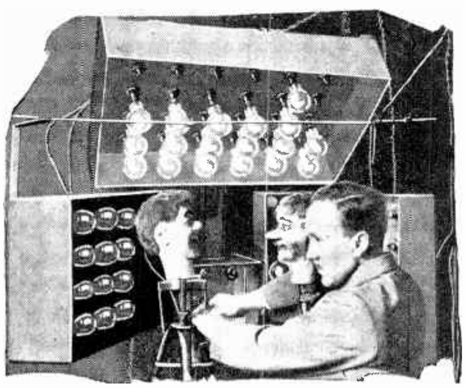
A great many experimenters have reported more or less success with a cathode ray tube for reconstructing the image at the receiver, as the reader will see by a study of the historical articles appended herewith. It is the strongest suspicion of the authors that in this cathode ray oscillograph or Braun tube, lies the solution of the practical television apparatus of tomorrow. The cathode ray has no inertia and can be traversed across the target, or fluorescent screen at the end of the tube, at any desired speed by a series of electro-static or electro-magnetic fields. This system as so far tried out is explained in some of the following articles.

CHAPTER II

Baird Television—Experimental Data

AFTER countless experiments and years spent in research, Mr. J. L. Baird of London (England) has at last succeeded in making his system of television a practical proposition. Demonstrations of his Televisor before leading scientific societies have convinced even the most sceptical spectator that the problems of televison by radio had been solved at last.

The apparatus used is shown in the photos; in Fig. 1 we have the transmitting televisor. A bank of powerful electric lamps illuminates the subject whose face, for instance, is to be shown in the receiver. The illumination is very intense, and for this reason the inventor used dummies in his laboratory experiments. The picture shows James and Bill, two ventriloquists' dolls whose eyes and lips can be actuated by cords.



This picture shows one view of the television transmitter used by Mr. J. L. Baird in London. Dolls are used owing to the great heat from the lamps necessary to illuminate the image. Fig. 1.

Between the lamp houses, at the center, a clear space is visible; the transmitter itself lies behind this aperture, it "sees" the subject through the hole and converts the optical image into electrical impulses. A microphone picks up speech and music, for the receiving televisor shows not merely an image, but reproduces also words spoken or music played.

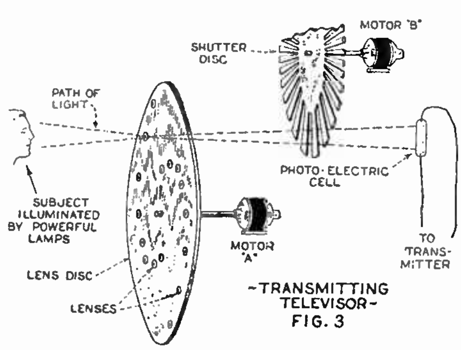
The latest model of the commercial televisor is shown in photo Fig. 2. The necessary instruments are contained in the cabinet, the adjustments are made by means of the small knobs visible near the base of the set. On the screen at the left the scene "seen" by the transmitter is reproduced, the loud speaker at the right adds the speaker's voice or music. Four standard radio tubes are used in the receiver, the instrument is entirely self-contained and costs but little more than a good multi-tube broadcast set.

For the present, the image reproduced in the receiver is in black and white only, but the inventor assured the author that he feels confident of being able to transmit scenes in their natural colors when improved apparatus is available.

The working principle of the televisor is explained by the diagrams; in Fig. 3 we have the transmitter in action. On the left is the subject whose image is to be transmitted, for instance a face. A short distance from the subject is a large metal disk carrying sixteen lenses of equal focus length. These lenses lie on two short spirals as a common center-line, so that each lens "covers" a different section of the face as the disk rotates.

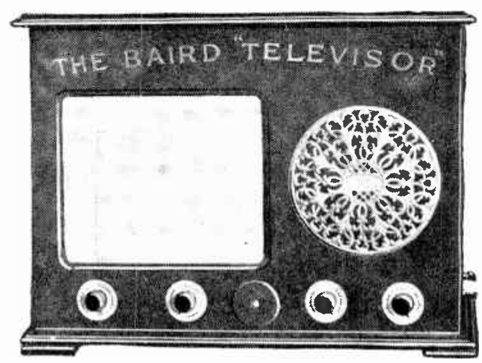
A small electric motor "A" rotates the lens disk at high speed. At a certain instant of the transmission, lens No. 15 may have arrived opposite the subject, it forms an image of a narrow section and projects it upon a photo-electric cell of special design which is shown at the right. If the image happens to be bright, the cell will pass a comparatively heavy current; if the image projected is dark, the cell will pass little or no current.

If we use the transmitter in its present form, we shall find that the images falling on the photo-electric cell are merely blurs drawn out into a narrow band. To get well-defined impulses, the image thrown by the lens disk is broken up by a rapidly rotating shutter disk. Slots have been cut into the rim of this disk, and as it rotates in synchronous relation to the lens disk, the light will either pass through the slot or—a fraction of a second later—be held back by the spoke of the shutter disk. A small electric motor "B" drives the shutter disk.



The diagram above shows arrangement of shutter disc together with lens disc and photo-electric cell in one of the television machines devised by Mr. J. L. Baird.

The electric pulsations which take place in the photo-electric cell are greatly amplified in the usual way and finally led to a radio transmitter, or else to a circuit if transmission is to take place by wire. Through the ether, they reach the receiving televisor, its construction is shown in Fig. 4. After the signals have been detected and amplified in the manner familiar to all radio fans they reach a neon tube, according to the received signal intensity. In front of the neon tube is a lens wheel, similar to that of the transmitter, but of smaller diameter. A synchronous motor "C" drives this lens disk at a speed uniform with that of the transmitter lens disk.



One of the recently developed forms of the Baird televisor with loud speaker at the right, is shown in Fig. 2, above.

Moreover, the lenses must be *in phase*, when at the transmitter end lens No. 15 is at the uppermost point, lens No. 15 of the receiver lens-disk must occupy *the identical position at the same instant.* A special synchronizing system holds the two disks automatically in phase. (See chapter on Synchronism.)

In our diagram, lens No. 15 is just opposite the neon tube, the light passes through the lens and produces a light spot on the receiving screen indicated at the right. On the receiving screen, the spot of light will appear relatively in the same position as the

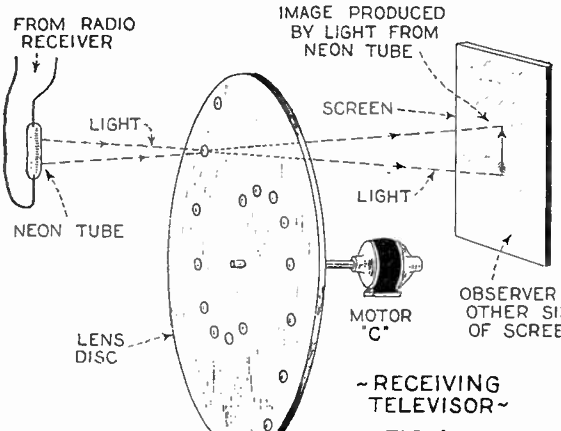


FIG.4

The diagram at the left shows arrangement of the revolving lens disc together with neon tube and translucent screen, such as ground glass, on which the image is built up. The man at the right is observing the image of the arrow as reproduced on the translucent screen, the image being built up by the rapidly changing spots of light thrown on a screen, due to the joint action of the light pulses from the neon tube and the revolving lenses on the whirling disc.

bright section of the subject's face which was analyzed by transmitter lens No. 15 at the particular instant and which caused the electrical impulse. If, for instance, the spot appears in the center of the field covered by the transmitter lenses, it will be indicated on the receiving screen by a spot of light placed in the center of the screen.

From countless more or less bright light spots, the image is built up on the receiving screen. Our eyes cannot separate the individual light splashes, its inertia is too great; and as in the movies, the light spots melt into one continuous picture.

It is very interesting to follow the repeated changes of electrical and optical impulses, the transformations they undergo when a simple subject is transmitted via radio are shown in the diagram Fig. 5. Our subject is here a small square cut from light gray cardboard (1). The rotating lens disk produces a blurred image as its lenses travel over the subject (2), the shutter disk breaks this up into say three well-defined separate *bars* (3).

Falling on the photo-electric cell, the three light impulses produce three bursts of current (4), they are amplified (5), and finally sent out as radio waves by the transmitter (6).

The receiving televisor detects the impulses coming through the ether (7), they are amplified (8), and cause the neon tube to light up (9). The lens disk catches the light impulses (10), and re-assembles them on the receiving screen where we behold a picture of our small gray square. All these changes take place in a minute fraction of a second.

One drawback of the transmitter as outlined in the above description was that the subject whose image was to be transmitted had to face the terrific glare of numerous powerful electric lamps, the glare proved even more trying than that in movie studios when a close-up shot is to be taken. To overcome this difficulty Mr. J. L. Baird tried rays lying outside the visible spectrum for illumination. Infra-red rays are invisible to the eye, but they affect the sensitive photo-electric cell like visible rays. In other words, the televisor is able to *see* in what appears to us complete darkness.

In the photo Fig. 6, the inventor is shown in front of the infra-red ray transmitting televisor, at the right and left are projectors sending out invisible rays. These comprise banks of powerful incandescent lamps behind hard rubber sheets, which pass the infra-red rays but cut off the visible rays. This new development opens up new fields for the televisor; in wartime, for instance, searchlights sending out infra-red rays could be used to spot an enemy approaching under cover of darkness, without the latter being in the least aware of it. In this case the receiver can be mounted below the projector, and in line with it.

Fog does not stop infra-red rays to the same extent as the visible rays, and it is by no means impossible that shortly ships and airplanes will carry *black-ray* televisors. In a heavy fog, or during the night, the look-out will be able to see well ahead, and collisions can be avoided with certainty.

The television transmissions can naturally be heard with any standard broadcast set tuned to the wave employed. The transmitted scene is heard as sound, each object having its own characteristic sound. Mr. Baird has used this fact in his visual phonograph, (see diagram Fig. 7, and Fig. 7-A); the sounds are here recorded on a phonograph cylinder in the usual way.

To reproduce the scene, the phonograph is fitted with the reproducer attachment, the sounds from the latter are led to a sensitive microphone, the resulting current is amplified and fed into a receiving televisor. On the screen, the scene comes to life once more, and the process can be repeated as often as desired, just as a phonograph cylinder can be played any number of times. (See diagram, Fig. 7.)

This trick of recording the fleeting visual impressions of someone's face for example, seems thoroughly uncanny to say the least. In fact, on first thought, it would seem almost impossible, but once we stop to analyze the action taking place in the televisor of any type, we find that over a given period of time, say one second for example: the image current from the photo-electric cell is a continuously and progressively pulsating one, as the diagram Fig. 7-A portrays. In attempting to record the televisor current after being amplified, the current pulsations are passed through a radio receiver unit, which is joined by a piece of rubber or metal tubing in the usual phonograph recorder.

All inventions suffered from childish ailments in their first years; think of Marconi's first radio set, the first automobile, the first phonograph and the first camera. A few years' work by a band of experts brought them to perfection, and to-day we take that perfection for granted and are inclined to judge new inventions by this high standard.

The future looks bright for television—the missing link in radio—and our historian turns to a new page, heading it 1927—Radio Television introduced—LOOKING-IN BEGINS!

C. A. OLDROYD.

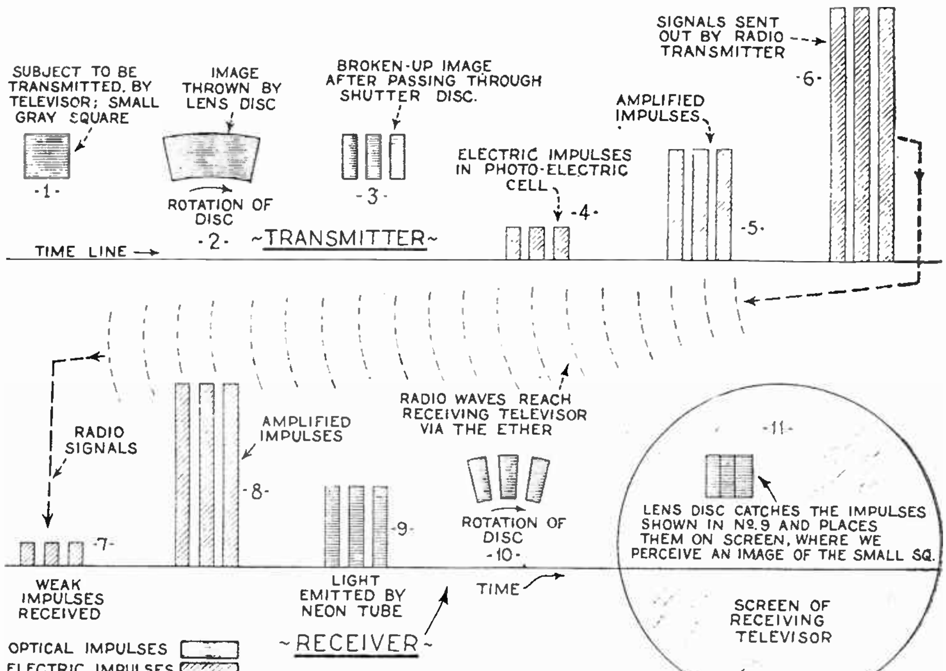
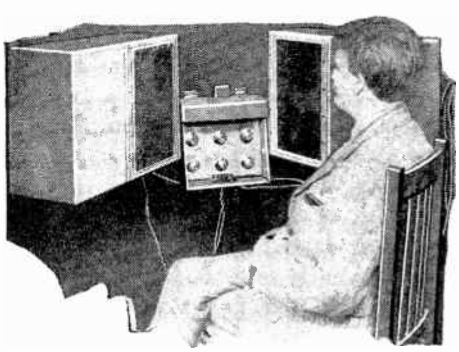


FIG. 5

The diagram above shows progressively the stages gone through in transmitting and reproducing an image by the Baird television system, of the type employing revolving lens discs at both transmitter and receiver. The subject being transmitted in this case is a small gray square at 1, and we see how it is reproduced finally at 11.



This picture shows one form of the Baird television transmitting apparatus with invisible infra-red sources of illumination, placed at either side of the central apparatus, which picks up the reflected rays from the subject's face. Fig. 6.

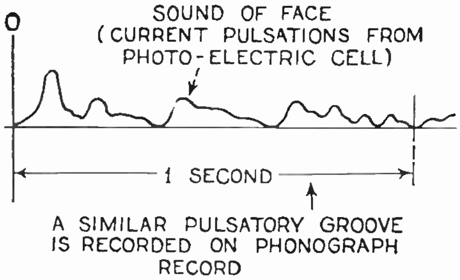


FIG. 7A

One of the cleverest stunts that Mr. Baird has accomplished is the recording of a television image on a phonograph disc or cylinder. The graphic curve above at Fig. 7A, gives some idea of the fluctuating "picture image" current as created by the photo-electric cell and amplifier.

At the right we see how the Baird phonographic television reproducer is connected to one of his receiving machines. With this system it is possible to reproduce a living image at any time from a wax record, once the image has been recorded thereon.

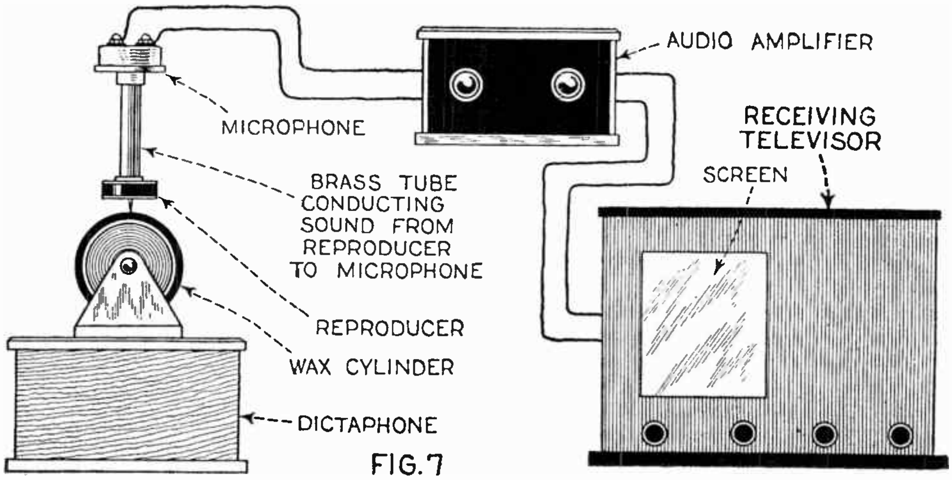


FIG. 7

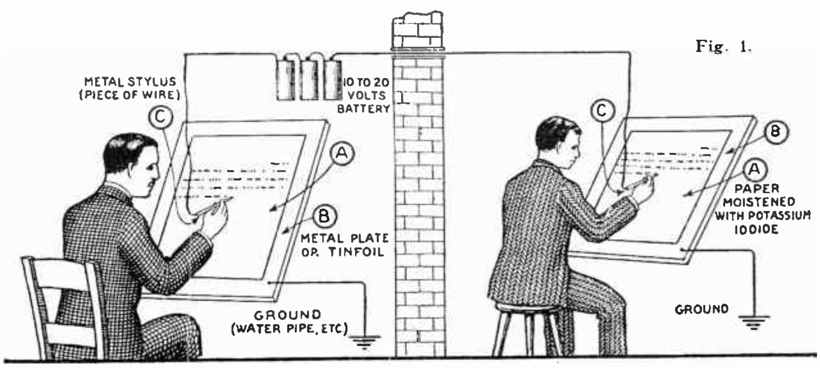
CHAPTER III

Picture Transmission Experiments

TELEVISION or the electrical process whereby one may see the living and moving image of a face or other object projected over a telephone or other circuit, is a very absorbing and interesting field for experiment. Another very interesting and less difficult branch of electrical science is the art of transmitting line drawings over a wire or radio circuit, and then reproducing these drawings on a revolving cylinder or disk at the receiving station, the reproduced picture being built up by dots or lines in the manner used by the Radio Corporation of America, and also the American Telephone and Telegraph Company. In the picture transmission systems the average time required to reproduce an ordinary photograph is about fifteen to forty minutes. Briefly considered the transmission and reception of pictures is based on the fact that the image at the transmitter is traversed by a pencil of light and the variations in the light beam for instance, are sent over a wire or radio circuit to the receiving instrument, where the successive signals are transformed into photographic or other impressions; so that after a certain time the recording pencil traversing the cylinder or disk at the receiver has progressively covered the whole surface and the result is a more or less perfect picture.

Let us look at Fig. 1 for a moment, and we shall learn one of the fundamental principles on which practically all picture transmission and reception is based. Here we have two people at either end of an electric circuit, which may be a two wire circuit or simply one with ground returns, as shown in the picture. By *ground* we mean that case where the return wire of the circuit is connected to a water pipe or other earthed metallic system. At the transmitter the operator may use a piece of wire or other metal electrode, and he moves the metal pencil back and forth across the metal plate, the second operator at the receiving station doing likewise. The speed with which the metal pencil is moved across the plate at the two stations should be fairly similar but need not be exact. At the receiving station we find the operator using a metal plate on top of which is a piece of ordinary writing paper which has been moistened in a solution of potassium iodide. You can obtain this chemical at small cost from your druggist, and the solution may be made by mixing about one-half teaspoonful of the potassium iodide salts in one-eighth glass of water. The authors found that a metal lead pencil containing black lead, formed a better electrode and gave better signals than a plain piece of wire or other metal. The transmitting operator does not need to use moist potassium iodide paper unless he cares to have a check on his signals. All he has to do ordinarily is to move the metal stylus along back and forth slowly, forming telegraph code dots and dashes by making contact between the plate and the stylus. Each time a dot and dash contact is made as the

Fig. 1.



One of the first steps in electrical "picture transmission" is shown in the illustration herewith. The two operators move the metal pencils back and forth along the platens at approximately the same speed. Through electro-chemical action, the dots and dashes are reproduced on the paper at the receiver, whenever the transmitting operator's pencil touches the metal plate.

A very simple home-made apparatus is shown here for demonstrating the principle of electric picture transmission, utilizing the "line by line" process of analyzing and building up the image. After you have had success with this simple demonstration apparatus, you can then separate the two cylinders and experiment in driving them synchronously.

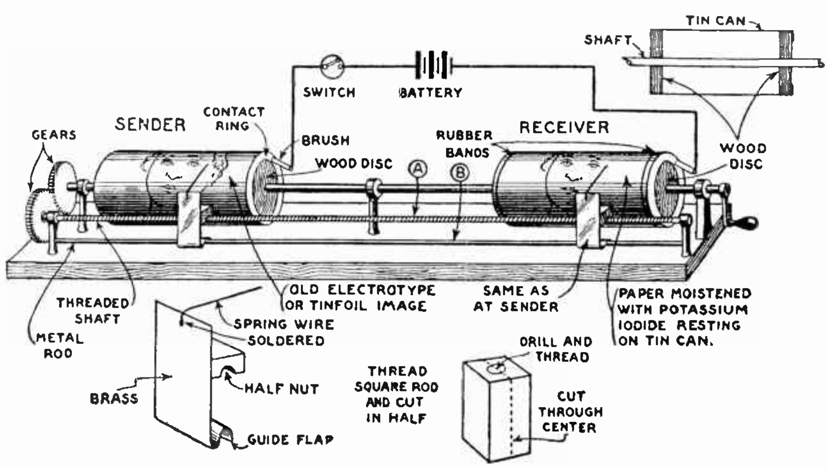


Fig. 2.

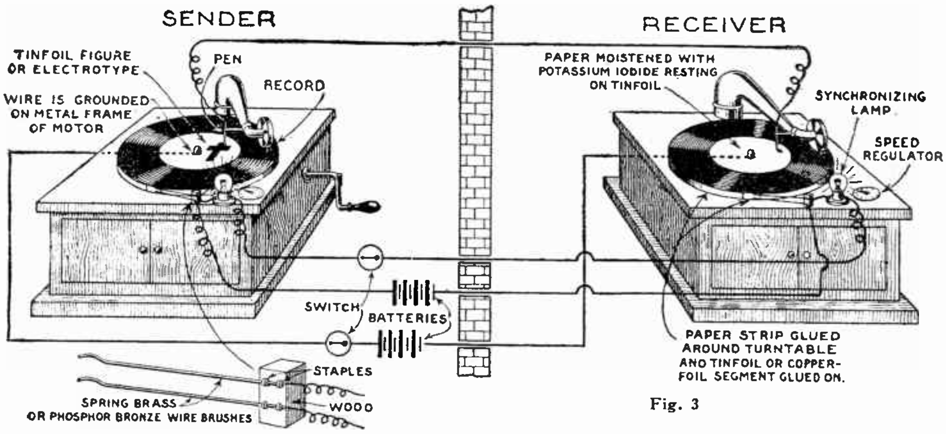


Fig. 3

A pair of phonograph motors, or rather two complete machines, can usually be procured without much trouble nowadays since the advent of radio broadcasting. The diagram above shows how two disc phonographs can be utilized for transmitting and receiving a drawing or other image by electro-chemical means.

stylus moves along the receiver, the operator who is moving the metal electrode back and forth in contact with the moistened paper, will see the dots and dashes formed as if by magic. Various battery potentials may be tried, but for short lines six to ten volts will be found sufficient. On longer lines a greater potential will have to be used to overcome the ohmic resistance of the circuit.

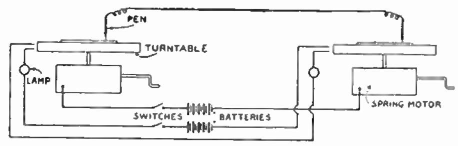
A simple demonstrating apparatus which will show the principles upon which picture transmission across the continent, as well as across the ocean, by wire and radio is accomplished, is shown at Fig. 2. Here two old cylinder phonographs or parts therefrom may be employed if you happen to find them available. Failing this, the two cylinders may be easily made from a pair of tin cans. The end of the can, such as a baking powder tin, is cut out and the can is supported on two wooden disks on the common driving shaft shown.

A handle is fitted to one end of the shaft supporting the cylinders, so that when turned the cylinders rotate, and also a pair of gears at one end of the instrument causes a threaded shaft, A, to rotate in a fixed relation to the revolving cylinders. Next you will need a pair of carriages, each of which is to carry a contact wire or brush, as the drawing shows. A stationary guide rod, B, serves to keep the carriages in an upright position as they are propelled along by the revolving threaded shaft A. In order to propel the carriages along the moving threaded shaft, half of a nut of the same pitch as the shaft A is soldered to the carriage, or better still drill and tap a square block of brass or iron, as shown in Fig. 2 and cut this through with a hacksaw. Solder one-half of the block to either carriage. The reason the half nut is used is so that you pick up the carriage at the completion of one picture and return it to the starting point without having to turn the handle on the machine and traverse the carriage back to the starting point.

At the transmitting end of the machine, a simple image, such as a cross cut out of tinfoil, or else an old electrotype, is curved and secured on the cylinder. If a tinfoil image is used, it will have to be mounted on a piece of paper taking care that the tinfoil is joined electrically by a piece of foil or wire to the contact ring at the end of the cylinder. Every time the brush wire on the transmitting carriage makes contact with the tinfoil or with one of the projecting ribs on the electrotype, if this is used, an electrical impulse will be sent over the circuit to the receiving cylinder.

At the receiver we find the metal cylinder covered with a sheet of writing paper which has been soaked in a solution of potassium iodide for instance. Every time an electrical impulse from the picture being transmitted arrives at the receiver, a brown line is formed under the brush on the carriage. You will find that the paper should not be too wet or the lines will run together. It should be just moist. The cylinders are preferably rotated right handed from the handle end of the instrument, and the carriages will then move from right to left. If you desire to have the carriages move from left to right, a third gear may be placed between the two at the left hand side of the machine, which will reverse the rotation of the threaded shaft A.

All of these parts may be found in the average laboratory scrap box or purchased for an insignificant amount. It is well to keep the thread on the shaft A as coarse as possible. A piece of No. 8/32 rod may be used on a small machine just to try it out, but if a heavier piece of rod about ¼ inch in diameter, threaded with about No. 20 thread is used, it will be much better for your first experiments, as the pitch between the lines on the cylinders will be much greater. This gives you a better chance to reproduce the image with this simple means, as experiments by the authors have proven. You can use as fine a pitch as one hundred threads to the inch on the carriage propelling shaft A, once you have built a more perfect form of receiving instrument on which the reproduced lines will not run together.



Simplified electrical circuits for synchronizing and also for transmitting and reproducing the image by means of two phonographs, are shown in the diagram above. Fig. 4.

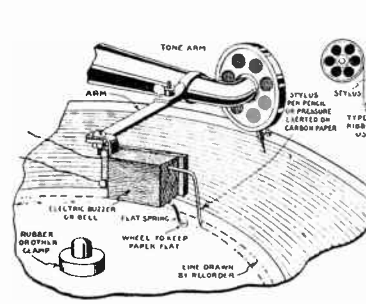


Fig. 6

This picture shows how an electric buzzer or bell may be arranged to act as a recorder for the electrical transmission and reception of drawings and other pictures. The recording unit is secured to the regular tone arm of the phonograph.

Using Two Disk Phonographs to Transmit Pictures

Most people have somewhere about the household a disk type phonograph, or possibly a couple of them. You can have a lot of pleasure, and also perchance make some new and valuable discoveries in the field of picture transmission by wire or radio, through the agency of two disk type phonographs employed in the manner shown in Fig. 3. Of course here we have stepped over the boundary line and "declared war on the enemy," said enemy being in the form of the synchronization of the transmitting and receiving phonographs. A little study will at once reveal why the engineers who have worked out the commercial machines for transmitting and receiving pictures electrically over a wire, have always had to solve as their first great problem the matter of keeping the two revolving disks or cylinders in perfect step with each other. In other words, if you make a chalk mark on the turntable of the transmitting machine, and you have a buzzer circuit to your neighbor's house who, for example, was experimenting with you, then every time the chalk mark came opposite a certain point, and you pushed the buzzer signal, a corresponding chalk mark on the revolving turntable at the receiving instrument should be opposite its fixed mark on the turntable shelf.

A simple and constant means of checking the synchronism between the two phonographs is shown in Fig. 3, wherein use is made of a pair of spring brass or phosphor bronze wire brushes, secured to a wood or other insulating block in any desired manner. Around the turntable you should glue a piece of paper, and over this strip of paper in turn glue a piece of tin or copper foil.

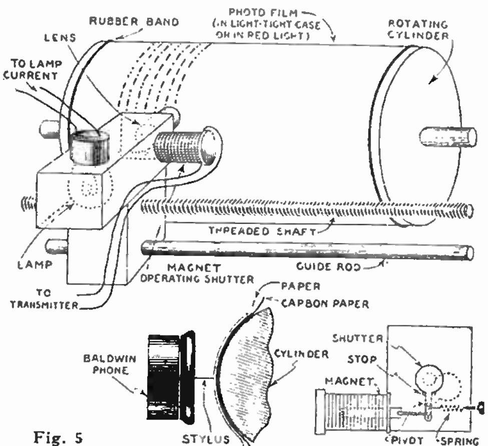


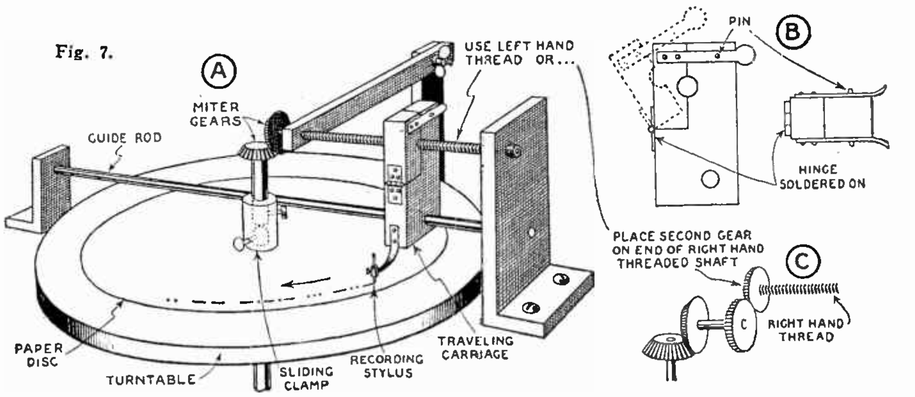
Fig. 5

Details are here given for the construction of a phonographic recorder suitable for use in reproducing drawings transmitted by electrical means.

This piece of foil may be about 1" long. Thus every time the two turntables are rotated synchronously or in step, the lights at either end will flash. In other words, they will flash once for every revolution. The average phonograph turntable speed is about seventy revolutions per minute. You will probably want to slow this down a little bit for picture transmission, as this speed is a little high, at least at the start, as the authors have found.

There are many ways in which a disk type phonograph may be rigged up with some cheap and simple paraphernalia to carry on experiments in picture transmission work. One of the simplest schemes which will be found intersting, is that shown in Fig. 3. Here we may utilize a zinc electrotype grounded to the shaft of the turntable, or else a simple tinfoil figure placed on a piece of cardboard, taking care that the tin-

Fig. 7.



By means of the attachments shown above, and which can readily be fitted to any disc type phonograph, it is possible to transmit and reproduce a larger image than with the arrangement described and illustrated previously, wherein the regular tone arm of the phonograph is used to traverse a recording pen across a small disc.

foil image is likewise grounded to the turntable shaft. Every time the metal point (which is being propelled across the revolving image by the regular needle and sound box of the tone arm, running on a standard record) makes contact with the revolving image, an electric current is sent over the line to the receiving disk, and here the current pulse passes through the potassium iodide impregnated paper. Each time a current pulse is received at the proper position of the pen point on the receiving disk, a brown image is formed, which corresponds in position and length with the momentary contact with the image at the transmitter.

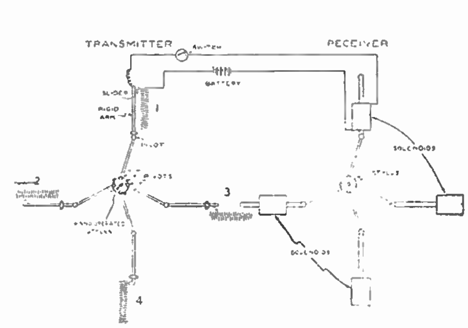
You will doubtless find, as have other experimenters, that the potassium iodide paper is not well adapted to this sort of work, especially if you are going to use a standard record to propel the sound box and regular tone arm carrying the recording pen across the paper or cardboard disk. The pitch of the grooves on the standard record is too fine and the lines come too close together on the receiver record disk. It would be much better to have a machinist turn a spiral groove in a metal or other disk, the same size as a standard record, making the pitch of the spiral groove about one-twentieth of an inch or even a coarser pitch than this.

In a machine similar to this which has been placed on the market for the purpose of making your own phonograph records, a clever trick resorted to in regard to propelling the sound box and tone arm across the record, lies in the use of a stiff bristle brush fastened in the chuck of the sound box instead of a phonograph needle. The object of using this bristle brush is that it makes contact with a number of grooves at the same time and thus nullifies the chances of the needle jumping the groove.

You will find it very interesting indeed to make improvements on the recording means for the picture transmission apparatus, and numerous other ideas which may lead to some interesting developments are given in the present chapter. A schematic wiring diagram for use with the two disk phonographs shown in Fig. 3 is given at Fig. 4. One common battery may be used for both synchronizing and recording circuits, but it is more satisfactory and a little simpler to use separate batteries.

Use of Synchronous Motors

Once you have obtained some fair results with this makeshift arrangement utilizing two phonographs, you will doubtless want to try a more accurate means of synchronizing the two revolving disks or cylinders. For this purpose use may be made of two, 110 volt A. C. synchronous motors which are available on the market, and which maintain a practically constant speed. You will find it very interesting to work out some electrical or mechanical means of keeping the speed practically perfect and similar for the two turntables, and some of the refinements in this branch of the work are discussed and shown in diagram in the chapter on synchronism. If you should arrange to drive the two transmitting and receiving disks or cylinders with two synchronous motors, then the simplest way to rotate them in synchronism and at the same speed is by means of a chalk mark placed



Simplest form of electric writing machine or Telautograph, utilizing four variable resistances and four electro-magnets or solenoids. Fig. 8-A

on the turntable of each machine, or else by use of the synchronizing brushes shown in Fig. 2. Now suppose you have started the synchronous motor driving the disk at the transmitter, and then the operator at the receiver wishes to check the synchronism. If the lamp is not lighting, he will know he is not in synchronism, and he may adjust the speed by means of a variable resistance or impedance in the motor line, or by some mechanical means, such as adjusting the phonograph speed governor if the motor drives the disk through the usual spring motor governor, as is sometimes done. In other words, the speed at the receiving instrument is to be regulated and watched for a certain period, to see that the machine is in exact synchronism, i. e., in perfect speed relation to that at the transmitter. After synchronism has been satisfactorily established, a buzzer or wig wag signal may be sent to the receiving operator, and the circuit through the picture transmitting circuit is closed. The two sound boxes should be placed on the phonograph records at about the same time, and the picture started after the turn tables have made a few turns.

Picture Recorded by Light Beam

Where either the disk or the cylinder type of machine is used for building up the picture transmitted by one of the foregoing methods, some experimenters may like to play around with the photographic method of recording the image. The American Telephone and Telegraph Company are using this system, with modifications and refinements of course, for transmitting photographs across the United States and between all the larger cities for newspapers and magazines. For experimental purposes, where simple drawings or designs only are to be transmitted and recorded, no elaborate light shutter will be necessary.

Looking at the illustration, Fig. 5, we see how a carriage is propelled along the cylinder by usual threaded shaft, preferably of coarse pitch for your first experiments, say 20 threads to the inch. As the incoming picture signals are passed through an electromagnet or solenoid, it is caused to open and close a light shutter made of a small piece of aluminum and a spring. A lens barrel is preferably employed to concentrate the light from a small battery or other lamp onto the revolving photographic film. This film is held tightly around the cylinder by a pair of rubber bands or by some other means which you may work out. The whole receiving machine should be placed in a light-tight box, or else the receiving may take place in a ruby or red light. This is the principal method used commercially. The lamp used will, of course, have to be placed in a light-tight box so that only the pencil of light from the lens strikes the photographic film. This pencil of light is sharply focussed by means of the adjustable lens barrel. With suitable lenses you can focus this light beam down to a small point, say about 1/32 inch in diameter or less. Unless you can focus the light beam smaller than this, you will need to use a thread not finer than 32 pitch on your carriage propeller shaft.

Raising and Lowering the Recording Stylus

The illustration at Fig. 6 shows a different method of recording the transmitted picture image, whereby the recording stylus is normally raised above the paper, but each time a picture signal arrives, the magnets draw it down against the paper and a line is drawn. You will probably find various forms of ink recorders are troublesome, and

Telautograph, which will provide a lot of pleasure to the experimenter. A still more elaborate form of this electric writing machine is used commercially in railroad stations and in many other businesses, including banks. The principle, on which the Telautograph works is that of varying the electrical resistance of two solenoid or electro-magnet circuits, so that as the current changes in the solenoid circuits, the iron plungers will be drawn in more or less.

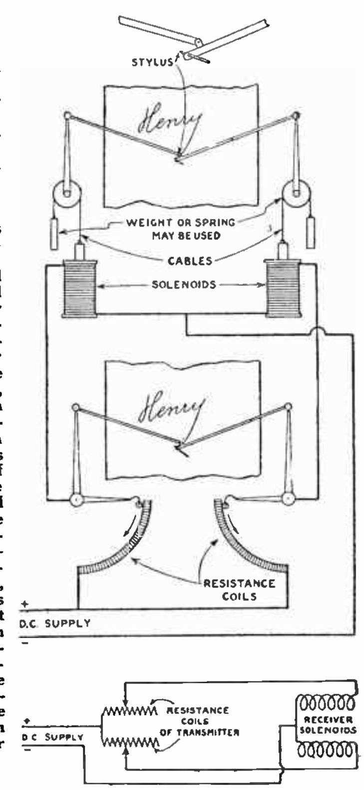


Fig. 8-B.

for your first experiments a very soft lead pencil point will probably be as useful as anything. The authors tried out another form of recording stylus which utilizes the green or blue lead, such as used in the Eversharp and other pencils of that type. It was found that if the paper disk on which the image is to be recorded was moistened with ordinary water, that these colored leads would draw a clear line instantly and positively. If you do much experimenting along this line, you can easily devise a simple magazine stylus which will feed more lead to the point automatically as required.

It is desirable to fit the magnetically controlled recorder, as illustrated at Fig. 6, with a small roller fastened on a flexible spring, this roller keeping the paper flat at all times and normally away from contact with the stylus pencil. For your first experiments, you may utilize an old electric bell or buzzer clamped to the tone arm of a phonograph, in the manner shown at Fig. 6. The small detail drawing in Fig. 6 shows another scheme for recording which utilizes typewriter ribbon. Here the metal stylus arm when it is pulled down by the magnets, causes the typewriter ribbon to come in contact with the paper through a slot in the metal guide plate. The typewriter ribbon will have to be rotated by hand once in a while to present a new surface, or this can be done automatically if so desired.

Recording the Image Full Size of Turn Table

The illustration at Fig. 7 shows a scheme whereby an image the full size of the turn table may be reproduced by the previously described apparatus. Here the turn table shaft is made to propel or rotate a threaded shaft extending along the radius of the turn table, this threaded shaft propelling in turn a traveling carriage fitted with a split nut. The carriage may be made of brass or other material, and may not be made all in one piece at first. The hole for the threaded shaft is drilled and tapped to the proper size tap, and the block, if made in one piece, is then cut at right angles as shown, with a hacksaw. An ordinary hinge is soldered on, so that half the block may be opened when the two retaining springs are snapped apart. A pin at either side of the main carriage block ordinarily holds the springs firmly. When a picture has been recorded, it is a simple matter of course to push the springs apart, split the threaded block open and slide it along the guide rod to the starting position again. A sliding tubular clutch or coupling is fitted on the vertical shaft carrying one of the mitre gears, this sliding coupling being necessary so that a new disk of paper can be slipped into place. As the turn table ordinarily rotates right-handed when viewed from the top, it will be necessary to use a left hand thread on the propelling shaft (and L. H. thread in the carriage unit) if arranged in the manner shown at Fig. 7-A, unless the picture is to be recorded from the inside to the outside. If it is desired to have the carriage travel from the outside toward the center, and the right hand threaded shaft is to be used, then a second gear will have to be employed, as shown at Fig. 7-C. so as to reverse the rotation.

A similar arrangement to that shown in Fig. 7 will, of course, have to be used at the transmitter where a tinfoil image glued on a piece of paper, or else an electrotype is to be fastened in place and transmitted. It should be kept in mind that if electrotypes are used in any of these machines, that it should be a line cut and not a half-tone cut, as the apparatus here employed is not refined enough to transmit a half-tone. In some of the other chapters in this book you will find the details which have been worked out by the experts of some of the large companies, for transmitting the varying lights and shadows found in half-tones.

Telautographs

While not directly connected with the subject of transmitting pictures electrically, in the every day sense of the word, yet after all the telautograph or electric writing machine, is really "one of the family." Many readers will no doubt find it interesting indeed to experiment with a simple telautograph or writing machine, many of the commercial machines being in daily use for train dispatching and in many other capacities.

The illustrations at Fig. 8-A show a simple arrangement of an elementary telautograph wherein the four solenoids or suction type electro-magnets the connected with four variable resistances or rheostats, 1, 2, 3 and 4. As the stylus, which may be an ordinary lead pencil, is caused to write a name or draw a picture at the transmitting end of the line, the recording pencil or pen is moved in a corresponding manner and reproduces the script or picture. It will be seen that as each resistance unit is varied, the strength of the current flowing through the respective solenoid at the receiver is also varied; and likewise the pull on the core of the solenoid.

In the commercial telautographs there are, of course, a number of refinements, such as a magnetic pen lifter, which keeps the ink from contact with the paper when the machine is not in use. The image is drawn on a continuous moving strip of paper from a roll, in the commercial machines, and if you have an opportunity of inspecting one of the factory built instruments, you will get many pointers to help you in building an experimental model. The schematic diagram of a two solenoid type of experimental telautograph is shown in Fig. 8-B.

CHAPTER IV

Methods of Synchronizing

ONCE the experimenter has obtained some practical results with the simplest television apparatus, wherein the transmitting and receiving disks are mounted on a single shaft, which obviates the difficulties met with in synchronizing

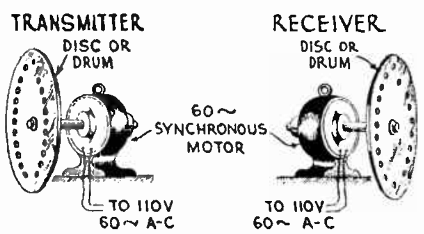


FIG. 1

The simplest means of operating the transmitting and receiving disc of a television outfit is to drive each disc by sixty cycle synchronous motors, as shown above.

the transmitter and receiver, he will then find himself interested in various methods of synchronizing.

In the diagram, Fig. 1, the simplest arrangement of a television transmitter and receiver is represented, the transmitting and receiving disks being driven respectively by 60 cycle, 110 volt A. C. synchronous motors. These motors are usually self-starting and are available from various manufacturers of electric motors, or they may be constructed from D. C. motors if the experimenter is a fairly good electrician. A few hints on this subject will be mentioned a little further on.

The illustration at Fig. 2 shows another hint for the experimenter and particularly useful for picture transmission circuits. Large size phonograph motors may be used with the ordinary spring motors, or better still the spring motor drive is removed or disconnected from the driving gears and speed governor, these gears being connected with a new drive shaft, on the end of which is mounted a suitable drum on which is wound up a cord carrying at its lower end a heavy weight, as shown. In this way

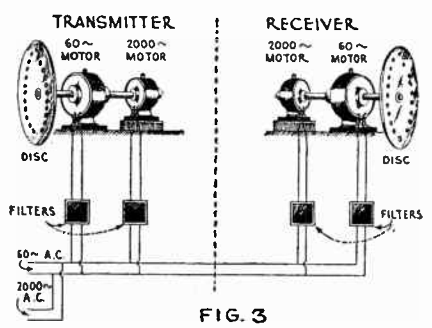


FIG. 3

In the Bell television apparatus, the transmitting and receiving discs are driven respectively by 60 cycle and 2,000 cycle motors, as shown in the diagram above.

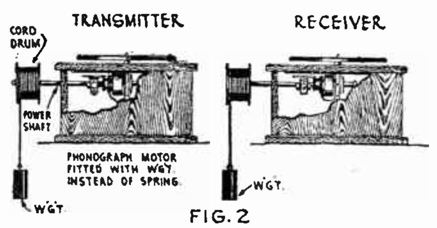


FIG. 2

Very good results may be had by utilizing gravity drive with heavy weights hooked up to phonograph motors, in the manner illustrated above. They give surprisingly constant speed when so arranged.

we have what is known as a gravity motor, and if these are properly built up they give a very constant speed. They are hardly useful for television requirements.

The diagram at Fig. 3 shows the Bell Telephone Laboratory synchronizing scheme used in the television apparatus recently demonstrated by their engineers. As will be seen the disks at the transmitter as well as at the receiver, are each driven by two motors mounted on the same shaft with the disk, one being a 60 cycle motor and the other being a 2,000 cycle motor. In the elaborate, yet highly simplified Bell television circuit, the 60 cycle A. C. and the 2,000 cycle A. C. are fed in parallel on to a common circuit, as will be seen. Each motor is supplied with its proper frequency through suitable filters. This, of course, is too intricate a detail for the average experimenter to be bothered with, and Fig. 4 shows a simple form of this circuit which the experimenter will find worthy of study.

In the dual motor drive for the television disk shown at Fig. 4, the 60 cycle motors at either end of the circuit are operated from a 60 cycle 110 volt A. C. circuit, for instance; while the 2,000 cycle (or lower frequency) motors are operated from a common 2,000 cycle A. C. circuit. The experimenter does not have to use as high a frequency as 2,000 cycles, but any value between 60 cycles and this figure. The frequency should be fairly high, as the higher it is the more accurate the synchronizing check. As will be found, 60 cycle synchronizing motors drift a little from time to time, the plus and minus components of the speed checking out or balancing up at the end of a given time. But as will soon be realized upon a little thought on the matter, any drifting of the motor from true synchronizing speed is out of the question for perfect results, and the Bell engineers have solved this problem by using the 60 and 2,000 cycle motors together on the same shaft. In fact so accurately does the 2,000 cycle motor maintain the speed, that in some cases an ordinary D. C. shunt motor is used to carry the brunt of the load instead of a 60 cycle motor. In one form of the Bell apparatus the 60 cycle motor is combined in the same casing with a D. C. motor, as indicated in the diagram Fig. 15.

The source of the 2,000 cycle or lower frequency alternating current for the checking motor could be obtained from a 2,000 cycle A. C. generator, but here trouble would be encountered in keeping the speed of the generator absolutely constant. Therefore, it is better to have recourse to some such form of generator like that shown in Fig. 5. This form of generator utilizes, for instance, a tuning fork operated by a pair of radio receiver magnets and coils connected with a vacuum tube in the manner indicated. It is desirable to use a correcting magnet, the circuit of which may be closed once every minute by an accurate clock. An oscillating audion with suitable pick-up circuit may be used. In the apparatus shown at Fig. 5, the oscillating currents may be checked with a pair of phones, by means of a d. p. d. t. switch, and then switched onto a transformer and a vacuum tube amplifier. The high frequency current thus amplified is then supplied to the circuit feeding the high frequency checking motors, one experimental form of which is shown at Fig. 5-A.

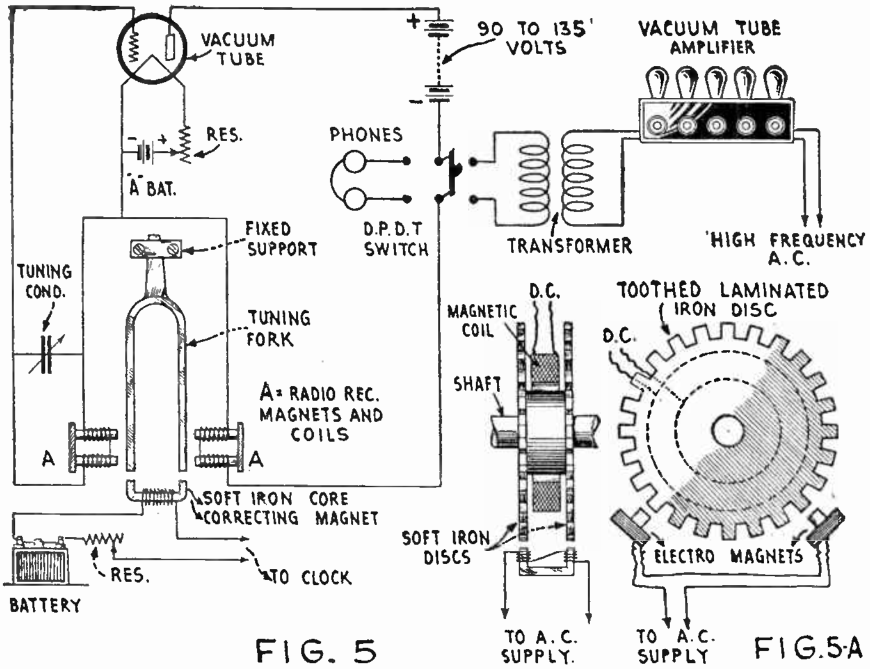


FIG. 5 FIG. 5-A

Fig. 5 above shows how a vacuum tube may be utilized in connection with a tuning fork and a pair of radio receivers, so as to produce a suitable current for operating a 500 or higher cycle A. C. motor. Fig. 5A shows simple synchronous motors.

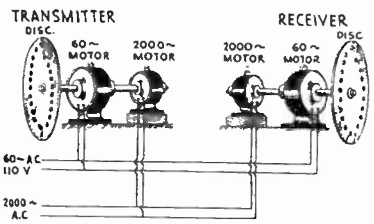


FIG. 4

This diagram shows a simplified form of dual motor drive for television disc.

This high frequency motor is built of two laminated annealed (transformer) steel disks provided with a suitable number of teeth, and they are magnetized north and south respectively by a stationary coil. This magnetizing coil may revolve and be supplied with D. C. through a pair of slip rings and brushes if desired. The A. C. windings are placed on laminated annealed steel cores, as the diagram indicates.

In Fig. 6 the method of synchronizing an ordinary shunt wound D. C. motor, as carried out by Captain Ranger of the R. C. A., for use in his picture transmission machines, is outlined. This synchronizing scheme works as follows: At a given moment, if all the contacts (tuning fork and commutator) are found closed, then the variable resistance, R, in the field circuit of the motor, is short-circuited and the speed of the motor is reduced; due to the fact that the field receives the full strength of 110 volt current from the D. C. supply line. At another instant, let us suppose that the contacts are found closed through the tuning fork and auxiliary commutator segments and slip rings at the left-hand end of the motor shaft; in this case the shunt field winding, F, of the motor will be momentarily short-circuited, and due to the greatly weakened field, the motor speed will increase. This goes on repeatedly, and alternately, so that the mean average speed value is practically constant throughout a given time.

While this method is quite satisfactory for picture transmission purposes, it is doubtful whether it would prove efficient for television. The synchronism of the motor is easily checked at any moment by watching a revolving neon tube which is secured to the shaft of the motor.

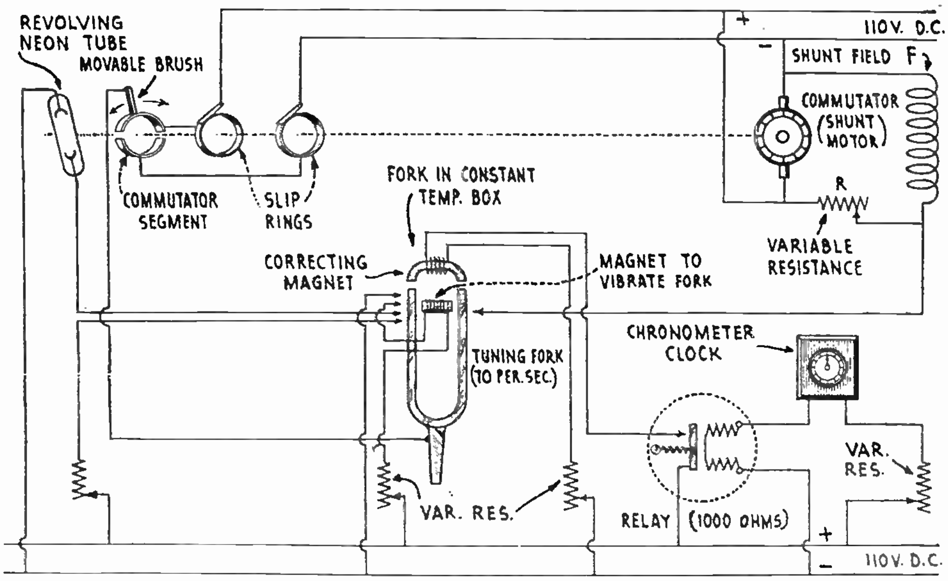


FIG. 6

This diagram shows independent and self-contained form of synchronous motor devised by Captain R. H. Ranger for his picture transmission machines. This machine is very interesting as it utilizes an ordinary shunt wound direct current motor with the addition of two slip rings and a small commutator mounted on the same shaft with the armature of the motor. The armature shaft carries at one end a revolving neon tube. When the fork contacts are closed under certain conditions, the motor speed is increased or decreased, as explained in the text. The clock checks the tuning fork once a second.

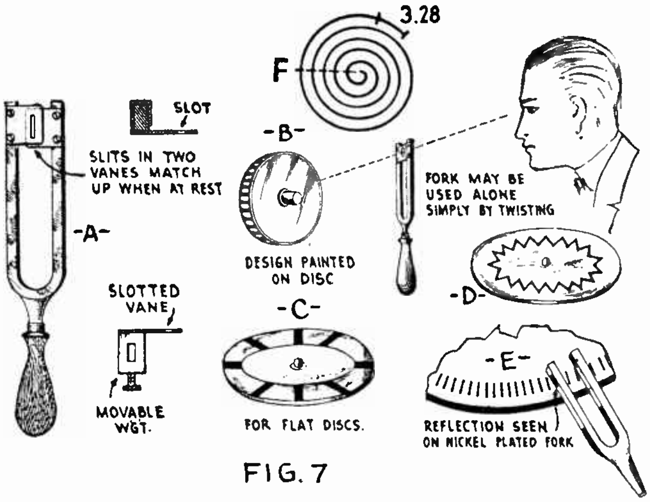


FIG. 7

One of the simplest ways of checking synchronism between the transmitting and receiving machines in the television system is by means of a Stroboscope. Several ways of using a tuning fork together with different designs, are shown in the drawing at the left. The authors found one of the simplest Stroboscopes to comprise a nickel-plated tuning fork, which when vibrated, caused the black lines on the revolving disk at E to become stationary when the disc speed was in step with the vibrations of the fork. Where a computation shows that an uneven number of divisions are necessary, the design may be made as shown at F.

This neon tube receives an impulse every time the fork arm closes the contacts shown in Fig. 6. The tuning fork used in the Ranger system is a 70 pitch fork, or gives 70 vibrations per second. The tuning fork closes the neon tube circuit once each cycle of the fork. The motor speed is 2100 r. p. m. or the thirtieth multiple of the fork frequency. The neon tube, therefore receives a current impulse 4200 times per minute, or twice for each revolution of the motor shaft. The result is that as you watch the revolving neon tube on the end of the motor shaft, you see it stationary, when the motor is in exact synchronism, as determined by the fork and the clock. If the speed is below synchronism, the tube will be seen to be turning slowly backward, while if the motor is above synchronism speed, the illuminated neon tube will be seen to drift slowly forward.

Stroboscopes For Checking Synchronism

There are various ways of applying the stroboscopic principle, but the simplest means involves the use of a tuning fork. In Fig. 7, several designs of a stroboscope disk are shown and also several ways of arranging two vanes on the ends of the tuning fork, with slits in them which match up when the fork is not being vibrated by striking it on the knee or on the edge of a table. With the proper fork frequency, proper number of marks on the revolving design placed on turn-table or disk, and the correct speed of the latter, the marks or design on the stroboscope chart will be seen to stand still. Herewith is a table which will help the experimenter; the lines drawn on the paper or cardboard chart to be placed on turn-table or disk, should be drawn with India ink, so as to appear as black as possible.

STROBOSCOPE TABLE

R. P. M. Shaft	R. P. Sec.	Tuning Fork Frequency	No. marks or divisions on chart.
60	1	128	128
120	2	128	64
180	3	128	42.6
240	4	128	32
1080	18	128	7.1
		72	4

A fairly strong light is also desirable and if a nickel-plated tuning fork is used, the authors found that no slotted vanes were necessary. The reflected image of the chart marks can be observed very nicely indeed on one of the nickel-plated legs of the tuning fork. The fork will have to be struck periodically so that it is kept vibrating at a good rate.

In designing the stroboscope charts, it is best to use as high a number of marks as possible, such as 128 for the case cited in the first line of the table. It will be seen, however, that any number of marks corresponding to a lower sub-multiple such as 64, 32, etc., could be used, but the authors found that the 128 marks are the best for the first case of one revolution per second, such as met with in phonograph turn-table speeds. This considers that a 128 pitch fork was used.

If N equals revolutions per second of turn-table or disk, F equals fork frequency in vibrations per second, and M equals the number of evenly spaced marks on the disk, then: $N=\frac{F}{M}$; $M=\frac{F}{N}$; $F=M\times N$.

In some cases it may occur that an uneven number of marks on the disk will result. It is hardly possible to divide the marks up in an uneven manner such as 7.1, as given in the last line of the table below; here a black spiral may be drawn on the stroboscope chart instead of the usual radial marks. By using a black spiral it will be seen that this can be made any number of units long, and fractions of units, as occasion may require.

In the diagram at Fig. 8, "A" shows one way of devising a synchronous motor from a battery motor. A starting motor serves to bring the synchronous motor armature up to synchronous speed.

The illustration at Fig. 8B shows synchronous motor built up from an old machine with battery field excitation for starting. Fig. 8C shows simple clutch for disconnecting starting motor after synchronous motor has been brought to proper speed and synchronized.

Synchronous Motors

The experimenter who is interested in improvising his own synchronous motor, had better look up the subject in books on A. C. motors available at any library. A few hints are given by means of the diagrams in Fig. 8, which may help the experimenter. At Fig. 8-A a method is shown for operating an ordinary D. C. battery motor as a synchronous motor. The motor is brought up to synchronous speed by spinning the armature by means of a belt or crank, or else with an auxiliary starting motor as shown. If the motor is a 6 volt one, and the step-down transformer has a 6 volt secondary, then 6 volt lamps are used for the synchronism indicators across either side of the main switch. With the connections shown, the motor will be in synchronism with the incoming A. C. supply, when the lamps are dark. In the middle of a dark period, the A. C. switch is thrown in. Of course, the field of the motor is already excited from a D. C. source such as a storage battery, before attempting to synchronize.

In the diagram, Fig, 8-B, is shown another suggestion for the experimenter where a battery or other motor is provided with a separate A. C. winding on the armature, connected with the usual slip rings, synchronizing lamps and A. C. switch. The D. C. armature winding is connected with the usual commutator and brushes, and once the motor is synchronized by speeding up the armature with an auxiliary motor belted to the shaft, the field excitation is quickly switched from the battery to the commutator of the machine itself. Some of these small synchronous motors are started as series motors on alternating current, the field winding being quickly switched to D. C. excitation in connection with the usual commutator and brushes on the machine,

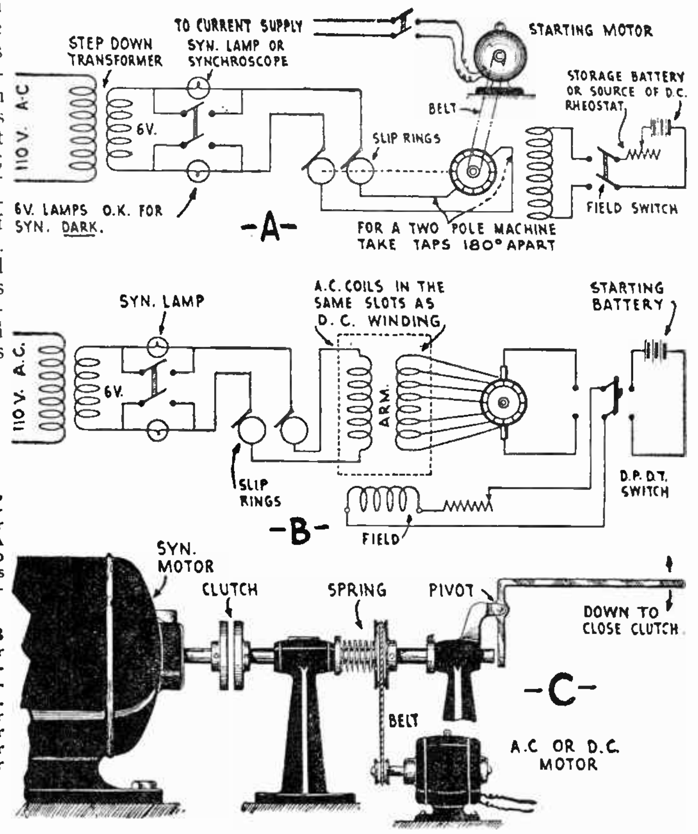


FIG. 8

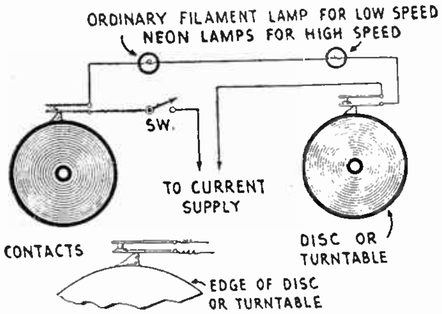


FIG.9

Simple synchronism indicator utilizing ordinary filament lamps for low speeds, and neon lamps for higher speeds. Whenever the transmitting and receiving discs are rotating in step or in synchronism, both lamps will light.

once synchronism has been established.

Fig. 8-C shows the use of a spring clutch and auxiliary motor for bringing the synchronous motor up to speed and synchronizing. Once the synchronous motor has been synchronized, pressure on the lever is released and the spring shown opens the clutch connected with the starting motor through a belt. This could be done automatically if desired. (Note that two slip ring leads in Fig. 8-A connect the two commutator bars 180° apart for a two-pole machine).

Other Synchronizing Means

In the diagram Fig. 9 is shown a simple synchronizing device which involves the use of two neon lamps, such as the 110 volt A. C. and D. C. "glow lamps" now available on the electrical market and commonly sold for switch markers or night lamps. A pair of contacts, such as those obtainable from a radio jack, are mounted in the manner shown and the disks at the transmitter and the receiver instruments each carry a metal cam or hump, shown in Fig. 9, so that every time the two disks are in perfect synchronism, both contacts are closed and the lamps light. For slow speeds, ordinary tungsten filament lamps may be used, but for high speeds neon lamps are required. If the two neon lamps are placed in series, then the voltage required will be about 200, but this is easily overcome by connecting the neon lamps in parallel. By making one set of the contacts, say those at the receiver, adjustable by means of a small worm gear and handle, and by suitably shaping the cams projecting from the edge of the disk, it is possible to adjust the brushes so that the point of synchronism can be very accurately checked with regard to a fractional part of one revolution of the disk.

At Fig. 10 is shown a simple scheme for checking synchronism, and here a contact is closed at the transmitter disk, let us say, which causes a neon lamp to glow for a fraction of an instant just behind the receiver disk, in which there is a slot. As becomes evident, both disks must be accurately in line and rotating at the correct speed, or otherwise the glow from the neon lamp will not be seen from the slot at the receiver disk.

If it is desired to check the synchronism of both transmitter and receiver disks, with respect to an individual or arbitrary source of frequency, then a tuning fork oscillator, as shown in Fig. 11, may be used. Each time the tuning fork closes the neon tube circuit, both neon tubes glow at that instant behind both the transmitting and receiving disks, and they are observed through a hole or slit in each disk respectively. The neon tubes may be mounted on the disks and revolved with them. When the disk speeds and fork frequency are in synchronism the tubes will appear to stand still.

An elaboration of this method for checking synchronism is shown in Fig. 12, where by means of three holes spaced in the manner shown, together with a stationary diaphragm, it becomes possible to quickly check the disk and tell whether it is in synchronism or running slow or fast.

One of the simplest ways of carrying on simple experiments with a television disk with regard to the constancy of speed is that shown in Fig. 13. Here an ordinary D. C. motor of the series or shunt type is operated from a storage battery or several of them connected in parallel to give a very steady voltage; from time to time, of course, it becomes necessary to regulate the rheostat so as to keep the speed of the motor up to the proper value.

Causing the transmitter and receiver disks at two remote television stations to rotate at the same number of revolutions per second, is one-half the problem; but the second half of the synchronizing problem lies in the checking of the synchronism of the receiver disk with regard to the position of a given hole in either disk. If, for instance, the number one or outermost hole of a spiral on a television disk is at a given point at the transmitter, then the corresponding hole on the receiver disk must be at the *same* point, at the *same* instant. A little reflection will show that while the receiver disk motor may be revolving at exactly the same speed as the transmitter motor and disk, yet the two disks could be any part of one revolution out of phase with respect to each other. This cannot be, of course, and the simplest way to check up the fractional revolution synchronism, is by means of the viewing diaphragm mounted on a rotating arm as shown in Fig. 14.

This method can be used by the experimenter, but if you saw a face at either one of the side positions indicated, the face would be on its side; if you happened to find that you were at the point of perfect synchronism when the diaphragm was moved to the bottom of the revolving disk the face would be upside-down. Of course, if you are viewing an ordinary object like a match box, you wouldn't care very much, as long as you saw an image and knew you were obtaining practical results from your experiments.

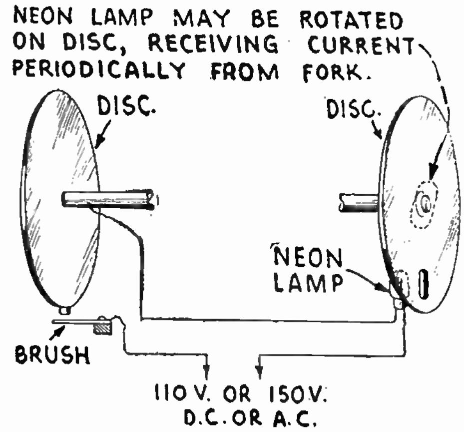


FIG. 10

Simple synchronizing scheme which will cause the neon lamp to be lighted each time the brush and segment or tooth on the transmitting disc makes contact, the light pulsations being visible only when the slot in the receiving disc is opposite the neon lamp.

The disk may be snapped into perfect synchronism by many cut-and-try methods, such as applying friction periodically to the edge of the whirling disk, until the picture is seen clearly; or again, by means of a magnetic clutch placed between the disk and the motor drive shaft, the magnetic clutch circuit being opened and closed rapidly while the image is watched until it is clear.

However, the scheme used by the Bell Laboratory engineers is quite simple and it does the job perfectly and methodically. This scheme is shown in the diagram Fig. 15, where side and top views of the dual A. C. motor drive and disk are shown. As becomes evident, both the 60 cycle and the 2000 cycle motors are joined rigidly together on a hollow shaft, through the center of which the main disk drive shaft, connected with the rotors of both machines, rotates. The large hollow shaft bolted to the outer motor frames allows the motor frames to be rotated through any part of one revolution, by means of the simple worm gear shown. A small mirror with suitable handle or rod extending to the side of the cabinet

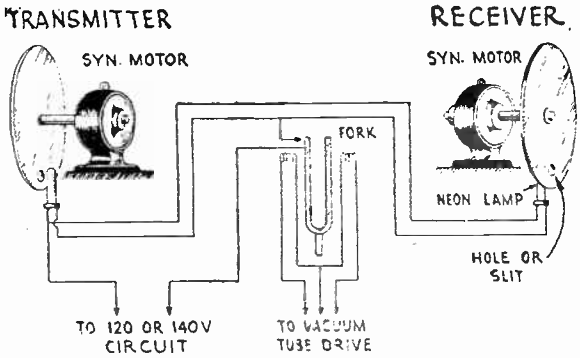


FIG. 11

By suitably choosing the vibration rate or speed of the tuning fork operated by a vacuum tube in the manner shown in Fig. 11, it becomes possible to tell when the transmitting and receiving disc are rotating in step, as the light pulsations in the neon lamps must be visible to both transmitting and receiving operators. By placing friction against the discs, or else by opening and closing the circuit, or by other means, the relative position of the discs must be changed until the light pulsations are seen through the revolving window.

Fig. 12 at the right shows how three holes or slots may be placed in one of the television machine discs, so that with a neon lamp placed behind the revolving disc, it will be possible to tell at a glance whether the disc is rotating fast, slow, or at a synchronous speed.

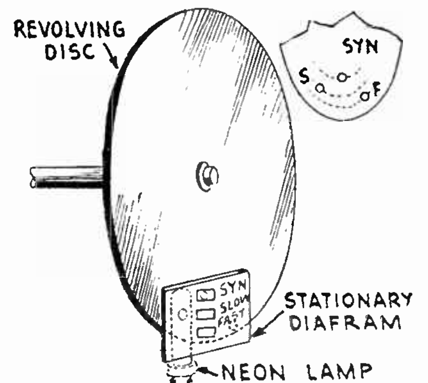


FIG. 12

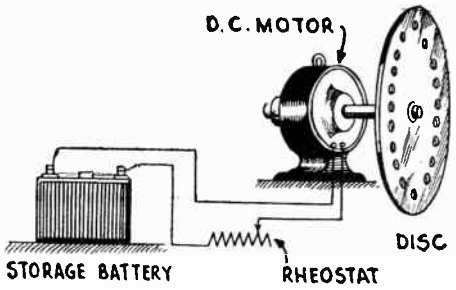


FIG. 13

Fig. 13 above shows about the simplest way of obtaining fairly constant speed in television experiments. From time to time the rheostat is adjusted so as to keep the battery potential applied to the motor at practically constant potential.

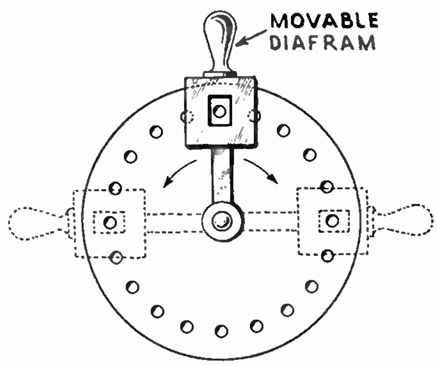


FIG. 14

The manner in which the Bell television apparatus is arranged, so that the image can be "framed," is illustrated in the drawing at the right. As shown in Fig. 14 it is possible to swing the image frame on a central pivoted arm until the image is seen clearly and completely. This is objectionable, as if one were viewing a facial image, it would appear upside down if viewed at the bottom of the disc. In the Bell scheme, the motor frame can be rotated by a worm and worm gear, in the simple manner illustrated herewith.

The illustration in Fig. 14 at the left shows one way of framing the picture on a television reproducing machine, which revolves the swinging viewing diaphragm around the central axis of the revolving disc. This is a simple system suitable for elementary experiments.

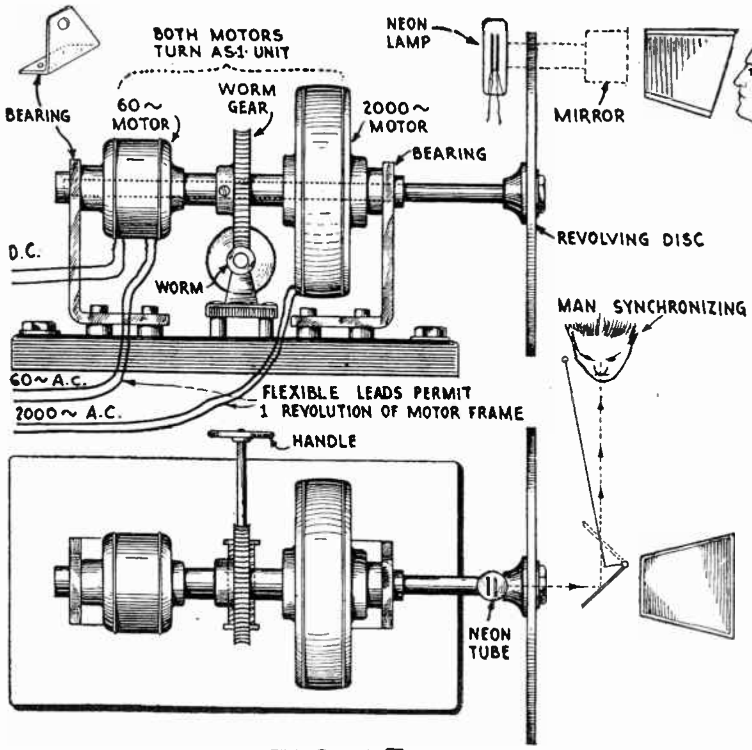
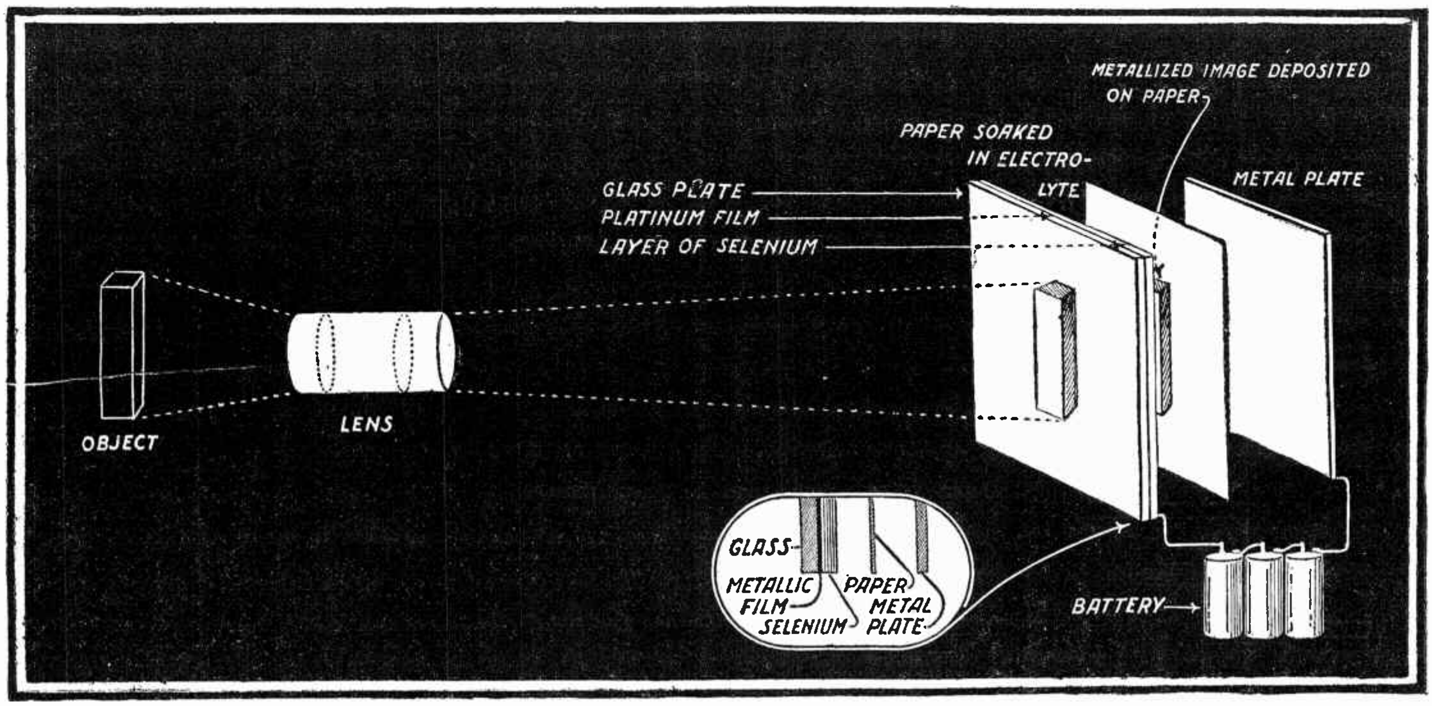


FIG. 15

allows the operator who starts the machine up to look in the mirror and view the disk image created by the whirling holes and neon tubes. He watches this image and turns the synchronizing worm gear handle slowly, until the image is framed properly and is also as clear as possible.

Another way of doing the same thing which the authors worked out before finding out about this method, is to gain control of the whirling disk in respect to the shaft by means of suitable gearing passing out through a hollow shaft. This method corresponds to the scheme used for regulating the pitch of airplane propellers while they are in motion. The Bell system is, however, quite simple and superior, the detail involved costing but little.

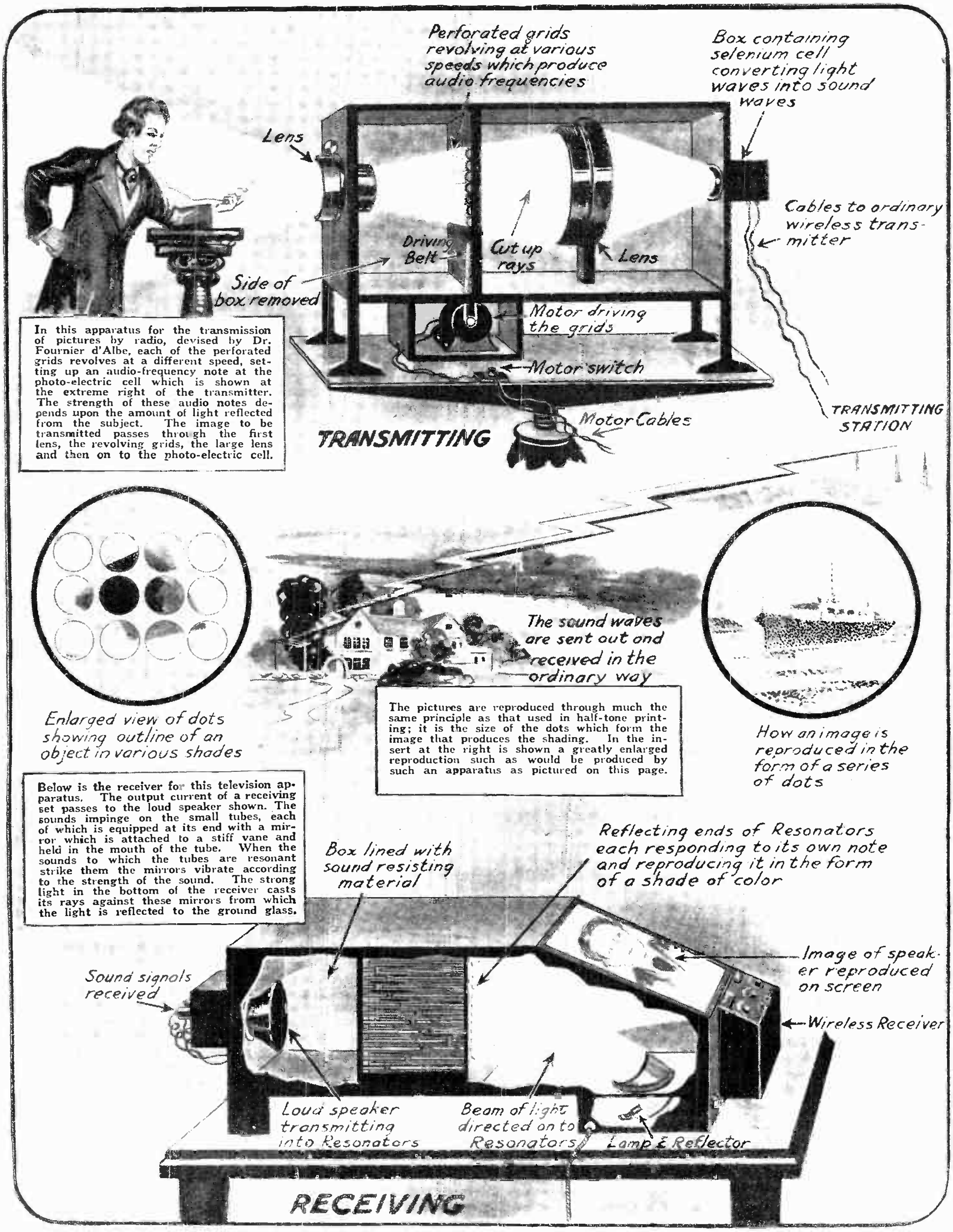
Photography With Electricity



Through the agency of selenium which is sensitive to light, a German scientist, Mr. K. Wilcke, has just evolved a method for taking photographs by placing a thin sheet of this metal upon a metallic film, usually of gold or platinum, and placing the whole against a piece of paper. An electric current is then passed from the selenium to the metal plate and the whole exposed to light. Where strong light falls on the selenium its conductivity is greatly increased, while its conductivity is proportionately less where the lights are not so strong. Through the electroplating principle, there is a deposit from the metal sheet to the paper giving fair reproduction of the object being photographed. This process has not been perfected for commercial use, but a number of scientists think that it holds great possibilities.
—Raymond Francis Yates.

Vision Via Sound Waves

Another unique departure from the straight television systems, but included here for the experimental value it might have, is this reproduction from the April 1924 issue of Science and Invention Magazine in which sound waves are used to reproduce the image. Very little has been done from this particular standpoint and it is conceivably possible to develop a method to such an extent that the loud speaker of the radio set would actuate the television device purely because of the sounds which it produces



In this apparatus for the transmission of pictures by radio, devised by Dr. Fournier d'Albe, each of the perforated grids revolves at a different speed, setting up an audio-frequency note at the photo-electric cell which is shown at the extreme right of the transmitter. The strength of these audio notes depends upon the amount of light reflected from the subject. The image to be transmitted passes through the first lens, the revolving grids, the large lens and then on to the photo-electric cell.

The pictures are reproduced through much the same principle as that used in half-tone printing; it is the size of the dots which form the image that produces the shading. In the insert at the right is shown a greatly enlarged reproduction such as would be produced by such an apparatus as pictured on this page.

Below is the receiver for this television apparatus. The output current of a receiving set passes to the loud speaker shown. The sounds impinge on the small tubes, each of which is equipped at its end with a mirror which is attached to a stiff vane and held in the mouth of the tube. When the sounds to which the tubes are resonant strike them the mirrors vibrate according to the strength of the sound. The strong light in the bottom of the receiver casts its rays against these mirrors from which the light is reflected to the ground glass.

CHAPTER V

Telegraphing Photos by Code

The Belin Code System

DURING the early part of the year 1921 unusual interest was evidenced, especially by the lay public, in the frequent reports from Europe that certain inventors, notably Belin and Andersen, had been successful in transmitting pictures over a telegraph or telephone wire.

The Belin system was at that time (January, 1921) described at length in *Science and Invention* magazine. M. Belin was then in this country making preparations for transmitting photographs and drawings, as well as writing, over an ordinary telephone circuit, by means of his rapid transmitting and recording instrument which he had perfected to a high degree.

Before discussing the Andersen system demonstrated in London in 1920 by invitation of the London *Daily Express*, which method involves the coding and decoding of a given picture, drawing or script, by means of numbers, let us glance at Fig. 2, which shows a highly magnified half-tone picture of a man's head. This represents an enlargement of a plate made for printing in a magazine. In the original the dots constituting the picture are so small that they could hardly be distinguished by the naked eye.

Now to show the correctness of the dot or point theory of picture construction as employed in the half-tone process, all you have to do is to place this magnified dot picture of the man's face about eight feet away when you will be surprised by the result; the dots all merge into one another in a very mystical way, and yet in a manner well-understood by photo-engravers, to form a natural likeness of the subject.

The numerous inventors who are developing systems for transmission and reproduction of photographs, etc., are almost invariably working along these lines, utilizing the fact that with fairly fine points or dots, or in some cases lines, a satisfactory picture can be reconstructed at the receiving end of the circuit. This fact can be demonstrated in the manner just explained in connection with viewing the cut at Fig. 2 at a considerable distance. In the event that the cut should be reconstructed by the receiving instrument or by decoding a cablegram or telegraph message composed of numbers indicating the positions of the various dots, lines, etc., of the original picture in a coarse manner or by large dots, the picture can be suitably reduced so as to give a faithful reproduction of the photo or picture in question.

It was then reported in a dispatch from London that the young Danish inventor, Thorvald Andersen, had devised an entirely new system of transmitting and reproducing photographs, over long distances, which system has great promise.

His arrangement of the details, make it possible to telegraph, telephone or radio a photograph as far as either of the electrical circuits his system employs may extend, which means, of course, across the ocean, or across the U. S.

The London *Daily Express*, who invited the young Danish inventor to demonstrate his system in England, published three photographs cabled from Denmark across the North Sea to the London office of that paper. These three pictures were those of King George, Lloyd George and Irene Vanbrugh, the well-known English actress.

A unique feature of this demonstration of the Andersen system was the fact that the three photographs selected by the editor of the London *Daily Express* were picked out from a number of photographs after the inventor had started on the journey from Copenhagen to London, and were transmitted via the Andersen system by his brother in Denmark. When the inventor arrived in London, the three cablegrams (in code) from his brother awaited him at the office of the *Daily Express*, each of which constituted the make-up for one of the celebrities aforementioned.

Mr. Andersen used a special apparatus for translating the cablegrams and reconstructing the picture therefrom, which instrument and method had to be employed in a photographic dark room. The details of the Andersen system were given out.

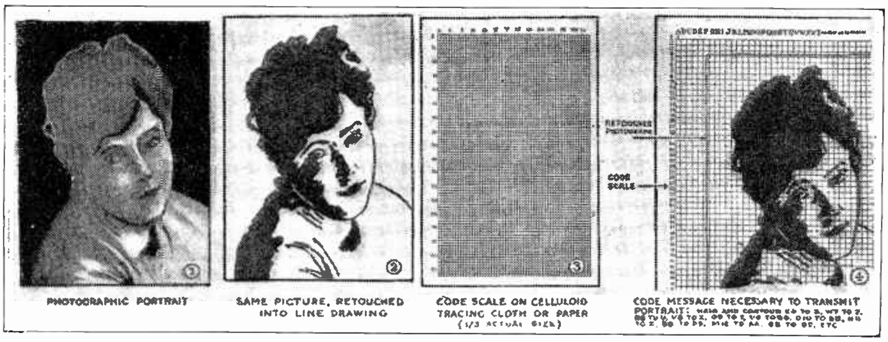


Fig. 1. The above pictures show successive stages in a new method evolved for the transmission of photographs or other pictures by code, over telegraph or telephone circuits, as well as by radio or cable. The original photograph at left was first retouched or redrawn so as to resemble a line-cut, as shown at No. 2. A transparent code scale (3) is then placed over the line cut as at 4, and the black and white portions of the picture coded by noting the lines which the black portions intersect.

The Andersen System

In the Andersen system the original photograph or sketch had to be accentuated by an artist, so as to represent a decided contrast between light and shade. The elements of this method, can be gleaned further by inspection of Fig. 1.

No. 1 shows a half-tone or photograph of a woman's face, while No. 2 shows the artist's or draftsman's line cut accentuation of the same picture, preparatory to its transmission by code.

Now it becomes an easy matter with a suitably divided and numbered scale to code such a picture so that it can be sent by telegraph, telephone or radio in the usual manner, to practically any distance desired. No. 3 shows a simple scale which the student of such subjects may like to reconstruct, and this of course should be made of celluloid. It may be divided by vertical and horizontal lines drawn with India ink and a draftsman's ruling pen in the manner indicated, and the horizontal lines or abscissæ lettered A, B, C, while the vertical ordinates may be numbered 1, 2, 3, 4.

When this scale is placed over the line cut or accentuated photograph representing the line cut, it becomes a comparatively simple matter to write a code message such as that given in the illustration, No. 4, whereby a person receiving the code message can, with a small scale and a piece of thin tracing paper placed over it, reconstruct the picture line for line. An improvement over the method of simply placing a piece of thin tracing paper over the scale, would be to place the scale and paper over a piece of glass and provide an electric light behind it which should make the drawing or picture more accurate and visible.

Fig. 2. This picture of a man demonstrates vividly how accurately a picture can be constructed, solely from black dots. Hold this picture at arm's length and the features of the man will begin to form; look at it from a distance of 8 to 10 feet, and you will be astonished at seeing the features fully developed.

It will be at once perceived, of course, that any method of this nature, whether it uses numbered squares or some other scheme, is practically always limited in its accuracy of reproduction of the picture by the size of the squares—the smaller the squares or the finer the lines forming the squares shown here for an illustrative example, the more accurate the products will be, and the larger the squares for a given size picture, the cruder the results obtained in the reproduction will appear.

The cablegram used in transmitting Miss Vanbrugh's photo contained but 145 words, while King George's photograph required 185 words.

A decidedly superior system of code transmission of photographs was described in as early as the April, 1923, issue of *Science and Invention* magazine by D. A. Jackson. This, instead of being a single "shade" picture, transmitted 5 changes of color, from black to white.

The Leishman Code System

The problem of transmitting photographs electrically is a vexatious and a knotty one. In the columns of this book we will read some very interesting descriptions of apparatus designed to this end. Among them are some by the inventor of this process. While many have been successful so far as the actual transmission of the picture goes, economically considered they have not been practical. Though in them we may not see the answer to this elusive problem, they are important factors—the known quantities upon which we may work to an ultimate success.

At this time the Leishman concern was furnishing telegraph photo service to many of the progressive newspapers of the United States by a method that was distinctly a departure from anything thus far introduced.

In newspaper picture work five gradations of shade, viz.: white, light grey, medium grey, dark grey, and black, are all that appear in the finished half-tone. This fact is taken advantage of in the new process and the first step is to divide the subject photograph into areas comprising a single shade. In the telegram these shades are designated by certain letters such as X white, F light grey, I medium grey, K dark grey, M black. With the various degrees of shades thus blocked out the photograph is ready for the coding process. This is done with an apparatus consisting of an ordinary drawing board with a scale at its top marking off abscissas and a T square with a similar scale on its edge marking off the ordinates. The scales are divided into eighteen prime divisions and each prime division into a similar number of sub-divisions. A letter of the alphabet is used to designate each, and since only eighteen are necessary those letters most easily confounded are omitted.

With this board it is possible to accurately locate any point as fixed and described by another board. If points placed along a line bounding a shade be accurately fixed by the operator of the board at the sending station and a record be transmitted to the operator at the receiving station, he will be able by means of his board to reconstruct that line. Given the letter corresponding to the shade he will know precisely the shade he is to fill in the area enclosed by the line.

The expense of sending the *Photogram*—as the inventor has termed it—must obviously be reduced to a minimum in order to make the venture profitable. It is therefore of the greatest importance that the fewest possible determining points be used. The placing of these, therefore, is done having in mind the two geometrical propositions *that two points determine a straight line* and that *three points determine a circle*. Any straight portion of an outline may therefore be described by, what in code, comes to two words. Any curve can be resolved into area of perfect circles, each of which may be described by words.

In order that the receiving operator may know the nature of the line he is to trace through the points he has located he is given a letter. These letters and their meaning are as follows:

S beginning of line, D end of line. A end of straight line, Q cusp, W end of straight dotted line, U cusp dotted. The last two, i. e., dotted lines, indicate also that the shades they divide are to blend.

Telegraph rules permit five letters to a word in code messages. These are utilized as follows: The first indicates the prime division on the vertical scale containing the ordinate indicated by the second letter. The third indicates which of the prime division of the horizontal scale contains the abscissa indicated by the fourth letter. As an instance TEDK is the co-ordinate of ordinate E in prime division T and abscissa K of prime division D. The fifth indicates the nature of the line according to the above tabulations. When the circumscribing line is completed, i. e., brought back to the point of beginning, the fifth letter gives the shading to be filled in. Other letters are used to indicate clouds, marine, a throng of people, etc.

The entire process is illustrated in figures 3 to 8. A sample of the code is seen in figure 5.

Fig. 3. From an actual photograph which is to be sent over the wires.

Fig. 4. Photograph with features outlined and shadows divided into five degrees of shade.

Fig. 7. This shows the shadows roughly blocked out—poster effect.

Fig. 8. And this is from the finished picture ready for publication. Compare 3 with 8.

LVGIS	MBGWQ	MJIJQ	MTITQ
QJJBQ	QUJDQ	SDIXQ	SQISQ
TEIBQ	TGGQQ	TMFQQ	TSEUA
TDEKA	SMEUQ	QXEMQ	QJEQQ
MVEQQ	MJEKA	MEEIQ	MDETQ
MBFWQ	LVGIQ	LMGKQ	LIGMQ
KVFWQ	KTFTQ	LDFBQ	LAEWQ
LJEGQ	LQDQQ	LUBWQ	MQAVQ
SAAMQ	SKAMQ	TDAVQ	TLBIQ
TUBTQ	TXBVQ	TVDAA	TXDDQ
UADMQ	UAEIQ	TWELA	UBETQ
TXFFQ	TUFQQ	TVFVQ	TUGAQ
TWGMQ	UAGXQ	TSIGQ	TGIFQ
MQFEE	QFFEQ	QMFIQ	QSFMG
QSFAQ	QBEWA	QAEVA	MMEVQ
QAFDM	QJFDM	MTFFE	QBFFQ
QMFLG	QGFLQ	MXFJQ	MTFFD
QAFIQ	QEFKQ	QGFJQ	QIFGK
QBFIQ	QFFIQ	QFFIQ	QEFFM
QFFGV	QJFIS	QKFKA	QFFLK

Fig. 5. This is part of the program or code Telegraph message—the form in which the picture is flashed over the wires.

Fig. 6. This is the complete outline obtained from the code, with proper shade letters within enclosures (right.)

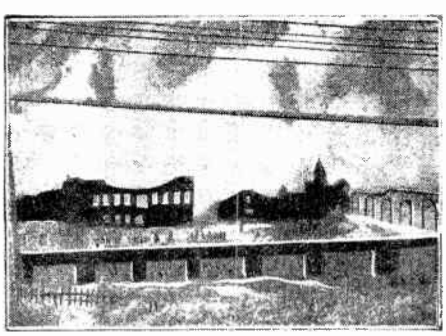


Fig. 9. Left: Before telegraphing: This is from the original photograph as it was taken at Sing Sing Prison, N. Y., just after the fire.

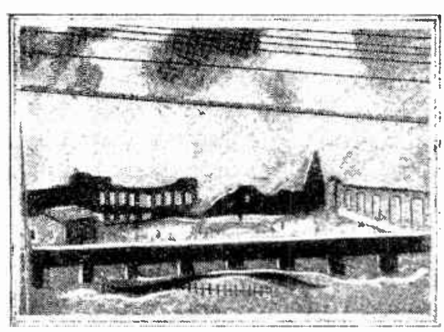


Fig. 10. Right: After telegraphing: Picture of the Sing Sing fire published by the many Western and Pacific Coast papers within twenty-four hours of the fire—really before the fire was out.

Some excellent results have been obtained from this system and though its scope of application is limited to some extent to photographs of no great amount of detail it possesses a number of advantages. For instance, there is no limit to the number of times a photogram may be relayed and the process lends itself to radio as well as wire telegraphy, nor is it subject to distortion from static and magnetic disturbances.

As early as April, 1923, photo service was being extended to all parts of the country as rapidly as possible. To efficiently handle this service, the country was zoned with a large city as a nucleus. The zone comprised all territory within twenty-four hour mailing service.

To further explain the operation of the Leishman code system for transmitting photographs by cable, an article by Leon Adelman on the subject appeared in the November, 1925, issue of *The Experimenter*, a magazine formerly published under the name *Practical Electrics*.

The first time in history a picture of a European news event was transmitted by cable on the day the photograph was made and reproduced the following day in New York City, Chicago and San Francisco, was in 1925.

The feat was accomplished by the use of the Leishman Telegraph Picture Process and the American Telephone and Telegraph Company's Tele-photo-graph process and stands as a record of achievement.

The Leishman process in November, 1925, was the only one that would operate on a trans-oceanic cable. It consists of the following steps: The picture to be sent is enlarged if it is a small one, usually to 18 inches square, and is placed upon the surface of a so-called coding device. This latter is a board having two scales, one horizontal and the other vertical, the letters of the alphabet representing the graduations of the scales. The coding board and photo being of the same size, the outlines of the various tones comprising the picture are traced by means of movable

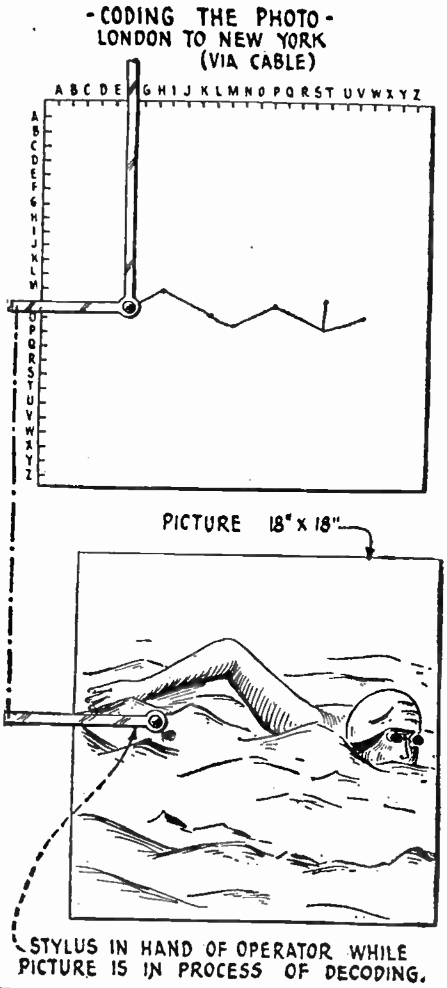


Fig. 11. Showing the method in which the picture was coded. A pantograph arrangement with a horizontal and vertical scale together with a code representing the intensity of tint of the various areas form the basis of the Leishman telegraph picture process.

arms similar to those on the Telautograph, and as this is done the positions of the tracing stylus are indicated on the two scales. There are more than 100,000 different positions possible on any picture and the readings on these scales indicate the movement of the stylus from one position to another.

The readings on the scales are thus in the letters of the alphabet and are incorporated into a code message with letters that indicate the exact shade of the various parts of the picture. The system is therefore one which is entirely different from those with which we are more or less familiar; such are the modulated carrier wave system, as used by the R.C.A., and the bichromated gelatin process of Belin and the Jenkin revolving prism methods of telephotography. These will be described later.

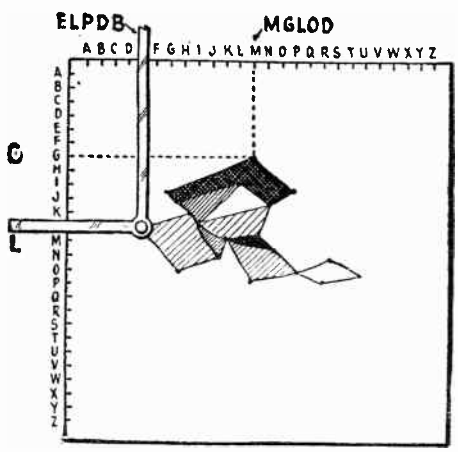


Fig. 12. At the receiving end the various letter combinations are plotted by the operator and filled in by the artist.

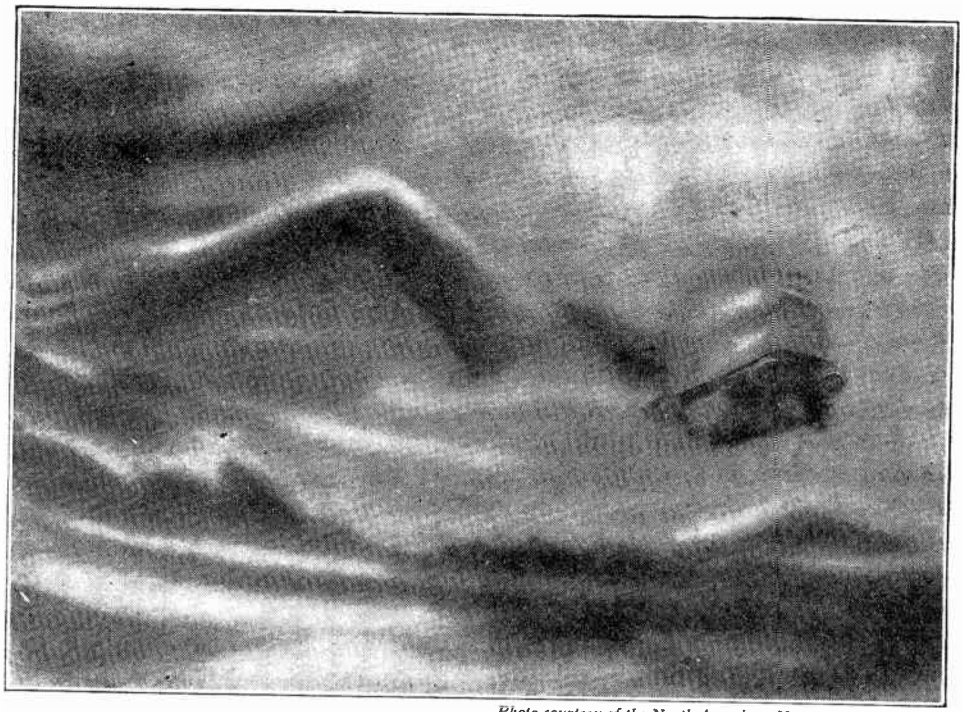


Photo courtesy of the North American Newspaper Alliance

Fig. 13. The unretouched photograph of Miss Ederle in her attempt to swim from France to England as drawn by the artist at the receiving end, New York City, a few hours after it was taken in the British Channel. Note minute details, even some of the bubbles in the water have been successfully reproduced.

The particular picture in this case was a photo of the now world-famous American swimming star, Miss Gertrude Ederle, which was taken while she was struggling her way through the choppy sea of the English Channel.

The photograph was developed in the usual manner and an enlargement was made. The enlargement was placed on the coding machine and an operator coded it. Each position of the stylus corresponded to a group of five letters, the first of which denoted the vertical position on the board: the second, the horizontal position; the third, fourth, and fifth, the intensity of the shading.

As has already been explained, there were five degrees of shades corresponding to plain white, light gray, medium gray, heavy gray, and black. It required 548 groups of letters with five letters to the group to code the picture of Miss Ederle. At the receiving station, an operator had a similar coding board and recorded the series of letter combinations as points. These points were then connected by lines which it is interesting to note were never more than 1/32 of an inch out of the way, and the areas were shaded according to the code letter prescribed.

Thus the picture is built up mechanically by the receiving operator and after final shading has been completed is reduced in proportion to about the size of the original photograph.

This was the process which was used at the receiving station in New York City. In order to send the picture further on to San Francisco, the American Telephone & Telegraph Company's photogram system was utilized, which is entirely different from the Leishman system.

The photogram method consists of the following steps:

A positive transparent print is made of the picture and it is wound on a rotating cylinder which has the light of a small lamp contained within it focused on its periphery. By means of a worm-gear arrangement, the beam of light cuts a tiny swath 128th of an inch wide, passes through the transparent positive and falls upon the active element of a light sensitive or photoelectric cell. This produces what is known as a modulator current which is super-imposed upon a carrier wave or radio frequency current. It is this modulated current which is transmitted and at the receiving station is brought back into the original picture by means of photoelectric recording devices kept in perfect synchronism with the transmitting apparatus.

Thus, while the photogram system requires absolute synchronism, the Leishman system is independent of synchronism. In the Leishman system an automatic tape is used to record the letter combinations and the picture can be decoded later at will.

One may be led to believe that minute details could not possibly be reproduced by this system, but the success of the process lies in enlarging the picture before transmitting it. The operator is enabled to outline carefully even the smallest detail and in the picture of Miss Ederle, it will be seen that several bubbles arising from the tops of the waves were exactly detailed.

It has not as yet been possible to send a fluctuating direct current such as would result when modulating by means of a transmitting microphone button, over a transoceanic cable. The attenuation in a line prevents such a method being used; as yet it has been impossible to use the modulated carrier wave system. The pulsating modulations which would result from decoding a picture in the manner such as is used in the photogram system or Belin's process would be very similar to the voice currents set up if telephone communication were attempted. And of course as we all know, sub-sea telephony over such great distances has been found impractical.

A further analysis of the Leishman process will show that it is a very simple practical method, which involves no special apparatus nor takes into account the time elapsing between transmission and reception as some of the other methods do. It is surprising to note with what exactness it is possible to build up a picture from mere combinations of letters. Even a poor artist can readily fill in with the necessary shades the areas which he outlines by connecting the various points, which he plots.

It would have been possible to send the letter combinations via radio or cable.

In the transmission of the various letters by cable, it has been found that some of them do not register very well and perhaps

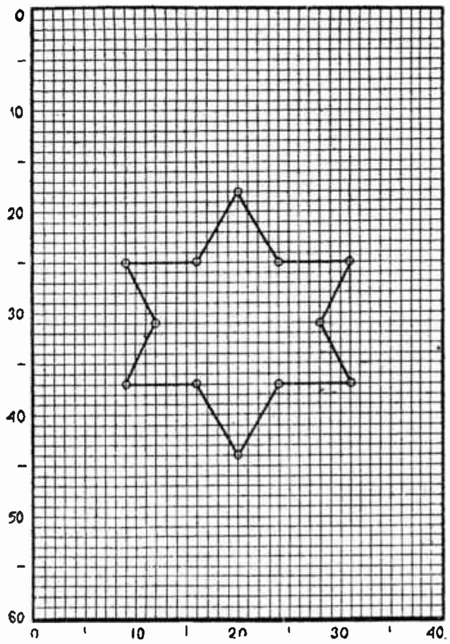


Fig. 14. Sending pictures by code. The star would require only twelve points to be specified, and represents a very simple object for transmission.

become unreadable at the receiving station. These characters are omitted and not all of the 26 letters of the alphabet are used. Another interesting fact is the time required to transcribe the character groups into the picture.

The following data illustrate the speed with which this particular photograph traveled. After it was taken when Miss Ederle was half way across the English Channel at about one o'clock Tuesday, August 18, a speed boat conveyed the photographer back to Dover where a train took him directly to London. There, in the London office of the North American Newspaper Alliance, it was coded by a Leishman operator and sent by cable to the New York office. It is interesting to know that the picture was sent in two parts so that the receiving operator was able to work on the first half of the picture while the second half was still being sent.

As soon as it was completed, it was filed with the American Telephone & Telegraph Company who relayed it by telephotographic process over telephone wires to Chicago and San Francisco, where it was delivered to the press.

Another step in the direction of sending pictures by code was described in the August and September, 1923, issues of *Practical Electrics*. This publication was later combined with *Science and Invention* Magazine. The article included a short description of the work of Andersen, Emil Belin and Prof. Korn. The article was written by Noel Deisch.

How to get photographs to the press in time to supplement a description of an event by graphic illustration is a problem that has fretted reporters and puzzled inventors ever since the invention of telegraphy made possible the sending of messages by wire. For a picture brings home in one glance the whole setting and effect of a scene, and with a force that no description in mere words is fitted to convey.

The airplane has been relied on for quick delivery of photographs, but it requires good hard cash to charter an airplane, and only seldom does interest in an event make the expenditure worth while. Then besides, an airplane is not rapid enough. If Lieutenant Maughan could continue his terrific pace of nearly 250 miles per hour all the way across the continent, he would still require over 13 hours of time to deliver a message from one of our coasts to the other, and that much time might mean an entire day's delay to a newspaper that must go to press at a regular hour.

The increasing popular demand for news photographs has spurred inventors to renewed efforts, and although it must be conceded that the apparatus they have so far produced have not wholly measured up to the strenuous requirements of commercial journalism, still, very tangible progress has been made towards a satisfactory solution.

All the various code systems that have been developed are based on very nearly the same principle, and this principle may be explained as follows: Suppose that you have a rectangle divided off into equal spaces by horizontal and vertical lines, as shown in Fig. 14. Suppose also that each one of these lines bears a number. Now if

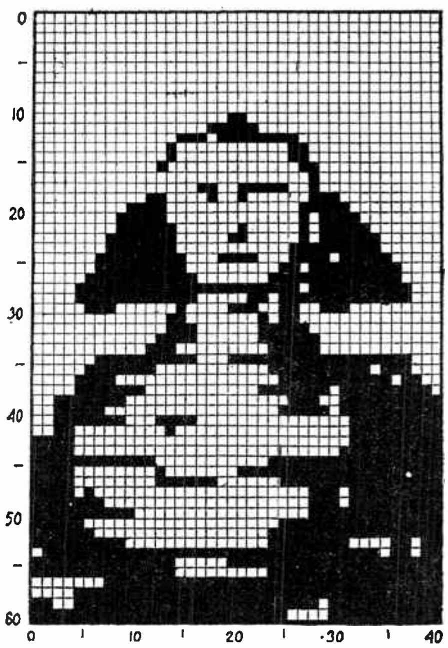


Fig. 15. The Sphinx sent by the code system. Here it will be seen that a very exhaustive specification would be required for transmission.

you should put a blot anywhere on this rectangle you could tell somebody seated at the table opposite you and furnished with a similar rectangle, on what part of your rectangle this blot was located, by telling him simply the two numbers corresponding to the two lines which crossed under that blot. There is just such a blot shown in our rectangle the top of the star, and for it the numbers would, of course, be 18 and 20. Now if your friend happened to be seated at the other side of the continent rather than at the other side of the room, he could locate the blot with exactly the same precision, and just as soon in point of time too, if you had the proper telephone connections. This simple fact is the basis of a system which has had at least one remarkable application, and which under certain restricted circumstances serves quite successfully.

Let us go back to our rectangle. It is crossed by only 60 lines in one direction and 40 lines in the other, and hence any given point cannot be located on it with any high degree of exactitude. If the point does not happen to be placed where two lines cross, the best we can do is to take the nearest intersection and let it go at that. Of course, when you then name the lines corresponding to this intersection the person at the receiving end will locate his dot right at the intersection, and for this reason it will not be fixed quite in the place that it is on the original sending rectangle. But if you should increase the number of lines sufficiently you could get any degree of accuracy that you might desire. Suppose you had 600 lines in one direction and 400 in the other; the possible accuracy would then be ten times as great as in the original instance, and we could then locate a point with pretty fair precision.

Now, if one point can be located, any number of points can be located, and since every object in a picture has an outline, and since every line is made up of points, it is evident that by sending numbers corresponding to a good many points on the outline, setting them down again correctly on the rectangle at the receiving end, and joining them together by a line, an outline drawing of the sender's picture will take form on the receiver's rectangle. The more geometrical the character of the original picture, the smaller will be the number of points required to specify its form completely. To send a picture of a square, all that will be necessary is to give the numbers corresponding to the four corners of the square. To send the picture of the star shown in our drawing we will only have to give the numbers corresponding to the summits of its several angles; *i.e.*, 18, 20; 25, 24; 25, 31; 31, 28; 37, 31; 37, 24; 44, 20; 37, 16; 37, 9; 31, 12; 25, 9; 25, 16. Even the picture of a house would not cause very much difficulty; but when we come to deal with lines of uneven contour, the number of points required is very greatly increased.

True, an outline drawing is not a finished picture, but by including suitable descriptive matter of each portion of the picture, a competent artist can fill it in completely, in a way that is satisfactory for certain purposes.

It will not be necessary to state that this system has not been much used, the reason being that it requires a very clever reporter at the sending end, and a competent staff of rapid-fire artists at the receiving end. Besides, the teamwork between the two stations must be perfect. Then again it is to all practical purposes impossible to send portraits by this method, which fact in itself almost excludes it from the newspaper field.

Still, the process was very successfully applied on one occasion, and on that occasion moreover two portraits formed a very essential part of the picture.

It was a Los Angeles paper that staged the feat, on the occasion of the battle be-

Fig. 16. Example of code transmission varying the size of the dark areas of the square, the total number of squares remaining exactly as before.

tween Dempsey and Carpentier, and so perfect were the arrangements that the 3,300 miles that separate Los Angeles from the arena in New Jersey was bridged in a little under three hours of time.

These are the successive steps that were

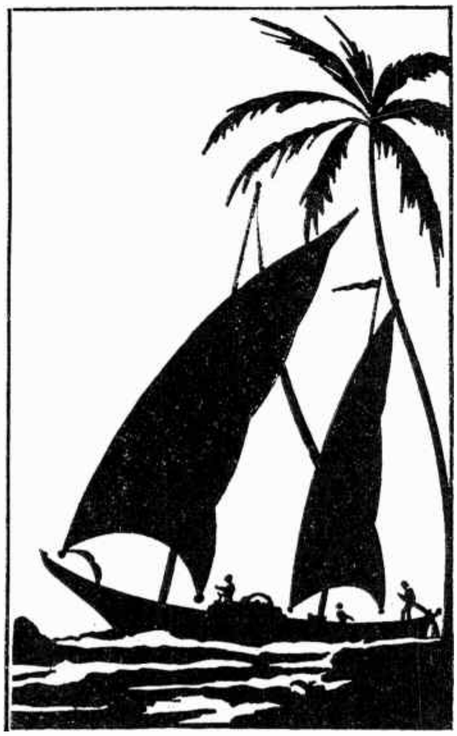


Fig. 17. A figure in solid black can be transmitted by the line system. This indicates a departure from the dot system, but we will see the dot system returned to for modern transmission.

gone through in the operation of transmitting the picture. After the photograph of the knock-out had been secured, an outline tracing was made of it, and over this tracing was placed a transparent piece of celluloid cross-lined much like our original rectangle. Wherever a line in the tracing passed through one of the cross-lines, a code number was set down that specified this intersection. For the entire picture 400 separate number combinations were required. This entire code was then telegraphed to the Los Angeles office of the newspaper, together with additional descriptive matter covering the shades and shadows, expressions, and the like. All that was left for the operators at the receiving end to do was simply to mark out the points on a ruled piece of drawing paper, draw in the outline, and fill in the spaces according to the telegraphed description. To transmit the picture required 50 minutes, to decode it called for 70 minutes more, and an additional hour was consumed in filling in the interspaces and finishing off the picture. The result was in every way satisfactory and in fact quite truthful to the original, as was shown later when the two pictures were published side by side.

A principle closely similar to the one described above is the basis of most of the mechanical methods of transmitting pictures by wire. To understand this principle, we need only take our original rectangle, all cut up neatly into squares like a checkerboard, and suppose certain of these squares to be filled in with black ink in such a way as to give a design, say a picture of the sphinx, as shown in Fig. 15. It would be easy to telegraph intelligence of exactly where each one of these black squares is located, and thus enable anybody at the other end of the line to duplicate our own design. For instance, we might merely give the numbers of the black squares that occur in each line, in succession, starting from the top.

But it will take no lengthy reflection to realize that when using this process we could only transmit very simple pictures. Of course the reproduction might be considerably improved by greatly increasing the number of squares, but even then every picture would inevitably look a great deal like the design on a Navajo saddle blanket.

Every picture made by this process must be a mosaic. Yet some very commendable pieces of art have been executed in mosaic. However, the artists who put those drawings together had at hand stones of different shades, whereas we are limited to full black and full white. That fact puts a very severe limitation on our efforts in the direction of artistic expression, but one which can be largely overcome by the simple expedient of using squares of different sizes. In that way we can produce a graduation of tone—shades varying from full black to perfect whiteness—and we will thus get not only the outlines of the picture but the shadows and half-tones as well, or use the system described in the previous chapter.

Fig. 3 shows a drawing that has been made up by just this very method. There are no more squares in this drawing than there are in the drawing of the sphinx, but the squares have been made of different sizes. Close at hand our drawing does not bear much resemblance to a picture at all. But merely set the page up straight and walk away until the squares do not appear as separate squares, but merge into each other, and it will take on an altogether different aspect. In other words, to make a perfectly clear and well modeled picture of ordinary size, the squares must be quite numerous. Instead of squares, we can, of course, use dots of any shape, for the shape of the individual dot has little influence on the general effect.

We have now arrived, for the half-tone illustrations used in magazines and newspapers are made up of nothing more than a great number of little dots of various sizes, set out at regular distances from each other. All we have to do is to telegraph the size of each one of these little dots to the other end, set them up there in the proper order, and our problem is solved.

Thorwald Anderson, a Dutch inventor, worked out a way of doing this. He had an apparatus at the sending station by which he determined the brightness of the picture at every point that will be represented by a dot. This intelligence was put into code, and the code telegraphed to any part of the earth that can be reached by wire or wireless. The operator at the receiving end was provided with a typewriter whose special type enabled him to make dots of different sizes, and he punched out these dots in succession, just as they were sent, side by side and line under line, on a sheet of white paper. When the whole operation was finished, a complete picture appeared on the sheet, which had only to be reduced upon a zinc plate to make it ready for the press.

This all sounds very simple, and one would think that Anderson's process should work pretty well. But a little arithmetic applied to the question will cause some doubt on this point. A good print for a sporting extra should be about 5x7 inches in size. Newspaper illustrations are usually made to have about 65 half-tone dots to the inch, and a square inch would thus contain 65x65 dots. In the whole picture there would, therefore, be 147,875 dots, and so many can be satisfactorily transmitted only by automatic mechanical methods.

Some American inventors worked out a process for accomplishing this some years ago. Their invention went by the name of the "electrograph" and involved making an enlarged zinc etching of the original photograph, to be used in the sending machine. To prepare this plate usually required about 40 minutes. To transmit the picture took only about 10 minutes more, and to reduce and prepare the received picture for printing, another 30 minutes; or a little over an hour and a quarter in all. The size of the picture was 9x12 inches, and there were 40 half-tone dots to the inch, so by reducing it one-third a 6x8 picture containing 60 lines per inch could be made up. Transmissions were carried on between St. Louis and Cleveland, which represents 770 miles of line, and although the results were "satisfactory" they do not appear to have been as good as those given by other processes that were being developed in Europe.

Nearly all inventors during 1923, abandoned the dot method, and sought to produce a nearly continuous image at the receiving station—a picture intended to resemble as closely as possible an ordinary photographic print. From this picture the half-tone plates are made up exactly as with an ordinary photograph.

To understand these processes, we will again go back to our rectangle. This time we will not suppose it to be divided by cross-lines at all—just a plain rectangle, except that it has a black-and-white design drawn on it. The receiving operator has another exactly similar rectangle, the only difference being that it is without the drawing. The problem is to transfer the drawing from the first rectangle to the second rectangle, even though several thousand miles of space may intervene between the two respective rectangles.

The reader will be asked to suppose that at the sending station there exists a pencil or stylus which regularly moves in a straight line from the top to the bottom of the rectangle on which his star is drawn, and that before each new stroke this stylus moves over an imperceptible distance towards the right. Thus, if it starts at the left of the edge of the rectangle, it will move over the entire area of the paper in a succession of vertical strokes. We must request the reader further to assume that at the receiving station another pencil sweeps down over the second rectangle at exactly the same rate. Both pencils therefore will be at exactly the same relative place on their respective rectangles at the same instant. Just how this can be done will be explained presently.

Assume again that each time the first pencil touches the drawing, the second pen-

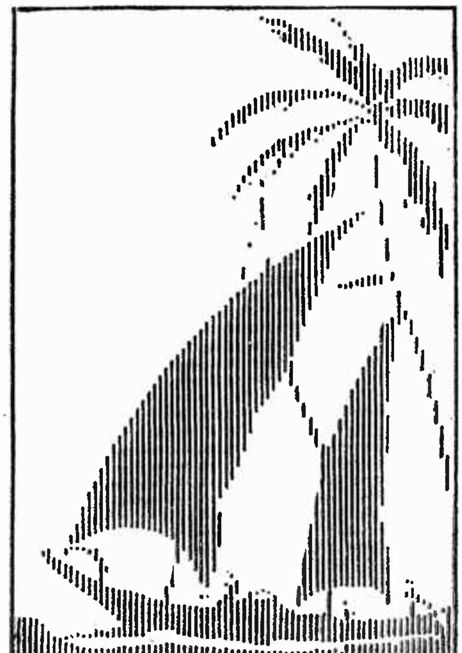


Fig. 18. The Nile boat and palm tree of the black unshaded original reproduced in line at the distant end of the telegraph wire.

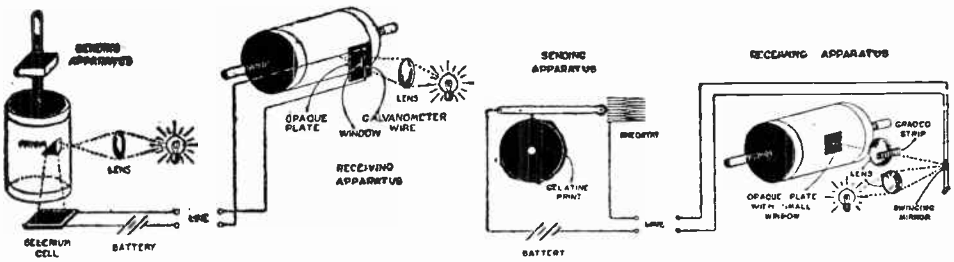


Fig. 20. Selenium cell apparatus for sending moving pictures; they are received photographically upon a film wound upon a rotating cylinder. Sending and receiving apparatus, also operated photographically, that allow for use of an oscillating mirror.

cil will push down hard, and in doing so will draw a line on the paper over which it moves. Just as soon as the first pencil has moved beyond the edge of the drawing the second pencil again rises, and a line will no more be drawn. Now it is evident that when the whole operation has been completed, that is, when the whole rectangular space has been gone over in this manner, the second piece of paper will bear an image of the original drawing, not in full black, but an image made up of a great number of vertical lines. The way the two drawings would appear when the receiving apparatus is adjusted to draw rather broad lines is shown in Fig. 17. If it were adjusted to draw a great number of lines crowded pretty closely together there would be a great deal more detail in the reproduction, but it would also take longer to send the picture.

Now let us consider how all this is carried out in practice. Take a piece of paper on which the picture to be sent is drawn and wrap it around a cylinder, fastening the ends of paper good and tight so that it will lie snug to the cylinder. Do the same with the blank paper at the receiving end. Suppose the two cylinders to be turned by a motor at exactly the same speed. If the axle on which the cylinder turns is threaded like a screw, the cylinder and paper will move along lengthwise as it turns around, and it will be evident that a point or stylus held against the rectangle will sweep over it from top to bottom, and also move sidewise. Of course in this case the rectangle moves and the stylus stands still, but it all amounts to the same thing, as Einstein tells us. That solves the first part of our problem; the one of contriving to have the two styluses to move at just the same speed, and to be at the same relative point on both cylinders at the same time. The next thing to be done is to provide that when the first stylus strikes a part of the drawing it will do something to make the second stylus draw a mark.

This final difficulty was worked out in several ways by various inventors long ago —by Bakewell in 1847, by Father Caselli in 1856, and by Meyer in 1865. A typical method is to make the drawing to be transmitted on a thin sheet of metal like tinfoil, using black varnish and ink. The tinfoil bearing the drawing is then mounted on a metallic cylinder. The stylus is a fine steel point something like a phonograph needle, and this point presses against the tinfoil or varnish as the case happens to be, while the cylinder turns under it. Now tinfoil is a good conductor of electricity, and so is the steel stylus, but varnish is not. The tinfoil is stretched over a metallic cylinder, and the connections are so arranged that an electric current will pass through the foil to the needle, and pass on over the line to the receiving station. That is, the current will pass so long as the needle is in contact with the tinfoil, but as soon as the turning cylinder brings a part of the design under the needle, the insulating ink in which the design is drawn will lift the stylus off the tinfoil an imperceptible distance and the current will cease to flow. We have then this state of affairs: when the stylus is passing over the tinfoil a current is passing through the wire, but when the stylus is going over any part of the drawing no current passes.

Suppose the stylus at the receiving end to be represented by a pen held up a very short distance from the paper by an electro-magnet. It is held up against the force of a spring which tends to pull the pen down upon the paper. But as soon as the current is shut off the magnet lets go of the pen, which then is pulled down against the paper and begins to draw a line. It will continue to draw until it is again pulled away from the paper by the electro-magnet, which last instantly responds to the passing current. All this is made plain in our drawing. (Fig. 19).

This is Meyer's solution to the problem. Caselli achieved the same end by slightly different means. Instead of executing his drawing in varnish on tinfoil, his picture was drawn in slight relief by a photographic process. The stylus was attached to a little lever, and each time it passed over a part of the drawing it lifted

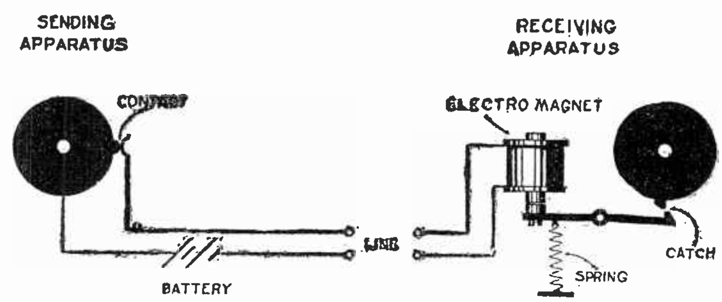


Fig. 21. Very simple arrangement by which perpetual synchronism between two rows of rotating cylinders at distant stations is obtained. This is used on the Belin apparatus.

slightly, and the lever made a contact and sent a current over the line. There was no pen at all in Caselli's apparatus. He used a paper so sensitized with chemicals that in merely passing through it the electricity left a mark, and thus he did away with a great deal of complication.

Both of these apparatus did in fact achieve some limited application. Caselli's was used on the French state telegraph lines for a time. But they all suffered under a double disadvantage: that only black-and-white drawings, and nothing in the nature of a photograph, could be transmitted, and also that there was not then the intense pressure that exists today for getting pictures to the press.

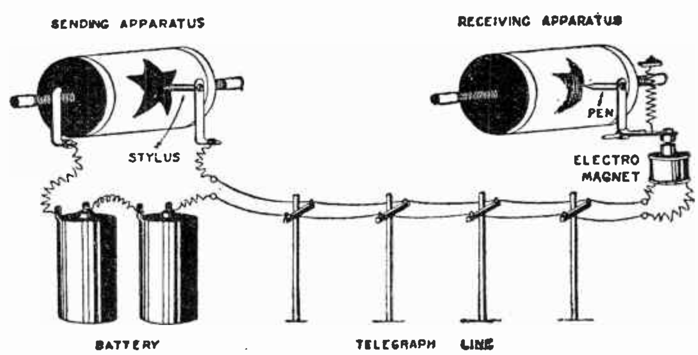


Fig. 19: Line transmission of a star illustrated in diagram, showing the system by which the Nile boat had its picture transmitted.

The Korn Method

We will now consider the processes of Professor Korn of Munich, and of Emile Bélin of Paris. Here we find ourselves in comparatively new territory. We, of course, still retain our cylinder, rotating on a threaded arbor, and crawling along an imperceptible distance with each revolution that it makes. But that is about all of our old apparatus that we still have use for, and we will have to make over even that essential part to a certain extent. For the Herr Professor of Munich, whose process we will first describe, does not use a metal cylinder at all, but instead a cylinder made of transparent glass. Around this cylinder he wraps his picture, but this picture is not drawn out on metallic tinfoil, nor even on paper, but consists of a photograph on transparent celluloid.

Now we come to the critical part of the process. Observe the left-hand figure above. The cylinder is placed vertically, and moves up or down as it turns. At a short distance from the cylinder is placed an electric lamp. A lens takes the light from this lamp and focuses it in an exceedingly small spot on the surface of the film. Since both the film and the cylinder are transparent, the light will pass through both. After it is through, it will strike a prism located on the interior of the cylinder, which will bend the beam of light at right angles and send it out of the open bottom end of the cylinder. Here the light falls on a selenium cell, through which a current of electricity furnished by the battery is continually flowing.

Let us go back and glance over what we have. There is a small spot of light falling on a picture, and the picture is on a cylinder, and the cylinder is rotating, But the spot of light stays in one place all the time, whereas the picture moves along under it. A picture is not all of one tone—it is light in some parts and dark in others, and as a light portion happens to move into place under the spot of light, nearly all of that light will pass through the picture, be reflected by the prism, and fall upon the selenium cell. But when a dark portion of the picture moves under the spot of light, hardly any of the light will pass through.

The selenium cell is therefore sometimes in the dark, sometimes illuminated, according to whether a dark or a light part of the picture happens to interpose itself be-

(*Continued on page* 108)

The Bartlane Process

And now we arrive at what is probably the ultimate in code picture transmission as we know it today. Perhaps some authorities will be able to increase the speed of photograph transmission and even better the results. Nevertheless, the Bartlane process at the present is the outstanding picture transmission method. An article descriptive of this appeared in the April 1926 issue of Science and Invention Magazine. Written by H. Winfield Secor

"ANTINOE" SINKING CABLED ACROSS THE ATLANTIC

At the left appears a picture of the foundering "Antinoe" as cabled from London to New York over the regular cable system. As shown on the right hand page the perforated tape containing the proper sequence of signals was made in London from the original snapshot of the "Antinoe." As the enlargement in the small circle shows, every part of the picture is composed of square dots similar to those of a half tone. These dots are of varying degrees of light and shade, and owing to their small size a faithful picture is built up as becomes evident by viewing the accompanying reproduction at arm's length.

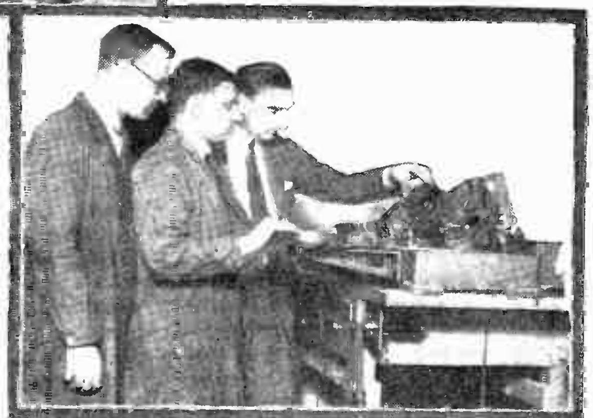
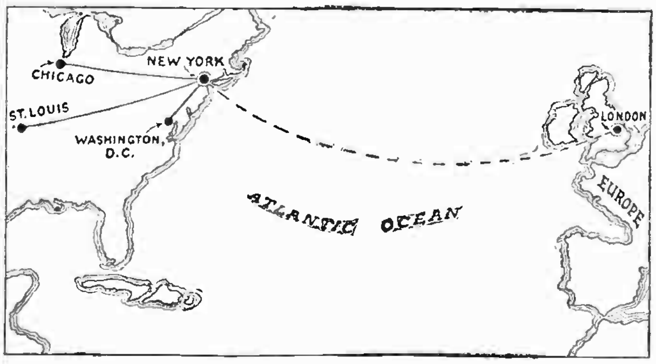
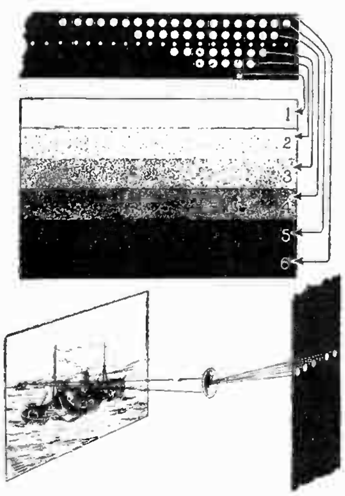


Photo at right shows machine for reproducing photo as well as preparing transmission tape in New York office of photo syndicate service. Man in center is Captain M. D. McFarlane, who in collaboration with H. G. Bartholomew of the "London Daily Mirror," evolved the Bartlane system of transmitting photos by radio or cable. The pictures may also be transmitted over telegraph lines if desired. The man at the extreme left of the picture is C. F. Willis, Bartlane expert, and man at right is F. S. Millar of the Western Union Cable Company. The photo shows first picture being received from London, September, 1925.



Map at left shows present facilities in actual operation for transmitting pictures such as "Antinoe" across ocean and to all parts of U. S.



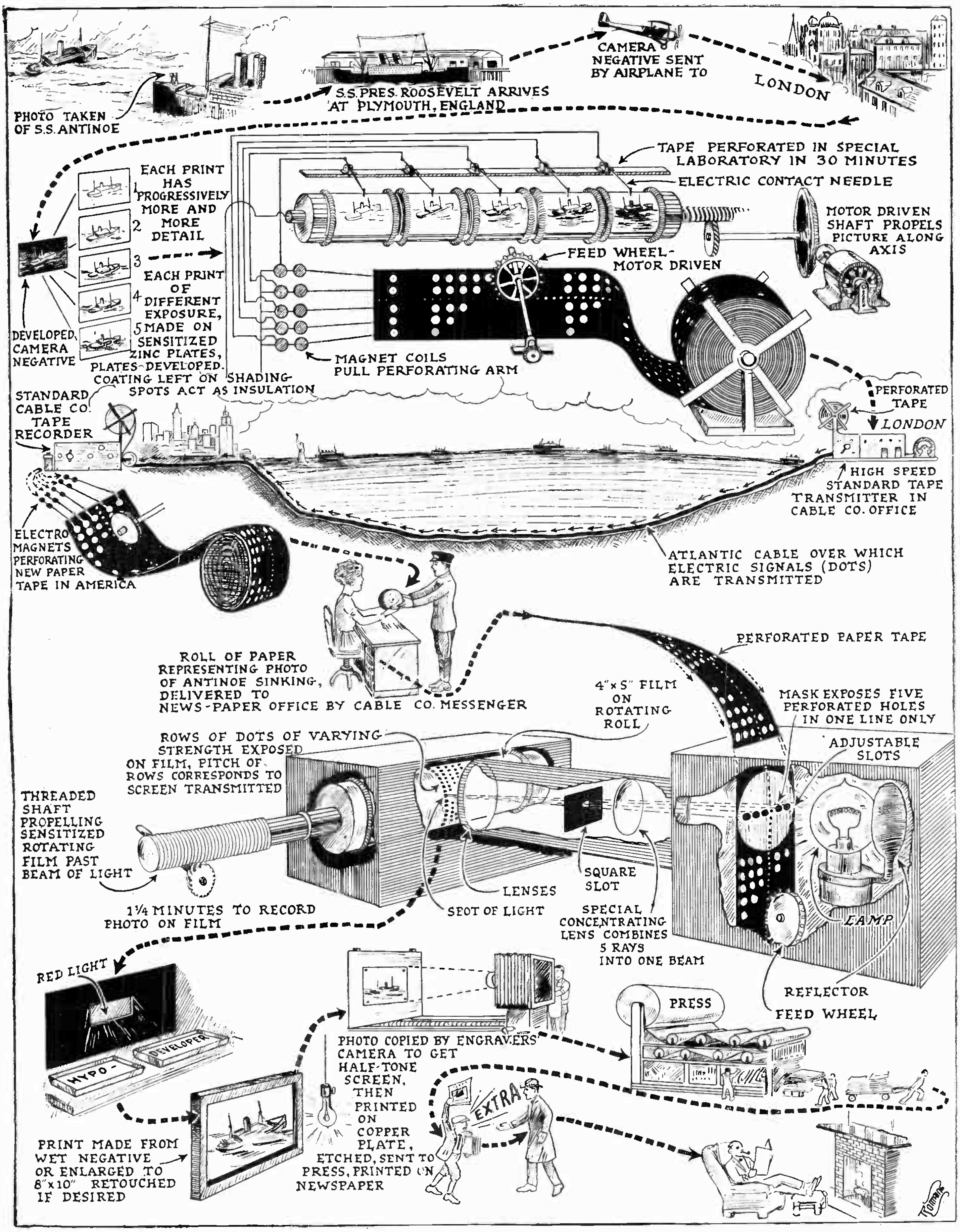
The diagram at the immediate right shows the tone scheme employed in this process It should be remembered to begin with, that no special cable transmitting or receiving apparatus is necessary. The snapshot received in London by airplane from the S. S. "President Roosevelt," was hurried into the laboratory, and five prints on zinc were made from the negative, each of a different exposure, giving the five principal tones of light and shadow. There are really six tones obtained in the complete process, as the diagram at right shows. The five prints on zinc leave certain parts of metal exposed and an electric circuit is established through these portions, corresponding to lights and shadows, each registering on certain perforators as shown on opposite page. The cable company receives the perforated tape, transmits its readings across the ocean, the new tape being delivered to the New York laboratory, and reproduced as a picture in the manner shown. A marvelous concentrating lens combines the light rays in the reproducer to make square dots of varying tone values.

Above we see the smiling face of New York City's new mayor the Honorable James J. Walker, as reproduced in London papers from a picture cabled across the Atlantic from New York. Did you notice the art border around this page? It is composed of five feet of the perforated paper tape, a small part of the two hundred and seventy feet of tape required to transmit Mayor Walker's picture across the Atlantic.

The tape forming the border of this page and comprising a part of Mayor Walker's photo shown above, is just one-half the width of the actual tape used. It takes a relatively short time to prepare the five tone negatives from the original picture in the transmission laboratory, and the tape signals for photo are transmitted across the ocean in a few minutes. Once the tape is placed in the reproducing machine it requires but one and one-fourth minutes to record the picture on the film, develop and fix it, and obtain a print from the wet negative.

How Photos of the Antinoe Were Cabled Across the Atlantic

On this page a complete description of the method of transmitting pictures across the Atlantic by means of the Bartlane process, is illustrated. The various stages in the process can be followed step by step.



When the crew of the S. S. "President Roosevelt" was rescuing those on board the S. S. "Antinoe," a photograph was taken of the latter vessel. This photograph was subsequently sent by cable to the United States for publication. The above illustrations show the various steps in the transmission. Five prints were made from the negative on zinc sheets. These were then developed and by the process used, the shaded parts were insulated from the metal and the light parts were not. Then, as contact needles were passed over the surfaces as shown, circuits were made and broken and the tape was perforated. These perforations were transmitted in the usual manner, received and recorded. The recorded tape was then photographically impressed on a sensitized film in the special manner illustrated. From then on, the process is plain.

CHAPTER VI

Direct Wire or Radio Picture Transmission (Codeless)

IN this chapter we are going to deal exclusively with the developments in the realm of telephotography from the earliest of apparatuses down to the present day, we have already seen the methods employed in the sending of photographs by code systems. Naturally, the next step is to either improve the code, send pictures directly without a code or do both. The subject as will be seen has been approached from both angles. The code method has been materially improved as was shown in the last chapter and the wire or radio transmission system was likewise considerably developed.

Systems of Bain and Bakewell

The problem of seeing at a distance is always preceded by the presumably simpler achievement of transmitting pictures by telegraphy.

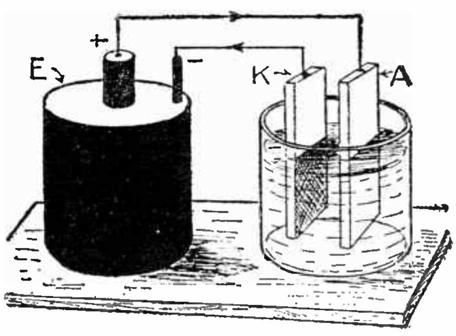


Fig. 1. Illustrative example of electrolytic deposition. The shaded part indicates metal deposited on the electrode.

The simplest and most readily understood method of reproducing a picture electrically is by electrolysis. The apparatus which works on this principle is based upon the fact that an electric current which is sent through a solution of metallic salts decomposes them into their constituents. Although very many of our radio friends are now familiar by experience with back-coupling and modulated oscillations, reflex operation and similar things, very often the simplest basic laws are quite unsuspected by them, so we can properly show the elementary diagram.

In the right-hand vessel, Fig. 1 there is a solution of copper sulphate in water, in which as electrodes two plates of carbon (A) and (K) are immersed and connected with the galvanic battery (E). Then as the current passes, the beautiful blue solution gives up its copper so that plate (K) is coated with copper, red and metallic, as indicated by the hatched lines. For producing a picture other solutions are employed; but this simple example is enough to make the topic clear.

Now we must expiain the apparatus produced in 1843 by Bain, but first put into practical form in 1847 by Bakewell. In the diagram Fig. 2 the sending apparatus is shown above, and the receiving apparatus below may be assumed to be at any distance. The design to be transmitted, which may be writing or drawing, is painted upon a plate of metal such as tinfoil, with an insulating point or varnish such as asphalt or shellac solution. As a simple example we show here a square crossed by its two diagonals. This leaf of tinfoil is then attached to the cylinder (T_1) and may be cemented thereto.

On the surface of the covering of the cylinder a metallic stylus (S_1) rests, whose insulating arm (A_1) is tapped with a thread at its back and through which passes the lead screw (Sp_1). The current of the battery (E) is conducted to the right-hand standard and the shaft, then through the drum (T_1), and then passes through the stylus point (S_1) when it is possible to do so, which is when the said point rests upon an uncovered portion of the tinfoil covering (B) of the cylinder. But when the point (S_1) reaches a part of the foil covered with the insulating pigment the current is cut off. Now if we turn the cylinder (T_1) on the shaft, while at the same time the point (S_1), by the action of the lead screw (Sp_1) is slowly drawn along the cylinder parallel to its axis, the point (S_1) will then cover the surface of the tinfoil with a discontinuous helical line whose successive lines lie close to each other. The drawing will therefore be transmitted step by step and decomposed, as it were, into openings and closings of the circuit.

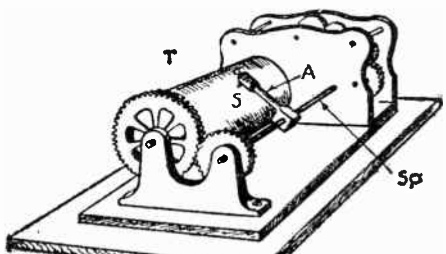


Fig. 3. The early form of the "telephotographic" device was driven by a clock spring. The stylus is moved transversely by a threaded rod or lead-screw geared to the drum shaft.

The next diagram shows the way in which this apparatus was constructed and a model made by Bakewell, which was driven by a clock spring.

But now the current thus produced must act upon the distant receiver and give us visible lines again. For this purpose the same arrangement as the transmitter is employed, including the metal drum (T_2), a metal point (S_2), and the transferring point (St_2). It is essential that the receiving apparatus shall move at exactly the same speed as the transmitter. Then we will find the stylus point (S_1) on the same portion of its drum (T_1), always in place corresponding to the receiving apparatus drum. The technician will express this by saying that both apparatus must be in synchronism. Now we wrap around the drum (T_2) of the receiver a sheet of bibulous paper (P) which has been moistened with a colorless solution, from which the electric current, just as it did with copper sulphate solution, will separate a definitely colored substance. Thus a ferrocyanide (as yellow prussiate of potash) mixed with ammonium nitrate and dissolved in water will give a dark blue color under the action of the current. The current transmitted in regulated intermission according to the lines of the drawing is carried through the corresponding parts of the receiving apparatus, including the moist paper spread upon and attached to the drum or cylinder.

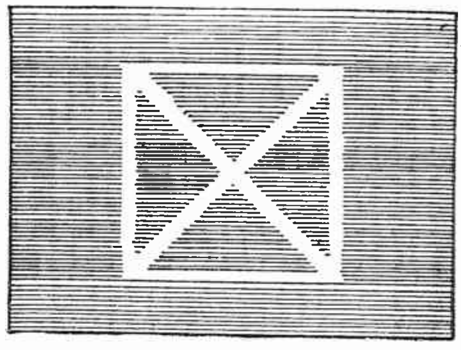


Fig. 4. The received drawing is a "negative" of the drawing on the transmitter drum, since the receiver stylus is lifted off the drum when the transmitter reaches point after point on the drawing.

It follows that the point (S_2) will reproduce on the paper in blue lines the design painted upon the tinfoil at the distant transmitting station. This will perfectly reproduce the design from the tinfoil, giving a point wherever the original drawing had a line, and will be broken off wherever the insulating composition comes. Now when the paper which has covered the entire surface of the cylinder (T_2) is unrolled and spread out we will have a perfect reproduction of the original, in white upon a blue surface, the latter composed of lines in close proximity to each other, as shown in Fig. 4. The above is electrochemical reception.

We have come to the important development of receiving a sketch or writing by the use of the electromagnet. We now

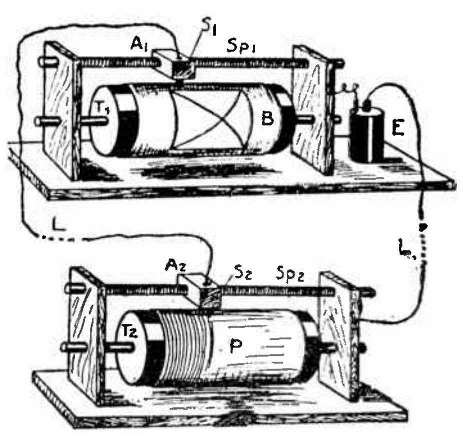


Fig. 2. An elementary form of the sending and receiving apparatus for the electric transmission of drawings is illustrated above. The receiving stylus actuated by the transmitter current reproduces a design on a synchronously driven drum. The two apparatus may be assumed to be many miles apart.

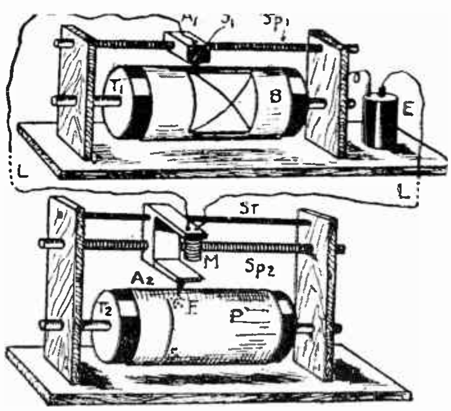


Fig. 5. The type of apparatus shown above operates by a positive action of the receiving stylus, the latter making a mark on the receiver drum when the transmitter current is interrupted by lines of the drawing.

refer to Fig. 5. The transmitter is of exactly the construction described for the preceding case. Again we find in the receiver a cylinder covered with paper, but the metallic stylus is replaced by a pencil

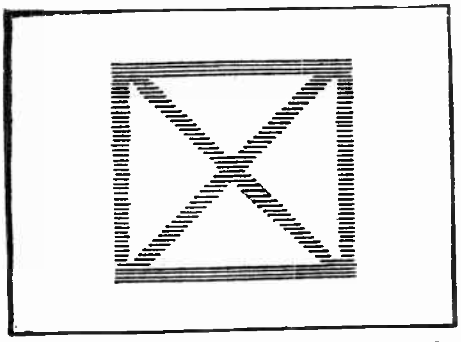


Fig. 6. A "positive" reproduction received on the apparatus shown in Fig. 5 is illustrated above. This is an exact duplicate of the transmitted drawing.

or a sort of fountain pen carried by an arm (A_2), which can be raised by an electromagnet so as not to touch the paper. A second bar (St) parallel to the lead screw (Sp) insures the position of the arm carrying the electromagnet, armature, stylus and movable arm.

When the magnet is passing no current the reproducing point bears with its weight and that of the armature upon the drum, and if this is rotated the same helical line will be drawn upon the paper. Now let the current from the battery be interrupted at proper intervals by the transmitter, which current goes through the coils of the electromagnet (M), it will raise the arm (A_2) and lift the inscribing point from the paper. This occurs as long as the stylus of the transmitter rests upon the insulated varnish on the tinfoil. But when at the transmitter any point of the design opens the circuit, the magnet (M) releases the inscribing point (F) so that it makes a mark upon the paper. By this apparatus we obtain the sketch reproduced in points and strokes lying very close to each other in tint or color upon a white ground, Fig. 6.

The two apparatus so simply described are subject to many modifications, but these do not affect the basic principles. Thus a departure is shown in the transmitter of Hubert, in which the design is produced on the paper in relief, so that the lines rise above the surface of the paper. The current by the contact (K) is carried to the receiver. But this is only possible when the stylus (S_1) is raised by the relief portion of the sketch and the movable arm (A_1) pressed against the cantact point (K) beneath

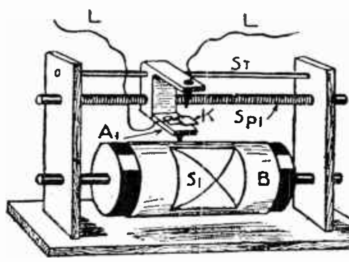


FIG. 7

Fig. 7. This modified form of "telephotographic" transmitter operates with the drawing to be transmitted formed in relief on the paper. The transmitter circuit is closed when the stylus is lifted by the raised portions of the drawing

which is a light spring for the purpose of making a good connection.

The current thus made intermittent produces on the chemical receiver the sketch in blue lines on a white ground, and with the electromagnetic apparatus in white upon a ground of parallel lines as shown in Fig. 4.

This has been described in the simplest possible way, but picture telegraphy cannot be carried out as smoothly as all this. Thus the greatest difficulty inheres in establishing synchronism; that is to say, identical speed of the two drums (T_1) and (T_2), which, of course, may be many miles apart. This is a complication which cannot be treated of here.

The question of the speedy transmission to be obtained by such an apparatus is of interest to us. If we have regard to the disturbances in the current, due to capacity of the circuit, self-induction, lag of the electromagnet and similar factors, which are bound to occur, but which with our present means we can well overcome, we can then under the most favorable circumstances produce 300 points per second.

A picture 3½X5 inches reproduced in points 100 to the inch will require some 170,000 points, so that if this is divided by 300 we will have 570 seconds, or nearly ten minutes required for the reproduction. But this time will have to be increased if we consider the delay due to difficulties in establishing synchronism. As we proceed we will see how synchronizing systems have gradually improved.

The Leishman Direct Wire System

In the latter part of 1917 the Electrical Experimenter asked Mr. Leishman to explain to its readers his system for the transmission of pictures by electricity—i. e., *Telegraphing pictures.* The actual workings of the instruments had never before been explained in detail to the readers of any periodical.

Even at that time the idea of telegraphing pictures was not new; in fact, a scheme for accomplishing this had been suggested fully seventy years previous to that article. Most experimenters that entered this field made use of the peculiar property of *selenium* for changing its electrical resistance when exposed to light. Mr. Leishman's system was far less complicated and expensive than those using selenium, and it was possible by its use to receive a very clear and distinct picture at almost twice the speed heretofore obtainable.

Mr. Leishman wrote: "In order to make this discussion within the understanding of all, I shall avoid all technical language and make the explanation as simple as possible. Let it first be understood that the telegraphing of pictures is not television; it does not make it possible to see the person to whom you are telephoning, as that would necessitate the transmission of moving pictures or about sixteen pictures per second. At the present time, such a thing is impossible for both electrical and mechanical reasons. It is possible, however, to send and receive one picture in a very few minutes. Some people ask what would happen should the picture collide with a building. This, as readers of the Electrical Experimenter probably know, cannot happen because the actual picture being transmitted remains at the sending machine, a reproduction being effected at the receiving end by the building up of minute portions, one at a time, until the entire picture is received.

"The telegraphing of pictures therefore resolves itself into the following distinct elements: A means for gradually covering the entire surface of the picture by some device capable of translating the light and the shade of the picture into pulsations or variations of an electrical current; and a means for successively recording these pulsations or variations in the form of what appears to be graduations of light and shade.

"How I accomplish these things can best be shown by first explaining how the tiny parts of the picture are successively transmitted and recorded. Obviously, this can best be done by an arrangement similar to a cylinder phonograph or dictating machine, both the sending and receiving instruments using this mechanism. The carriage that is sending or receiving, gradually progresses from one end of the cylinder to the other on a spiral or screw, and the picture itself rotates on the cylinder. This makes it possible for all parts of the picture to be covered in the same succession at both ends of the line. The cylinders must of course revolve in exact *synchronism* to prevent distortion, but for the sake of clearness this will be explained later.

"The next problem is that of causing light and shade to affect the passage of an electrical current. This, of course, properly constitutes the sending device. As previously stated, some systems vary an electrical current by causing the light and shade of the picture to act upon a portion of selenium through which the current passes. This is a very direct way of solving the problem, because there must be an 'eye' that recognizes light and shade

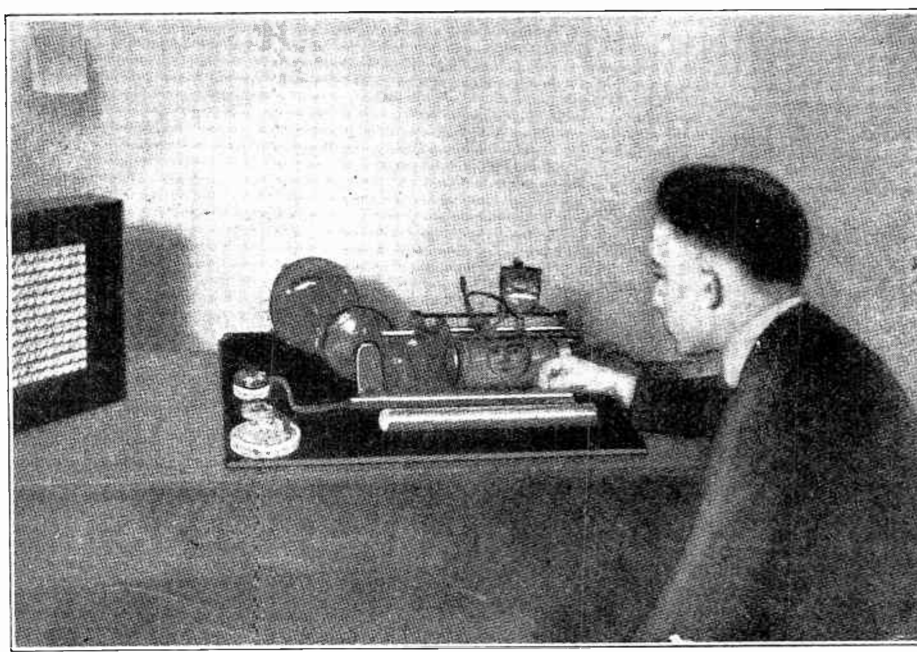


Fig. 8. Mr. Leishman and his machine for telegraphing pictures, photos, script, etc., over telegraph or telephone lines.

and that will vary an electrical current accordingly. It is possible, however, to accomplish this in an easier, cheaper and less complicated way. I perceived immediately that a picture composed all of black and white could be made to make and break a current by forming the black or white on an insulating material upon a metal plate and causing a current to pass from the plate to a tracing needle, so that the insulating parts would break the said current.

"This idea then had to be elaborated upon to permit the transmission of a *half-tone*. All newspaper half-tones, and the great majority of those in magazines, are really composed entirely of black or white; that is, any given point is either the one or the other. Examine one of these pictures closely and you will find it to be composed entirely of little black dots, the shaded effect being an optical illusion due to the size of the dots. There are a fixed number of these dots to the linear inch, varying in newspaper work from forty to eighty. If the half-tone is what is known as sixty screen, then there are sixty dots to the linear inch; and the light and shade, as before stated, is produced by the size of the dots, the lighter portions having *small dots* and the larger portions having *large dots* that sometimes join and produce a mass of black.

"These dots may of course be formed of insulation and will break the current for a period of time proportionate to their size. This is the general idea of transmitting a half-tone.

"Before explaining the exact operation of my picture transmitting device, it may be well to explain the method of preparing the half-tone in order to obtain the insulating dots. For this, I follow up to a certain point the regular process of photo-engraving. The picture to be transmitted is first photographed through a screen, the function of which is to break up the picture into dots whose sizes vary as previously explained. A copper or zinc plate is then coated with a solution of glue, bichromate of ammonia

Fig. 9. This reproduction of a photograph by the Leishman Process shows particularly well the way in which features are brought out. Hold picture at arm's length to obtain best effect.

and water. This is placed in contact with the developed negative and is exposed to strong light. The bichromate of ammonia is the element acted upon. When the plate is washed, the part that has not received the light washes away, leaving the rest fixed to the plate. Upon heating, the gelatine picture turns to a chocolate color. The regular photo-engraving process goes still further, but this is all that is necessary in the preparation of a picture for transmission, as the dark portions form a very thin and highly satisfactory insulation.

"The plate is then rolled into a thin cylinder and slipped over the cylinder of the machine. The transmitting carriage consists of an arm into the end of which may be screwed an ordinary phonograph needle, which is held against the plate by a spring. A current passes between the needle and the cylinder excepting when an insulating dot passes beneath the needle. As previously explained, the mechanism permits the needle to cover every part of the picture. In this manner a picture is transmitted.

"At the receiving end of the line, the current from the transmitting machine passes through the coils of the electro-magnets on the receiving carriage. These attract a very light armature, causing the saffire or diamond in the forward end to press against the cylinder. This pressure does the recording. The stylus may be made to cut a stencil; scratch camphor smoke from white enameled paper; scrape white wax from dark paper; or press upon a carbon sheet, thereby recording and reproducing the picture upon ordinary paper. The pictures illustrating this article were received by the latter method. In this manner, all the dots on the sending machine are accurately reproduced on the paper at the receiving end. These dots, since they vary in size according to the light and shade of the picture, form an excellent half-tone likeness of the original object.

"Some of the readers of this article may wonder why the recording is not done by making a pen out of the receiving stylus and causing it to write upon ordinary paper. The reason lies in the fact that a pen and ink arrangement is necessarily more complex than the system above explained; it gets out of order easier, and when recording at the rate of *two hundred and fifty-one dots per second*, which is the speed at which a picture is recorded, it is not as efficient as the methods described.

"The construction of the receiving arm should be very light to overcome friction, gravity and inertia. It should also be sufficiently stiff to avoid vibration. Friction can be very largely eliminated by using jeweled bearings. The electro-magnets used for actuating this arm may be polarized so that the current has merely to change the degree of magnetization. It is possible to make a receiving carriage that will respond to feebler impulses, but this is not as desirable as speed.

"By connecting a rheostat in series with the receiving carriage, the current can be adjusted to make the receiving arm record as efficiently as possible, and pictures can be made lighter or darker at will.

"There is another detail worth mentioning in regard to the sending apparatus. Unless some means is taken to prevent it, a spark forms at the break of the current, which of course takes place as an insulating dot passes under the needle. This can be prevented in three ways. One terminal of a condenser may be connected to the cylinder, and the other to the needle; or enough resistance may be introduced into the line to absorb the energy; or resistance may be shunted across the gap so that the current at break merely becomes too weak for the electro-magnets at the receiving machine to attract the recording arm. The latter plan has the advantage of reducing what may be called the inertia of the line, due to its capacity and inductance. This, however, is of little consequence excepting in long distance work.

"So far as the use of this system with wires is concerned, there remains to be discussed only the *synchronizing* of the sending and receiving cylinders. It sometimes happens that power is furnished from the same generator at fairly distant points. In this instance, synchronism is merely a matter of using synchronous induction motors. But in the great majority of cases, no such convenience may be resorted to. It is then best to use direct current motors operated by storage batteries with a sliding contact rheostat in the circuit.

"The operator of the receiving instrument watches the recording of the picture; and if the machines are not in perfect synchronism, he is warned by a deviation of the straight lines formed by the picture's upper and lower borders. If the line turns in one direction, his motor is going too slow, so he cuts out some of the resistance. An opposite deviation warns him to move the handle of the rheostat the other way. When storage batteries are used, the current is steady and very little adjusting of the rheostat is required.

"Automatic synchronization is of course desirable. One means of doing this, which greatly interferes with speed, very much resembles the method used by the Western Union Telegraph Company for hourly correcting their 'standard time' clocks. At each revolution of the sending cylinder a

Fig. 10. Another sample of the work which the Leishman machine will reproduce in a few minutes over existing telegraph circuits.

heavy current is sent to the receiving machine, magnetically correctng the cylinder by stopping it momentarily. Some such means for synchronizing is absolutely necessary where the recording is not visible; but where the recording can be seen, manual control, of the nature described, may be used, although mechanical synchronizing is preferable. (Mr. Leishman argued the impossibility of television at this time.)

"A good deal has been said regarding the operation of my system by *radio*. It will be obvious that the transmitting apparatus may be connected into the circuit instead of the wireless key, and the picture transmitted in the usual manner. At the receiving end, an Audion detector and amplifier make the signals sufficiently strong to operate a relay, and this throws in a local circuit to record the picture."

In his second article on picture telegraphy to appear in the ELECTRICAL EXPERIMENTER, Mr. Leroy J. Leishman explained another of his systems. This method reduced gravity, friction and inertia to a minimum and made use of a new and very superior type of synchronizer. The system was referred to in the preceding paragraphs.

Our readers are, no doubt, familiar with the cylinder phonograph arrangement for covering all parts of the picture in the same succession, and with the necessity for perfect synchronism to prevent distortion. A familiarity with these essentials will be taken for granted, and the only means for accomplishing the latter will be explained.

Let us first consider the sending of the picture. It is well known that selenium has the peculiar property of changing its electrical conductivity according to the intensity of light to which it is exposed. Selenium is therefore particularly adapted to form the "eye" that translates light and shade into corresponding intensities of an electrical current. Dr. Korn makes use of selenium in this regard, but in a way that differs considerably to the Leishman method. The latter has endeavored to make it unnecessary to have the sending cylinder in a dark box, and in so doing also eliminated the necessity of using a film.

sending machine, very good pictures are obtained when the cylinders revolve in synchronism.

A cathode ray may be diverted from its path by a magnet, and the same thing is true of many other rays. Quite a variety of optical effects may be produced in a magnetic field, many of which lend themselves to the uses of telephotography because the effect of gravity and friction is not felt, and the inertia is nil compared with mechanical ways of receiving. In a rough manner, these rays may be used by causing them ordinarily to pass over an electro-magnet through the aperture of the dark box; and when the magnet is energized, the ray is either bent entirely away from the aperture or its effect materially lessened.

Of course, there is a little inertia in the selenium cell even though connected with a Wheatstone bridge, and also in the magnet that controls the beam of light at the receiving end; but the further we get away from purely mechanical telephotography and the more nearly we approach the actual connections between light and elec-

Fig. 12. Photograph of President Wilson as reproduced at distant end of telegraph circuit by Mr. Leishman's apparatus.

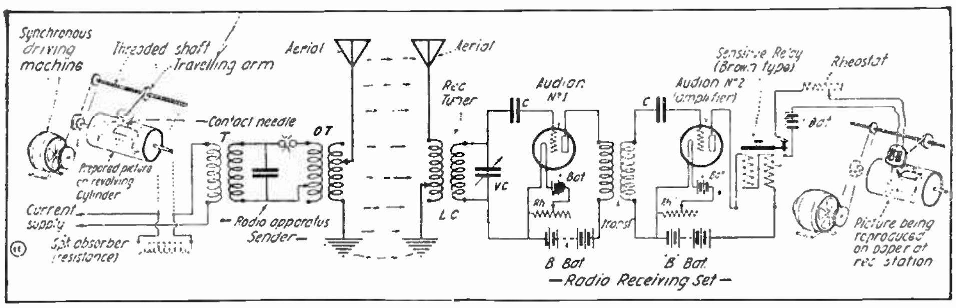


Fig. 11. General arrangement of Leishman transmitting and reproducing apparatus for telegraphing a picture via wireless.

A small selenium cell is placed in the back of a deep and comparatively large dark box. Lenses are arranged in front of the dark box and brought as close as possible to the sending cylinder. The purpose of this arrangement is to have only a very minute portion of the cylinder focused upon the cell. The picture to be transmitted is wrapped around the cylinder. On both sides of the dark box, very strong lights are placed to illuminate the picture. The cylinder has a threaded shaft, so that it advances as it revolves. This permits every part of the picture to be focused in turn upon the selenium cell, which varies the current according to the intensity of the reflected light. In this manner the picture is transmitted.

The receiving is equally novel. Light is not subject to the law of gravity and has no friction and no inertia. The electro-magnets at the receiving station therefore act directly upon a magnetically affected actinic ray. This beam of light may be polarized, a cathode ray, or, in fact, any ray upon which magnetism will exert its influence.

We shall first explain the polarized light arrangement for receiving. Unlike the sending cylinder, the receiving drum is inclosed in a dark box, close to the aperture of which is located an analyzer through which all light entering the box must pass. The light is polarized by Nicol prisms in line with the aperture of the dark box and the analyzer. Between these is placed an electro-magnet, through the core of which the light passes. This apparatus may be adjusted to produce either a positive or a negative by arranging the prisms so that no light enters the dark box excepting when the magnet is energized, or vice versa, when it is not energized. The light rotates in the plane of polarization. If a film is placed on the receiving drum and the magnet connected in series with the

tricity, the greater the speed.

But in justice to the mechanical schemes for telegraphing pictures, let it be said that they work as fast as the *lag* in several hundred miles of wire will permit them.

Without synchronism, telephotography would be impossible. In another chapter Mr. Leishman explains a manually controlled synchronizer, and makes reference to an automatic system. In connection with this system, he has arranged automatic starting and stopping features.

When the machines are not in operation, the starting relay on the receiver is connected direct to the binding posts, to which are attached the wires from the sending machines. The arm of this relay is held by gravity against a contact to effect this connection. The arm is then inclined about 15 degrees from the perpendicular. When the sending machine starts, the first impulse causes this relay to pull its arm against a different contact, against which it is also held by gravity, as the position is 15 degrees the other side of the perpendicular. This breaks the relay connection and starts the motor which operates the machine.

An important part of the synchronizer is a drum of non-conducting material, preferably on the same shaft as the sending and receiving cylinders. On this drum, in longitudinal alignment, are a very thin strip of copper or other conducting material and two resistance elements. All of these are electrically connected to the shaft. The current to these resistance strips is supplied from opposite sides, the purpose of which will be obvious later. Three brushes —one for the copper strip, and the other two for the resistance elements—are arranged so as to make contact with these as the drum revolves.

When sending a picture, the thin copper strip is connected through the shaft to one outgoing wire; and the brush is connected

in series with several batteries and the other outgoing wire. This connection causes a heavy current to be sent to the receiving machine whenever the copper strip and the brush make contact; that is, once every revolution.

Now let us go back to the receiving machine at the point where we left it. Now that the starting relay no longer short-circuits the incoming current, the said current is permitted to pass to the synchronizer or to the picture receiving apparatus, as the case may be.

The two resistance elements on the synchronizing drum are used in receiving; and if their connections are borne in mind, it will readily be seen that if the heavy impulse from the sending machine is received when the brushes are in exact centers of said resistance members, the current in the two brushes will be equal; but if the brushes are either above or below center at this time, there is a differential effect in the current—that is, the current is heavy in one and light in the other, this effect becoming greater the further the brushes are from center.

The synchronizing impulse is necessarily heavy to distinguish it from the picture transmitting current. This being the case, it is imperative to provide some means to keep the heavy current from entering the circuit that receives the picture, as it would burn out the magnets. The seams of the picture are arranged to come in line with the synchronizing strips on the non-conducting drum, so that the heavy impulse is never received when the picture itself is being transmitted, but while the seam is passing. It is, of course, necessary to have the synchronizing impulse received when the brushes at the receiving machine are passing over the resistance pieces. Supposing, then, that this current always comes when the brushes and synchronizing strips make contact, it is easy to arrange other contacts and brushes so that the entire current passes into the synchronizing circuit while this part of the cylinder is passing, and so that the current at all other times passes into the circuit that receives the picture proper. So long as the cylinders are revolving in synchronism, this means can be relied upon to distribute the two currents into their proper circuits; but until synchronism is established, at the beginning of a transmission, another arrangement accomplishes the purpose.

This system operates in conjunction with the means for getting the resistance strips to pass beneath the brushes when the synchronizing impulse is received.

The principal part of the mechanism is

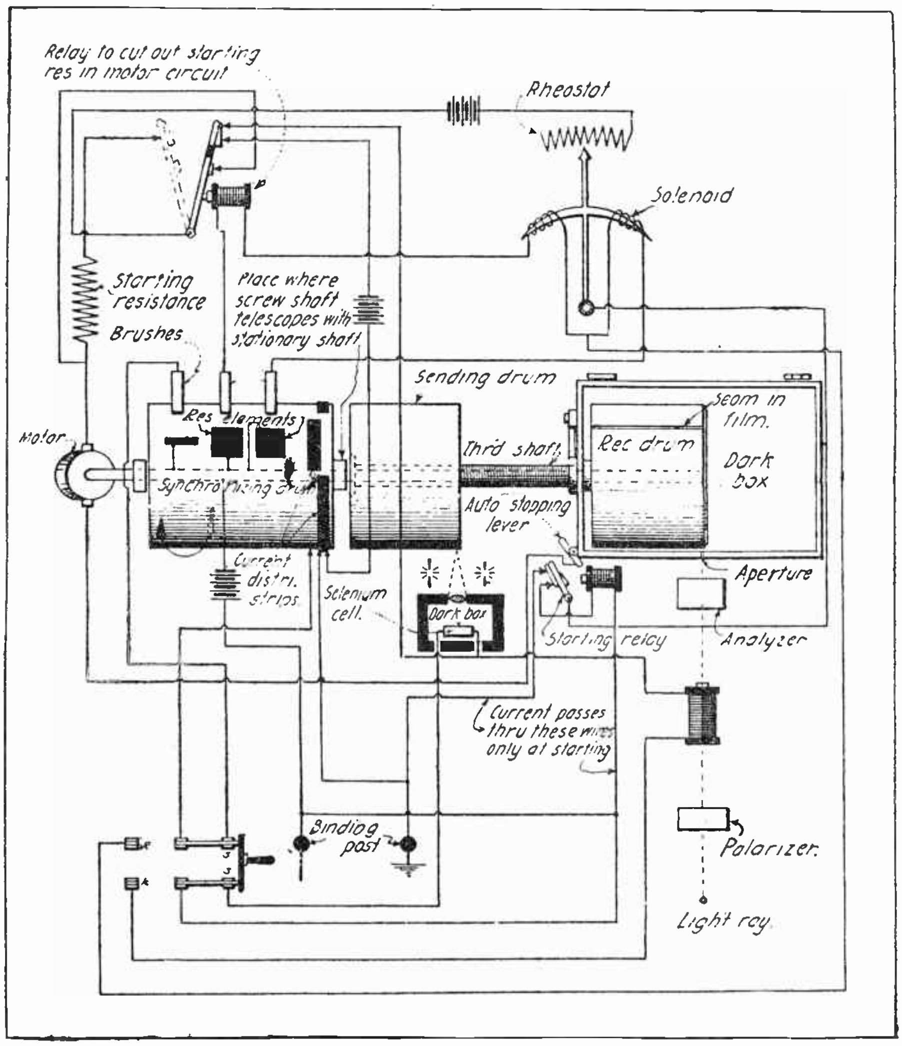


Fig. 13. This diagram shows the electrical connections and arrangement of the various apparatus in Mr. Leishman's telephotographic instrument, intended for transmitting pictures over telephone or telegraph wires. Among other interesting departures the inventor makes use of a novel polarized light ray, which is deflected by an electro-magnet.

another gravity relay. In its first position, this serves to connect the motor with its source of current through a circuit containing considerable resistance. This causes the motor to run slower than the one on the transmitting instrument. This being the case, the heavy impulse is finally received (and it takes only a few seconds—seldom more than ten revolutions) when the resistance elements are under the brushes. The current is now permitted to flow from the brush through the coils of the relay, which throws the gravity arm, causing the resistance in the motor connections to be short-circuited, so that the motor then runs at the approximate speed of the motor of the transmitting machine.

Until the relay is operated, by the presence of a current in the synchronizing circuit, the circuit that sends the picture remains open. This is necessary to keep the coils for the lighter current from being burnt out, as the currents cannot be distributed until the brushes and resistance elements are in contact when the synchronizing impulse comes in. As soon as this relationship is established the relay, which operates only under the heavy impulse, causes the picture transmitting circuit to be closed. This relay performs the twofold purpose of closing this circuit and of short-circuiting the resistance that is in series with the motor.

It has already been explained that the current is equal in the two brushes that touch the resistance strips providing the current is received when they are at center; and that the differential effect increases the further they are from center, one brush having the greater current above center, and the other brush the greater when below center. Each brush is connected with a solenoid, into the centers of which protrude the horn-shaped arms of a rocker that pivots on a friction bearing. A hand on this rocker forms the contact on a sliding contact rheostat in series with the motor. As long as the machines are running in synchronism, the current in the solenoids balances the rocker arm so that the current to the motor is steady; but as soon as there is a slight deviation in the synchronism, there is a change of current in the solenoids which pulls the rocker arm to one side or the other, thereby moving the rheostat contact so as to give the motor more current if it is too slow, or less current if it is too fast. This system of synchronizing is positive, and because of the resistance strips and the differential circuits, a very slight change causes the apparatus to respond.

When the picture has been received, the cylinders continue to revolve until they have advanced far enough to strike the arm of the starting relay and throw it to its original position, breaking the motor circuit and stopping the machine.

A clear understanding of this synchronization system will aid the experimenter in building a simple picture transmission system of his own. Mr. Leishman's apparatus is described in detail in another chapter in this work.

Arthur Korn's System

One of the inventions perfected during the war—independently of any strategic considerations, no doubt—is Prof. Arthur Korn's *Transatlantic Telephotography*. The use of a light sensitive cell played a prominent part in these early experiments.

To show the close relation between code and direct wire systems, this method is inserted here.

Our readers are, of course, conversant with the Professor's *transcontinental telephotography* which previous to the World War made part of the routine work of some prominent European dailies, enabling photographic pictures of people and events to be wired from Berlin to Stockholm, Copenhagen, London, Paris, etc., as well as vice versa. This process, because of the enormous capacity of transatlantic cables and the resulting inertia, could not be adapted for transoceanic service and a new process had to be devised.

In its first stages it resembles the familiar method used for transmission on transcontinental lines. The picture to be transmitted, in the shape of a translucid film, is wound upon a glass cylinder performing a rotation round its own axis as well as a slow forward movement in the direction of the latter. All the elements of the pictures thus pass in turn at the spot where the beams of a Nernst lamp, of very constant luminous intensity are concentrated. After traversing a given film element, these beams will strike a selenium cell, whose resistance, of course, varies in accordance with their luminous intensity; these fluctuations of resistance being converted into corresponding variations of current intensity in the circuit comprising the selenium cell.

Now, whereas in the case of ordinary telephotography these current fluctuations are transmitted over a telegraph line, in order at the other end, by an inversion of the same series of operations to be reconverted into variations of luminous intensity, and accordingly into shades reproducing photographically the original film at the sending station. This is not feasible in the case of transatlantic telephotography.

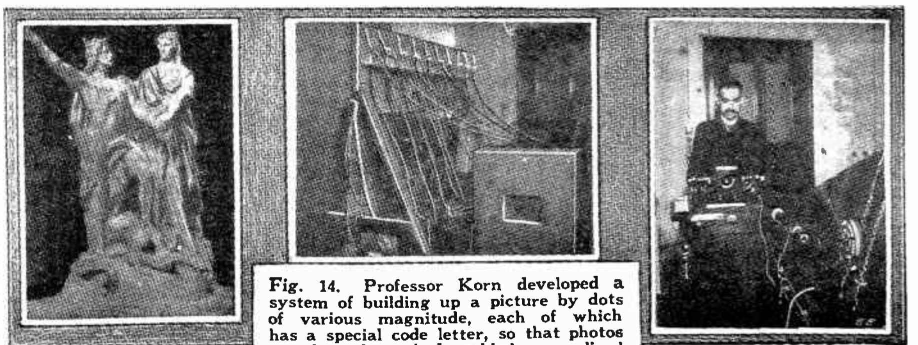


Fig. 14. Professor Korn developed a system of building up a picture by dots of various magnitude, each of which has a special code letter, so that photos can be telegraphed, cabled or radioed practically any distance.

Prof. Korn, therefore, designed a most ingenious relay, where all contacts are replaced by electric sparks and arcs, and by the intermediary of which the current fluctuations were made to act on a high-speed telegraph of the Siemens and Halske system where each current intensity, in the perforated strip, produced a given combination of holes. After converting these perforations in the same telegraph into a *series of letters*, where each of those chosen —fourteen in all—*correspond to a given combination of holes and accordingly to a given current intensity and a certain shade of film element; these letters were, like an ordinary cablegram, transmitted across the ocean.*

What there is received at the other end, then, is only a series of several thousand letters, which at any time and any place desired, can be reconverted into a picture faithfully reproducing the original photograph. Several processes can be used in this connection, the most simple (already employed with satisfactory results) being based on the use of a *special typewriter*, which in the place of letter type *carries at the end of each lever a small circle or square of dimensions corresponding to the shade expressed by the letter in question* The stronger the shade, the greater will be these dimensions, the intensity of the imprint on the paper thus varying in proportion. The letter "X" indicates the end of a line and the beginning of a new one.

By simply copying, on this remarkable typewriter, the cablegram received at the distant end, the original picture is thus reproduced, element for element and line for line. The typewriter will preferably be operated by electricity or compressed air, thus accelerating operation and rendering it more uniform. By subdividing the cablegram into several portions, each of which is entrusted to another operator, further speed is had.

By augmenting the number of letters composing the scale of shades and accordingly the number of component elements of the picture there are obtained more delicate reproductions.

Mr. H. Gernsback, editor of *Science and Invention* Magazine and *Radio News* has repeatedly astonished the world by his predictions of inventions and by his suggested improvements. Commenting on the work of Prof. Korn in Germany, in an editorial in *Radio News* Magazine for August, 1920, we find this article:

Fig. 15. At the left a reconstructed picture is shown, which was telegraphed by code letters over a long telegraph line. The right-hand photo shows Dr. Korn reconstructing this very picture from a code telegram on his special typewriter, each key of which has a dot of certain size on it. Instead of a letter these varying dots make up the picture.

Hugo Gernsback's Comments

One of the least exploited branches of the radio art no doubt is *radio photography*, better known as sending pictures or drawings by wireless.

Of course there is nothing new about this and ever since the days of the coherer, serious efforts have been made to send pictures by radio. More than thirty years ago actual experimental apparatus had been used for this purpose and the results in some cases, while mediocre, showed that the thing could be done in a practical manner with better apparatus.

Fundamentally, sending pictures by radio is not much more difficult than sending them by wire. As is well known, Professor Korn, in Germany, as well as other experimenters, have achieved notable results in transmitting pictures over wire, and this art is known as *telephotography*.

In radio, the same principle holds good and the method in a few words may be described as follows: At the sending end a picture or drawing is usually made upon tinfoil or any other conductive surface, the picture being printed in an insulating ink. From this it will be seen immediately that there will be certain areas which are covered with an insulator, while other areas are metallic and consequently conductors. We now take the piece of tinfoil with the picture printed or drawn upon it and wrap it on a metal cylinder. We then rotate the cylinder upon its axis while a metallic stylus presses upon the tinfoil. This stylus advances just exactly as a phonograph needle advances on the old-fashioned cylinder phonograph. It becomes evident that the stylus will at some time travel over the tinfoil and at other times over the insulating ink. If the stylus and the metal cylinder, upon which the tinfoil is wrapped, are connected to an electro-magnet and battery so that it will operate an ordinary telegraph key, then in that case the key will be depressed every time the stylus touches the tinfoil and will likewise be released every time the stylus travels over the insulating ink. From this it will be seen that short or long impulses are sent out from the radio station all depending upon the physical make-up of the picture. After the stylus has completely traveled over the surface of the picture, the latter will thus have been translated into dots and dashes of various durations of time.

If at the receiving end we have an apparatus which runs synchronously with the speed of the cylinder at the sending end, it can be readily seen that if we have a similar stylus with a pencil or pen, a picture will be reproduced by the receiving apparatus, which must in all respects be exactly the same as that which constitutes the picture at the sender. Were it not for the bugaboo of synchronism, there would be very little trouble in thus sending pictures by radio, but here the great difficulty arises. Thus far it has been almost impossible to get two disconnected pieces of machinery to revolve at exactly the same speed for long durations of time. There will always be a certain length of time where the speed of the two machines are not in synchronism with each other, and that means, of course, a distorted picture at the receiving end. Theoretically, it should be an easy matter to send pictures by wireless and there is certainly a great future for this art. Up to the present it has not been exploited whatsoever, and is still in the experimental stage.

It seems, however, that there must be some method by which the trick can be turned without the use of cylinders that must rotate synchronously. In the olden days we were also tied down to a coherer that worked sluggishly and not at all perfectly; this naturally gave rise to imperfect pictures. We are not much troubled with such things in these days of the vacuum tube and once we have overcome static which, of course, now often interferes while sending pictures, we will be on the road toward quickly sending pictures across the continent or even across the ocean without much trouble.

It will be observed that Mr. Gernsback believes that the defects of synchronism can be overcome in some other manner.

"Yes, but how?" says the experimenter. "We cannot conceive of any other possible manner."

Perhaps the method eventually put into use will be as remote from synchronism as the coherer is from the vacuum tube—who knows? It remains for our future inventors to solve this perplexing problem.

Edouard Belin Method

Edouard Belin, a French inventor and electrician, invented an apparatus for transmitting autographic writing, photographs and the like, by what may be termed a telegraphic process. In a few minutes a photograph or other design could be sent hundreds of miles; an occurrence of any sort or an important personage could be photographed and the picture could be received hundreds of miles away inside of an hour.

To do this the inventor used a varying electric current, whose variations were produced mechanically at the sending station, and due to this current a mirror was caused to vibrate at the distant receiving station. The spot of light from the mirror was received on a sheet of sensitized paper and a photographic reproduction of the object at the distant station was produced on development of the latent image.

The transmitting apparatus comprised a cylinder on which was mounted the picture or script to be transmitted. This could be a sheet of gelatine, which had been so treated that the dark parts of the image on it were in relief or a sheet of manuscript so prepared that the writing was in

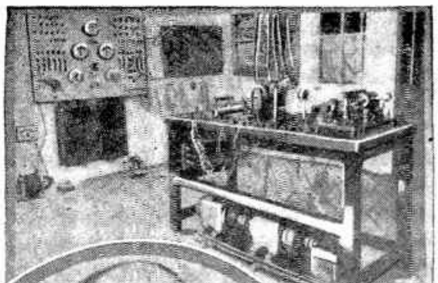


Fig. 19. At left: The perfected receiving apparatus used in the Belin system of telephotography which successfully transmitted photographs and handwriting over a long distance.

Fig. 21. Half-tone reproduction of film on which General Mangin's portrait was received over the Belin system, without retouching.

Fig. 20. Center picture shows the inventor of the telephotography system, M. Edouard Belin.

Fig. 23. General Pershing's photograph as transmitted by the Belin telephotograph. (It has not been retouched.)

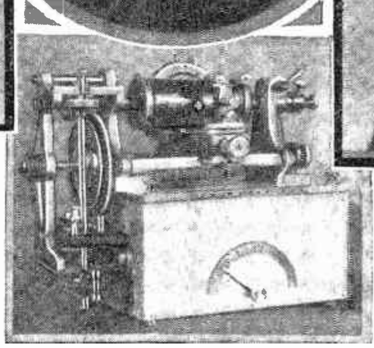


Fig. 22. Right. Portable sending instrument used in the Belin telephotography system. The cylindrical negative causes a microphonic contact to transmit impulses over the circuit to the "receiver," which records the image photographically on the film, as here reproduced.

relief. In transmitting, the cylinder rotated and an arm rested upon it and was caused slowly to traverse the length of the cylinder, exactly like the needle in the old-fashioned cylindrical phonograph. Thus the arm was thrown into vibration and the vibrations acted upon a microphonic-type resistance by which a varying current was caused to pass over the telegraph line connecting the two stations. This current varied in exact reproduction of the mechanical variations of the arm resting on or touching the sheet on the sending cylinder.

At the receiving station, perhaps hundreds of miles distant, there was on the receiving instrument a cylinder rotating in exact synchronism with the sending cylinder. On this was mounted a sheet of photographic sensitized paper. The varying current from the line acted upon a mirror, somewhat as the current affects the mirror in the reflecting mirror type of galvanometer. The motions of the mirror corresponded in extent to the strength of the current impulses. The light reflected from the mirror was brought or focussed by lenses to the form of a spot or small disk on the drum, or rather on the paper coating it. The actinic effect of the spot on the paper varied with the motion of the mirror so that a photograph of the relief object on the distant sending cylinder was eventually reproduced on the paper affixed to the receiving cylinder.

The sequence of operation is fourfold. The specially prepared object for reproduction acted mechanically on an electric resistance, so as to cause the production of a varying or irregular undulatory current. These were the first two steps—the first mechanical, the second electrical. Then the current, as the third step, also an electrical one, caused the mirror to oscillate. The fourth step may be taken as optical; this step was the focussing of light reflected from the mirror upon the sensitized paper. It is at this stage that one of the most characteristic features of the process appears. The work was done with very feeble currents, of what may be crudely termed microphonic intensities. So all the work that was given them to do was to cause a small and exceedingly light mirror to oscillate, and it was its imponderable beam of light, which, acting on the sensitized paper, brought us to the last step—the final photographic one.

We give in addition to the illustrations of the apparatus, both sending and receiving, some interesting examples of the work of the system. The photographs (unretouched) of the representatives of the French and American armies, Generals Mangin and Pershing, were transmitted in a few minutes, perhaps the principal delay being the time required for the development of the photographic image.

The general disposition of parts is given in Fig. 24, which, taken with the text above, makes the principle clear. The cylinder with its picture or writing in relief, is shown with the microphone on which the arm acts mechanically. The line with induction coil and battery and other requirements, transmits the vibration from the microphone to the distant receiver-like device, whose diaphragm carries a mirror. This reflects the light through a system of lenses to the sensitized paper on the receiving cylinder.

The Paris correspondent of *Practical Electrics*, Jacques Boyer, further described Belin's apparatus in the March-April issue of the aforementioned publication.

The problem of transmitting pictures to a distance, by means of electrictiy, has occupied the thoughts of many inventors in modern times, but it fell to the lot of an English mechanic, Bakewell, to invent the first telautograph capable of reproducing any pictures at a distance.

A specimen of this kind was shown in the London exposition in 1851, and a short time afterwards the Abbé Giacomo Caselli developed his celebrated Pantelegraph, which underwent many changes from its original form of 1854, previous to acquiring its final development in the laboratory of the Paris constructor, Gustav Froment, in 1863.

By means of this instrument Nobili, the accomplished student, was able to transmit from one city to another with the exact fidelity of a photograph, any signature whatsoever, a portrait, a picture, music, etc. Then the French Government, impressed by the results obtained by Caselli, brought forward a resolution to be voted on by the legislative body, which arranged for the introduction of the Pantelegraph on the railroad from Paris to Lyons.

Since February 16, 1863, the administration permitted the public to transmit autographic dispatches between these two cities, and in 1867 the Director of Telegraphs, M. de Vougy, had a second apparatus on the Marseilles—Lyons road. The charge for its use was based upon the dimensions of the surface of the paper employed, at the rate of 0.20 francs per square centimeter; which is about 25 cents per square inch. The telegraph office sold the metallized paper required for the production of the characters.

Nevertheless, in spite of its excellent results, the Pantelegraph had little success. The people of that day did not understand its importance, and the Government gave up its exploitation. The Abbé Caselli went back to his own country, and died at the age of 76 years, in the hospital Santa Maria of Florence, 1891. Modern society, which owes its happiness to scientists, too often rewards their works in this way.

Following Caselli, Meyer, an employee of the French telegraph, invented an apparatus which resembled a Pantelegraph very closely. We will also mention as a matter of record the experiments of Minclin in this line; the phoroscope of De Lazare Weiler, the telautoscope of the French physician Senlecq d'Ardres, the telephotograph of De Porosino, the apparatus of Ayrton and Perry, of Carey, of Bidwell, the telectroscope of Jean Schzepanik, which made considerable stir two or three years before the exposition of 1900, Ritchie's telautographe, pretty well forgotten today, and the electric eye of the Russian, Professor Rosing.

In their turn, Korn of Munich, and the Frenchman Edouard Belin, took up the question about 1907. In fifteen years of laboratory work and with a patience which never succumbed, this last man developed the fixed and portable telestereographs, capable of working regularly on all telegraph lines or even by radio.

During the years 1920-21 in particular, the inventor carried out numerous experiments either between telegraphic stations which the Belin Company controlled or owned in Paris and Lyons, or between Paris and Bordeaux, Nice, or else on international circuits. Among other achievements, he produced in August 14, 1920, on the Paris-Antwerp line, the first telephotographic newspaper reports which the "Matin" of Paris and the "Daily Mail" of London published the day after they were received. Finally, in the course of the Washington conference, October, 1921, his telestereographs, installed in the United States, succeeded in receiving various mes-

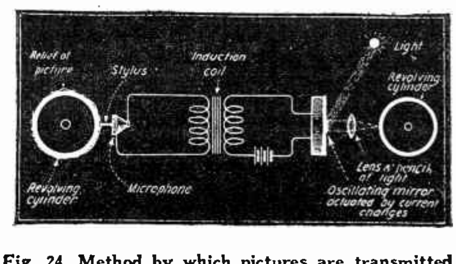


Fig. 24. Method by which pictures are transmitted and received by the Belin system.

Fig. 25. Thumb-prints which led to the arrest of the prisoner; the message asking for identification of the criminal is reproduced in autograph below the thumb-prints.
A picture as reproduced, exactly as it was transmitted by the telestereograph, as the Belin apparatus was called.

sages sent from France, and in transmitting messages to Europe.

We must now see to what technical progress are due these remarkable results. The action of the Belin telestereographs depends on the photographic sensitiveness of bichromatized gelatin. In carbon printing, invented by Portevin, photographic proofs are obtained with paper sensitized by bichromatized gelatin mixed with a pigment, which becomes insoluble when exposed to light. Taken out of the printing frame, they are washed in warm water, and the gelatin dissolves more or less according to the degree of opacity of the different parts of the negative. It is a case of photography and electricity working hand in hand.

This evidently gives proofs with high and low areas corresponding respectively to the whites and blacks of the original negative. The half lights (tones) are given by intermediate thickness, accurately proportional to their intensity. Finally, the luminous values of a proof are transformed into electric current changes on a telegraphic line, and the receiving instrument changes these electric variations back into pictures.

Theoretically, the transmission of a drawing becomes the same as that of a photograph, but there are nevertheless practical modifications. The line drawing is a monochrome, with no variation of shade: such are pen drawings, musical characters, printing, and thumb prints. Thus, the Telestereograph gave the greatest service to international police in the capture of criminals. The thumb prints shown above were transmitted from Paris to Havre and brought about the capture of a dangerous criminal. On the other hand, the examination of the half-tones shows that the images are really formed of continuous flat tints, or of a limited number of shaded tones, or of very numerous graded zones. These definitions being understood, we have to see how we can send a line picture which only has two tone values in it.

The two-tone values may be translated into currents of varying intensity and similar direction, or one value may be given by currents in one direction, and the other by opposite currents, or one value can be given by a current and the other by a cessation of the current. The transmission of a line drawing to a distance is comparable to plain telegraphy. For sending texts or line drawings with the Telestereograph model, Fig. 28 and Diagram 26, the texts in question may be traced on any kind of paper with an ink which leaves a solid line in slight relief on the paper. The paper is then clamped on a cylinder and turned regularly by machinery, actuated by battery or clock-work. Clock-work is used in the portable apparatus, Fig. 29. In the course of this movement, the lines of the drawing, which are in relief, touch a point T, Fig. 26, on the extremity of a very light arm, which is one of the essential

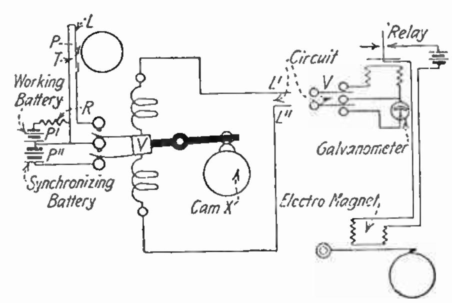


Fig. 26. Diagram of the transmitting end of the Belin apparatus for transmitting pictures by telegraph or telephone line.

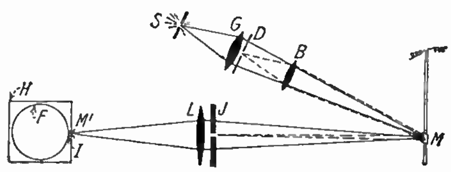


Fig. 27. The receiving plant of the Belin apparatus, illustrated diagrammatically. The reflected light acts upon a photographic film and reproduces the picture.

parts of a minute circuit breaker, all of whose parts can be regulated by means of a micrometric screw. This reproducer rests on a carriage so that it can move along the cylinder on parallel ways, and a screw moves it longitudinally parallel to the axis of the cylinder.

The action of the feed screw and rotating cylinder combined, cause the point P of the transmitters to follow a helical path on the cylindrical surface.

Every time a line passes under the point P of the transmitter the flexible plate L is lifted from its rigid support, the current which passes through it is broken, and the circuit is closed, only when the raised line has passed to one side and has released the point of the transmitter mechanism.

It is clear that if we put the transmitter in series with the battery and with the line L/L", the receiving station will receive impulses considerably transformed, because of the constants of the circuit. Belin prefers to pass the current only at the moment of the motion of signals, which he effects by putting the transmitter in parallel with a resistance at the receiving station, Fig. 27. Successive impulses of current are received by the galvanometer with extreme rapidity and sensibility; for receiving the lines and half-tones, Blondel's oscillograph is used, because of its being perfectly dead-beat, and on account of its high frequency. The Einthoven galvanometer is preferred by Belin for receiving photographs. An incandescent electric lamp is used for the source of light, S, as it is very constant, and its filament, of a very regular diametrical shape, is placed in a metallic case, in front of which is a condenser lens G, with a diaphragm, D, in front of it, whose vertical opening is regulated by means of two plates, actuated by a micrometric screw. A convex lens, B, focusses the light on a mirror, M, the rays coming from a luminous source, and by careful regulation the exact focussing of the light is effected. The incident and reflected rays fall into the same vertical plane, but the oscillograph causes them to vibrate horizontally. The ray reflected by the mirror M, is passed through a narrow opening in a screen J, then through a convex lens, and projecting the image of the mirror at the point M¹. On the surface of a cylinder is a sheet of bromide paper, and the cylinder rotates in synchronism with the transmitting cylinder. This latter cylinder is carried by a special frame H, which opens as shown on the right. A cylindrical tube I, has its outer end closed by a silver plate, pierced by a hole of diameter equal to the longitudinal displacement of the cylinder for one revolution. With this arrangement, once the frame is in place, the light goes through a circular aperture of diameter adapted to cover in its helical path the entire surface of the sensitized paper.

The receiving cylinder moves longitudinally, corresponding to the longitudinal movement of the transmitter at the transmitting station. Each time the current passes, the mirror of the galvanometer moves, and it is only when the current passes that the light falls upon the paper, but at all other times the reflected spot of light is deflected and falls upon a screen. This arrangement can be reversed, so that either a positive or a negative can be received as desired. The transmitting and receiving cylinders must turn in perfect synchronism.

The receiving cylinder is made to turn very slightly faster than the first, and at the completion of each revolution it stops, until the transmitting cylinder has caught up to it. A fork-shaped arm V, with slightly flexible blades, establishes the con-

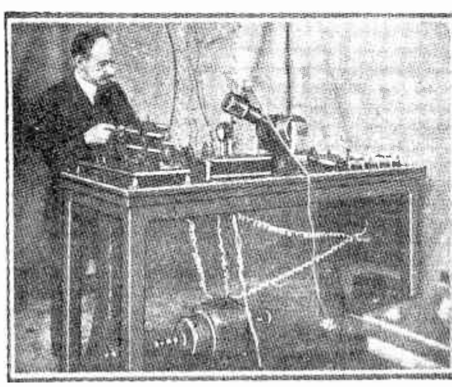


Fig. 28. The Belin apparatus for transmitting pictures and other subjects by electricity

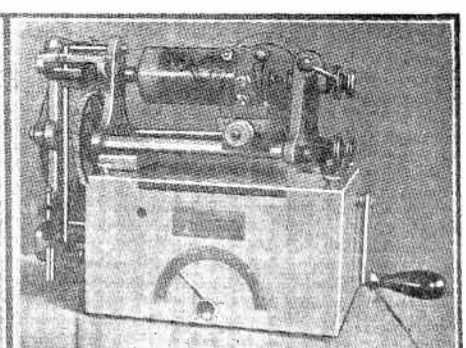


Fig. 29. Enlarged view of the Belin apparatus with which the inventor sent pictures and other subjects recently in this country, as well as abroad. This is the portable instrument.

nections between the telegraphic or telephonic lines and the apparatus. These two plates oscillate between three contacts, acting as a delicate current changer. The two first contacts are connected to the main battery, the second and third to a battery of polarity the reverse of that of the synchronizing battery

The shaft which moves the cylinder carries the cam which makes the fork vibrate with proper frequency.

At the receiving station, the shaft of the cylinder carries an eccentric which at the end of each turn elevates the projection on the armature of the electro-magnet on the relay circuit. A friction drive on the electric motor permits it to continue its rotation, in spite of the sudden check of the cylinder. When the two cylinders begin to move again, the working current acts upon the oscillograph, and then the receiving cylinder suddenly stops when the eccentric on its shaft raises the projection on the armature. At this moment, the cam of the fork being diametrically opposite, the fork oscillates and substitutes for the oscillograph polarized relay currents. About 1/50th of a second after this, the vibrating fork at the transmitting station sends reverse current over the line. The relay closes the local circuit of the electro-magnet, which attracts its armature, and the motor shaft begins a new rotation, and so on until the entire image is transmitted.

To transmit a photograph on the telegraph line a proof of the original is taken on carbon paper transferred by the regular process to the copper cylinder, and after drying, an image in low relief is obtained. The transmission and reception goes on as has been already described.

Suppose, now, that someone is taking a picture with his kodak. He will take a proof in bichromated gelatin, which before drying he will place upon the cylinder of the Phototelegraph. Then he will go to the telephone booth, or to any private line, and will put his apparatus in communication with the line. At the other end his correspondent will connect his apparatus and receive the photograph. The operation is conducted without interfering with the use of the line for telephoning.

In the Summer and Autumn of 1921, Mr. Belin exchanged photographs and manuscript messages between offices of the "New York World" and the "Post Dispatch" of St. Louis. He also sent by telephone or radio, text and photographs from America to Europe. He has also adapted his apparatus for use with alternating current.

It is fair to call this one of the important developments in the electric transmission of intelligence, and one which should have profoundly influenced newspaper work.

Radio Teleinscription

That amateurs were already interested in the transmission of pictures by radio is evident by the following article on Radio Teleinscription, by Austin Riu which appeared in the October, 1921, issue of *Radio News* Magazine. Mr. Rui himself built the apparatus here shown and we will permit him to give his own description of its operation and construction.

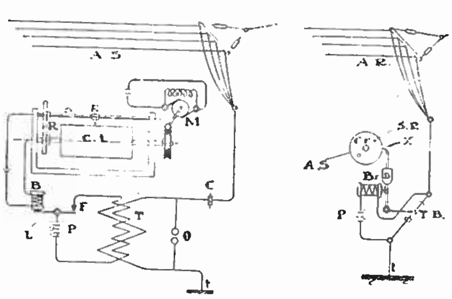


Fig. 30: Diagram of connections of both transmitter and receiver.

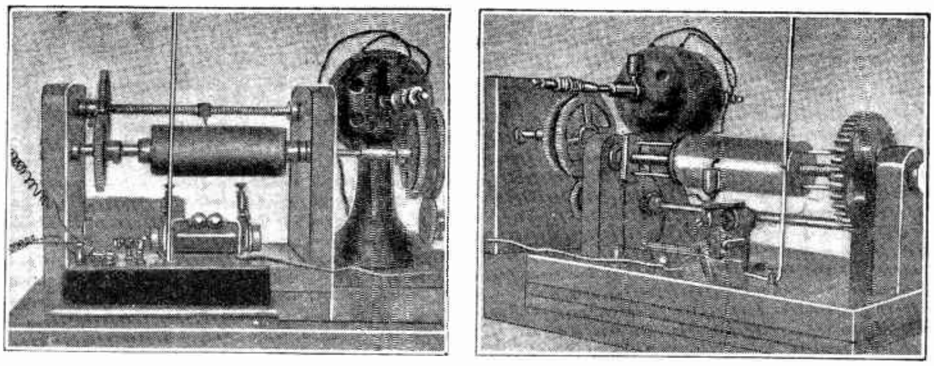


Fig. 31. On the left is the transmitting apparatus for the transmission of pictures by radio. The spark coil and gap may be seen fixed on the base supporting the whole set. On the right is the receiver with the coherer and writing device mounted on the electro-magnet armature.

"I shall endeavor in this article to describe a simple instrument that I built myself and which can be used for the transmission of drawings, documents or writing.

"In this experimental set, the new improvements of Radio were not considered and I used a Branly's coherer, which gave me very good results. Of course, if continuous waves were used with, at the receiving end, an amplifier and relay, the distance over which messages could be sent would be very much increased, but for experimentation I did not judge it necessary to complicate the set to such an extent.

"The construction of the transmitter and receiver is not very complicated for an amateur possessing a few tools and having enough hand-practice to turn out successfully a work of this kind.

"As may be seen in the diagram and on the photograph, Fig. 31, both transmitter and receiver consist of a cylinder having a constant angular velocity. The only delicate point is to adjust the speed of the motors in the two stations so that they run constantly at the same speed. A centrifugal regulator helps considerably in keeping the speed constant.

"Referring to the diagram, it may be seen that when the cylinder of the transmitting instrument runs, the two gears R run the screw S, displacing the piece E along the cylinder, in the same way as the diaphragm in the old-fashioned phonograph, thus exploring the whole surface of the cylinder.

"At the receiving station, the cylinder runs at the same speed as the transmitter, moving with two small rods SR and the axis screw AS. The transmitter cylinder is made of copper and is electrically connected with the two gears R. When it is desired to send a document, a map for instance, it is first drawn on the cylinder, (or a sheet of tinfoil, which is applied upon it) with insulating ink, then the device is started at both sending and receiving stations. At the latter station a sheet of white paper is glued to the cylinder. When the needle of the piece E is in contact with the copper cylinder, the electromagnet B attracts the lever L, but releases it when the needle comes in contact with the insulating ink, opening the circuit. The contact F then closes the circuit of the primary of the induction coil and a train of waves is sent through the aerial.

"At the receiving station this wave train impresses the coherer, closing the circuit of the battery P, and the electromagnet BR attracts the lever bearing the ink-well and pen supplied by capillarity, and marks a dot on the white paper covering the cylinder.

"It is easy to understand the complete process, which is a repetition of what was just explained, the drawing, map or writing being reproduced by dots very close together, forming continuous lines and reproducing perfectly anything which is set on the transmitter.

"It is important, in order to obtain accurate reproduction, to use a screw having a close pitch, as the screw S should move the piece E very slowly, so that it explores every spot of the cylinder while it rotates.

"In the instrument I built, the cylinders have a diameter of 2 5/16" by 4 1/2" long; with the screw S having a pitch of .02", four minutes are required to send a full drawing covering the entire cylinder.

In an editorial in the November, 1921, issue of *Radio News*, Hugo Gernsback tried to further stimulate the radio amateur's interest in the transmission of pictures. His editorial entitled "The Radio Experimenter" spoke of this phase of the radio subject in the following terms:

We have often in these columns urged the Radio experimenter to get off the "beaten track," and do something original. Of course, a good many of our amateurs are not asleep by any means, and are doing wonderful work, but they are very much in the minority these days, and for every amateur who gets off the "beaten track," there are at least a thousand who are satisfied to plod along in the good old way.

Why does not the amateur who has a little machine shop get off the "beaten track," and do some experimenting in the transmission of pictures? Once in a great while, we print an article from some enterprising amateur who has had the spunk to build such an apparatus. Just the same, we predict that when five, or ten years at the most, are up, every amateur will have his radio picture machine.

In 1921 the signatures of General Foch, and General Pershing were sent across the Atlantic by radio on the Belin apparatus. There is no good reason why the amateur cannot do the same thing for smaller distances at any time.

In the very near future, the amateur in New York will buy the first copy of a New York evening paper, wrap it around his cylinder, and send out a whole sheet by radio. A thousand miles away another amateur will have a receiving machine that will reproduce the printed page, type, pictures and all, in less than a half hour. This is a thing impossible to do by ordinary wireless telegraphy, if every word has to be transmitted. The radio picture transmission solves all this. Thus, in time, a great piece of news "breaking" in the city, will be sent broadcast by the enterprising amateur, who will send the entire front page of the newspaper, for instance, and the radio facsimile can then be exhibited in a distant town from 18 to 24 hours in advance of the receipt of the actual newspaper.

All this is not a mere dream; it has already been accomplished. It is up to the amateur to make the thing popular.

No informative work on telephotography would be complete without including the developmental ingenuity of Dr. Arthur Korn, the professor of physics in a German Technical School. Dr. Alfred Gradenwitz further described this work in the July, 1922, issue of *Radio News*. It might be mentioned here that Dr. Gradenwitz is a Berlin correspondent of both *Radio News* and *Science and Invention* and he is well posted in giving authoritative information. This subject has already been touched upon in previous pages as related to wire transmission.

Dr. Korn's Apparatus

The story of many an achievement of modern science sounds more romantic than the wildest products of human fancy: reality often is more marvelous than boldest fiction. Let me tell you the tale of the portrait sent out into ether on the waves of electricity, picked up anywhere within the range of the sending outfit and reconstituted within a minimum of time.

Some days ago, I had the pleasure of meeting Dr. Arthur Korn, Professor of Physics at the Berlin Technical High School, who had just come back from Rome, where, on an invitation by the Italian Government, he had submitted his methods of Tele-Photography to severe, and most successful tests. He gave me an account of these tests, handing me at the same time some excellent tele-photographic prints for reproduction in this magazine. The following is the substance of his report:

Prof. Korn's method for the wireless and cable transmission of photographs had, truth to say, already been worked out in principle in 1914, and the first practical tests between Europe and America were to have taken place in connection with the San Francisco World Fair. The construction of the experimental outfit to be used to this effect was delayed by the war. Though laboratory tests, as far back as in 1915-1917, gave excellent results, the first opportunity of makings tests between remote stations was afforded in the year 1922, when from the Centocelle (near Rome) radio station, photographs were sent by wireless to ships on the high sea as well as to Massaua (Abyssinia, Red Sea); the presence of the King of Italy with the first transmissions lent additional solemnity to the inauguration of this method, which was then used for wireless picture transmission between Rome and the United States.

Fig. 32: Portrait of the King of Italy transmitted by radio by Dr. Korn in experiments conducted at the request of the Italian government.

Inasmuch as the receiver—apart from the usual wireless receiving outfit—only requires a special typewriter, no material difficulty had to be overcome at the receiving end. The sender, which is the most important and most interesting part of the plant, was installed in Rome by Dr. Korn himself and his assistant, the Italian engineer, Carazzolo. In the case of telephotographic transmission to ships, an Italian marine officer would take the special typewriter with him on board the vessel where pictures were to be received. One picture was received on board the armored cruiser "Andrea Doria" off Spezia, another on a torpedo-destroyer cruising on the high sea. In connection with radio-telephotographic transmission from Rome to Massaua, the picture being sent (the King's portrait, shown here) was at the same time recorded on a checking typewriter in Rome; in order to make sure that the radiogram representing the picture had been received correctly at Massaua, this radiogram was sent back by wireless from Massaua. These tests actually showed the typewriter method to be admirably suitable for cable as well as for wireless transmission to any distance.

Though the method itself has been discussed at length in my article on the "Cabling of Photographs," published about the year 1920 in the ELECTRICAL EXPERIMENTER, it will be well to briefly recall the underlying principle as well as any alterations resulting from the substitution of radio for cable transmission:

At the sending station, there is installed a glass cylinder rotating around and advancing along its axis, on which the original picture—in the form of a translucid film—is wound. The light from a Nernst lamp (which is a very bright and constant illuminant) is, by a convenient lens system, concentrated on a small element of the picture; owing to the rotation and progression of the cylinder, the various picture elements will thus in succession come into the focus of the lighting system.

After penetrating through the photograph and the glass cylinder, the light will strike a selenium cell, traversed by the current of a constant battery. Inasmuch as this light is more or less intense, according to the variable graduations of successive picture elements, the electrical conductivity of the selenium cell will vary in proportion, and along with it the current intensity passing through the line. The sensitiveness of the arrangement is greatly increased by substituting a pair of selenium cells to a single cell.

Whereas in the case of Korn's telephotographic method, these currents varying in intensity in accordance with the various shading of picture elements, are at the receiving station, by inverting the stages of this process, used to reconstitute the original picture, they, in the present case, serve to produce what the inventor terms a "provisional record," representing the sequence of picture elements in a perforated tape or in a series of letters, the various combinations of holes (or letters of the series) constituting a predetermined scale of shades. Let us suppose, for instance, that an "A" corresponds to the lightest shade and a "Z" to the darkest, the other letters corresponding to intermediate shadings. Prof. Korn has, for the first time, by means of a remarkably sensitive relay, thus succeeded in automatically converting the original photograph into a letter telegram. This can, independently of the tele-photographic outfit, be sent by radio to the receiving station, in order there to be reconverted into a picture. To this effect, a special typewriter is provided at the receiving end, where each type, in

Fig. 33: This portrait of Mrs. Arthur Korn, wife of the inventor, was the first to be transmitted by this system.

the place of the letter marked on the keyboard, will record a minute square of corresponding shade, thus reconstituting, element by element, the original picture.

About one thousand words are required for a portrait; a special code, however, enables this to be reduced to three hundred words. From a wireless station, a given photograph can simultaneously be sent to any number of other radio stations (also to ships on the high sea), if these, in addition to an ordinary radio receiver set, comprise a typewriter such as above described.

This method will find useful applications in the illustrated press, in banking and other lines of commercial activity, for the broadcasting of meteorological bulletins, for advertising and, alas, for military purposes as well. One of the most important uses, however, will be for the purposes of the criminal police, portraits of criminals being, in a minimum of time, circulated broadcast in all directions and to any distance, and being even received on board ship.

The Dieckmann Process

This is a method for the wireless transmission of drawings and refers primarily to its application in aviation as given by Dr. Gradenwitz in *Radio News* for August, 1922. In this system the D'Arlingcourt principle of synchronization is carried out. Here one cylinder is made to operate a trifle faster than the other. Generally the receiver operates quicker. Part of the revolution is for the picture transmission and

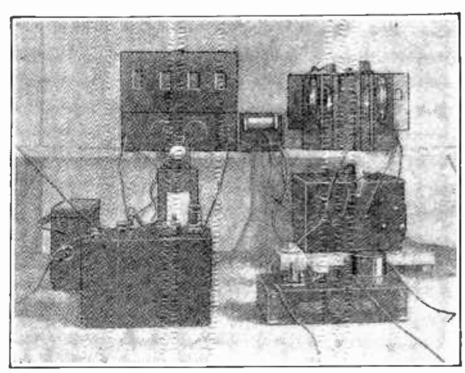


Fig 34: A view of a complete station for sending and receiving pictures by radio; on the shelf are the amplifiers and in the foreground the transmitter and relay.

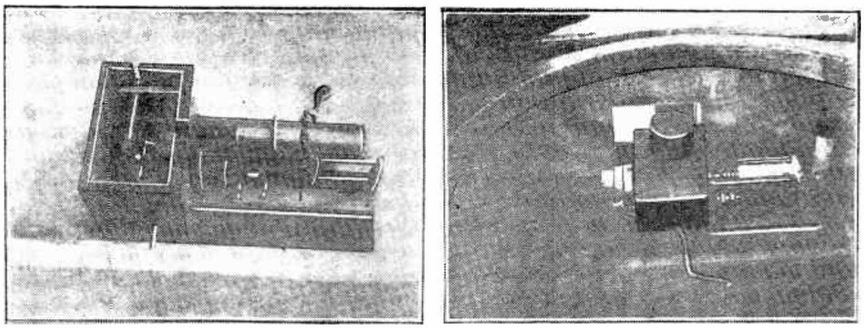


Fig. 40. Two views of the cylinder bearing the picture with the synchronizing system. On the right it is shown installed in an airplane

the remaining smaller portion, for synchronization at each revolution.

During the last stage of the war, the German army tried to develop radio-telephotography for the rapid transmission of drawings, sketches, reports, etc., from aeroplanes to stations located on the ground or on board ship. Inasmuch as the Armistice luckily cut short all war-like pursuits not immediately followed by any practical realization, but the method seemed to be a good one and will likely be put to peacetime applications. This is sufficient reason for our placing an account of it before our readers:

The method is the invention of Dr. Max Dieckmann, director of the Research Laboratory for Radio Telegraphy and Atmospheric Electricity at Graefelfing, near Munich, and can, of course, with but slight alterations, be as well adapted for telephotographic transmission over telephone or telegraph lines. Figs. 35-39 show the arrangement of the transmitting and receiving stations as well as of the synchronizing device.

The sending station comprises a standard sender for damped or undamped waves. A telautographic transmitter is connected up in parallel to the key. This consists of a clockwork *a*, which drives a cylinder *b*, carrying at its circumference the picture to be transmitted, and a contact style *c* which, as the cylinder is turning, explores the picture in an helical line. The cylinder and contact style are connected up to the key either directly (in the case of small senders) or (in the case of big senders or if an inversion of the picture from "positive" to "negative" is desired) through the intermediary of a relay *R*. Inasmuch as the picture, etc., is drawn with conductive ink, the circuit will be closed and a train of waves sent out into space, each time the style is in contact with some portion of the picture.

The antenna at the receiving end is connected up to a standard receiver for damped or undamped waves working on a telephone over a sound amplifier. The telautographic receiver is inserted in the place of the telephone receiver or in parallel to it and, like the sender, mainly consists of a clockwork *d*, a cylinder *g* driven by the latter and carrying at its circumference the recording paper, the recording style *q* and, finally, an arrangement for "synchronizing" the sending and receiving cylinders, i.e., for insuring uniform working of the cylinders, Fig. 35. Connection with the amplifier is not made directly, but through the relays R2, R3 and a rectifier. A short description of the synchronizing device is given in the following:

According to the D'Arlincourt principle, the uniformity of working between the sending and receiving cylinders is, in the case of telautographic methods, generally obtained by causing one of the cylinders to complete each rotation slightly before the other, arresting it the time required for the other cylinder to make up for its delay and, eventually, releasing it by the action of an electro-magnet.

Now, in order to have to use two forms of current—differing as to their intensity, direction, wave-length, etc.—for actuating the synchronizing device, on the one hand, and reproducing the original picture, on the other, Dr. Dieckmann uses the following ingenious arrangement:

Of the total time available for each rotation of the cylinder, part is used exclusively for picture transmission, and part exclusively for synchronizing. Figs 36 to 38 will serve to make this clear. For the sake of simplicity, Fig. 36 has been drawn on the hypothesis that the receiver and sender communicate directly over a wire, it being, of course, immaterial whether the recorder receives its impulses over a line of conductors or by wireless from a radio station. The dotted sections of the line in Fig. 36 should, therefore, be replaced by the organs of wireless transmission.

As seen also in Fig. 36, the sending cylinder *b* is set rotating by a clockwork, the contact device *c* being at the same time shifted so as to explore the circumference of the cylinder *b* along a spiral (helical) line, a current being closed or opened in accordance with the conductive or non-conductive condition of the various portions of the picture. The clockwork at the receiving station will, in a similar way, set the shaft *d* rotating, which through the friction clutch *f* carries along the receiving cylinder *g*, unless this be stopped by a locking device.

This locking device, as represented apart in Fig. 37, comprises an electro-magnet *h*, a stop lever *i* kept back by a spring, and a cam *k* rigidly connected with the receiving cylinder. The current at the receiving end simultaneously flows through the electro-magnet of the recording style *q* and that of the locking device *h*.

When no current is flowing through the electro-magnet, the receiving cylinder *g* is free to rotate, and the same will be the case if some current flowing through the electro-magnet *h*, the lower part of the stop lever is attracted (see dotted position in Fig. 37), provided that the cam *k* is not opposite the upper end of the stop lever. Only in case the passage of the cam in front of the upper part of the lever *i* coincides with the excitation of the electro-magnet *h*, will the receiving cylinder be stopped, the time taken by the current through the magnet *h* to cease and by the stop lever *i* to be released by the spring.

A band of a width corresponding to *m* (Fig. 38), and transversal to the direction of rotation, is, on the receiving cylinder, reserved for synchronizing. This band comprises three sections *n* lying between two sections *o* and *p* free from any telautographic reproduction. The width of the central section should be such as to make

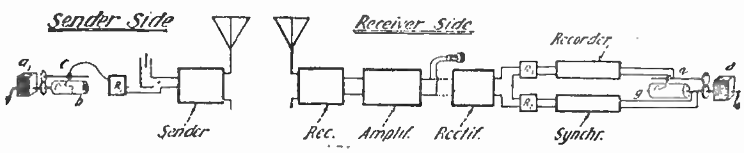


Fig. 35

These sketches show the system of picture transmission by radio and line telegraphy. It was developed during the war for the needs of the German army

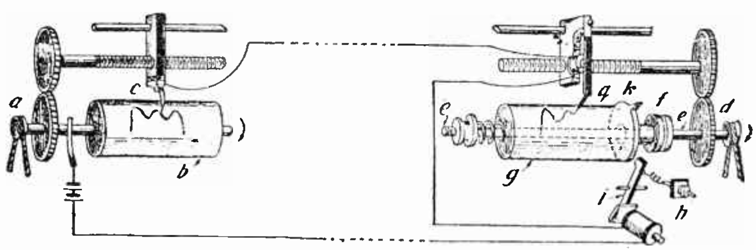


Fig. 36

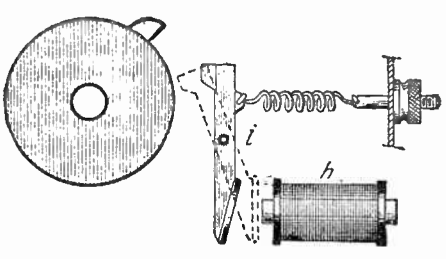


Fig. 37. The synchronizing system

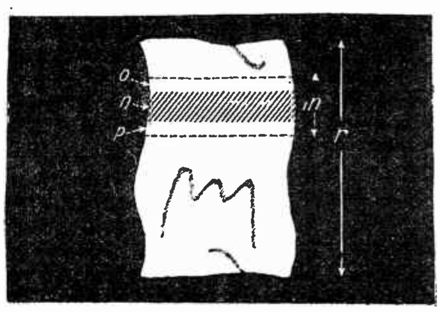


Fig. 38. A developed view of the cylinder showing the marks used for synchronizing the receiving apparatus

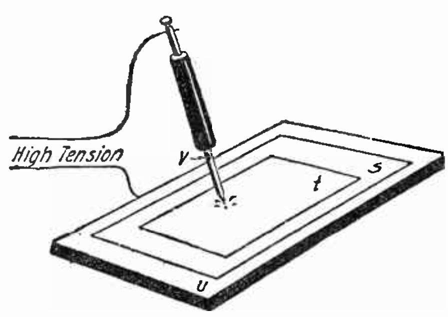


Fig. 39. This sketch illustrates how colored pictures may be sent by radio by means of special papers supporting some colors which are melted by the heat of a spark passing through

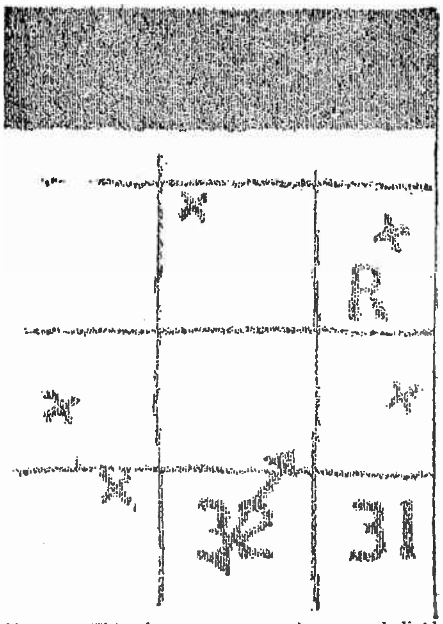


Fig. 41. This chart represents the ground divided into squares with the position of guns as seen from an airplane. This picture was sent from an aircraft to its base by radio.

the time required for passing through it greater than any possible difference in the working of the two cylinders.

While the sending cylinder is rotating, current impulses will be sent out in a sequence corresponding to the conductive or non-conductive portions of the picture the style is sliding over, and these impulses will in the receiver both actuate the recording style *q* and excite the magnet *h*. If the cam *k* then has once been stopped by the stop lever, while the contact style *c* was sliding over the picture section *n*, it will with the next revolution again find the stop lever *i* ready to stop for the synchronization, provided that the width of *n* is sufficient in proportion to the necessarily higher number of revolutions of *g*. If there is a possibility of the receiving cylinder *g* rotating at double the speed of the sending cylinder *b*, the band section *n* will have to be of a width more than half the height *i* of the picture. If the possible difference in the rotation of the two cylinders is less, *n* may, of course, be chosen narrower in proportion.

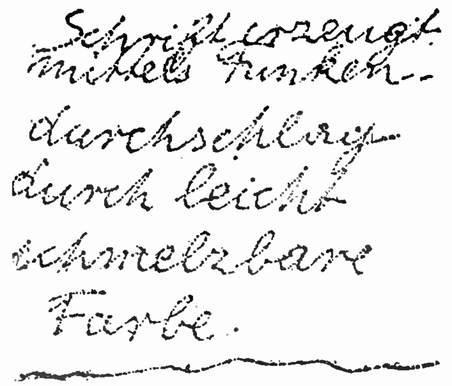


Fig. 42. The writing sent by the process described in this article is quite readable and instructions may be sent by this system which are not understandable to any station but the one to which it is sent as both apparatus are synchronized.

This synchronizer is so safe in working and so substantial that ordinary gramophone motors with coarse regulators may be used to drive the sending and receiving cylinders.

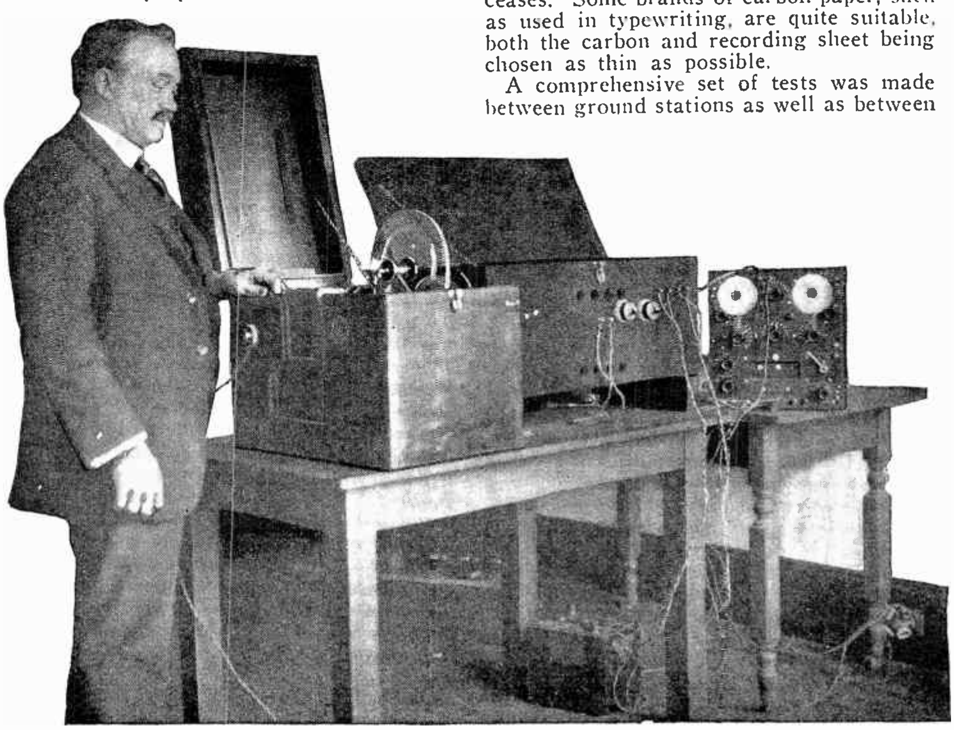
As regards, finally, the production of electrically conductive (or non-conductive) drawings to be used for transmission to a distance, a number of methods have been suggested, the use of "fat" pencils for drawing on non-varnished metal foils having proved quite suitable. On the other hand, there was no simple method available for the immediate reproduction of colored marks at the receiving station. Dr. Dieckmann, therefore, designed a new process allowing colored marks to be produced in a most simple manner and which would seem to be suitable also for a number of other purposes. Fig. 39 will make the underlying principle clear.

To the recording surface *s* there is applied a thin paper of tissue *t* coated with a layer of an easily melting color, which is turned toward the recording surface. Below the recording surface there is placed the conductive lining *u*. If now a small electric spark be made to pass between the point of the recording pencil *y* and the lining *u*, the heat of the current will be sufficient to melt the color at the point pierced by the spark and to reduce it to a liquid condition. The recording surface at that point is thus covered with an adherent color solidified immediately as the spark ceases. Some brands of carbon paper, such as used in typewriting, are quite suitable, both the carbon and recording sheet being chosen as thin as possible.

A comprehensive set of tests was made between ground stations as well as between aeroplane and ground stations. Each original sheet was 13x18 cm in area, of which about 13x15, i.e., about 200² cm corresponded to the picture proper. With screws having an 0.8 mm. thread, the width of the picture comprised about 180 strokes, while in the case of a satisfactory adjustment the length of the shortest marks likewise was about 0.8 mm. The available picture area thus could be covered with 160x180=28,800 picture elements. About five to six minutes were required to cover the whole picture sheet, 80 picture elements being produced in less than a second and 4.800 in a minute. This limit should be warranted in order to insure reliable working of the electro-magnetical relays.

Some of our pictures were taken during tests made in October, 1918, i. e., immediately before the end of the war. The method, in this connection, was found fully

Fig. 43. Rough sketch sent by radio. Note the details which are visible. All these pictures are here shown full size.



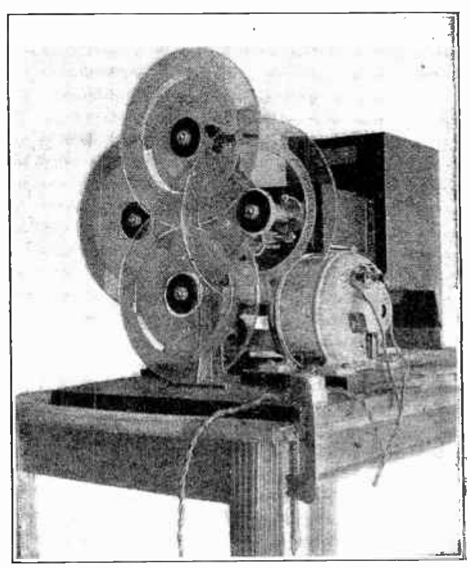


Fig. 44—Left. Mr. C. F. Jenkins and his apparatus for the transmission and reception of photographs by radio. This apparatus copies half-tone camera studies from flat surfaces, transmits them, and at the receiving end they are impressed on common photographic plates.

Fig. 45—Above. Part of the receiving apparatus. By use of these revolving glass rings, the lights and shadows of a picture are built up, line by line.

suitable for the transmission of topographic sketches, reports, etc., from aeroplanes to the ground.

The C. F. Jenkins System

Already in the early part of January, 1923, the transmission of photographs was an accomplished fact. At this time pictures of the late President Harding and former Secretary of Navy Edwin Denby were borne on electromagnetic waves from the radio research laboratory of the United States Navy Department at Anacostia, D. C., to the second floor of a building at 1519 Connecticut avenue, a distance of approximately seven miles. The process of sending the likenesses of these Government dignitaries required about six minutes each and at the receiving point the lights, shadows and half-tones common to picture reproduction were impressed on a conventional photographic plate.

Some of the photographs transmitted by radio, among them being pictures of late President Harding and former Secretary of Navy Edwin Denby. The photo marked 2 shows each shaded line as it was received.

The transmission of photographs by both wire and wireless even in 1923 was not a recent scientific departure. A Frenchman, a German, and an Englishman, had already been credited with having invented methods for speedy conveyance of pictures by radio, but for the most part line etchings were the mediums by which the picture characteristics were translated into photographs at the receiving points. Invariably, too, all photographs were transmitted and received on cylindrical surfaces. The demonstration signalized in Washington, the fruition of an invention of C. Francis Jenkins. This was the first time in which half-tone camera studies were copied from flat surfaces, impinged on electro-magnetic waves, and impressed on common photographic plates at the receiving point. When developed, these negatives proved to be likenesses of the subjects treated at NOF, the naval radio research laboratory at Anacostia.

The demonstration was witnessed by representatives of the United States Navy Department, United States Post Office Department, and the amalgamated motion-picture industry. The interested group of spectators from the Navy Department included Admiral F. S. Robinson, member of the general naval board; Admiral Henry R. Zeigmeir, in charge of the bureau of communications; Commander Stanford C. Hooper, head of the radio division of the Bureau of Engineering; Captain J. T. Tompkins, and Lieutenant-Commander E. H. Loftin, in charge of patents for the radio division of the Navy Department. J. C. Edgerton, then in charge of the radio division of the Post Office Department, and John M. Joy, representing the motion picture industry, also viewed the reception of the pictures at the laboratory of the inventor, at 1519 Connecticut avenue.

The transmission of the photographs from Anacostia was supervised by Commander A. Hoyt Taylor, in charge of the radio research laboratory of the Navy Department at this point, or NOF, as it is popularly identified by wireless amateurs. Four subjects were broadcast within one-half hour, photographs of the late President Harding and the then Secretary of Navy Denby, and two penciled sketches. The latter consisted of a map and a sketch containing both written and printed letters. The likenesses of President Harding and Secretary of Navy Denby, as may be seen from the prints here reproduced, are not clear from a photographic viewpoint, but the resemblance of the subjects is faithfully preserved. Six minutes were required in which to effect the transmission of each photograph, a period of time the inventor contemplates reducing to one-sixteenth of a second. The latter time factor, if made possible, will render feasible the broadcasting of motion pictures.

We shall later see this was actually accomplished in this and in another manner.

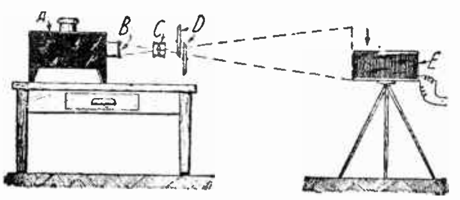
The photographs of the two Government dignitaries were transmitted from Anacostia on a wave-length of 412 meters. While the pictures are being sent through space, a strange, irregular noise may be heard by those having radio-telephone receiving sets. Consequently, the newspaper reporter who used the caption "Pictures Seen and Heard in Radio Demonstration," in his story of the event, did not distort the fact to such a great extent, save that he might have added that these noises cannot be interpreted. Variations in picture characteristics, of course, cause changes in the sounds produced. Moreover, James Robinson, a laboratory assistant of the inventor, was enabled to identify the picture of Secretary of Navy Denby as it was being received since he had transmitted and received this particular photograph so frequently previous to the official demonstration that certain sounds seemed to be common to the picture characteristics of the likeness of the subject. Other wireless receiving outfits in the vicinity of Washington, in resonance with a wave-length of 412 meters, doubtless "heard pictures being broadcast," but were unable to determine the cause for the strange sounds.

The transmitting unit in appearance resembles a stereopticon machine, and really some of the mechanism fits this description. The photographic copy, sketch, sheet of music, or other positive print is first illuminated, either by a projection lantern or stereopticon. Stationed directly in the path of this illuminating device are four prismatic rings, which revolve about their axis. Two of them rotate very much slower than the other pair. Concerning this prismatic ring, Mr. Jenkins says:

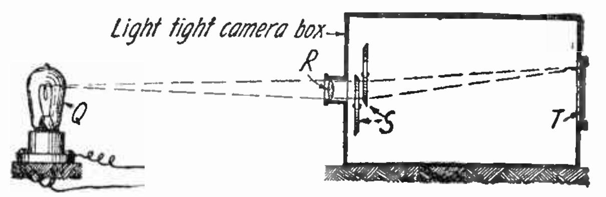
"The prismatic ring is equivalent to a glass prism which changes the angle between its faces, and in rotation gives to a beam of light having a fixed axis on one side of the prism, and a hinged or oscillating axis on the other side of the prism.

"That is, a small pencil of light coming from a fixed source and passing through the overlapping surfaces of two rotating prismatic rings, having their diameters at right angles where the diameters cross, and one of the plates rotating many times faster than the other, will cause this pencil of

(*Continued on page* 108)



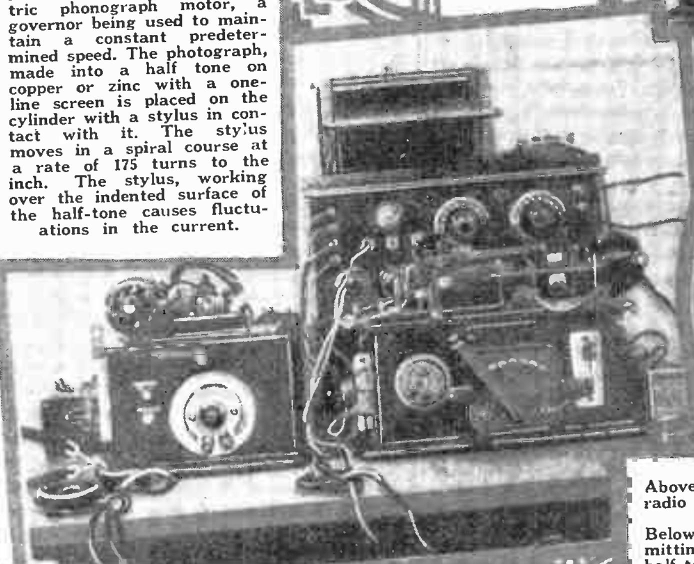
Left: Picture Broadcasting station. A—Magic Lantern. B—Picture. C—Lens. D—Rotating Prismatic rings. E—Light-sensitive cell box. Right: Receiver. Q—Fluctuating light. R—Camera lens. S—Prismatic rings. T—Camera plate holder.

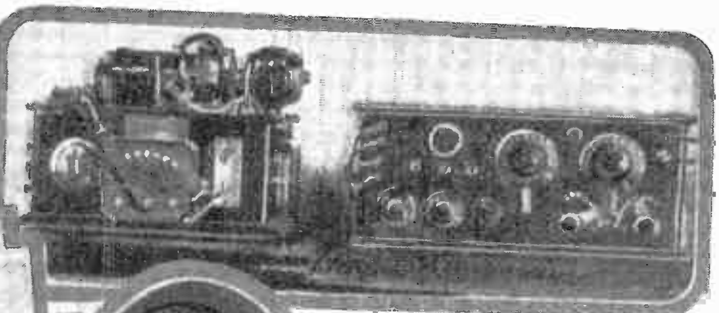


The Ferree System

In the January 1924 issue of Science and Invention Magazine, A. P. Peck described a system of transmitting photographs by radio. The image received was reproduced on chemically treated paper by an electrical current. The current itself changed the color of the paper. Samples of the actual photographs and their reproduction appear on this page.

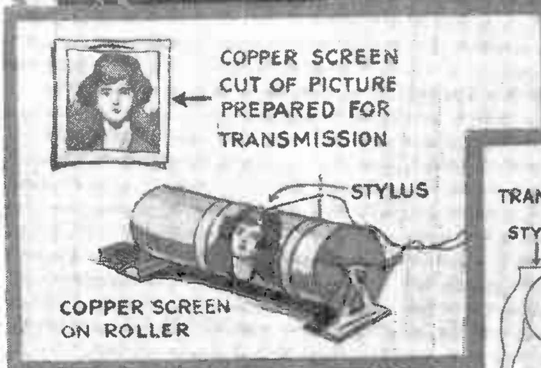
Below and to the right will be seen the transmitting apparatus used in another system for sending photographs by radio. As will be noted, the apparatus takes up little more space than the average receiving set. A cylinder is rotated by means of an electric phonograph motor, a governor being used to maintain a constant predetermined speed. The photograph, made into a half tone on copper or zinc with a one-line screen is placed on the cylinder with a stylus in contact with it. The stylus moves in a spiral course at a rate of 175 turns to the inch. The stylus, working over the indented surface of the half-tone causes fluctuations in the current.

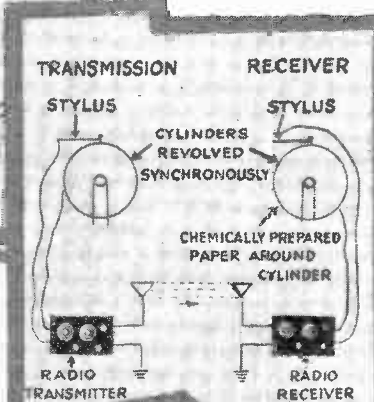


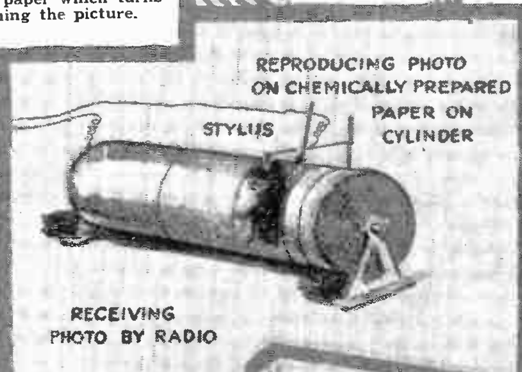


Above: The receiving apparatus used by Mr. Ferree in the reproduction of photographs transmitted by radio. At the right in the above photograph is a standard radio receiving set and at the left will be seen the apparatus for reproducing the transmitted photograph. Mr. Ferree has perfected his apparatus to a very great extent. With this apparatus, it is possible to carry on communication over the same lines on which the photograph is being transmitted, both transmissions taking place simultaneously.

Above: The inventor of the system of radio and wire transmission of photographs, Marvin Ferree.
Below at left: A diagram of the transmitting cylinder and stylus contact. The half-tone is prepared on either a copper or zinc plate and then formed on the cylinder so as to fit the latter perfectly. The cylinder turns at the same speed as the receiving cylinder pictured below at right. The receiving stylus acts on a chemically prepared paper which turns black or gray, forming the picture.







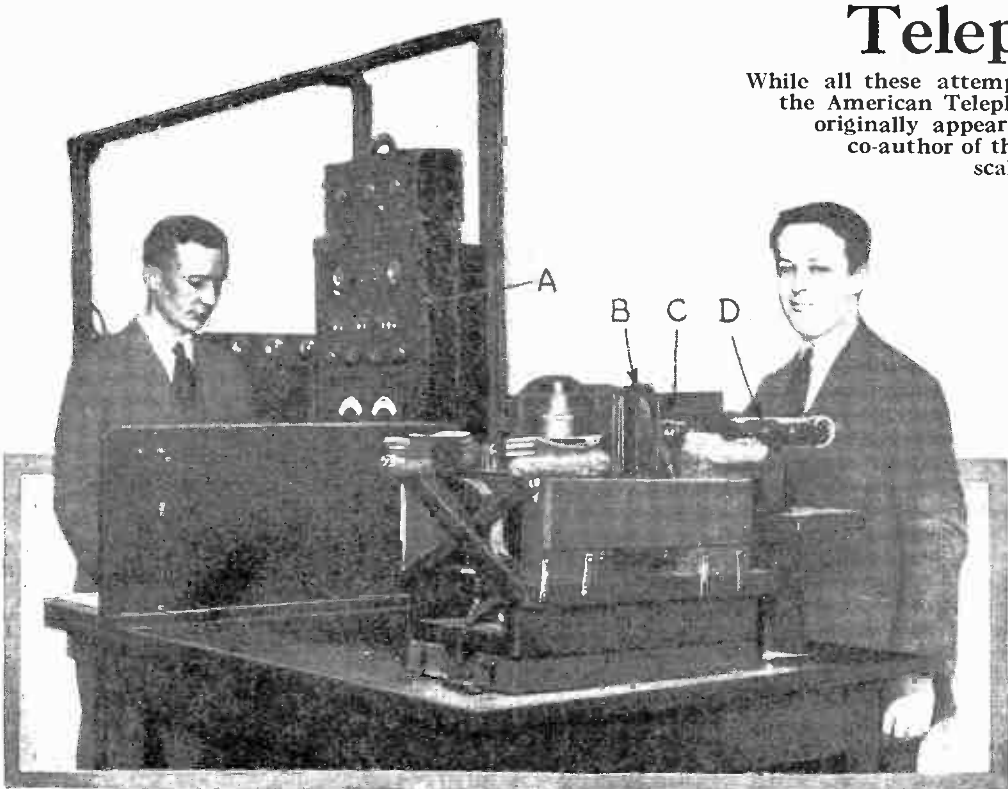
Above: The original photograph and reproduction after being transmitted by radio. The top photograph is the original and the bottom one the reproduction. At the receiving end, no trace of the screen used in making the half-tone is visible, the only effect being a few vertical lines.

Above will be seen two unretouched photographs of America's most beautiful girl, Miss Catherine Campbell. The original is at the left. The reproduction at the right was telegraphed over a 400 mile line. The entire time of transmission is in all cases less than five minutes.

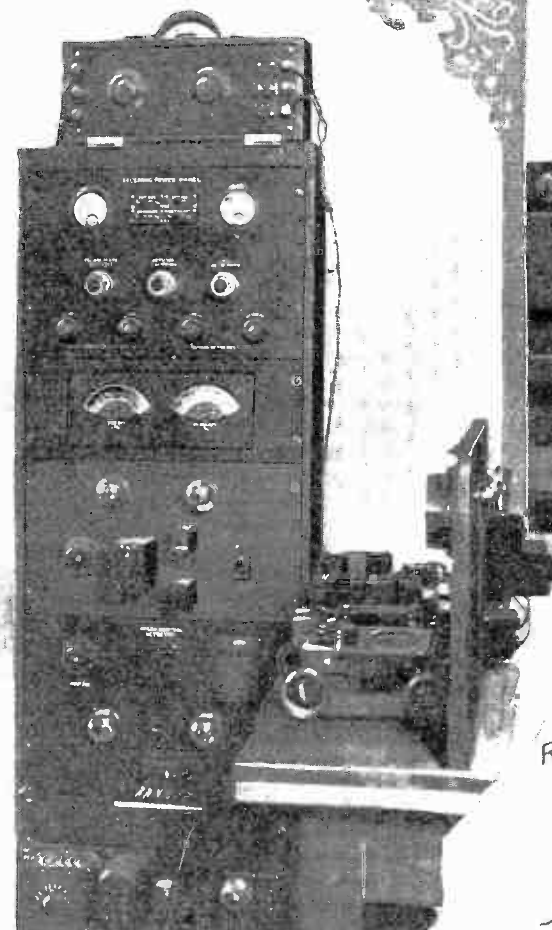
The scene of an automobile accident transmitted 900 miles by radio. The original is the lower photograph and the transmitted copy is at the top. With later developments along this line better transmission will undoubtedly be accomplished and practically perfect photographs will be reproduced.

Telephone Wires

While all these attempts at the transmission of photo the American Telephone and Telegraph Co. were not originally appeared in the July 1924 issue of Science co-author of this work. At the present day, this scale of prices for the transmission of



Through more than 600 miles of telephone wire and dozens of switchboards, photographs have been transmitted by a device of the American Telephone and Telegraph Co., from Cleveland, Ohio, to New York City. The detail of the reproduced pictures were so perfect that half-tones of them were made and published in the daily papers in New York. The actual wire transmission required but four minutes and thirty-six seconds. In a recent test, a picture taken on the streets of Cleveland was reproduced in New York in less than forty-four minutes after the camera man snapped his shutter. In the photograph at the left, A is the control switchboard containing the vacuum tubes, meters and other apparatus not a part of the immediate receiver; B is the light valve; C is the lens and D is the film revolving on the cylinder.



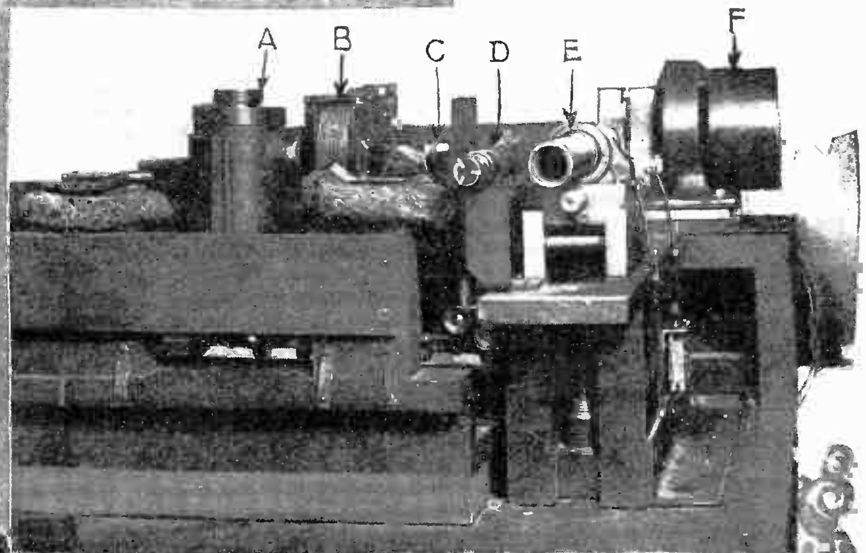
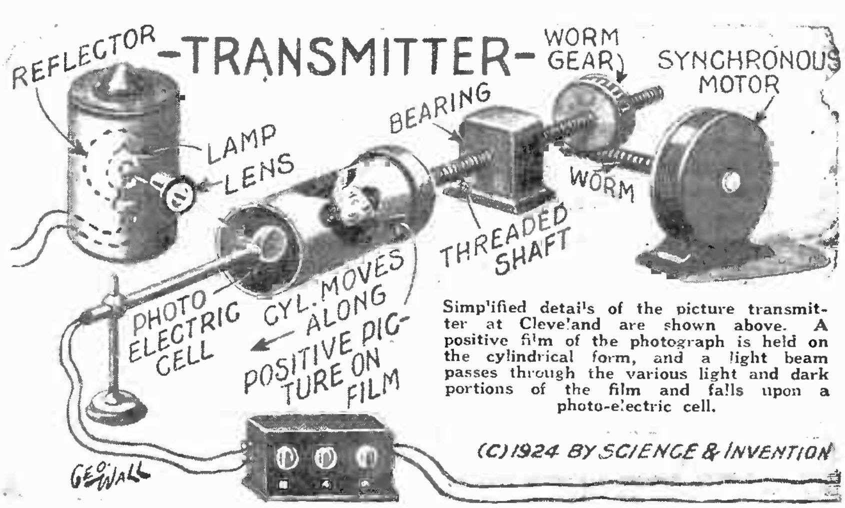


Photo above shows close-up end view of receiving cylinder, E, containing the photographic film. This cylinder, E, is driven by synchronous electric motor F. A strong light beam from housing A, passes through the light control valve B, and lens C, on to the film on revolving cylinder E. D represents prism and telescope for checking light ray form. The receiving apparatus room is lighted with red lamps.



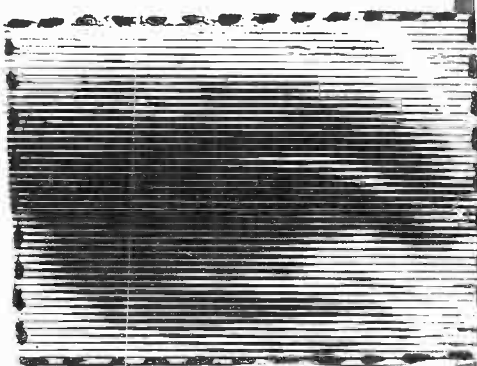
Simplified details of the picture transmitter at Cleveland are shown above. A positive film of the photograph is held on the cylindrical form, and a light beam passes through the various light and dark portions of the film and falls upon a photo-electric cell.

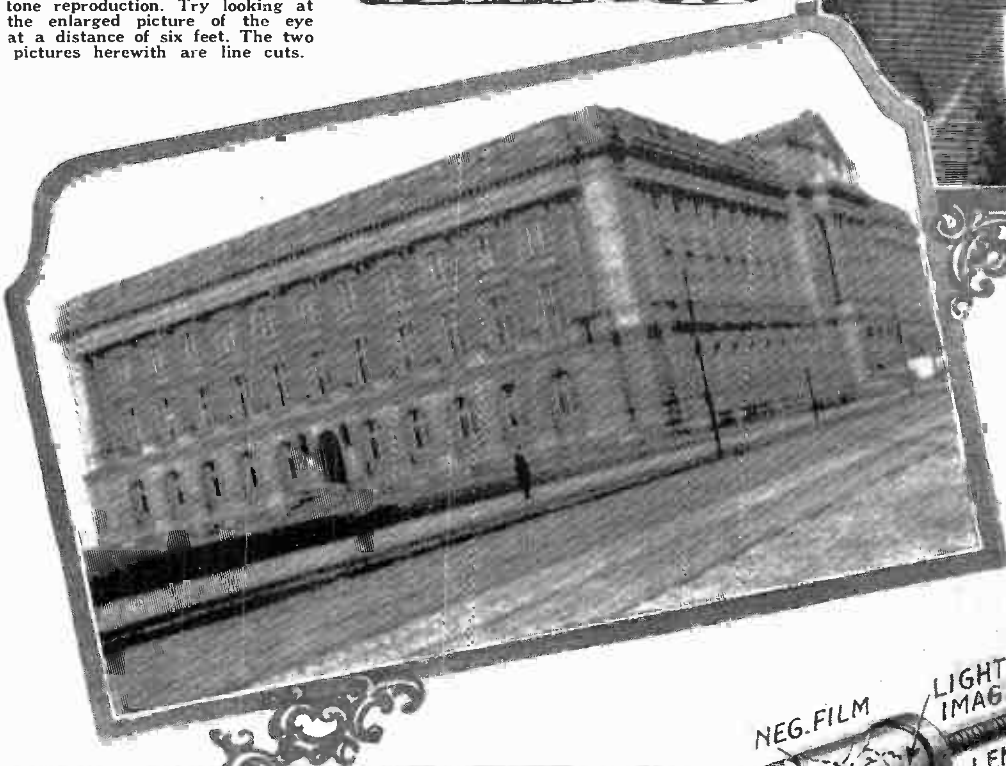
Front view of the control panel, A, at receiving station showing power vacuum tubes, meters, etc. This apparatus is seen at the left of the picture at the top of page, the operator behind the center panel board giving the signal to Cleveland when the apparatus has had a new film placed on it, and everything is ready for reception of the picture.

Carry Pictures

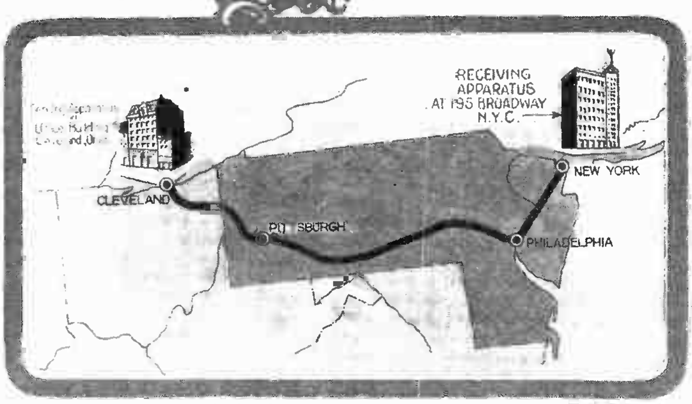
graphs were going on by either wire or radio, code or other systems, standing idly by as the following article clearly shows. This and Invention Magazine and was written by H. Winfield Secor, system is so perfect that it is in daily use and a regular photographs across the continent is posted.

The picture at the right shows a close-up of a greatly enlarged view of President Coolidge's left eye, the exact area being indicated by dotted lines in his portrait at the extreme right. The uncanny manner in which the picture is traced by the constantly fluctuating beam of light at the receptor is made more evident by a close study of the two photographs shown herewith, and particularly the enlargement of the eye. The picture is made up of lines of varying width which correspond to the light and dark portions of the picture. The two photographs reproduced herewith appear in fine engraving, but they may also be reproduced in half tone, using 65 screen, corresponding to the pitch of the lines on the apparatus as now set up. The print has to be turned 45 degrees in photographing it through a screen for halftone reproduction. Try looking at the enlarged picture of the eye at a distance of six feet. The two pictures herewith are line cuts.

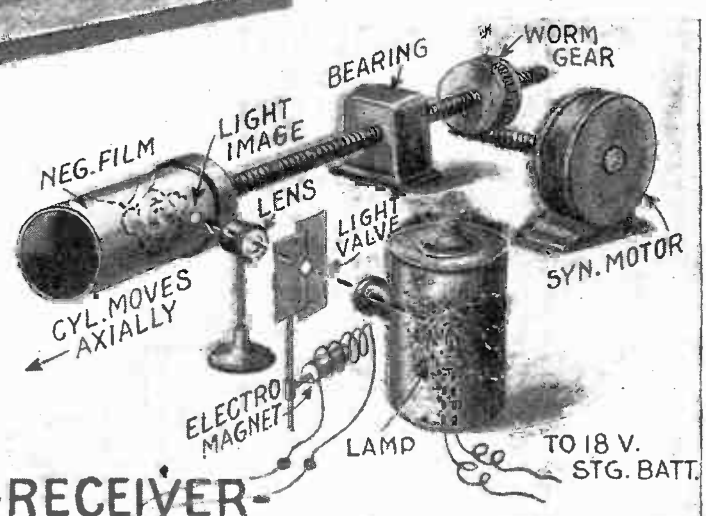




The picture above of President Coolidge and the picture of the building at the left, both of which were transmitted from Cleveland to New York City, in approximately four and one-half minutes, give a clear idea as to the excellent results obtained by this new system of transmitting pictures over an electric circuit, as developed by the engineers of the A. T. & T. Co., and the Western Electric Co. These experts succeeded in transmitting pictures in 1923, but it was in 1924 that the first public demonstration was held. The commercial aspects of the new picture transmission system were not as well worked out as they are at present.



The circuit over which the picture currents traveled between Cleveland and New York City is shown in the official map above. Vacuum tube amplifiers as shown in the diagram below, were used at certain points along the line to boost the picture currents and the vacuum tube found another role in supplying the necessary control currents for the synchronous motors.



Here we are at the receiving end of the picture transmission circuit. The fluctuating electric currents passing over the circuit (radio transmitting and receiving stations may be used) act on the magnetically controlled light valve shown above, which constanty changes the diameter of the beam of light passing through the lens on to the unexposed film rotating progressively before it, and causes lines of constantly varying constriction to be photographically formed on sensitized film. The synchronous motor and worm gear rotate the receiving cylinder in exact step with the cylinder at the transmitter. With a positive film used at the transmitter, the received image will be in the form of a negative. As soon as this is developed, prints can be made.

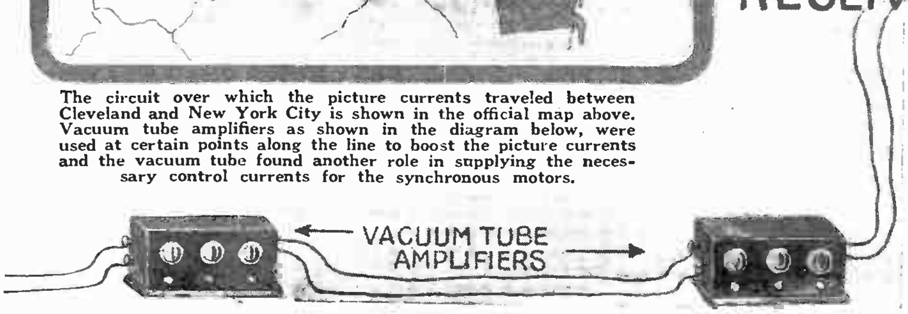


Photo Radiograms

In February, 1925, Leon L. Adelman described how the photo radiograms were transmitted back and forth across the Atlantic Ocean. This was the result of a development of the Radio Corporation of America who also, at the present writing, have a scale of prices for photo transmission from one continent to another. Already one will see that the transmission of photographs has been placed on a commercial basis.

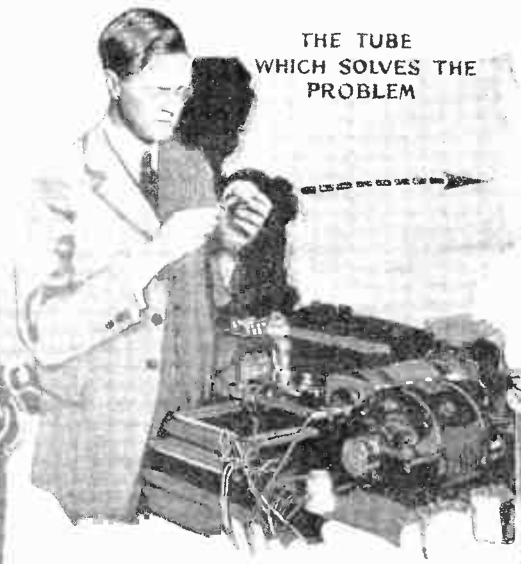
The era of rapid transmission of pictures from country to country by means of radio is here. Across thousands of miles of space, hurdling oceans and continents alike, this agency we call Radio has been harnessed to carry the images of places and personages and happenings in one corner of the world to places and people in distant countries.

The full extent of this accomplishment cannot be foreseen at this time. But one can believe it to be a great forward stride in radio science, and an important contribution towards "localizing" the news of the world.

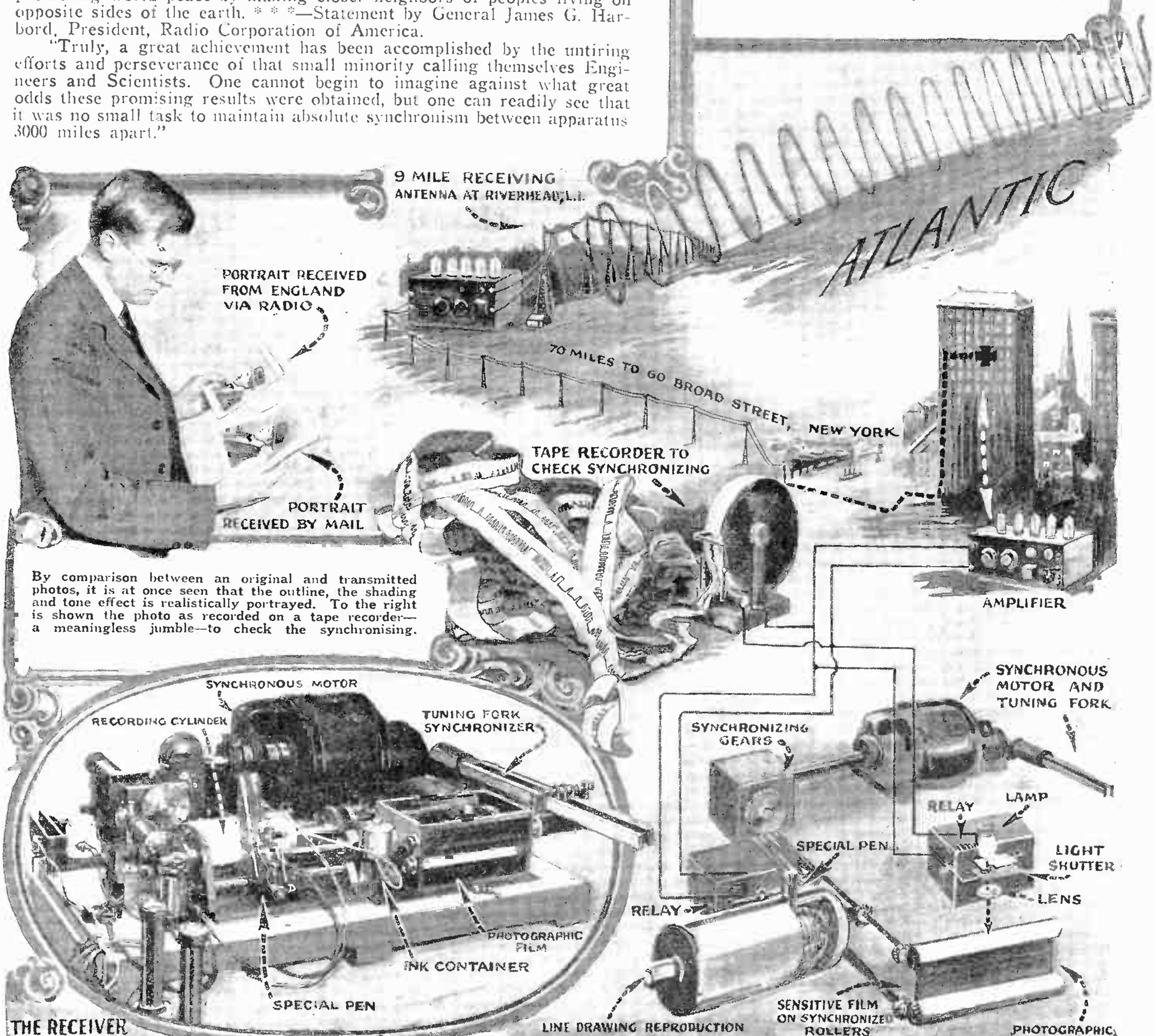
As we study the forward marches of science and their effect of steadily shrinking the world to what will ultimately become a single, big community of fellow humans, we must admit the growing necessity for the development of a universal language. Until this new process is worked out in its tedious way and accepted by the nations of the world, Photo-radiograms, which speak the truly universal language of pictures, will go far to bridge the gap that different latitudes and tongues have interposed between the peoples of this sphere on which we live.

There is an old Chinese proverb to the effect that "One picture is worth ten thousand words." This is as true today as the day it fell from the lips of the Chinese sage, for, since primitive man made his first crude drawing, pictures have been in constant use. So innate is our "picture sense," through centuries of cultivation, that one good picture may truly convey to us, at a glance, an idea or story that would require many words in the telling. It is not too much to suggest that the transmission of pictures across the world will play an important part in promoting world peace by making closer neighbors of peoples living on opposite sides of the earth. * * *—Statement by General James G. Harbord, President, Radio Corporation of America.

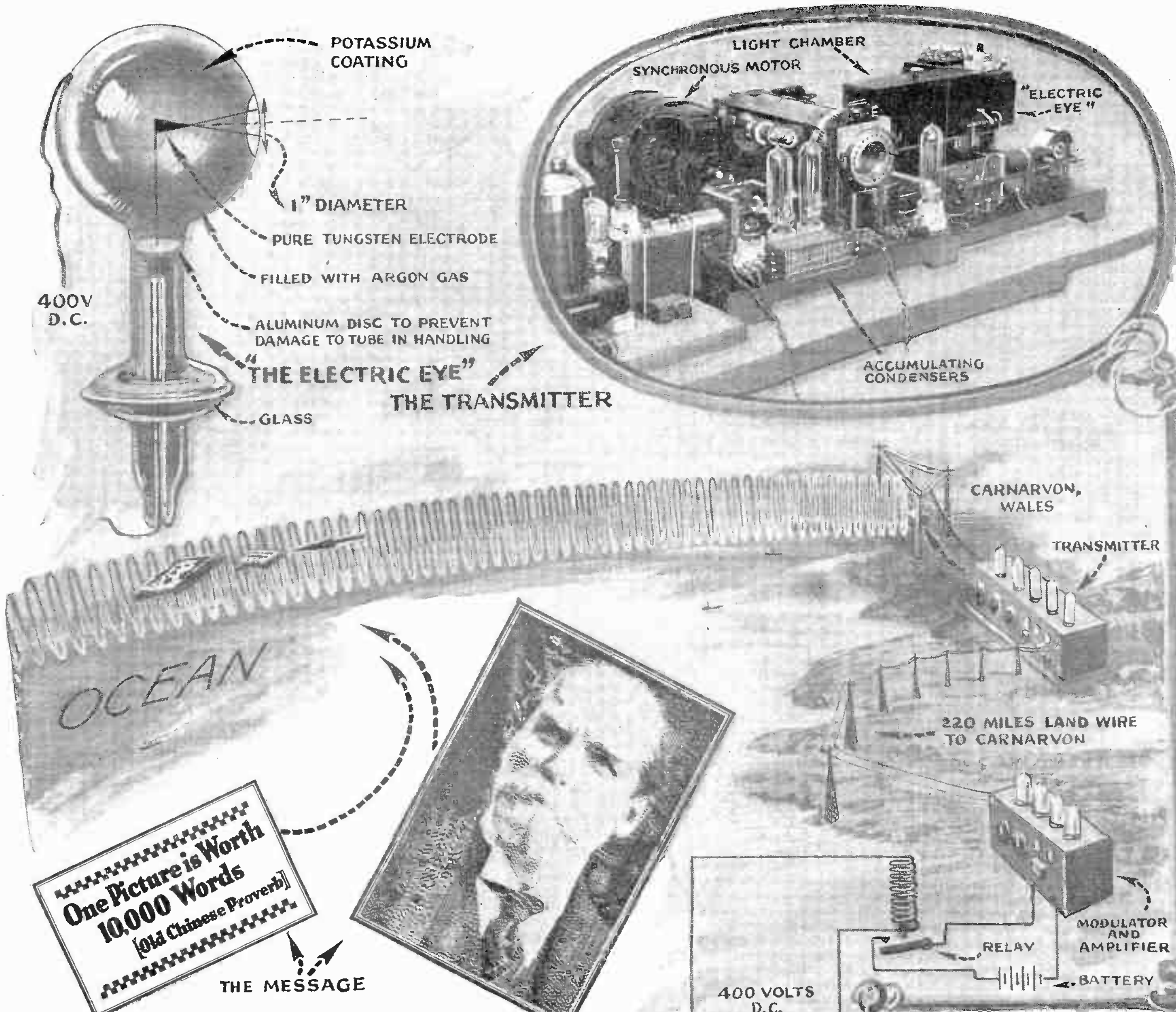
"Truly, a great achievement has been accomplished by the untiring efforts and perseverance of that small minority calling themselves Engineers and Scientists. One cannot begin to imagine against what great odds these promising results were obtained, but one can readily see that it was no small task to maintain absolute synchronism between apparatus 3000 miles apart."



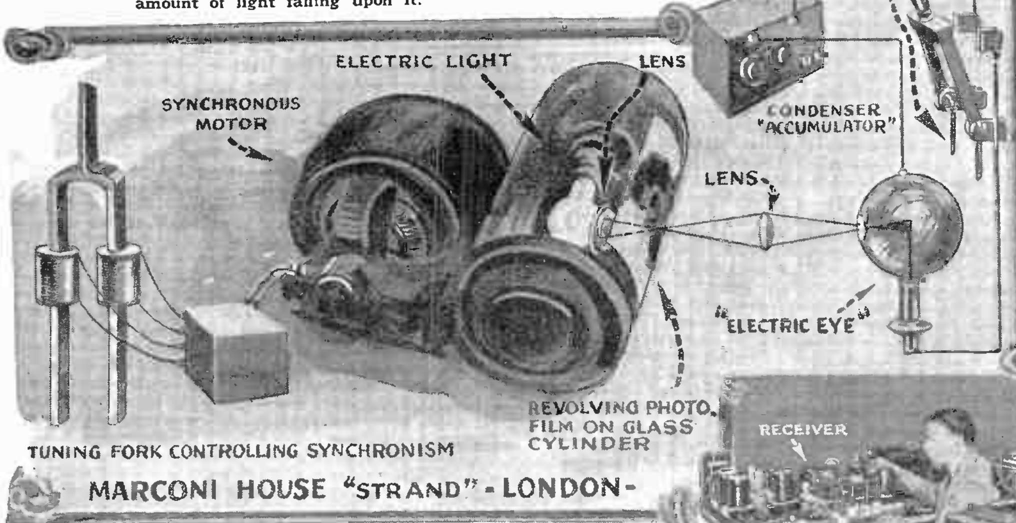
Captain Richard H. Ranger, the developer of the system and the inventor of its unique features, is shown with the "electric eye," the tube which is responsible in a great measure for the successful operation of the apparatus. Not only photographs, but all kinds of printed matter such as newspapers, typewritten letters, and manuscripts are easily reproduced radioally.



By comparison between an original and transmitted photos, it is at once seen that the outline, the shading and tone effect is realistically portrayed. To the right is shown the photo as recorded on a tape recorder—a meaningless jumble—to check the synchronising.



The "electric eye" shown at the top is a photo-electric cell whose electrical resistance varies in accordance with the amount of light falling upon it.

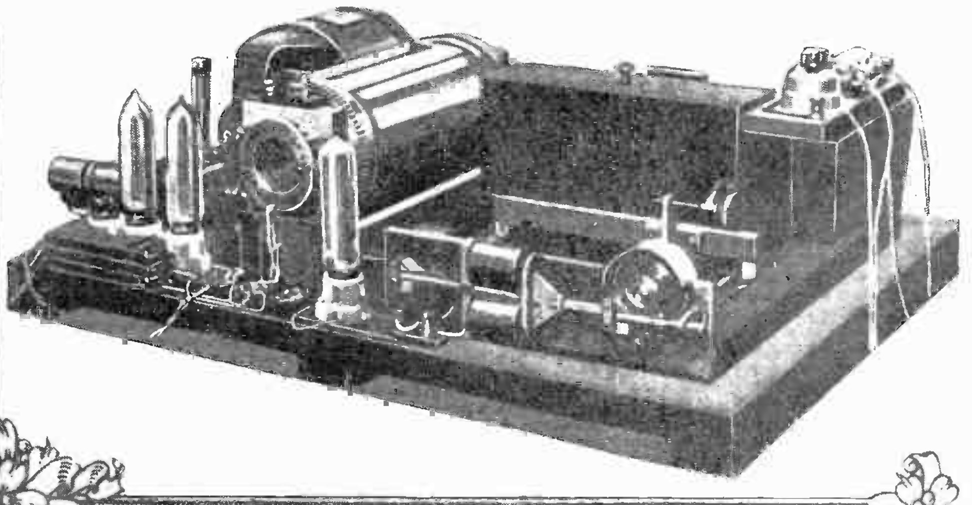


Ordinarily, the current delivered by the "electric-eye" would be a pulsating current of varying intensity and would ultimately result in a much inferior picture. Thus, a condenser "accumulator," another development by Captain Ranger, is interposed and breaks up the light variations into a series of dots and dashes. This system of modulation is found to be excellent, and in conjunction with the necessary transmitting apparatus gives a much more clearly defined reproduction. 400 volts D. C. is required for the successful operation of the photo-electric cell. Note transmitted photos at upper left.

Immediately above is shown the glass cylinder on which is placed the picture to be transmitted. Within is an incandescent lamp, the light from which is focused in a minute beam onto the film. As the light and dark portions of the picture are traversed by the light beam, the intensity of the ray is changed. This ever changing beam after having passed through the film is again focused through another lens outside the cylinder onto the sensitive element of the photo-electric cell. This device transforms the light waves into electric impulses or waves which can be transmitted by radio, much the same as a regular dot and dash message.

The receiving station where the apparatus is in absolute synchronism, records the photos in three ways, by tape, by pen sketch and photographically. Above: Complete outfit.

A photograph of President Coolidge as reproduced on the receiving apparatus of the Photoradiogram system.



Another view of the transmitting apparatus, comprising the glass cylinder, a photo-electric cell and the electromagnet operating the gear which moves the lamp and the photo-electric cell along the cylinder.

RADIO CORPORATION'S PHOTORADIOGRAM SYSTEM

The first public demonstration of the Radio Corporation's "Photoradiogram System," the transmission of photographs by radio, was given on Sunday, Nov. 30, 1924, when the photographs of well-known men of the world were flashed across the Atlantic Ocean and reproduced at this end of the circuit, at Broad Street, New York City. A description of the system follows:

For the actual operation of the transmitter, the picture, printed matter or whatever is to be sent, is first photographed on an ordinary camera film. This is developed and then placed on a glass cylinder, being held firmly in place by metal clips. The picture is now ready to be transmitted.

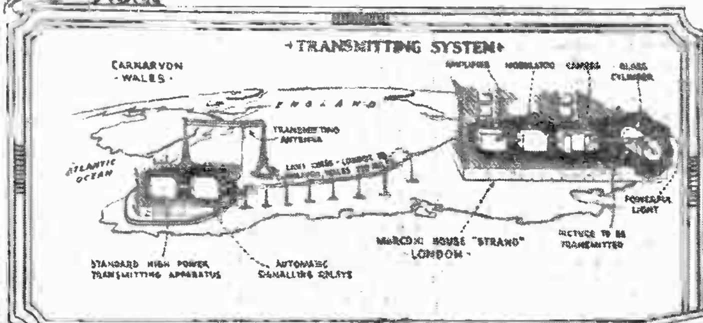
Light Penetrates Film from Inside

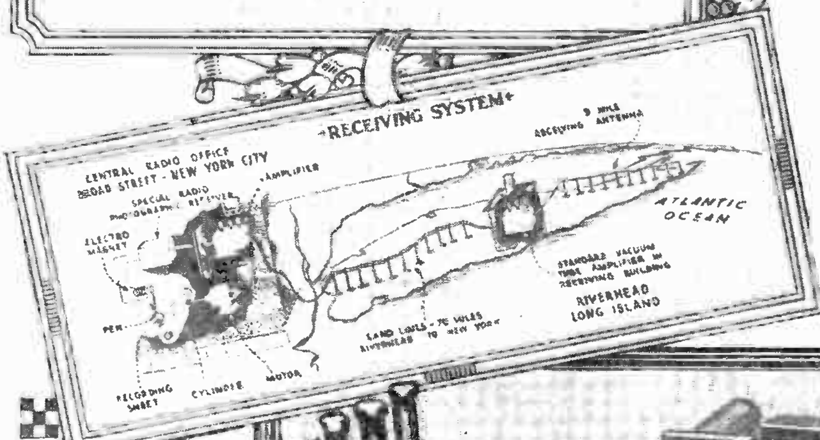
Inside the glass cylinder is an incandescent lamp, the light from which is focused in a minute beam onto the film as the cylinder is set in motion. As the light and dark portions of the picture are traversed by the light beam, the intensity of the ray is changed. This ever changing beam, after having passed through the film, is again focused through another lens outside the cylinder onto the sensitive element of a photo-electric cell, a recent development of the General Electric Co., which transforms the light waves into electrical impulses or waves, which can be transmitted by radio much the same as a regular dash and dot message.

The "Eye" of the Transmitter

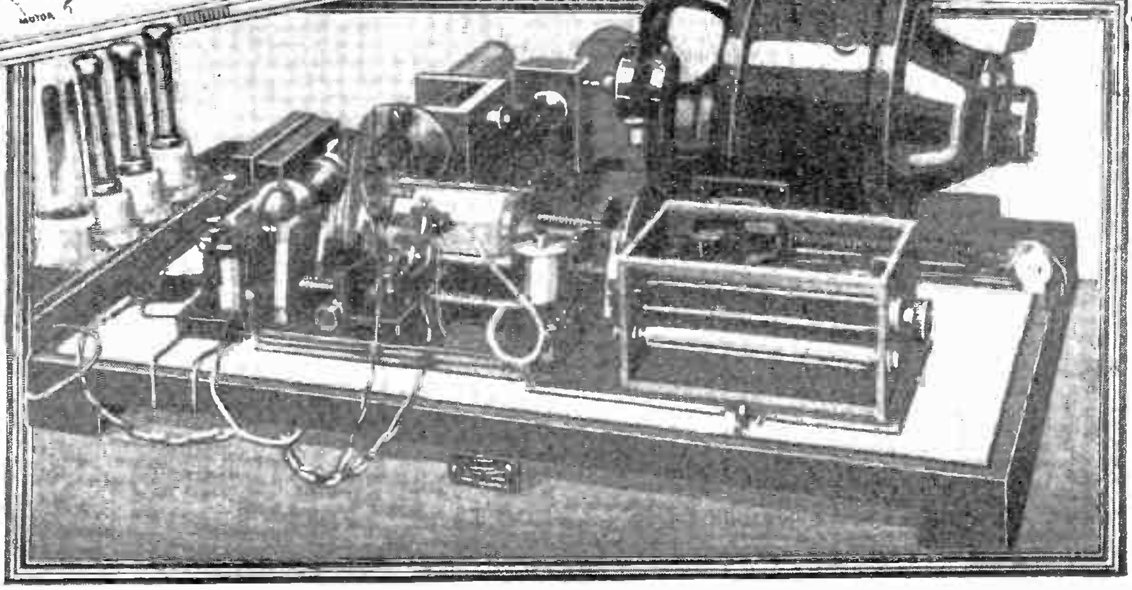
This photo-electric cell is commonly spoken of in the laboratory as the "eye" of the transmitter. The electrical resistance of this cell changes in accordance with the amount of light which falls upon it, and in this way takes care of the shading of the picture in transmission.

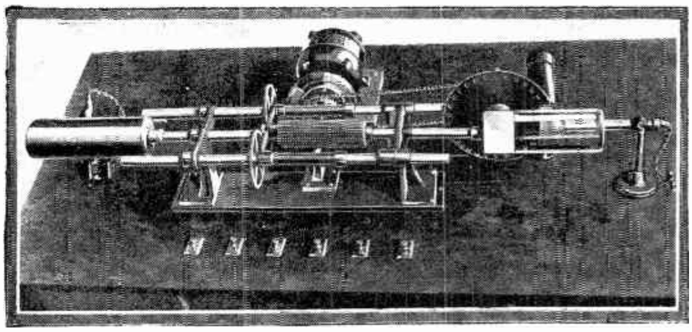
The photo-electric cell functions particularly without any lost motion. That is, the instant the slightest change in the amount of light reaches the cell, a corresponding change in the output current of the cell



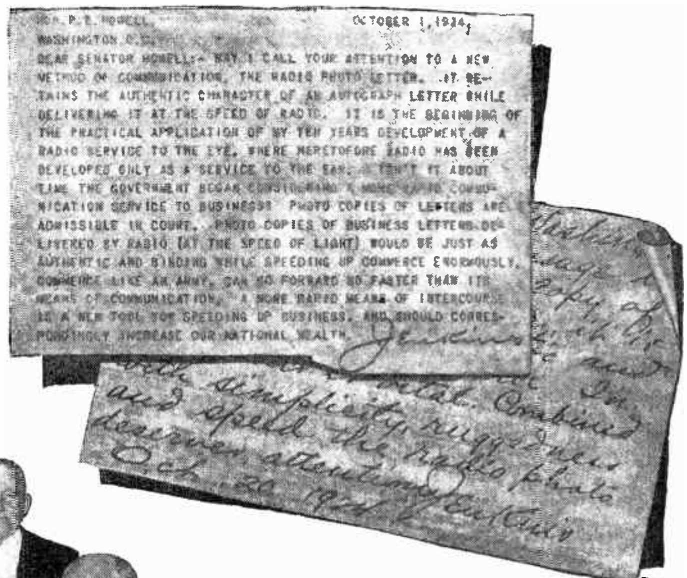


The sketches above show how the pictures are sent and received over land lines before reaching the transmitter and after being received by radio. On the right is another scene of the receiving apparatus. The pen, marks dots on the paper stretched on the revolving cylinder, producing the effect shown in the sample picture.





The machine for sending radio-photo messages and for receiving at the same time. For such a complicated performance the machine is unusually simple in its makeup.



HON. P. E. HOWELL, OCTOBER 1, 1924,
WASHINGTON D.C.
DEAR SENATOR HOWELL:- MAY I CALL YOUR ATTENTION TO A NEW METHOD OF COMMUNICATION, THE RADIO PHOTO LETTER. IT RETAINS THE AUTHENTIC CHARACTER OF AN AUTOGRAPH LETTER WHILE DELIVERING IT AT THE SPEED OF RADIO. IT IS THE BEGINNING OF THE PRACTICAL APPLICATION OF MY TEN YEARS DEVELOPMENT OF A RADIO SERVICE TO THE EYE, WHERE HERETOFORE RADIO HAS BEEN DEVELOPED ONLY AS A SERVICE TO THE EAR. ISN'T IT ABOUT TIME THE GOVERNMENT BEGAN [illegible] COMMUNICATION SERVICE TO BUSINESS? PHOTO COPIES OF LETTERS ARE ADMISSIBLE IN COURT. PHOTO COPIES OF BUSINESS LETTERS DELIVERED BY RADIO (AT THE SPEED OF LIGHT) WOULD BE JUST AS AUTHENTIC AND BINDING WHILE SPEEDING UP COMMERCE ENORMOUSLY. COMMERCE LIKE AN ARMY, CAN GO FORWARD NO FASTER THAN ITS MEANS OF COMMUNICATION. A MORE RAPID MEANS OF INTERCOURSE IS A NEW TOOL FOR SPEEDING UP BUSINESS, AND SHOULD CORRESPONDINGLY INCREASE OUR NATIONAL WEALTH.
Jenkins

Samples of radio-photo letters transmitted on Mr. Jenkins' apparatus.

one time. Then, too, this particular machine cannot be employed for picture transmission.

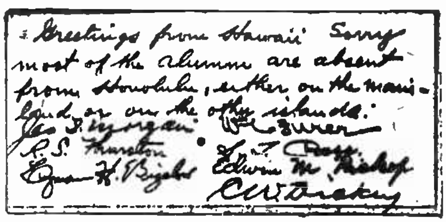
Drawing a comparison between the utility value of the transmission of photographs and typewritten communications, Mr. Jenkins states: "Of these one naturally thinks first of pictures for news illustration of telegraphic text in the daily newspaper. But it is more probable that the transmission of radio photo news copy will be the most useful service, for this method overcomes time, distance, isolation, storms and breakdowns of the usual means of communication, and serves a thousand daily newpapers at no more expense than service to a single patron. Nor does radio interference and 'static' prevent the reception of perfectly readable copy. A hundred words a minute from typewritten copy is an everyday attainment already, and one thousand words per minute soon is confidently predicted."

The application of this method of communication—the radio photo letter—finds an illustration in the possibility of sending and receiving the headlines of the front page of a newspaper in this manner.

Business letters by radio, according to Mr. Jenkins, would speed up commerce and yet such communications would be none the less authentic and binding. These same letters, because of their photographic accuracy and autographic authenticity, would be admissible as evidence in court.

Vice-President Charles G. Dawes and Gen. James G. Harbord, who introduced him at the M. I. T. dinner. © Henry Miller News Service

**Honolulu to New York Technology Banquet
Waldorf-Astoria, N. Y., Jan. 19, 1926.**



Greetings from Hawaii. Sorry most of the alumni are absent from Honolulu, either on the mainland or on the other islands.

A facsimile of the message from Honolulu, as it was received in New York by the photoradiogram process.

A Radio Dinner

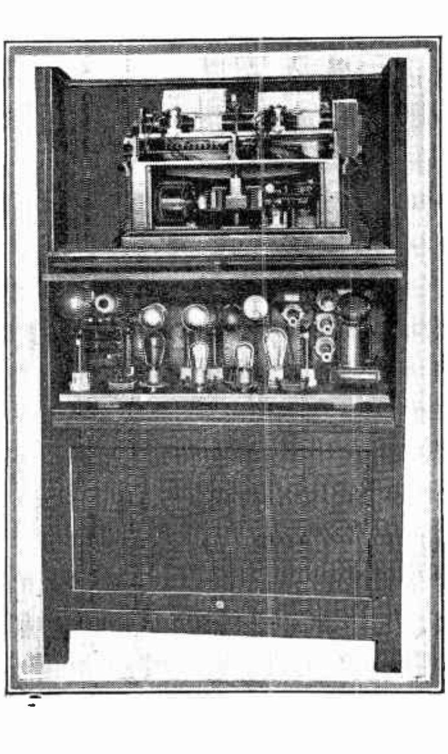
A unique radio dinner in which photoradiograms were sent to the guests was described by G. C. B. Rowe in April, 1926, issue of *Radio News* and a portion of which description follows:

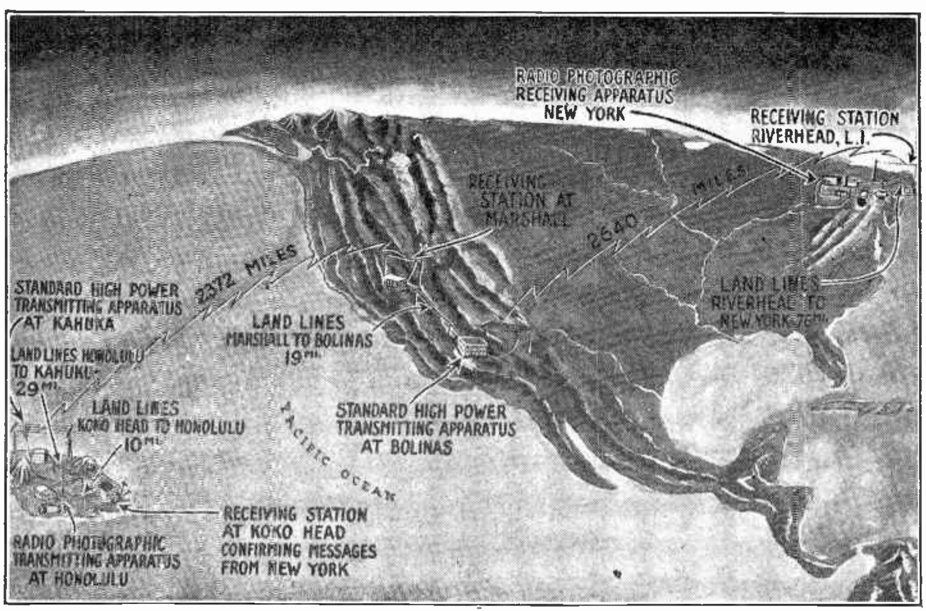
On January 19 of the present year there was given the dinner which will be famous as the first one at which 20,000 people sat down.

Naturally this remarkable dinner was not held in the Yale Bowl or any such place as that; but the diners drew up their chairs to tables in sixty-seven cities that are scattered over the United States, Cuba, Canada, England and Hawaii. The diners for the most part were graduates of the Massachusetts Institute of Technology. In four of these sixty-seven cities speeches were made by men prominent in public life, and heard by all the diners, by means of radio receivers in each banquet room.

Seven stations were linked in a radiating chain. They were WJZ, New York; WRC, Washington; WGY, Schenectady; WBZ, Springfield; KDKA, Pittsburgh; KOA, Denver, and KFKX, Hastings.

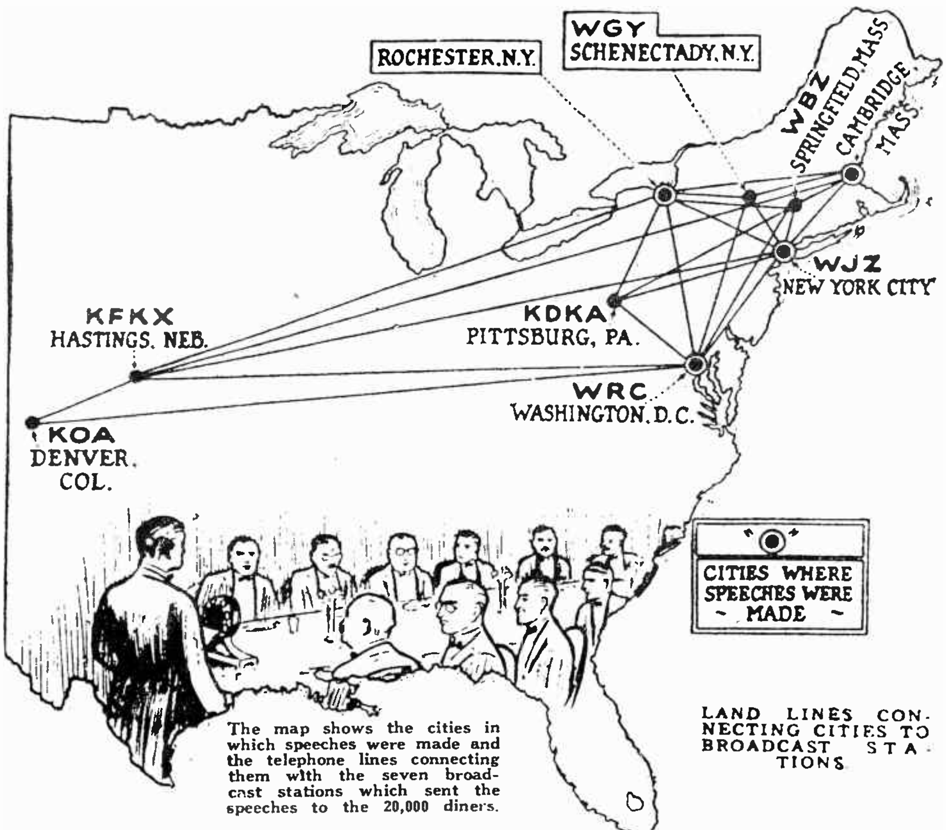
A feature of the dinner that was exclusive to the 700 diners at the Waldorf Hotel in New York was the showing of radio photographs of some of the speakers on a





The above diagram shows the path travelled by the photoradiogram waves in their 5000-mile trip from Honolulu to New York City.

The illustration at the left shows the interior of the receiving apparatus used in the photo-radiogram process for sending pictures by means of radio. On the top shelf is the printing apparatus, underneath which are the amplifier tubes.



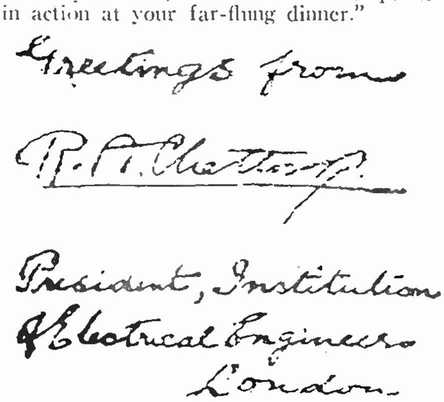
The map shows the cities in which speeches were made and the telephone lines connecting them with the seven broadcast stations which sent the speeches to the 20,000 diners.

George Eastman of Rochester, N. Y., who addressed the diners by means of radio from that city. (This is a facsimile of a photograph sent by the photoradiogram process.)

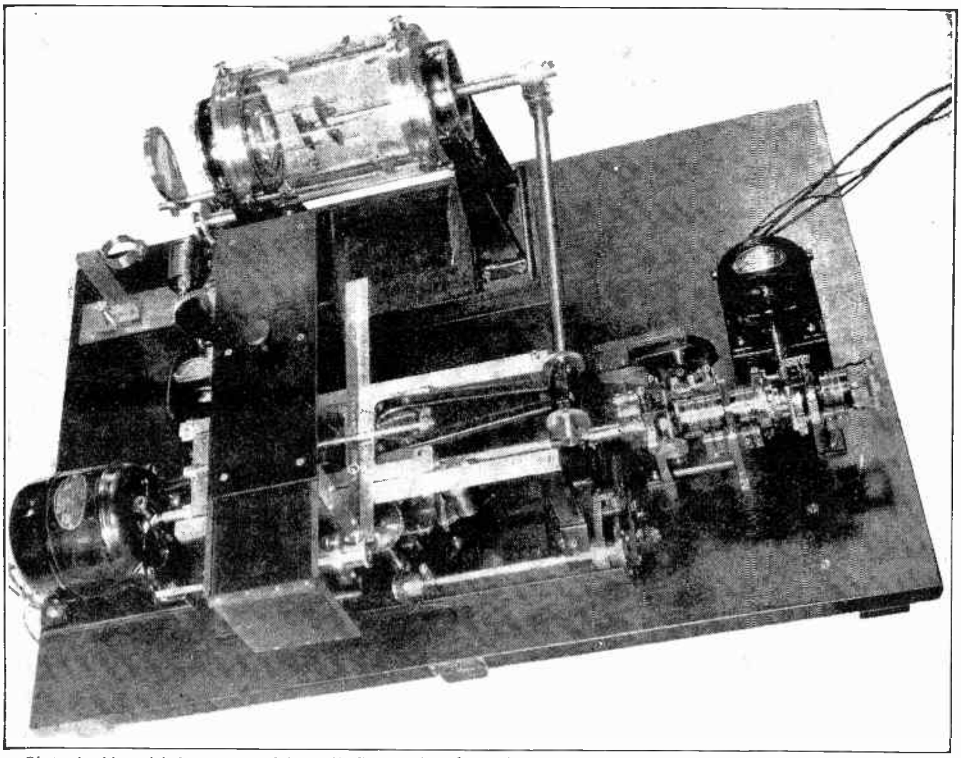
screen, while their words were being heard by means of radio. The photographs had been sent to New York from Washington and Cambridge, some days in advance, by the photoradiogram method. These same photographs were sent out during the dinner as sound waves from the R. C. A. broadcast station in the lower section of New York.

After being sent through the air, these waves were picked up at New Brunswick, N. J., and Riverhead, L. I., and sent by land wire to the dinner at the Waldorf. Here they were decoded and turned back into photographs by a special apparatus set up in the hotel. Here it took about twenty-five or thirty minutes to build up each picture from the transmitted waves, although the radio signals for each black and white space on the photographs were flashed through the air in the fraction of a second.

"These photoradiograms," predicted David Sarnoff, who was toastmaster at the New York dinner-party, "carry promise of much greater achievement. From the present generation of electrical scientists may come the key to instantaneous visual communication by radio. When that time comes, as I confidently believe it will, radio television will be able to unite you, not only in sound, but in sight. You will be able, not only to hear, but also to see the speakers in action at your far-flung dinner."



These greetings were sent by radio across the Atlantic Ocean from London by the photoradiogram process.



Photos in this article by courtesy of the Radio Corporation of America.

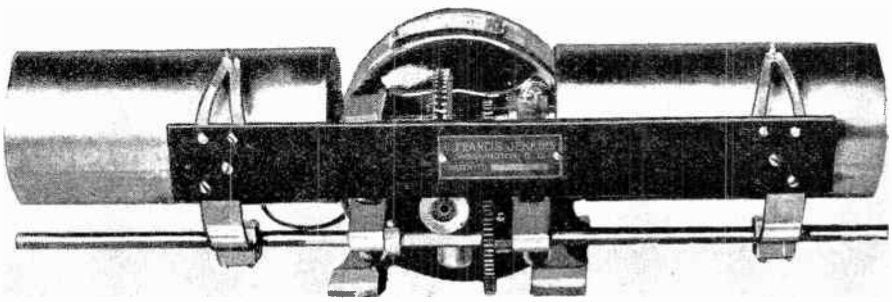
Above is shown the transmitting apparatus for the broadcasting of photographs, maps, etc., by means of radio

Fac-simile Letters by Radio

All the diners who were within a twenty-four-hour mailing distance of New York received at their places at table photostat copies of messages that had been sent by alumni in Hawaii, England and San Francisco, to New York by means of the photoradiogram process. In order to have these copies in New York at the time of the dinner this method was employed as the quickest known. The process for the transmission of letters is the same as that for photographs, a small portion of each letter being sent at a time. In that way it was possible to send out to the diners photostat copies of the letters, so that the handwriting of old friends could be recognized.

Jenkins Telephotography for Amateurs

Preceding even the telephoto letters the radio amateurs next heard about telephotography in the form of Mr. Jenkins' machine. This was a device which could be attached to an ordinary phonograph and was intended primarily for radio experimenters. By this means they were able to send photographs to each other through their own short wave sets. It might be interesting to note that this machine actually manufactured, was sold to amateurs at almost cost price so that they could familiarize themselves with the fascinating subject of telephotography. An article on this subject appeared in the May,



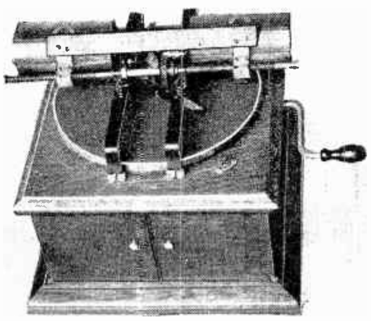
Another form of the device employs a small motor for turning over the cylinders which carry the "pens" and the chemically treated paper.

1925, issue of *Radio News* written by S. R. Winters.

During 1925 the army of approximately 20,000 radio amateurs in the United States were on the threshold of a new and fruitful period of experimentation. Radio photography—the sending and receiving of photographs, sketches, script, maps and autographed letters—was placed into their hands.

C. Francis Jenkins at this time invented and built a small and simple machine that put radio photography within the reach of the radio amateur. It marked the introduction of a practical realization of what Mr. Jenkins prefers to call a service to the eye, just as radio now is a service to the ear.

The machine built for use by radio amateurs is inexpensive and, when compared



A phonograph may be used to synchronize the copying devices at the two stations.

with its marvelous accomplishment, is very simple in construction. This unit may be connected to a small electric motor or victrola as a governor control, which engages with a gear as a means of driving a shaft. On each end of this shaft a brass cylinder is mounted. A cylinder threaded shaft engages with the cylinder shaft through a pair of gears. Mounted on this threaded shaft is a pair of arms connected together with an insulated bakelite bar. The rotation of this threaded shaft moves the bar of bakelite longitudinally with respect to the cylinders. Furthermore, mounted on this insulated bar are two contact fingers, one coming in touch with the cylinder used for sending photographic impressions and the other makes contact with the cylinder employed in receiving the maps, sketches, pictures, etc.

The message, whether taking the form of a business letter or a sketch to represent a radio diagram, is written with a pen on white paper. The ink used in making this impression is peculiarly adapted to this purpose. This strip of paper containing writing to be sent by radio is wrapped around one of the brass cylinders and secured thereto with a fragment of sticky paper. A switch is closed in an electric circuit which connects the cylinder at the contact finger with the transmitting machine. Whenever a line of writing passes under this contact finger a radio wave is propagated into space. At all the receiving stations of this photo-letter system of communication the incoming radio signals pass through the contact finger on the receiving cylinder and make a chemical mark on the paper. That is to say, every time a line of writing at the sending station passes under the contact finger a mark is made on every receiving station cylinder.

The including of a Jenkins' duplex photogram machine, so called, in the radio equipment of the amateur station meant that when these pioneers in wireless development tire of exchanging telegraphic code with friends in Australia that they can switch to the picture-sending unit and show the Australian amateurs, at long range, scenes of the objects about them. These photographic impressions may take the form of a pencil-writing greeting, a sketch of the antenna system at his station, a map of the section in which he lives, or a picture of the transmitter that he uses.

The action of the apparatus is the simplest possible. The picture to be transmitted is drawn on paper with a copper sulphate solution in such a way that when the needle passes over the written lines the chemical ink transmits an impulse through the cylinder and needle, which is, in turn, sent into the radio transmitter.

At the receiver, an amplifier is used after the detector, and the amplified impulses sent out by the transmitter are passed to the receiving pen and cylinder. A paper moistened with potassium iodide or ferrocyanide is placed on the receiving cylinder. When the amplified current passes through the needle the electrolytic effect discolors the paper, giving perfect reproduction of the original picture.

The beauty of this system is, of course, its simplicity. The victrolas at the two stations may be exactly synchronized by adjusting their governors.

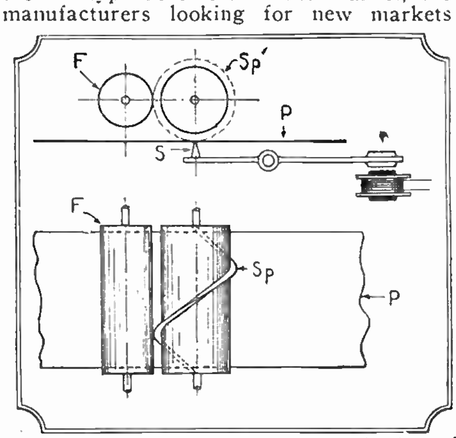
These devices were manufactured by Mr. Jenkins and sold to amateurs.

The Friedel System

Even though the attention to television had already been drawn, it must not be supposed that the subject of picture transmission had been forgotten. Thus in August, 1926, issue of *Radio News* we find Dr. Walter Friedel discussing the subject of broadcasting of pictures. It must be remembered that even the transmission of simple drawings are of great advantage. Weather maps would be of the greatest value to farmers, business men and navigators. The value of pictorial broadcast service to the police need not be described.

In addition to this, many things may better be conveyed in graphic form than by the ear. Numbers, as in quotations on the exchanges, are more trustworthy in black and white; many events may be best explained by means of curves and diagrams. With the general introduction of radio-picture receivers, these will become available; and the possibility of transmitting illustrations of educational radio lectures will multiply their value many times. The radio advertiser should find very valuable possibilities along this line.

It will be impossible to prevent the general introduction of picture-broadcasting, and this will help to prevent the saturation of the radio market for new apparatus. If there should be a surplus of the old-type receivers in the market, the manufacturers looking for new markets



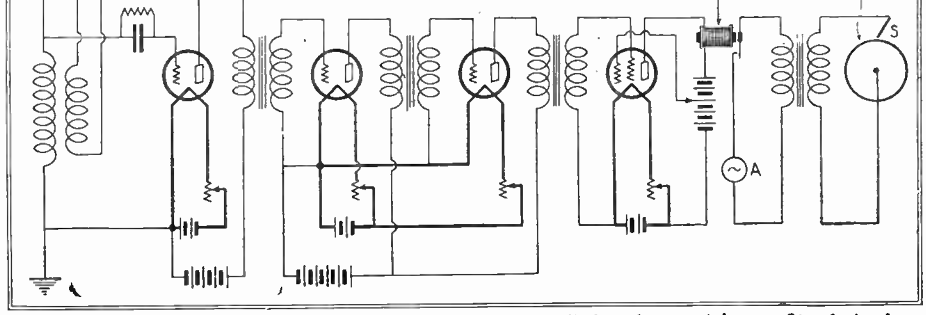
A cylindrical roller with a spiral edge, Sp, is used instead of a stylus in later models.

will produce in large quantities simple, cheap and practical picture reception apparatus.

In their manufacture, contrary to the case with the usual broadcasting, while the transmitting apparatus may be very expensive and complicated, the radio-picture receivers for the public must be inexpensive and easy to operate. This indicates that we should return to the simple methods of picture reception which were invented in the nineteenth century.

Chemical and Electrical Recorders

The first method employed in connection with the electric telegraph was electrochemical reception of signals; the incoming impulses pass from a metal stylus to a revolving metal cylinder over which a specially-prepared paper is stretched, causing a mark during the duration of the



The circuit diagram of the amplifier, relay and recording cylinder of a receiving outfit, of simple construction, utilizing well-known methods.

effective current. The use for impregnating purposes of a solution of potassium ferrocyanide $K_3 Fe (CN)_6$ and sodium nitrate $Na NO_3$ results in a bright blue ("Prussian blue") mark at the point of contact formed by the passage of a current of 20 to 30 milliamperes. If potassium iodide (KI) made into a paste with starch and perhaps a little calcium chloride ($CaCl_2$) are employed, a blue or bluish-black color is obtained with the passage of 40 milliamperes of current, and about three hundred signals may be recorded in a second. These markings, however, fade with the evaporation of the liberated iodine.

The disadvantage of this system, however, lies in the friction between the stylus and the moving paper, which prevents the latter from moving at an even speed. This is overcome by using a stylus which is not in actual contact with the paper.

One figure shows the circuit diagram of the amplifying system, relay and recording cylinder of the apparatus last mentioned. The amplified current operates the relay M, which closes the AC circuit and causes the electric stylus, S, to function. It is caused to travel back and forth across the width of the paper on the cylinder, and at each signal impulse a spark jumps from the stylus to the cylinder and perforates the paper. The picture is formed by the series of perforations thus made.

Dieckmann has improved this method by placing over the paper wound on the cylinder, a thin sheet of suitable typewriter carbon paper. The heat of each spark melts the colored film and a dot of ink is left on the paper beneath.

The mechanical construction of this receiver is not very complicated, resembling that of the old type of talking machines which used cylindrical records; the cylinder may be driven by a small motor or by clockwork. However, since the cylinder is small and the paper must be changed frequently, it is more desirable to employ a continuous roll of paper fed to the cylinder, so that the apparatus will be always ready for reception.

An Improved Roll-feed Receiver

A view shows the latter type of construction. In place of the stylus we have a spiral edge, S_P fitted to a cylindrical roller at a wide angle to the axis. It revolves once for each sixteenth of an inch that the paper advances. The edge is kept inked by the roller F. At every incoming signal, the paper strip P, which is constantly unrolling from one spindle to another, is pressed against the blackened spiral edge S_P at its point of contact with

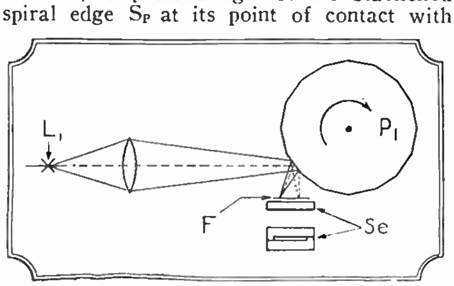


Fig. 95. A schematic diagram of the author's machine for the transmission of pictures.

the edge S, which is parallel with the axis and extends across the full width of this paper. By means of this device a picture composed of perfectly straight rows of dots may be obtained, though all the parts of the apparatus are constantly moving. A great advantage is that the picture can always be easily inspected; and this is of value, because a guide line may be transmitted in order to check up on the synchronism. There are many methods of keeping the receiver in exact synchronism with the transmitter, though this is usually considered to present the principal difficulty. Different methods of synchronizing will be dealt with later.

Transmission of Moving Pictures

In the transmission of actual moving scenes, the difficulty is to obtain a sufficient amount of light from any one point. The light which is received from one spot of a scene is *reflected* light, while that employed in the transmission of photographs, for instance, is *concentrated* light; so that in the latter case the result received may be made as strong as the original. We have the same condition, in principle, when from the transmission of a single picture we advance to that of a series of pictures to give the optical effect of motion. This result from the transmission of moving pictures we may call Telecinematography.

Two illustrations show diagrammatically the methods which the writer has devised for the transmission and reception of moving pictures by radio. One is the transmitter shown in schematic section. The film F is run smoothly, not intermittently as in

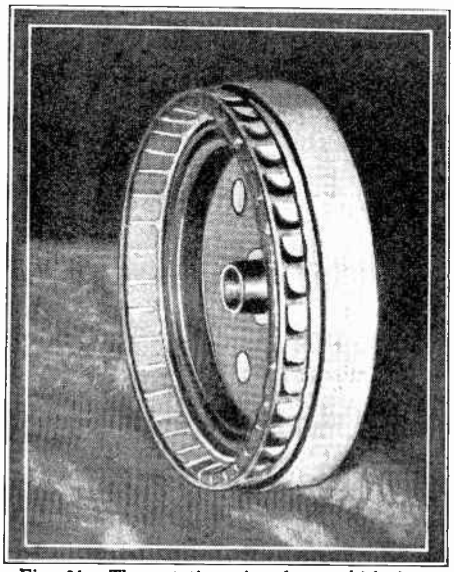


Fig. 94. The rotating ring lens, which is a great aid to the efficient reproduction of pictures at the receiving end.

ordinary projection, in front of the selenium cell, S_e; or a photo-electric cell such as the Luminotron may be used. The active surface of the cell must be as long as the film strip is wide.

In order to illuminate all the points of a line in the picture, from the light source L_1, the rotating polygonal mirror P_1 is placed so that it will reflect the rays of light through the film. Its rotation causes the spot of light to travel across the width of the film; and as the strip moves forward, all the points of the picture will successively be illuminated. This light passing through the film sets up current vibrations of varying strength in the light-sensitive cell, which serve, after sufficient amplification, to modulate the carrier wave of the transmitting station.

The Picture Receiving Apparatus

At the right is the construction of the receiver, which is more complicated. The light emanating from the source L_2 is varied in intensity in direct proportion to the incoming signal impulses, and passes through the Kerr cell, K, with its two Nicol prisms, N_1 and N_2. The insertion of the rotating polygonal mirror, P_2, causes the luminous ray to traverse the lines indicated by the arrows, thus reconstituting the picture in every line and point into which it was decomposed at the transmitting station.

It is necessary, however, to add still another device, the rotating ring-lens R, which redistributes the lines of the picture into a whole, and causes each successive picture to appear in the same position on the screen. This device, invented by Mr. Buchner, who has employed it successfully in his motion picture projector, is illustrated in the photo-engraving. The objective lens, O, then throws the final reproduced picture on the projection screen, which has a phosphorescent light-receiving surface.

The Telefunken System

Several important inventions, made by German scientists, have practically removed the last difficulties in the field of simple "phototelegraphy" and have served to open a promising field of investigation. Though the developments made are still confined to the laboratory, the experiments conducted have been entirely successful and certainly indicate the practicability of the system.

We will explain in the following paragraphs the new "phototelegraphic" apparatus worked out by the Telefunken Co. in Berlin, with which tests were carried on between Königswusterhausen, near that city, and Vienna, the capital of Austria. The subject matter of this appeared in the November, 1926, issue of *Radio News*.

Present forms of automatic radio telegraph systems permit a transmission and reception speed not greater than 100 to 500 words per minute, and sometimes much less, as the actual speed depends on atmospheric conditions. Bad atmospherics partly or entirely destroy the telegraph signals, and for this reason high-speed communication is greatly hindered.

The Telefunken system of phototelegraphic transmission is far more reliable, as it is practically independent of atmospheric conditions. Static and other forms of electrical disturbances cause only small black dots and thin lines on the received photogram, which in no way detract from the legibility. Not only is this new system more reliable, but it is far superior to present automatic systems, as it is possible to attain a transmission and reception speed of 400 to 600 words a minute.

The speed of the system can be materially increased if the transmission and reception is done on a short wave-length, less time being required in such an instance for the complete transmission and reception of a photogram of a given area. In fact, it has been found possible to transmit 400 words within the space of a few seconds. About 16 square inches are required for 200 words, and two or three times this area is reproduced in a minute, at regular commercial speeds.

So well does this system retain the for-

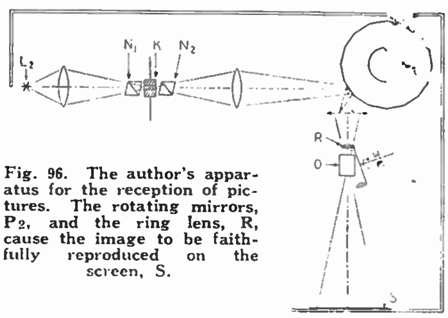


Fig. 96. The author's apparatus for the reception of pictures. The rotating mirrors, P_2, and the ring lens, R, cause the image to be faithfully reproduced on the screen, S.

mation of the original script transmitted that the received photogram can be used immediately for reproduction in newspapers or magazines, whether it be of handwriting, type, a photograph or a sketch. Of course, where exactness is demanded in the transmitted material, such as scientific sketches or photos of artistic value, the weather conditions must be favorable; as it can be seen that small dots or thin lines might be ruinous to the reproduction at the receiving end.

Various systems of phototelegraphy now in use in Europe and America have reached a high point of development; but there are two distinctive advantages which go to explain the superiority of the Telefunken system. The first is the possibility of sending from the original telegraphs directly, without any form of photographic or other preparation; the second the very high

sending-speed, coupled with the perfect quality of reproduction.

The improved operation of the transmitter is attributed to the new ring-shaped photo-electric cell developed by Dr. Schröter of the Telefunken Co. (See Fig. 103.) The high speed and quality of reception is made possible by the light relay invented by Dr. Karolus of Leipzig, called after him the "Karolus Cell." (See Fig. 101.) It makes practical use of what is known as the "Kerr effect," and is entirely free from mechanical inertia in its operation.

The transmitter consists of a large cylinder enclosed in a light-proof box (Figs. 100 and 106). An electric motor rotates the cylinder and at certain intervals changes its lateral position. On the cylinder is mounted the telegram or photo to be transmitted. The light from an electric arc is concentrated on the face of the cylinder by means of a system of lenses. The photo-electric cell or "optical microphone" is mounted between the arc light and the cylinder so that the concentrated light rays have free passage through the center of the ring-shaped electrode.

The spot of light thus directed on the telegram is only .008-inch square, thus covering a mere thread-line of the cylinder surface. The rays of light reflected from the cylinder strike the outside surface of the ring-shaped cathode of the photo-electric cell and affect the potassium coating, which emits electrons when exposed to light, in exact correspondence to the light and dark spots on the telegram traversed by the ray of light.

The anode of the photo-electric cell is formed by a grid of fine wires which readily allow the reflected rays of light to pass through to the cathode, but take up the electrons emitted by the potassium. The variations of current thus created in the circuit of the cell are passed through suitable audio-frequency amplifiers and in turn

Fig. 97. At the left is an unretouched reproduction of the German radio engineer, Count Arco, a director of the Telefunken Wireless Co. This portrait was transmitted by the process described in this article from Konigswusterhausen, which is near, Berlin, to Vienna.

Fig. 98. This is the electric-arc projector of the transmitter shown in Fig. 106. Its intense ray is thrown upon the projecting object lens (See Fig. 100) and passes through the tiny "pupil" of the "electric eye"—the photoelectric cell of Fig. 103. It is then reflected with varying intensity (depending on whether it falls on an area black, white or grey) from the spot on the mounted telegram on which it is focused, to the coated surface of the photo-electric cell. The variation of current thus caused is used after amplification to modulate the transmission.

modulate the radio-frequency currents generated by the transmitting tubes.

The same arrangement of cylinder, driving motor and electric arc is used at the receiving end. (See Figs. 99 and 102.) The rotation of the receiving and transmitting cylinders is brought into synchronism in a very simple and ingenious manner; no transmission of separate synchronizing signals is required.

The Karolus Cell

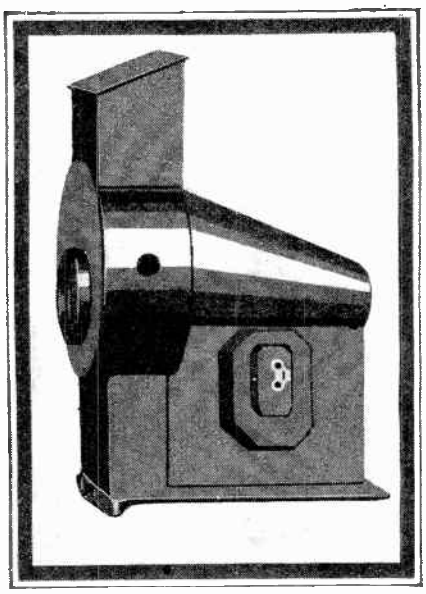
Again several lenses concentrate the rays of the electric arc towards the surface of the enclosed light-proof cylinder, on which a negative film is mounted. With the system of lenses is incorporated the sensitive light-relay, the Karolus cell, which is connected to the output of an audio amplifier, following the radio receiver. The modulations of the transmitter's carrier wave thus cause amplified potential changes across the two electrodes or condenser plates in the Karolus cell. The cell itself is formed of glass and filled with carbon disulphide. The rays of light which have to pass the cell, that is to say, the small space between the condenser plates, are previously *polarized* by suitable Nicol prisms. Due to the already-mentioned "Kerr effect," the polarization plane of the light rays is rotated or twisted in accordance with the potential changes across the condenser plates. This varies the intensity of the light leaving a second pair of Nicol prisms following the Karolus cell.

The rays controlled by the cell are now directed, point by point and in thread-lines of exactly the same dimensions as in the transmitter, upon the reception film, forming a negative from which any desired number of positive prints may be made.

As the Karolus cell is entirely free from mechanical inertia it can handle a nearly unlimited frequency of applied-potential changes. The cell will also handle an enormous intensity of light without overheating, because of its small size, so that it is especially suited to television work.

The Berthold Freund Method

In the January, 1927, issue of *Science and Invention* Berthold Freund, the inventor, mentioned a few important facts concerning picture transmission which should be of exceptional value here.



As has already been pointed out, the system of picture telegraphy which works at the transmitting station with a contact point, indicates the method of the so-called copying telegraphy or Telautograph, as it was carried out for the first time in the year 1847 by Bakewell and in the period 1902 to 1906 by Prof. Korn, who improved materially the photographic registry at the

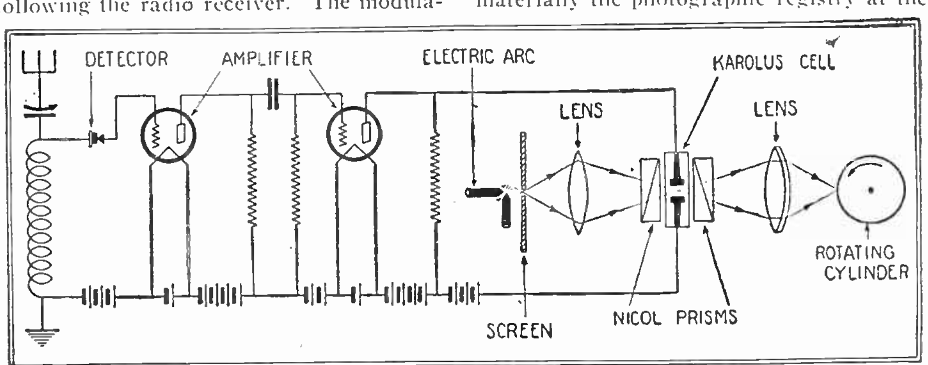


Fig. 99. The receiver circuit. Notice how the plate of the last vacuum tube is connected to the condenser of the Karolus-cell. The variations in the plate current cause a corresponding change in the transparency of the cell, by the phenomenon of polarization.

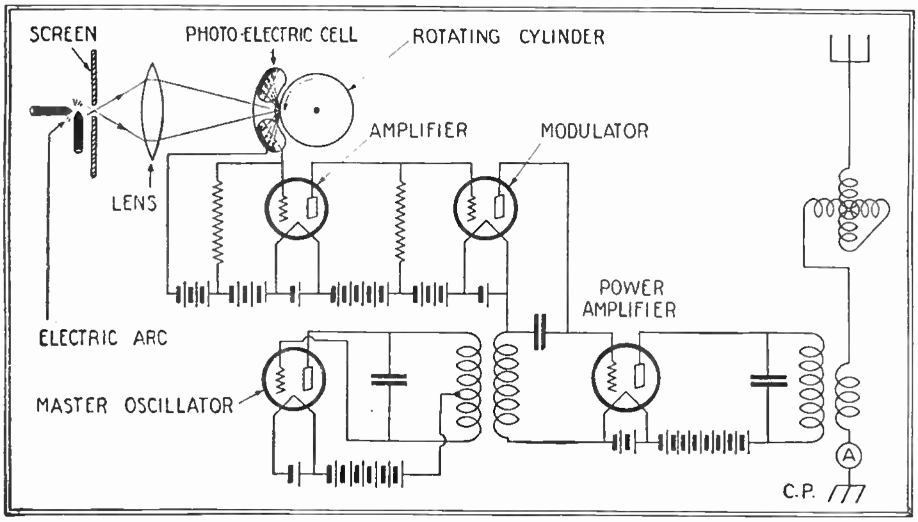


Fig. 100. Above is shown the circuit employed in the transmission of pictures by radio. Notice the peculiar construction of the photoelectric cell and its connections.

Fig. 105. The photograph above shows the appearance of an image which has been transmitted by the Freund system. It will be noted that there is practically no distortion visible.

receiving station. It is clear that with the help of this contact method any "black and white" picture, as for example a sketch, an autograph, print or photograph, transferred to the metal foil can be sent over the line, but the exclusive restriction to "black and white" pictures or line pictures, is a great disadvantage of this method which in practical applications of picture telegraphy often cuts out the transmission of pictures in tone, and this point is of considerable importance. And it is also a disadvantage that in this method the production of a picture on metallic foil must precede the transmission thereof.

Therefore, pictures with all variations in shade, for example photographs, which could be sent directly by picture telegraphy, are much to be desired. This can be accomplished by using the selenium or

Fig. 104. An unretouched reproduction of a photogram, which was sent by the process described in the accompanying text.

photoelectric cell.

The peculiarity of selenium of changing its electric resistance, according to whether it is in the dark or in the light, was discovered in the year 1873 by Smith. It is found that the electric resistance of selenium is approximately proportional to the strength of light to which it is exposed. If one, therefore, places between the poles of a battery, and attached to the electrode, a layer of properly prepared selenium, and exposes this selenium to a changing degree

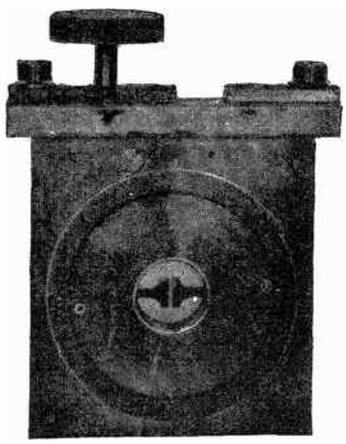


Fig. 101. The Karolus-cell. Note the two condenser-electrodes inside the glass cell and the terminals for connection to the receiver. The handle allows adjustment of the electrodes.

of illumination, the strength of the battery current passing through the layer will change constantly as the light changes in intensity. This simple arrangement, entitled, "The Selenium Cell," is here appealed to for the realization of the problem of the electric transmission of tone pictures such as photographs.

Already in the year 1877 Senlecque published a description of an electrically operating television apparatus with a selenium cell. In the year 1881 Bidwell succeeded with the help of a selenium cell, in carrying out the reproduction at a distance for the first time of a tone photograph, and in the period 1902 to 1906 Prof. Korn improved the operation materially, among other things by effecting the production photographically of the picture at the receiving station. The principle of this "selenium method" or direct "phototelegraphic" method is the following: If on a photographic plate which may be a negative, just as formerly spoken of in copying telegraphy, we produce two parallel

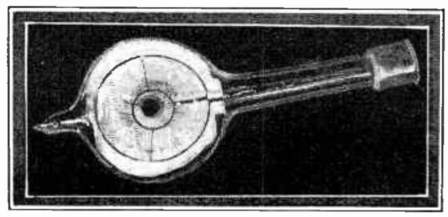


Fig. 103. The photo-electric cell invented by Dr. Schroter. Note the potassium cathode on the inner glass surface, the grid-anode and the hole in the center of the ring.

straight lines lying close together, these picture traces will consist of a continuous series without a gap of surfaces of various depths of shade. Now if instead of the metallic point of the copying telegraph, a ray of light extremely thin and converging, is caused to move over the photographic layer and if this light ray after passing

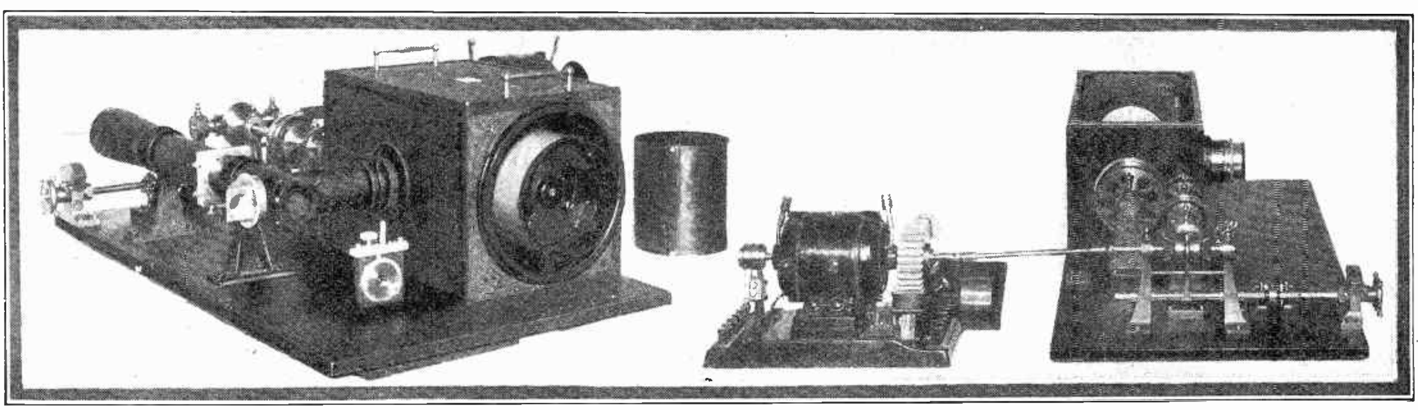


Fig. 102. The Telefunken-Karolus receiver system showing at the right a cylinder on which the unexposed negative film is mounted. One Karolus-cell may be seen in position in the center of the optical device and one standing in front of the receiving cylinder case.

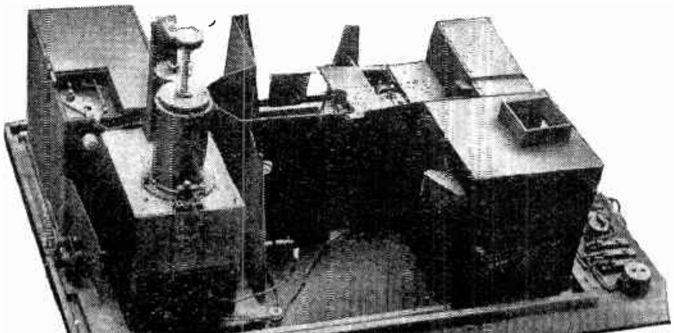
Fig. 106. The Telefunken-Karolus transmitter system. From left to right: the electro-motor for driving the cylinder, the synchronising device, the transmitting cylinder showing a mounted telegram (a part of the photoelectric cell may also be seen), and a system of lenses concentrating light from the electric arc upon the cell.

through the plate falls upon a selenium cell placed behind the plate, then on account of the varying transparency of the successive portions of the picture-trace the light falling on the selenium cell will be changed in its intensity without being cut off. These changes in the illumination of the selenium cell varying with the tone value of the picture traces bring about corresponding changes in the resistance of the selenium cell, and consequently corresponding changes in the intensity of the electric current flowing through the cell. The variable current intensity thus obtained gives a measure of the successive parts of the picture in regard to their brightness referring to the picture traces. This "photoelectric" current of changing intensity is carried to the receiving station and affects here a source of light, for instance by the motion of the little plate of the suspension galvanometer, which in normal position cuts off the ray of light, and then lets more and more light pass according to the degrees through which it is turned by the incoming current. By the light ray thus allowed to pass, a still finer point of light is caused to fall upon a photographically sensitized layer moved with synchronic speed, all being done by optical projection, and this leaves upon the traversing layer a thin line varying in tone which reproduces the lighter or darker portion as the amount of light is expressed or affected by the photo-electric incoming current. This photographically obtained line of varying tone expresses precisely the picture traces of the photographic plate at the sending station. And now as we in repetition of the described process by means of light rays and the selenium cell obtained at the sending station all the closely located picture traces optically, that is to say photoelectrically, and as the receiving station produces the original picture traces expressed in a similar way and close together in rows, we get the reproduction of the tone pictures to be transmitted with all the delicacies of shadow and shade.

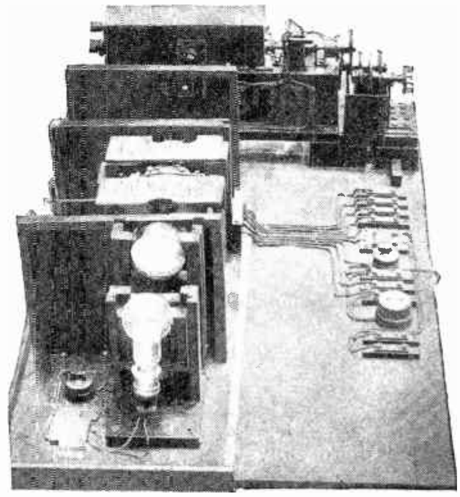
In the practical application of this selenium apparatus, exactly as in the telegraphic copying process, the picture as it may be lies upon synchronously rotating cylinders in the form of photographic films, both at the transmitting and receiving stations, and are obtained in the narrow helical tracings as described.

The two methods of picture telegraphy, the Telautographic, and the direct phototelegraphic methods, previous to the World War occupied the field of work. Here they were concerned almost entirely with transmitting pictures over telephone and telegraph wires, but during the war and especially after the war, wireless telegraphy came into great prominence, as also did wireless telephony, which brought the wireless transmission of pictures more and more into prominence. This was required in the course of the war, especially for military needs, and after the war by the all-important standing which wireless telegraphy obtained for the great Trans-Atlantic news service. One experimented therefore, naturally with both methods of picture transmission, the Telautographic and the direct phototelegraphic, with the idea of carrying out the transmission by wireless, when the telegraphic impulses or the photoelectric current was employed for regulating the transmission energy of the radio station. Even during the war, Professors Korn, Dieckmann and others, carried out experiments with the wireless transmission of pictures on telautographic and telegraphic copy methods, and they succeeded in producing good wireless transmission of sketches at a short distance, but various difficulties sprang up in these methods, principally in exceedingly great uncertainty of success which with increasing distance always grew greater. These difficulties directly after the war forced these picture telegraphic methods into the background, and in their place a third method of picture transmission was developed, which in its essentials had already been long known, but had practically been hardly used. This was a so-called intermediate "mat" or "cliché" method. This method is based on the use of a variable photo-electric current from a selenium apparatus. This is not employed directly for guiding the production of the picture traces at the transmitting station. By means of this current, a sort of half-tone reproduction of the light value of all points of the picture is obtained in a form adapted for telegraphic transmission. This intermediate form thus produced constitutes the so-called "intermediate cliché."

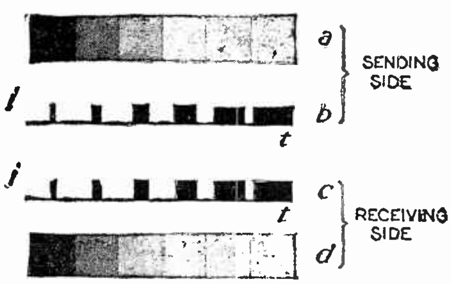
It was Prof. Korn, who in the year 1922, with his intermediate cliché apparatus, carried out the first indirect transmission



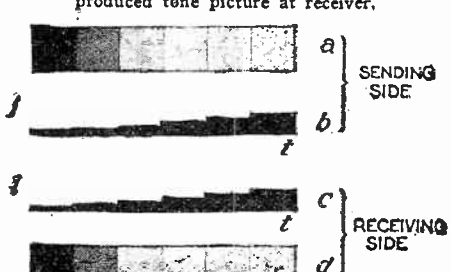
At the left is a photo of the transmitting apparatus used in sending pictures over wire or radio by the Freund process called photo-telautography.



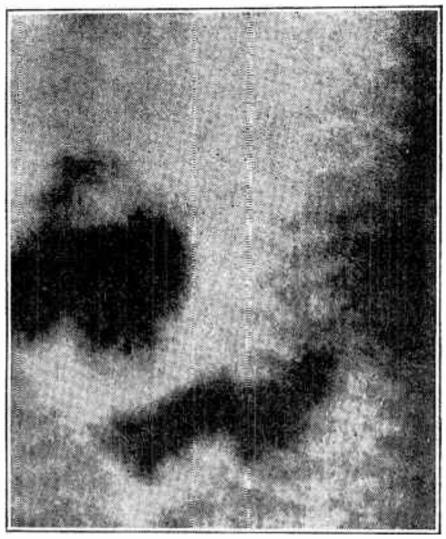
The receiving set shown at the right is similar in many respects to the standard radio sets used in receiving programs broadcast for entertainment.



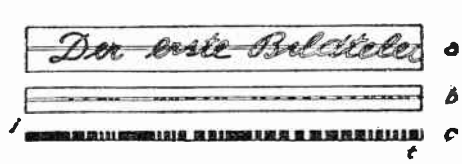
(a) Tinted row of surfaces to be transmitted. (b) Telegraph signal by which tone values are indicated. (c) Received impulses. (d) Reproduced tone picture at receiver.



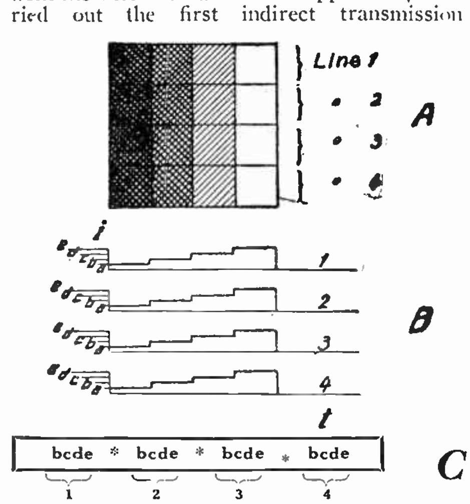
(a) Graduated tone-points to be transmitted. (b) Varying photo-electric current transmitting the tone values. (c) The varying current at the receiving station. (d) The tone values reproduced as received.



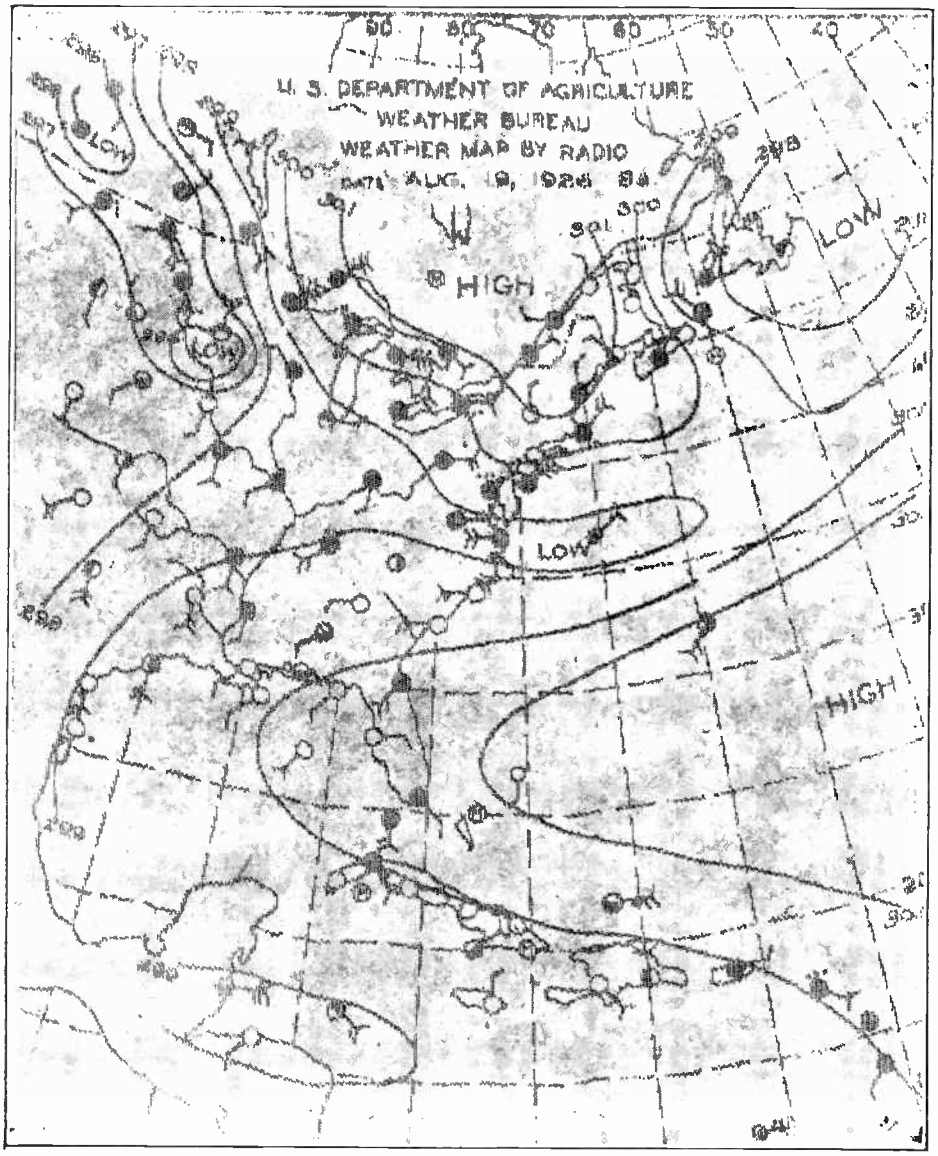
A high magnification of a small area on one of the received photographs show a smoothness of texture hitherto unattainable with commercial processes of photo-transmission. The high-lights and shadows are brought out in perfect detail, the artistic effect suffering not at all.



An illustration of how a simple design is transmitted. (a) One of the "picture lines" of the design to be transmitted. (b) The black and white dots of the "picture lines." (c) Represents the transmitted current of the "picture line."



The principle of the "intermediate electro-method." (A) Surface tinted by points including 16 areas. (B) The current from a selenium cell corresponding to the four lines of the surface, (A). (C) The "intermediate electro" given out by the selenium apparatus representing the tinted surface, A.



An unretouched reproduction of a weather map just as it is received on ship-board.

Europe to America. In his apparatus the intermediate cliché consists of a long typographic telegram tape that is thus produced. The varying photo-electric current of the selenium apparatus is connected to an automatic arrangement, in which for each current intensity step, a particular letter of the alphabet is assigned and is registered. Each photo-electric current intensity corresponding to a point on the picture, registers a letter corresponding to one of the light values of the points of the picture. The ten thousand letters or more expressing the many picture-points are produced on a long telegraphic tape, the so-called intermediate cliché in the form of an ordinary printed telegram. The wireless production of this printed telegram can be done by hand or by rapid telegraphy in regular telegraphic transmission. At the receiving station the incoming letter-telegram is written down accurately and then with the help of an arrangement like a typewriting machine, a point of special size corresponding to each letter, is impressed so that the picture is brought out as a series of points. This form of indirect transmission with intermediate cliché requires no synchronism. The translation of the picture to a telegram can be done at any desired time, as also can the production of the picture at the receiving station end. By these methods therefore no disturbance of the telegraphic functions takes place. After similar indirect intermediate electro methods somewhat later in 1923, the Radio Corporation of America carried out the transmission of pictures between America and Europe, while at a more recent time frequent wireless transmission of pictures both in the direct phototelegraphic methods (1924, Jenkins in America), as also in the black-white method (1924, Marconi, London), the latter between Europe and America was successfully carried out. The above described three methods of picture telegraphy incorporate the present points of view, in accordance with which picture transmitting apparatus have hitherto been constructed.

But each of these methods practically solve only a particular problem of picture transmission. Thus for example, the Telautograph makes possible a direct picture transmission by the use of telegraphic signals, and is now in condition to cover the entire transmitting area of a broadcasting station. On the other hand, it only transmits black and white or line pictures, and cannot send any tone pictures such as photographs directly. It requires for such purposes a preliminary preparation of a metal foil replica. On the other hand the direct telephotography which is carried out by use of a selenium cell or of any one of various other photo-electric tubes, presents the advantage that it needs no metallic foils or special replicas, and can send out tone pictures with the greatest delicacy of shade, directly produced, and repeated with true photographic quality. It possesses, however, the disadvantage that the transmission range of the wireless picture transmission compared to that of the Telautograph is very limited. Of course it involves the reception and reproduction of extremely fine changes in intensity of the wave energy in which the receiving station must exactly reproduce. Atmospheric and other disturbances play an important part here.

The last named intermediate cliché method, possesses over both the methods just spoken of the advantage that no synchronizing apparatus is required, and the picture goes on in the form of a common typed telegram, and is received as such. The picture can, therefore, be reproduced in the progress of work at any desired time. A further advantage appears in this method. It requires no interruption or disturbance of the normal telegraphic operations. During the telegraphing transmission in the opposite direction is possible and no picture transmission plant is required at the radio station. But here comes a disadvantage. For the preparation of the intermediate cliché, a period time which may be one or several hours, is required for its preparation, and moreover the time required for the telegraphing and the expense of telegraphing is proportionately high, and much time has to be expended at the receiving station for the reproduction of the picture. A picture transmission system which shall suffice for the requirements of practice, in reference to quality and economy, must unite the advantages of the above three systems in his own apparatus.

In working out this question to which Berthold Freund has devoted himself, he succeeded by the use of a new transmission process for pictures invented by himself, to reach almost the requirements indicated above. The system provides—and it is especially adapted for wireless telegraphy—a direct phototelegraphic process—a process in which the picture to be transmitted is put at once into the transmission apparatus, in which it is treated on the line system in the photoelectric way and is reproduced directly at the receiving station. The transmission of the tone values of the picture in the new process is not affected as in the hitherto direct photographic processes by currents of varying intensities, but by automatically controlled current pulses of constant intensity but of varying duration, all affected by the tone values of the picture. Every point of the picture for example in this way can give a telegraphic signal of definite length, so that the length of these signals is a measure for the tone value. These current or telegraphic impulses are of the same nature as the telegraph signals of the old telautograph symbols written on metallic foil. At the receiving station in the new process the incoming telegraphic impulses are not repeated as in the telautograph as black and white symbols, but immediately give the proper tone values fixed by photography. The processes alluded to are carried on at the sending station as well as the receiving station entirely automatically, and with extraordinary rapidity, so that the transmission of the picture at very high speed is possible. A quantity of specifically technical details prevent all disturbances of the processes. In consequence of this the principles of the new picture telegraphy only briefly described here, has a large number of technical and economic advantages over the apparatus hitherto employed.

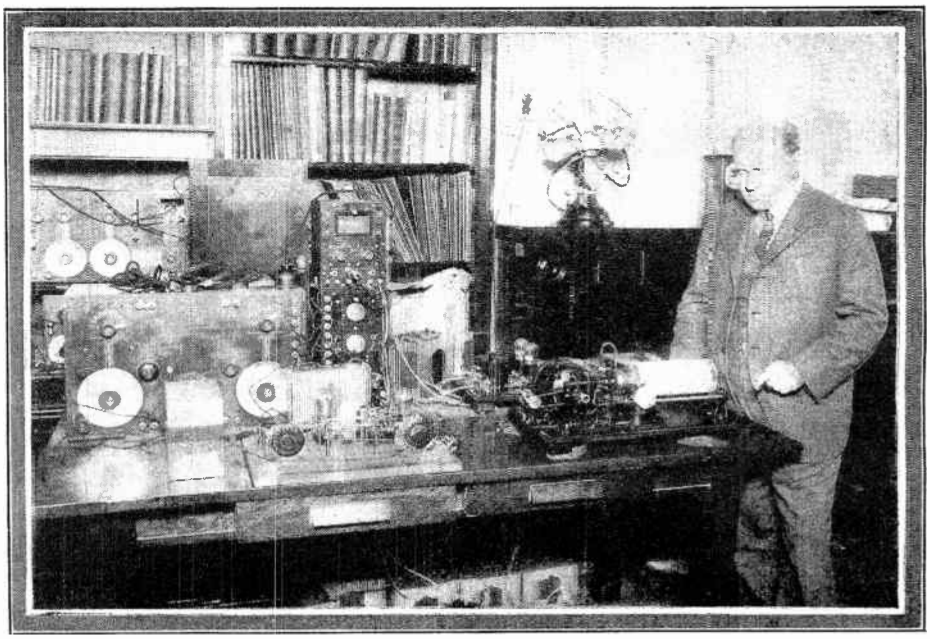
Broadcasting Weather Maps—Jenkins' System

In the January, 1927, issue of *Radio News*, two articles on this subject appear. They both describe the system developed by C. Francis Jenkins.

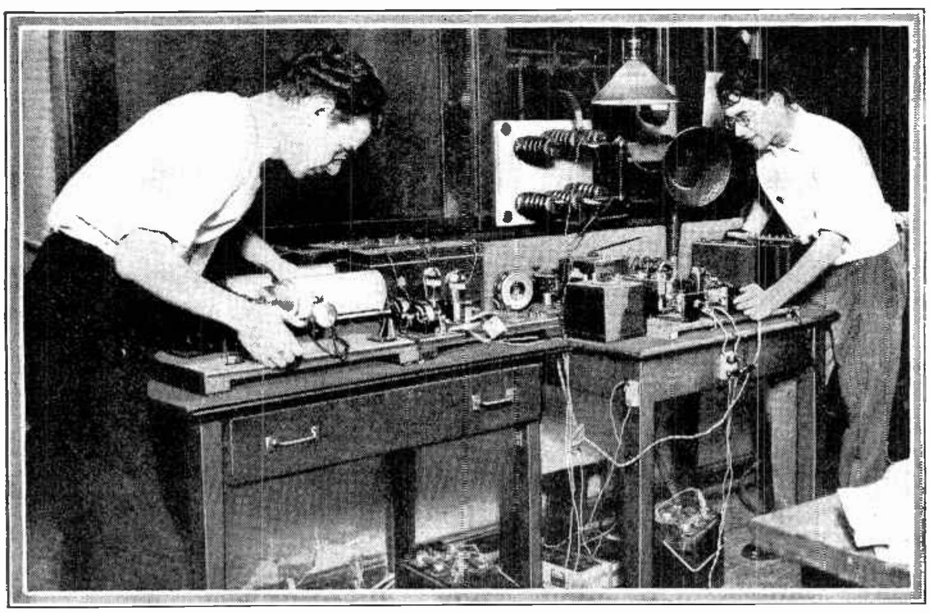
The Navy Department permitted the Weather Bureau and the Jenkins Laboratory to install their transmitter in the powerful naval station NAA at Arlington, Va. The transmission set loaned by the Navy and used for the transmission of the weather maps operates on 8,330 meters and is rated at 40 kilowatts. The Navy provided not only the transmission facilities, but two warships for special receptions. These ships were the U. S. S. "Kittery" and "Trenton."

Tests which have been conducted between the Weather Bureau and NAA showed highly pleasing results. An experimental laboratory and receiving equipment were installed in the Weather Bureau under the direction of C. Francis Jenkins, the inventor; Dr. Charles F. Marvin, Chief of the Weather Bureau, and E. B. Calvert, Chief of Forecasters, and a well known advocate of radio in the work of the Weather Bureau. Dr. Marvin, as well as other officials of the Weather Bureau who were engaged in these experiments, saw in the transmission of weather maps by radio a beginning of a new and important era in meteorological navigation at sea. The Navy Department, realizing the great value to its ships in being able to obtain correct pictures of weather maps immediately after their preparation by the Weather Bureau, gave its closest cooperation, through Commander Hooper, Chief of Naval Communications, and watched the outcome of this pioneer adventure into visual radio broadcasting.

A complete weather map adapted to radio transmission and embracing the areas with which navigation is always concerned was prepared daily by the Weather Bureau. The map was then printed on an 8- by 10-inch sheet of photographic film and this negative used for the actual transmission. The map received was of the same size.



E. B. Calvert, chief of the forecast division of the United States Weather Bureau, can now see how his own weather maps look after they have traveled through the air. This photograph shows Mr. Calvert with the Jenkins radio-weather-map receiving set, which has just been installed in the Weather Bureau.



Students at the University of Chicago worked with the Bureau of Standards; they are here shown receiving the weather maps broadcast from Arlington.

The Jenkins system by which pictures are transmitted by radio is highly interesting. The photographic negative of the weather map is placed about a glass cylinder which revolves at a steady rate while advancing one-fiftieth of an inch with each revolution. A very small beam of light, passing through the cylinder from the inside is prevented from passing the film by its intense opaque background. But whenever the clear white lines of the map pass the beam, a bit of light will continue on through and falls on a sensitive photo-electric cell. The momentary flicker of light decreases the resistance of the thallium sulphide cell and a slight surge of current passes through. This surge is amplified by power amplifying tubes and in turn operates the giant control relay of the 40-kilowatt transmitter; it is very similar to ordinary key modulation. The wave is broadcast as an irregular series of dots and dashes which is very confusing to ship radio operators who try to decode them, not knowing what they mean.

The wave is received and amplified by an ordinary radio long-wave set and is then passed on to the reproducer. It is further amplified by two UX-171 tubes in parallel. The receiving instrument is similar to the transmitter except that the operation is reversed, and the photo-electric cell is replaced by a pen or ink stylus. This pen is placed in front of the cylinder upon which is wound the sheet of paper used for producing the map. The radio impulses actuate the pen in the same manner that they operate the diaphragm of a telephone receiver.

The speed of the cylinder and the forward advance of the pen is held in synchronism with the transmitter by a very ingenious device. Proper synchronism was the critical point of development and until the discovery of how to control this, reproduction could not be successfully obtained. The synchronizing mechanism will not permit the receiver to run too fast or slow, but will automatically check the cylinder at each revolution so that it will start off in harmony with each new revolution of the transmitting cylinder. This is accomplished by a synchronizing signal sent out at the beginning of a new revolution by the transmitting station radiating the signals.

Ship radio stations equipped with the Jenkins system may pick up the map transmission. This means much to navigation officers toward the intelligent handling of their vessels in all kinds of weather and providing for coming changes in the weather. The simplicity of the radio weather maps and their clearness of reception are such that they prove of the utmost value to all navigation.

For many years the Weather Bureau has been broadcasting every day a special weather bulletin, by means of which ship captains have been preparing their own weather maps at sea. The direct reproduction process provides for instant service and the elimination of the old coded method. The long familiar "USWB" weather bulletin, known to all operators since the early days of radio, may soon be a thing of the past. The Weather Bureau is now convinced that the day is not far distant when meteorological advices and information is available to all ships at sea by this direct reproduction method.

CHAPTER VII

Television

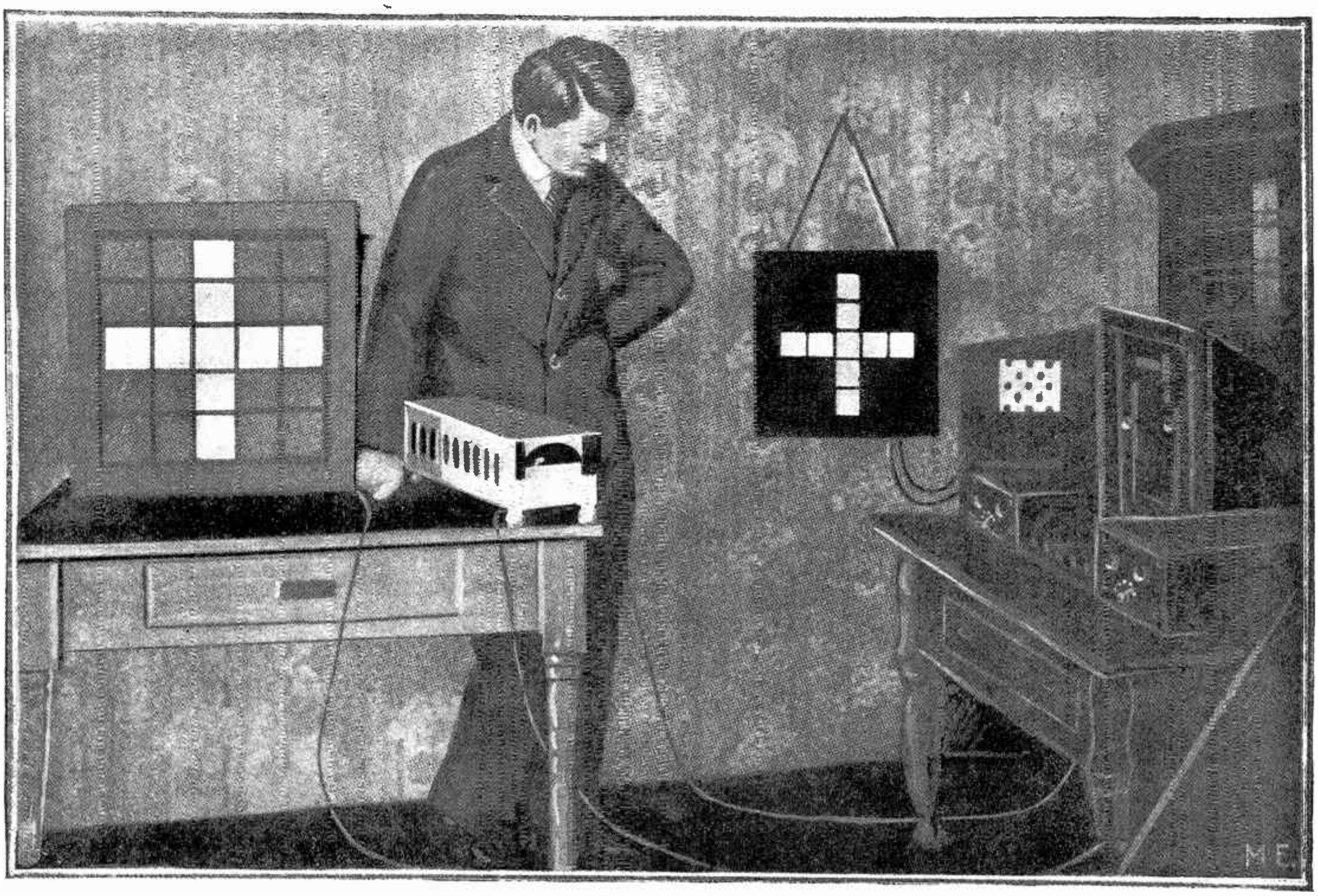


Fig. 1. The transmitter has twenty-five cells each within a square, this operates as many relays sending alternating currents of different frequencies over the same line. At the receiving end, relays operating on harmonious frequencies, control lights and reproduce the image.

Perhaps the first time in history the word television was first employed was by Mr. Hugo Gernsback. It appeared originally in December, 1909, in an article in Modern Electrics. Before that time, the word itself had never been used. Mr. Gernsback was the editor and owner of M. E., this earliest of magazines devoted to the experimenter and his cause. The article on "television and the telephot" which we reproduce herewith is the first that ever appeared in a popular scientific publication. It is taken from Modern Electrics of December, 1909, and was written by the editor.

Every now and then we see newspaper reports that Mr. So and So had discovered the real secret of television, only to be told again a few weeks afterwards that it has not been realized after all.

For almost 25 years, inventors all over the world have been working strenuously to solve the problem, yet up to 1900 none succeeded, apparently because they all seem to work along the wrong lines.

The principle of television may be briefly stated thus: A simple instrument should be invented which would reproduce objects placed in front of a similar instrument (called Telephot) at the other end of the line. In simple language, it should be possible to connect two mirrors, electrically, so that one would show the other one and vice versa.

As in a mirror, the objects must be reproduced in motion (at the far-off station.) The theory further requires that both instruments (one at each end) must be reversible, that is, each instrument must receive as well as transmit.

A good parallel of this requirement is found in the ordinary Bell telephone receiver. As is known, the Bell receiver (without the use of a microphone transmitter) will receive as well as transmit, that is, one can talk into a receiver and also hear the other party, using one and the same instrument.

In the Telephot it should be possible to see the party at the other end while that party should see you, both through the medium of your Telephot.

Unlike the mirror, however, you should not be able to see your own image in your own Telephot. In this respect the Telephot differs from the mirror analogy.

It will be immediately seen how difficult the problem becomes, because if you could see yourself in your own Telephot, as well as the picture of your friend, it is obvious that there would be a "mix-up" of personalities, the consequence being that you could not recognize your friend or yourself, while your friend at the other end could of course not recognize you or himself.

In the telephone the case is not so difficult, as it is absolutely natural that one party talks while the other listens; if both talk and listen, neither can understand, because the voices mix up.

In the Telephot this parallel does not hold good, as there is nothing to restrain you from looking at your friend at the same time he is looking at you.

Of course the problem can be simplified by getting the true parallel of the telephone, thus: When you wish to see A you keep in the dark, while A stands in full light. If A wants to see you he turns off his light while you switch on yours.

However, this would be impracticable and is not the true solution of the Telephot.

So far most inventors seem to think that the problem can only be solved by means of the selenium cell, which being sensitive to light, can send out electrical impulses in the same ratio as the light falling upon the cell. Thus, if a strong light is thrown on a selenium cell a strong electric impulse is sent over the line which when operating a light relay (described here) can be made to throw a strong light upon a screen.

As a picture is made up of nothing but light and dark points it is easily seen that if several thousand very small selenium cells were arranged in a plane and just as many light relays at the other end, a good picture could be projected upon a screen—in theory. The trouble is that it is practically impossible to make two selenium cells with equal sensitiveness and this is the most important part, as if one is not as sensitive as the other, it will of course not transmit the same impulse. It can be easily imagined what kind of a picture a station would transmit having several thousand selenium cells, all of a different sensitiveness!

Then the next trouble is that each cell at best requires one wire (the ground *might* be used as return). Think of two stations which, in order to work, require 3,000 to 5,000 separate wires! This seems to be as bad or worse than Sönmering's first telegraph (in 1809), which required 27 wires to operate. In Morse's subsequent telegraph only one wire is required, which unquestionably will be the case with the perfect Telephot.

Another great trouble with the selenium cell is that it works sluggishly, that is, its resistance will not drop instantaneously from the highest value to the lowest. This is bad, as it would necessarily blur the picture at the other end. Furthermore, to work anywhere satisfactorily the selenium cell requires strong light.

The writer does not wish to throw cold water on selenium and selenium cells, as it is quite possible that the latter may be improved to such an extent as to do away with the shortcomings mentioned above, although the greatest difficulty, the one that each cell requires at least one wire, is and will be the greatest stumbling block.

Many different systems have been proposed in the past to solve the problem by means of selenium cells and although the list is quite long only a few will be mentioned in this article, as all present systems follow more or less along the same lines.

Knothe Device

A. Knothe proposes to solve the problem as follows: C (Fig. 2), represents a camera into which the lines coming from the batteries enter. The space between each pair of wires is bridged by a selenium cell S. If now light enters the camera it falls on S (and all the other cells), and closes the circuit which operates the spark coils J. This furnishes a discharge as a single ray in the X-Ray tube H at the receiving station E. This single ray is thrown as a single point on the fluorescent screen F.

It is understood that several hundred cells, spark coils and parabolic mirrors K are necessary to transmit a picture. The X-Ray tube would therefore necessarily be of monstrous dimensions. All the wires, 1, 2, 3, 4, up to several hundred, must of course, be well insulated, so that no sparking occurs between them.

All these requirements make the arrangement almost impossible and quite impracticable.

The latest "Telephot" (one must remember this article was published in 1909) has been designed by Mr. Ruhmer, the well-known Berlin expert. Last June Mr. Ruhmer demonstrated a working model, which although it did not transmit pictures, served well to demonstrate the usefulness of the selenium cell for certain purposes.

Fig. 1 shows the model clearly. The principle is as follows:

The transmitter has 25 squares, each containing a selenium cell. If any one of the 25 cells is exposed to light, it operates a sensitive relay, which sends an alternating current of a certain frequency over the line.

At the receiving end one resonating relay is stationed for each selenium cell at the sending station. The impulse sent from the selenium cell therefore operates only that relay having the right frequency.

Each relay operates an incandescent

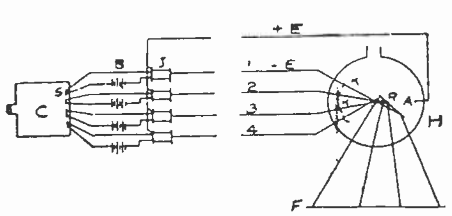


Fig. 2. Light entering camera, C actuates selenium cells S, closes circuit to spark coils J, and produces rays in X-Ray tube H.

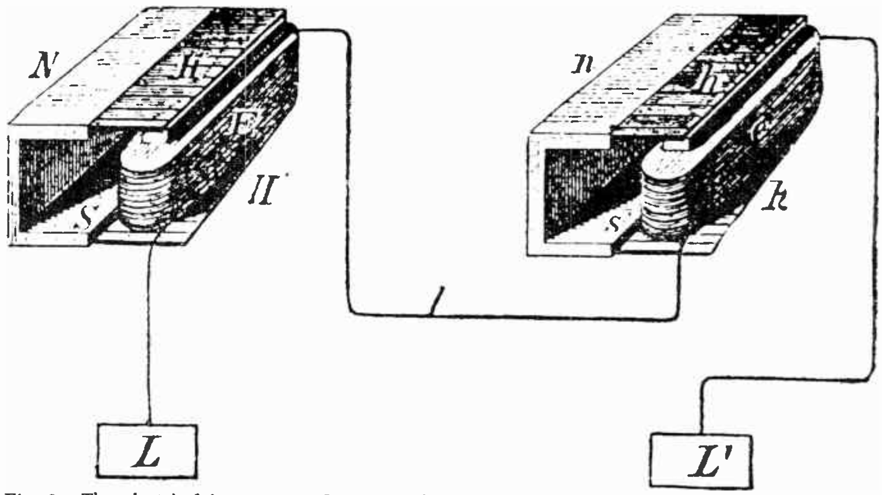


Fig. 3. The electrical harmonica. If any of the prongs H are put in motion, currents are set up in E, pass to c and cause a corresponding reed in h to vibrate.

lamp which is placed in the same square at the receiver as the selenium cell at the transmitter.

If several cells are exposed to light at the transmitter, several alternating currents, but all of different frequencies are sent over the line. These currents do not mix, but operate only the relays for which they are intended.

These in turn operate the lamps in the various squares, assigned to them.

Mr. Ruhmer has perfected the selenium cell to a fine degree, and as his model worked very rapidly, it will be seen that the sluggishness of the cells has been overcome to a certain extent.

Simple geometric figures were transmitted quite successfully as can be seen in the photograph, where 9 squares at the transmitter were lighted and the same number, in the same position were reproduced at the receiver. This is quite remarkable if it is remembered that only *one wire* is used between transmitter and receiver.

Mr. Ruhmer intends to build a transmitter containing 10,000 cells, to reproduce pictures at the Brussels international exposition in 1910. The cost will be over one and a quarter million dollars and the writer is of the opinion that it is almost impossible to operate such a model on account of the 10,000 different frequencies necessary to accomplish the result.

A simpler way could be brought about by the idea proposed by the writer some eight years ago.

Fig. 3 represents the well-known electrical harmonica, which for the sake of those not knowing the instrument, is described herewith:

A musical steel harp H is fastened to a permanent magnet NS. If any one of the steel harp-prongs is touched it will swing back and forward, at the same time sending an induced current through the windings of the electromagnet E. If we connect a similar instrument h through the line l, and ground LL' to H' it is evident that if we touch any of the steel prongs of one of the instruments, the same steel prong on the other will be made to swing. If we have 12 prongs on each instrument and we touch prongs 1, 6, 9, 12 of H', all at the same moment, prongs No. 1, 6, 9, 12 of h will be made to sound at the same time too, and so on.

Suppose we build such a harmonica having, say, 500 prongs F, Fig. 4, each responding readily at an extremely light touch.

Exactly over each of the 500 prongs we place a minute electromagnet E, 500 in all (only 6 shown in illustration), so when one of the small electromagnets is acted upon by means of a weak alternating current flowing through same it will cause the prong underneath it to swing as long as current flows through the electromagnet.

Now each of the small electromagnets is connected to a selenium cell of which 500 are placed in a plane.

It will be easily seen that if one or more of the selenium cells are acted upon by light, one or more of the small electromagnets is acted upon and as a proportionate amount of current in proportion to the intensity of light at the selenium cell flows through the small electromagnet, or electromagnets, it will cause the prong or prongs to vibrate in the same proportion of intensity as the light falling on the selenium cell.

If cell No. 1 is illuminated by a 10 C. P. lamp, assume that the small electromagnet connected to it causes its prong to swing through a distance of one millimeter. Then if cell No. 50 is only illuminated with light of the intensity of 1 C. P., prong No. 50 will of course only swing 0-1 millimeter and so on. Thus each prong will be caused to swing in exactly the same proportion as the amount of light falling upon the selenium cell, to which it belongs.

As each prong swings it sends a current over the line L' L". If now No. 1 and No. 6 of the electromagnets are energized through the selenium cells both cause their prongs to swing and send impulses over the line. At the receiving station G, prongs 1 and 6 must swing in the same proportionate intensity as the prongs at the sender H, consequently electromagnets E' 1 and E' 6 are energized (the prong acting as a telephone diaphragm, the electromagnets having a permanent magnet as a core). E' 1 and E' 6 now operate the light relays LR1 and LR6.

Now, then, if the selenium cell connected to E1 is illuminated with say 10 C. P., a proportionate amount of energy —call it 10 energies—are received at LR1. The light relay therefore passes 10 energies of the small tungsten lamp LT through its opening, and 10 energies are projected on the screen S. If the cell connected to E6 receives the light of 100 C. P. it is evident that LR6 receives 100 energies and the screen is lighted with 100 energies and so on.

Thus it will be seen that if we have enough selenium cells at H and enough light relays at G any picture in motion will be transmitted correctly and reproduced in its true phases on the screen S.

It is only a matter of building the apparatus and instruments with sufficient precision.

The light-relay is an instrument which has the purpose of utilizing very weak

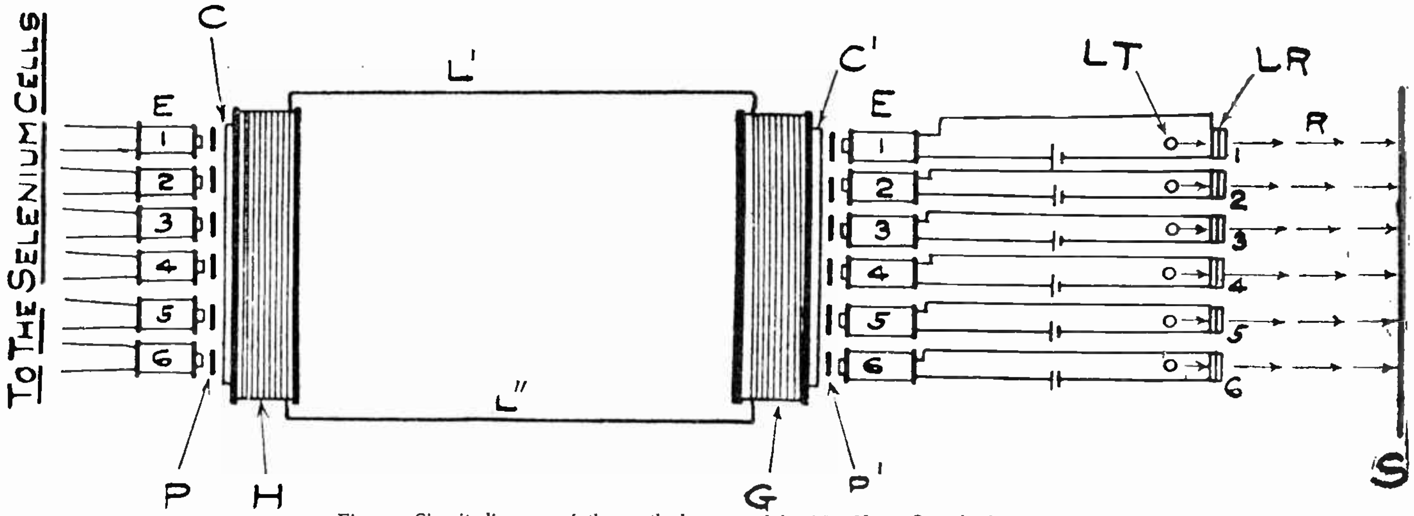


Fig. 4. Circuit diagram of the method proposed by Mr. Hugo Gernsback in 1909.

electric impulses to throw a beam of light on a screen, which in intensity is proportionate to the strength of the electric impulses. In other words, if the impulses are strong, a large amount of light is caused to fall on the screen; if the impulses are weak, a small amount of light falls on the screen.

Fig. 5 shows the instrument in perspective. Between the poles of a strong electromagnet NS, two extremely fine metal wires A and A¹, are stretched. The wires may be stretched more or less by the regulating screws q q'.

The two poles N and S, are each provided with a hole O and O¹, through which light rays are sent in the direction p, p₁. On the two wires, a and a', a very light piece of aluminum foil B is attached in such a way that no light can normally pass from O to O₁.

If, however, a weak current passes from a to a', the aluminum foil is deviated in the direction f or f₁, as the case may be. In order to obtain very exact motions of the foil the thin wires are best replaced by fine metal bands 0.01 and about 6 centimeters long. The resistance of each band is about 75 ohms.

As far as the writer knows his plan so far, is the only feasible one which can be used to transmit objects in motion over a single wire and at the same time receive a proportionate amount of energy at the receiving end to that received by the selenium cells at the transmitter.

No patents were taken out on this invention by Mr. Gernsback, as he considered the device too complicated for general use.

The material was passed along to experimenters in the form of an article, as mentioned before, in the December, 1909, issue of Modern Electrics, a magazine of which Mr. Gernsback was the editor and owner.

It is stated that more than twenty-five years ago a Polish Prof. Szczepanik, of Krakow, first conceived the idea of transmitting pictures to a distance by means

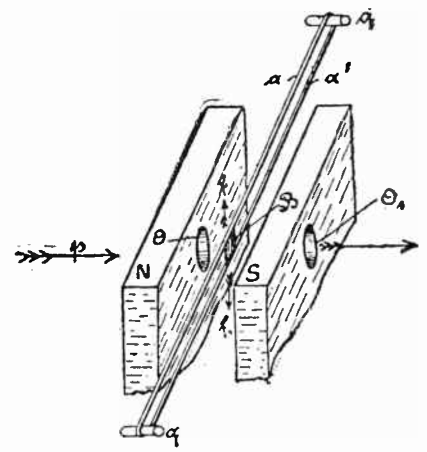


Fig. 5. The light relay described in this article.

of an electric current and the use of selenium on account of its change of electric conductivity with varying intensity of light falling upon it. Some remarkable experiments have been made by Ruhmer, of Berlin, in the transmission of images and in 1910, the well known French Scientists Rignoux and Fournier, have designed similar apparatus and made some interesting experiments along these lines.

Failure has attended their efforts to obtain instantaneous vision by means of a single selenium cell on account of the inertia of selenium not allowing the single cells of those days to transmit more than 30 signals in a second.

Multiple Selenium Cell Transmitters of Ruhmer, Rignoux and Fournier

A system of multiple selenium cells was then utilized by Ruhmer as well as Rignoux and Fournier and was described in the July 1910 issue of Modern Electrics. The latter experimenters utilized a row of selenium cells as shown in the accompanying illustration, Fig. 6, with the transmission wires attached, a letter "T" at the transmitting station being indicated in illustration Fig. 7, while Figs. 8 and 9, show the letters "T" and "E" as appearing at the receiving station. The current from each cell reaches a receiver with galvanometer and mirror with a unique device so arranged that the mirrors can reflect the light of a lamp and project it on a screen. The position of these points of light correspond to the position of the cells of given numbers and taken as a whole, reproduce the image at the receiv-

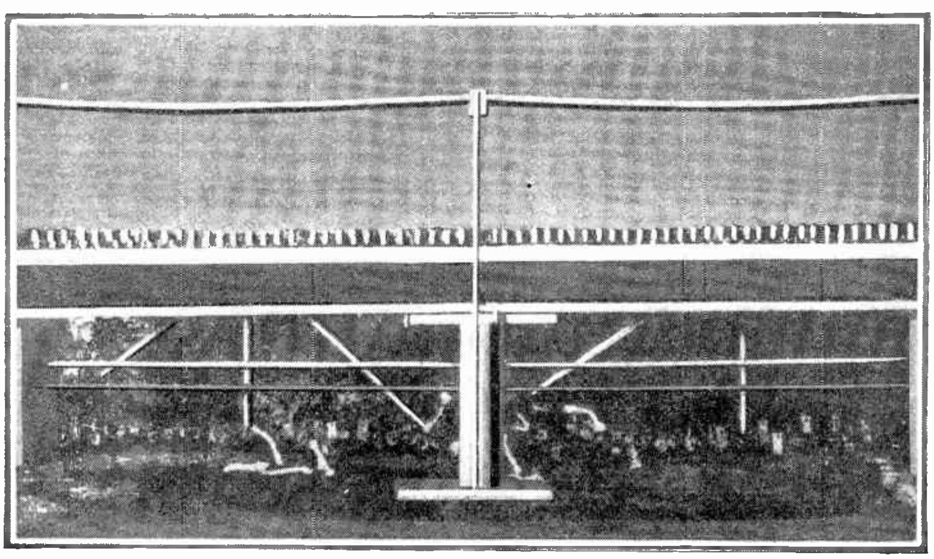


Fig. 6. A row of selenium cells used in the early experiments in television.

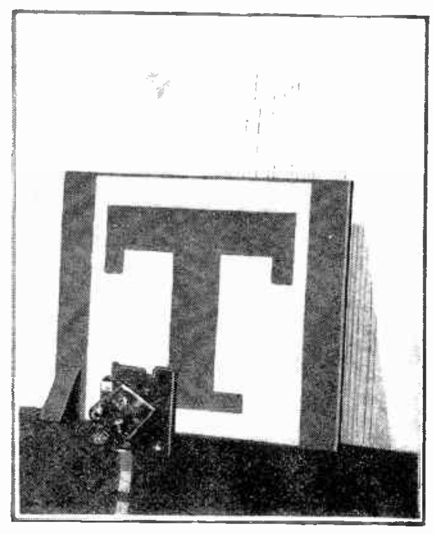


Fig. 7. A letter used at the transmitting station during early experiments with television.

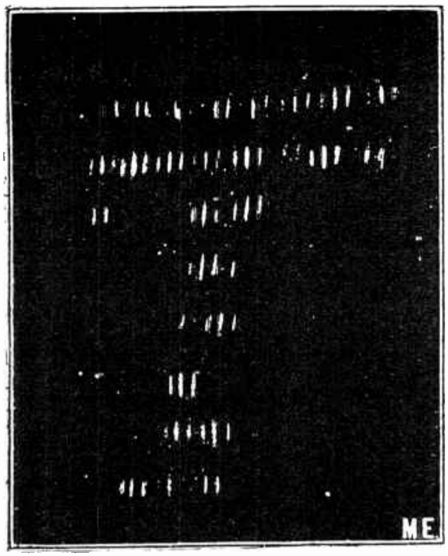


Fig. 8. The letter "T" as received at the receiving end of the early television mechanisms.

ing station similar to that at the transmitting station.

It was even at this day maintained that the telephot as it would ultimately be constructed will contain only two transmission wires, one for the selenium and the other to insure the synchronism of the apparatus with a rotary collector which would gather the currents running from each selenium cell.

It was held that for long distance transmission, each cell will be connected to a relay which will be utilized to replace the feeble current by a much stronger one, but proportional to the first.

These currents were to be collected by means of a rotating device operating at a speed of 600 revolutions per minute and the currents sent successively through a single wire of the line. A polarizing coil was to be employed and numerous experiments demonstrated that over thirty thousand signals could be transmitted with the greatest regularity, the electric signals being transmitted and translated into luminous signals with accuracy, and projected by means of a set of mirrors revolving synchronously with the collector of the transmitter. All the various points so transmitted were to be produced every tenth of a second, since the collector, as well as the disc containing the mirrors, turned at a rate of 10 revolutions per second. The impression on the eye, therefore, was to be continuous and it was thought that by means of only two wires, the transmission of an animated picture of an object placed at the transmitting station would thus be realized and a practical system of television developed.

It is thus seen that the idea of modern television is not strictly new. It can be rather classed as a gradual development, which even if quite good is not at its ultimate stage of perfection.

The De Vendenil System

As early as July, 1910, the revolving shutter in present day usage was described by A. C. Marlowe, then the Paris correspondent of Modern Electrics.

This was devised in France by M. De Vendenil. Between the image and selenium cell is interposed a revolving shutter so as to uncover all the points of the image in succession. In the rear of the shutter (Fig. 10) is a plate N, having the opening A B C D representing the image. Before it, rotates the circular disc M, and it has a series of circles traced upon it so as to cover the whole of the image A B C D. On each circle is a small hole 1, 2, 3 etc. The hole 1 moves over the image and when it reaches the end of its row, hole 2 commences to move over the second row and so on, so as to uncover all the points of the image in succession. Later in this book we will see how this shutter is again brought to use. In Fig. 11 we have the transmitter. The image is projected by the lens P through a second lens R and thence on the selenium cell S. Between the two lenses is mounted the above-mentioned shutter M N, so that in reality there is only one point of the image thrown on the selenium at a time. To produce the corresponding effect in the receiver he used the variations in an acetylene flame which are given, Fig. 13, by using a chamber which is divided into halves by a diaphragm A. The line current acts upon a magnet B, so as to operate the diaphragm and this gives differences of pressure in the acetylene gas which occupies the second chamber and feeds the flame. We thus have varying brightness of the flame according to the current in the line. This device is mounted in the receiver at E F, and the flame sends light through the lenses G and J to the final screen L. Between the lenses is a second rotating shutter like the above, so that each point of the image is thrown in succession on the screen.

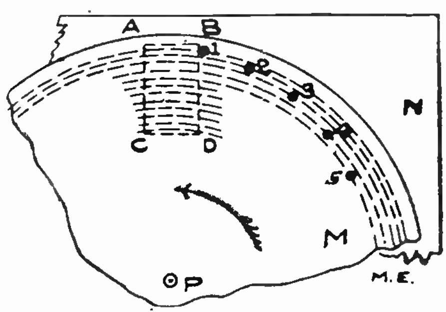


Fig. 10. The revolving shutter employed in 1910 is practically the same as the modern type.

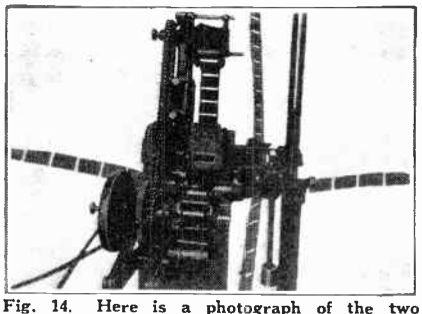


Fig. 14. Here is a photograph of the two shutters employed in the Armengaud method of television. The shutters travel at right angles to each other.

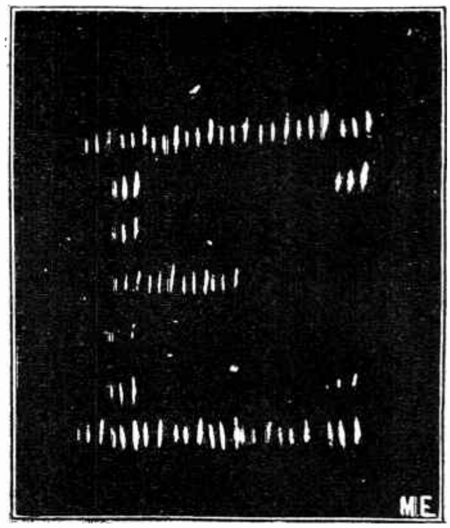


Fig. 9. The "E" is a bit straighter than the "T" opposite.

The Armengaud System

M. Armengaud, of Paris, was at this time at work on an apparatus in which the shutter worked in a different manner to cover the image. The latter is formed by the lens M on the ground glass screen C. Behind it is the selenium cell S. Between the image and the cell is the shutter A-B. In order to allow all parts of the image to be covered in 1/10 second, he used the shutter device (Fig. 16) consisting of an endless horizontal band A, which is mounted on rollers so as to move beltwise in the direction of the arrow. Behind it is a vertical band B, which is arranged in like manner to take a rapid downward movement. The square portion which is given by the crossing of the two bands is disposed so as to cover the whole surface of the image, and acts as the screen placed at AB as before seen. In the band A, which is opaque, are a number of vertical slits A, A′, A″, etc., equally spaced. The band B has likewise a set of slits B, B′, B″, etc., of the same width. Light from the image will be cut off from the selenium cell except at the crossing point M of the slits A′ and B′, etc. We have thus a small square which gives light from one point of the image upon the cell. When both bands are moved in the direction of the arrows, this point will be displaced so as to uncover different parts of the image so that the opening passes over all its surface. The whole is mounted as seen in the photograph, using moving picture bands with their mechanism in the two cases. The films are blackened by developing, and the gelatine is removed so as to make the slits or clear spaces. A small electric motor works both bands. The mechanism is somewhat modified here. Film B has a downward movement, but the slit B (or B′ etc.) is brought to a stop so as to allow one of the slits A

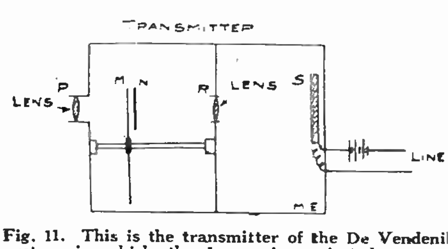


Fig. 11. This is the transmitter of the De Vendenil system in which the image is projected upon a single cell through a revolving shutter.

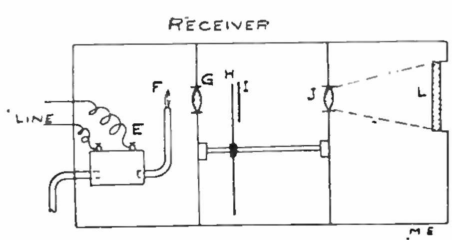


Fig. 12 shows the receiver in which the image is reconstructed; note box leading to flame F.

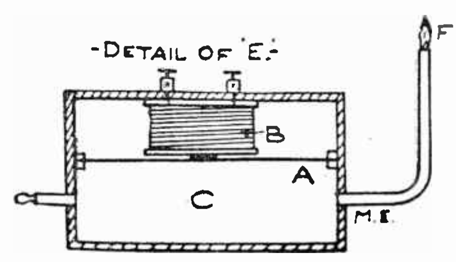


Fig. 13. Here is the light changing device indicated by a box in the previous figure. When diaphragm A moves, flame flickers.

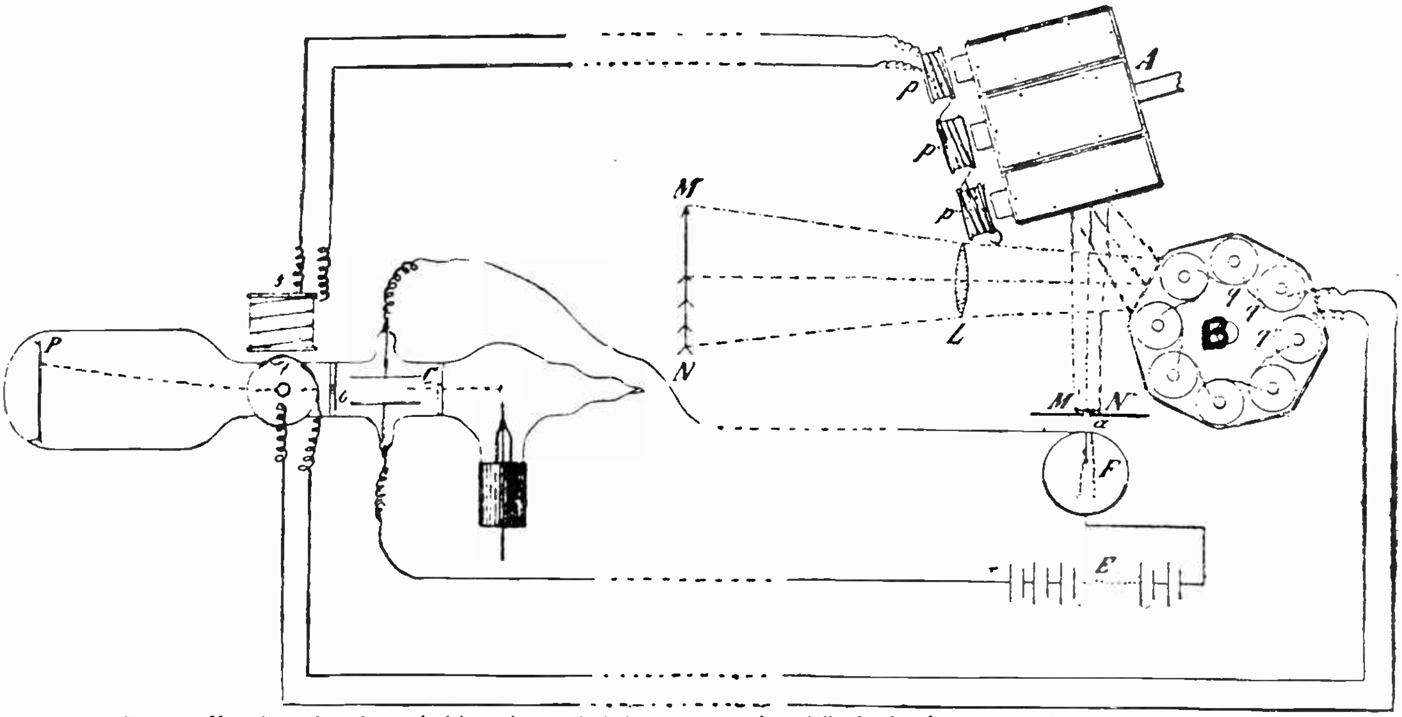


Fig. 17 Here is an ingenious television scheme which has not as yet been fully developed to a state of practicability. It makes use of the Braun cathode ray tube.

to pass across its whole length. The band B then comes down one step so that another of the slits B comes into place, and this is again passed over by A, etc. However, the spacing of the vertical slits is such that at each move, the next slit B will come to a point lying next under the former position, so that a new line of the image is uncovered each time. This is done by spacing the slits B at, say 9/10 of the height of the image instead of at 10/10. The vertical band requires to be stopped each time, but the horizontal band can be moved without stopping, it is found. The receiver had not yet been constructed at the time of this article and we never heard whether it proved practical, but it was proposed to use the method shown here, in which the current comes to a galvanometer D with swinging mirror, and the light is thrown on the lens L, so as to reach the screen N. Before the lens is a shaded color screen which gives bright and dark parts according to the current or the swing of the mirror. Before the ground glass screen N is a moving band shutter like the above.

The Rosing Telephot

This apparatus is quite an improvement on previously described similar instruments and its originality should make it many friends. Our modern machines seem to have drifted away from the principle shown here, which, by the way, was described in Modern Electrics as early as June, 1911. It was invented by Prof. Rosing.

On the receiving end a Braun tube is used. The cathode rays excite at every given moment a point of the fluorescent screen of the tube, whose position coincides with the light element of the image to be transmitted. To variate the light intensity, Mr. Rosing did not use a selenium cell, but a photo-electric cell, which did not work as sluggishly as the former.

Such a cell is constructed in the main of a glass bulb containing hydrogen or helium, sometimes also, in part, caesium-rubidium, sodium, or potassium-amalgam. Opposite the amalgam surface a platinum electrode is fused into the glass.

When now the negatively charged amalgam surface is lighted, a discharge occurs almost immediately (Hallwach's effect). According to Righi & Stoletow, the intensity of the photo-electric current thus produced is directly proportional to the light-intensity; it also follows accurately the fluctuations of the latter.

Our illustration shows the Rosing arrangement. The sending station is at the right, the receiving station at the left; six wires were necessary to connect the stations. However, the inventor claimed it possible to bring this down to four.

At the sender the picture, M' N', of the object, M N, to be transmitted is first thrown through the lens, L, on the two Polygon-mirrors, B and A, thence on an opaque screen which has an opening, a. The two mirror arrangements, A and B, rotate around their axes, which are placed at right angles to each other. The image, M'N', thus suffers displacements in two directions. On account of the rotation of the mirror, A, the picture is displaced in a vertical direction with respect to the plane of the illustration, while on account of the rotation of mirror, B, it becomes displaced in a direction lying in the same plane as the illustration.

If now, for instance, the mirror, B, rotates considerably slower than the mirror, A, the combination of the two mirror rotations will produce a zig-zag movement of the picture on the screen in such a manner that one after another all points of the image will act on the photo-electric gas cell, F, through the opening, a, of the screen.

At the receiving station, by means of the two electro-magnets, s and t, which are arranged at right angles to each other, the cathode rays of the Braun tube will be displaced by a similar movement, in such a way that each moment the light spot, P, will take a similar position on the fluorescent screen, with respect to the reproduction surface, as the transmitter image-point takes with respect to the image-surface. For this purpose, the electro-magnet, s, which deflects the cathode rays in a vertical direction (with respect to the plane of the illustration), is connected with the windings, p, of the mirrors, A. The electro-magnet, t, which acts on the rays in a direction lying in the plane of the illustration, is connected with the wind-

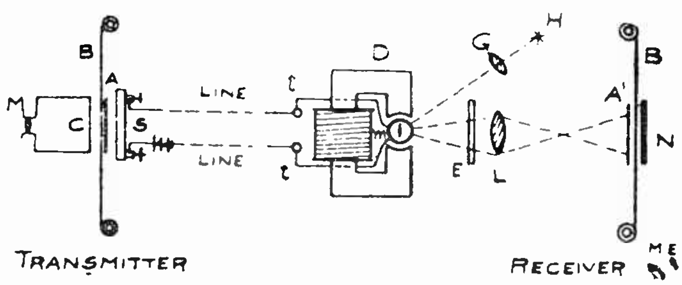
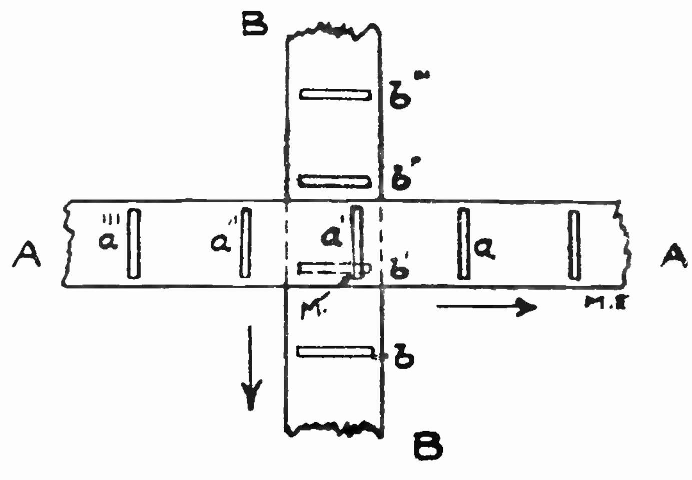


Fig. 15. Here is a schematic representation of the television method outlined in the accompanying article. Both transmitter and receiver are illustrated. A and B show the two shutters operating at right angles to each other.

Fig. 16. Right. Here is a detailed view of the shutter arrangement. The arrows indicate the direction of movement and the small letters a, and b, represent the slots in the endless bands.



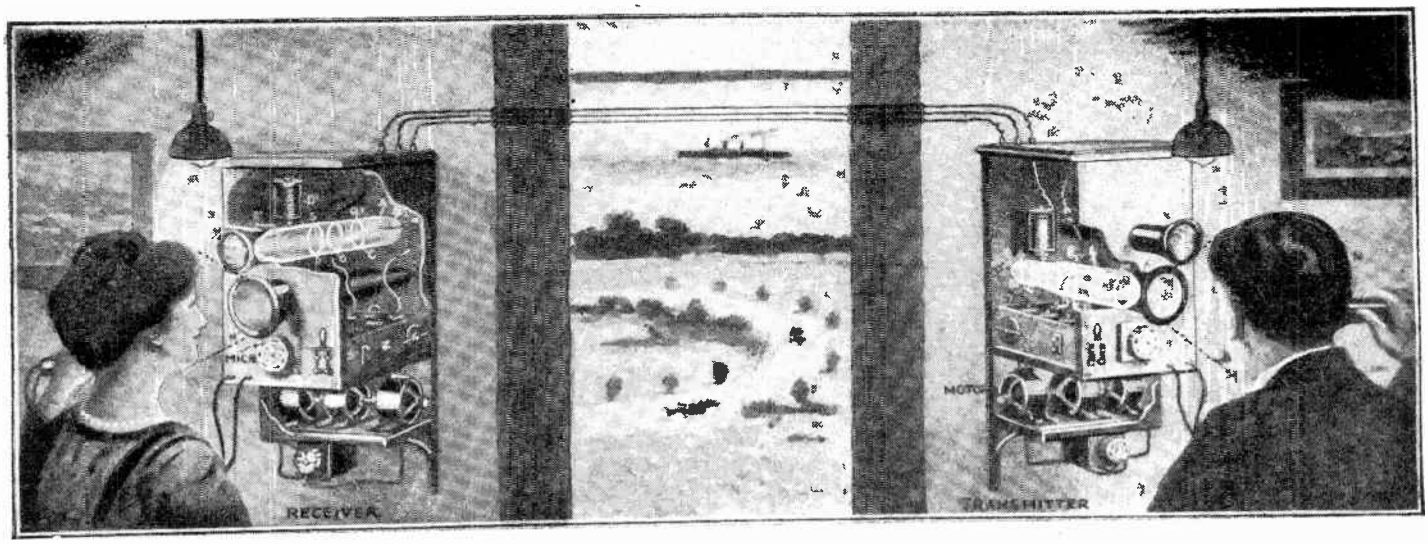


Fig. 18, at left, shows image of a man at right being transmitted and reproduced on screen in front of lady. Her face is transmitted and reproduced at Fig. 2 (right) before man. Mr. A. A. Campbell-Swinton's scheme

ings, q, of the mirrors, B. In the specially proportioned windings, p and q, induction currents will be produced by means of the electro-magnets which are placed near the edges of the mirrors. The intensity of these currents is proportional each moment to the rotation of the mirror; the same of course holds true for the magnetic field produced by the electro-magnets, s and t, and therefore the cathode rays and also the fluorescent point on the screen actually move synchronously and isochronously with the movement of the image to the opening, a.

The transmission of the different light effects of the transmitter image-point is obtained by the electro-static action on the cathode rays of the condenser plates, C, arranged in the tube. One of these is connected with the positive pole of the battery, E, the other with the platinum electrode of the photo-electric gas cell, while its light-sensitive surface is connected with the negative pole of the battery.

According to the intensity of the light of the various image-points to be transmitted, the condenser will be charged more or less at various times. The cathode rays under the action of the electric field thus produced are deflected downwards in the plane of the illustration.

Between the condenser, C, and screen, a second diaphragm, o, is inserted into the cell. The opening of the latter is so constructed that the cathode rays are shut off when the electro-static field is not excited: only when the condenser is charged, and the rays are deflected more or less, can the latter pass the opening, and thereby produce a fluorescent spot of proportionate intensity on the screen.

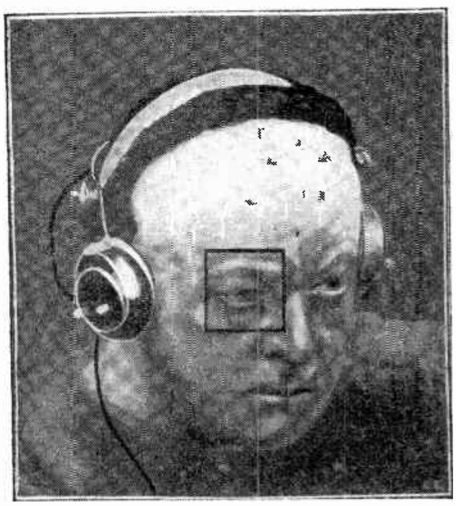


Fig. 19. This picture is made of many small dots, although you wouldn't think so. Note marked eye in Fig. 20.

In order to correct phase displacements between the deflection and modulation of the cathode rays, one rotates the spool systems, p. and q, a few degrees with respect to the axes, a and b.

H. Winfield Secor described a very interesting form of television apparatus in the August, 1915, issue of the *Electrical Experimenter* subsequently known as *Science and Invention* Magazine. It seems that the method outlined by Mr. Secor, even though seemingly better than modern systems, has been discarded for no thoroughly practical reason. Mr. Secor was Associate Editor of the *Electrical Experimenter* and now continues his educative work as Managing Editor of *Science and Invention* Magazine.

Selenium, as we know, changes its electrical resistance proportionately to the amount of light thrown on same. Therefore, as every picture is made up of light and dark shadows, it is evident that if such a picture is properly projected on a group of selenium cells that the different cells will change their electrical resistance proportionately to the amount of light projected on them and corresponding conjointly to the light and dark shadows of the view before the instrument. Simply explained, this system works as follows:

Each selenium cell on the transmitter would be connected up with its individual lamp (very small, of course), and thus it is perceived how, at the receiving station a picture or view could be reproduced in black and white and intermediate tones, for the reason that each selenium cell would allow a different amount of current to reach its individual lamp.

This may seem a little ambiguous or complicated to those not familiar with the subject, but what we are driving at may be the more readily perceived or understood by inspecting Fig. 19. The portrait photographed, reproduced by the half-tone process, exhibited at Fig. 19, is photographed onto the copper plate used in printing the reproduction on this page, through a finely ruled glass screen. This screen therefore causes the original photograph to be broken up into many small dots. The illustration here referred to, for instance, has about 140 dots to the inch. By looking in an ordinary manner at the photograph here reproduced, no distortion is noticeable, and the picture appears quite natural. Nevertheless, *it is made up entirely of dots*. You can convince yourself of this by inspecting our illustration with a lens.

The second view, at Fig. 20, shows a largely magnified portion of the (marked) eye on the face of the half-tone cut. This shows how the reproduction of the face is made up of small dots, and by closely looking at any newspaper illustration, which is usually photographed through a coarse screen, this *dot make-up* of the picture will be very evident. Some illustrations in magazines and books, which are reproduced on highly polished and specially coated paper, are photographed through such a fine screen that the keenest eye cannot perceive any break-up or dot formation.

As aforementioned, a number of workers have endeavored to solve this problem of "seeing over a wire," as it is commonly referred to, and one of the best methods tried in a laboratory, on a crude scale, is that of making use of a large number of selenium cells.

However, there are several drawbacks to this solution of the problem, some of them being enumerated below.

Selenium cells manifest a quality known as "time lag" in their electrical operation or action, and this means that it is difficult to build any such apparatus, as we now have under consideration, to act in an anywhere near perfect manner, when the selenium cells will show varying degrees of "time lag," or, in other words, when they tend to be sluggish in their action of changing from high to low resistance, etc. This lag is small, of course, and it must be understood that in considering the basis of this whole process that with the dot formation, even though made up of a vast number of small lamps, compactly grouped

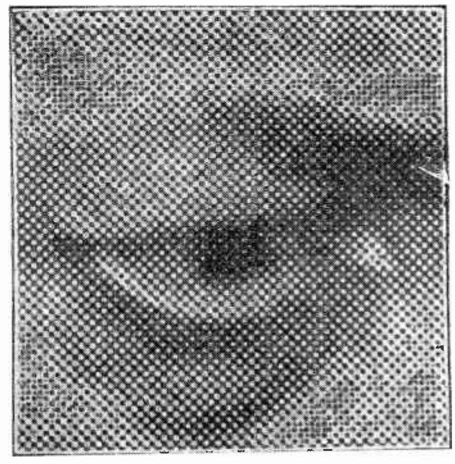


Fig. 20. Hold this 18 inches from you and the effect will be seen to give the facial features noted inside the marked square on the face at Fig. 19.

at the receiver end of the line, that the changes in the lamps' intensity, which is of course primarily dependent upon the action of the selenium cells on the transmitter, must be quite rapid, and this may be more readily understood when it is known that in the ordinary motion picture, with which we are all familiar, there are from 16 to 20 different pictures projected on the screen per second. This has been found to give us a fairly steady picture owing to the "lag" of the human eye in perceiving an object in motion. That is to say, the eye does not lose its impression simultaneously, but the object's impression on the retina of the eye remains for a fraction of a second, and this explains how motion pictures are made possible by the present methods in vogue.

It has been estimated by a well-known English authority and scientist, who has worked along the line of Television, that if the selenium cell process was to be used to give good close-grained results on a surface only two inches square, there would be required 150,000 wires, 150,000 selenium cells, 150,000 lamps. While even to obtain an effect no better than that used in the coarsest process blocks, as used by ordinary daily newspapers, there would be required at least one-tenth that number of selenium cells, lamps and wires.

Working on this basis, but reducing the number of cells, etc., to be used, to a figure of 90,000, this scientist calculated that the cost for a 100-mile transmission circuit, including apparatus at both ends, would amount to the staggering sum of $6,250,-000. This considers simply a monochrome reproduction in black and white only of the view or object over the circuit. If the apparatus in question should have to be triplicated, so as to give a colored picture, by the well-known three-color process, then the cost would naturally rise to three times the amount stated.

From this figure it is to be seen that evidently such a solution of the problem is far beyond us and not capable of industrial or practical applications, in the strict sense of the word.

Some workers in this field have also devised or advocated at different times very clever and ingenious methods, which seem quite good theoretically, for using a less number of selenium cells, lamps, etc., but to gain the same effect as if a large number of cells were used, by suitably moving a beam of light over the various cells successively at very high speed, and some similar arrangement being used at the *lamp* end of the circuit, where the picture is to be reproduced. This would act upon the principle of the retina retention of impression, as previously mentioned, and such ideas are based upon the theory that with proper apparatus, which unhappily is nearly impossible to construct from a mechanical standpoint, that each cell could be used for a fraction of a second.

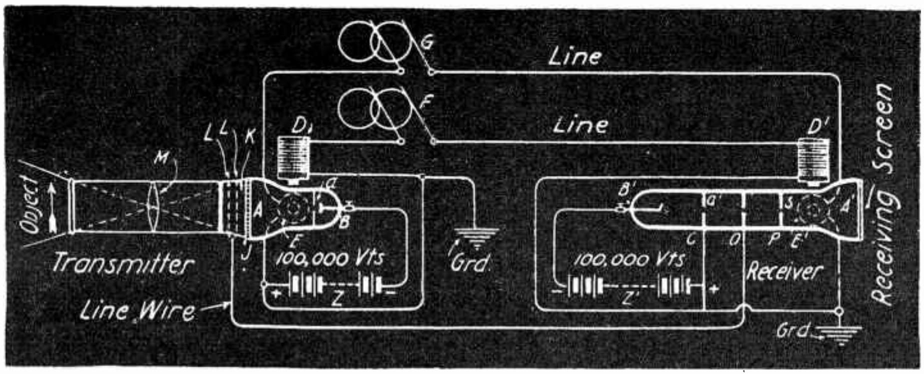


Fig. 18a. Diagram of Proposed "Television" Scheme.

System of Campbell-Swinton

A promising (theoretical) system of Television—the Telephot—or the instrument for "seeing over a wire," makes use of a stream of cathode rays, which can be deflected and changed in their direction of production very rapidly, and moreover, these rays possess an infinitesimal amount of momentum or mass. This method has been brought forth by an Englishman, Mr. A. A. Campbell-Swinton, president of the Röentgen Ray Society, of London.

The apparatus based on his descriptions and ideas are shown in the illustration at figure 18. In this picture detailed apparatus only is shown for transmitting pictures one way, or, in this case, from right to left; the detailed receiving apparatus being then at the left of the picture and the transmitting apparatus with high frequency A. C. generators, etc., being shown at the right. Both transmitting and receiving tube openings are shown, however. It is evident that one can easily, and without any awkward motions, glance slightly upward to view the reproduced face in the smaller upper screen, which is shown placed at a small angle. A dictagraph or super-sensitive telephone transmitter is probably best for such instruments and is observed under the *television screens*. Six wires are required to transmit pictures both ways.

We may now briefly consider the operation of this apparatus advocated by Mr. Campbell-Swinton, and which has been favorably received by the scientific world, *although as yet not practically demonstrated.* The schematic diagram, Fig. 18a, will help the reader to understand the diagnosis of its operation. Three line wires are necessary between the apparatus, as observed from the illustrations at Figs. 18 and 18a. At the *transmitter* end of the line there is used a focusing lens barrel "X". The object whose reproduction is to be electrically transmitted over the line is arranged at the tube opening, as at "N." A Crooke's vacuum tube is used at "A" and at "B" is the cathode electrode of the tube, from which the cathode rays are shot forth at an incredible velocity and which have practically no mass or momentum. An anode "C" of circular form is placed in the tube, which has at its center a small aperture or opening "a." Through this opening a small stream of cathode rays may pass; these rays being produced by a high potential *continuous current* from a source "Z," giving in the neighborhood of, say, 100,000 volts. Placed at right angles about the tube "A" are two electro-magnets "D" and "E," and these are energized by alternating currents from the A. C. generators or dynamos "G" and "F." These magnets allow of readily controlling or deflecting the cathode rays stream in a vertical and horizontal direction, respectively.

At "J" in the transmitter tube is placed a special screen, the whole surface of which is searched out by the stream of cathode rays, every tenth of a second, under the combined action of the A. C. electro-magnets "D" and "E." It should be mentioned here that the dynamos "G" and "F" produce *widely different* frequencies of alternating current; one of them producing, say, 1,000 complete positive and negative alternations per second, and the other 10 such complete alternations per second. The special screen "J" is proposed to be a gas-tight structure, made up of a very large number of extremely small metallic cubes, which are all carefully insulated from one another, but, however, presenting a smooth clean (metallic) surface to the cathode ray discharge on the one side and in contact with a suitable gas, as, for instance, sodium vapor, on the other. It is proposed to construct these screen "cubes" of some metal, like rubidium, which readily discharges negative electricity under the action of a ray of light, the negative charge being imparted to the cubes whenever the thin, pencil-like beam of the cathodic ray falls upon it. The receptacle "K" in the tube chamber is filled with some gas, such as sodium vapor, for the reason that such a gas conducts negative electricity far more readily under the influence of light than in the dark. A metallic screen of gauze, parallel to "J" in the tube is placed at "LL," and through this screen the image of the object at "N" is projected by means of the condensing lens "M," until after passing through the vapor of sodium it is eventually focused on the screen "J." The gauze screen "LL" is electrically connected through a line wire, as seen in Fig. 18a, to the metallic diaphragm plate "O" in the receiver tube "A1."

Referring now to the receiving instrument, as indicated in our illustrations at Figs. 18 and 18a, there is placed at the end of the Crooke's vacuum tube a fluorescent screen "H," and upon this screen, under certain conditions, which will be explained directly, the cathodic rays impinge, and certain parts of this screen are searched out every tenth of a second by the thin ray, under the combined action of the two A. C. electro-magnets "D1" and "E1" which are placed similarly to the A. C. electro-magnets "D" and "E" at the transmitter station. As will be observed, the magnet coils "D" and "D1" are energized by the same A. C. dynamo "F" and also the A. C. magnet coils "E" and "E1" are excited by the alternator "G." It is therefore evident that the two magnetic-control circuits "D" and "D1" and "E" and "E1" and their resultants are therefore in perfect synchronism, i. e., their actions take place at the same time.

A Crooke's vacuum tube "A1" is used also at the receiving station as indicated, and its cathode electrode appears at "B1". The disk of this electrode, which shoots forth the cathodic ray, is slightly inclined so as to project the ray at a downward angle, through the small opening "a1" in the anode electrode disk "C." Thus, under normal conditions, the cathode rays pass through opening "a1," but they would be stopped by the diaphragm "P" and its centrally located orifice "S." They, in this case, are not brought under the deflecting action of the A. C. electro-magnets "D1" and "E1" and thus do not reach the image screen "H" before the observer at all. At "O" is a metallic circular disk, which is electrically connected with the screens "LL" at the *transmitter* instrument. Under ordinary conditions the cathode rays at the receiver cannot pass beyond the diaphragm "PS," but they can be made to do so, if slightly repelled by the lower diaphragm plate at "O." In this case, they will then fall on the screen "H" and cause *that part* on which they fall to *fluoresce* (i.e., light up).

Now assume that a uniform beam of cathode rays passes at marvelous velocity and without any appreciable inertia or mass in the tubes "A" and "A1" and that also the A. C. electro-magnets "D" and "E," "D1" and "E1" are energized, as previously explained. Also, suppose that the image of a person, for instance, appears at "N" before the tube "X"; this image is focused and projected through the lens "M," and through the gauze screen "LL" on to the back of the metallic screen "J," which, as will be remembered, is made up of a very large number of small metallic cubes. Then as the cathode rays in "A" oscillate under the combined action of the A. C. electromagnets "D" and "E" they will cause a negative charge of electricity to be imparted in turn to all the metallic cubes, of which the screen "J" is composed. In the case of the shadows of the projected image, or considering those cubes on the screen on which no light falls, nothing will happen in the action of the apparatus, the charge dissipating itself in the tube. Therefore, in the case of those cubes on the screen which are brightly illuminated by the bright parts of the projected image, the negative electrical charge imparted to those cubes by the cathode rays will pass along, owing to the action of the sodium vapor, which is ionized under such circumstances, and so on until it reaches the gauze screen "LL," whence the charge will travel by the line wire to electrode "O" in the tube "A'" at the receiving instrument.

The plate at "O" will therefore become charged and will slightly repel the rays in the tube, with a result that they will thus be enabled to pass through the aperture at "S" and strike, for a fraction of a second, upon a minute portion of the screen, corresponding in position to the small cube surface on screen "J." This is possible, owing to the fact that the electro-magnets 'D'" and "E'" are working in perfect synchronism or step, electrically, with the magnet coils "D" and "E" at the transmitter.

It will be understood, of course, from this description that this action will take place successively, but *not* simultaneously. In other words, referring back to our previous discussion of how a picture can be built up out of black dots, etc., it is easily perceivable how this device could produce a picture if the illuminated spots on the screen are successively shown in a sufficiently rapid manner. In the case of our little metallic cube surfaces at "J," that are illuminated successively, there appear bright spots at simultaneous periods on screen "H" at the receiving instrument. These bright spots at "H" are of course to appear so quickly, and succeed one another so rapidly and smoothly, that the appearance they present to the eye will be one continuous picture.

It is quite conceivable that the apparatus of the future, which will enable us to see the party at the opposite end of a telephone line, for instance, may indeed work on this principle or a modified one. There is no other method which can work so rapidly and with so little inertia as this one utilizing the Crooke's tube, in which a cathode ray is caused to rapidly oscillate or be deflected through various angles in the same way as the Braun oscillograph tube is used for depicting radio-frequency wave forms. It was the Braun vacuum tube oscillograph that suggested the idea to Mr. Campbell-Swinton for this really ingenious *proposed method of perfecting a Television apparatus.*

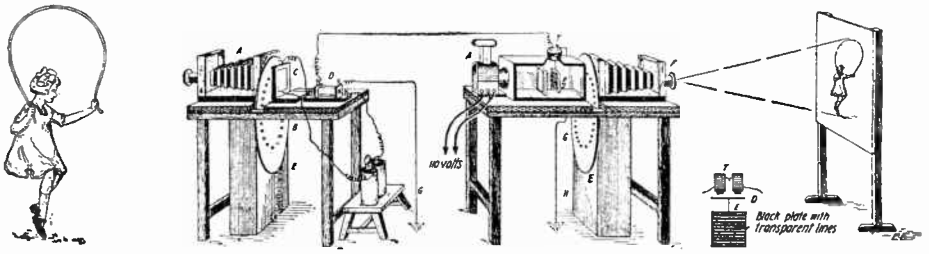


Fig. 22. The Dussaud Telephot uses two perforated discs B revolving synchronously. The holes are arranged helically; thus every point of the picture is covered during one revolution of the disc. Selenium cell C transmits impulses to receiver T, which vibrates plate E. The latter only passes parallel rays of light. With this machine it is—theoretically—possible to transmit objects in motion, electrically.

A Coming Invention

Little did anyone dream that when Mr. Hugo Gernsback wrote an article on "Television and the Telephot," that the system would be developed and perfected as early as 1927. This article on a coming invention was featured a little less than ten years ago in the *Electrical Experimenter,* to be explicit in the May, 1918 issue of that publication.

There are certain inventions which, although not as yet existent, we may take for granted will be invented some day without any doubt whatsoever. While the layman may not believe in the science of prediction, still there are quite a few things in physics that can be quite safely prophesied ahead of time. There are many inventions which have been predicted in the past and which are quite certain to be realized in the not too distant future. That they have not already appeared is by no means the fault of science, generally speaking, but simply because certain minor phases in the various endeavors have not as yet advanced sufficiently to make such inventions possible. A point in case:

Jules Verne, almost fifty years ago, predicted the submarine down to the last bolt. His prediction, of course, was laughed at and called impossible. At that time it was impossible, for the simple reason that the technique had not sufficiently advanced to make such a boat possible. Furthermore, Jules Verne had quite a clear conception how the ultimate submarine would be constructed, and he so described it in his marvelous book, "20,000 *Leagues Under the Sea.*" Of course, in those days the internal combustion engine had as yet not been invented, which was one of the chief drawbacks and which is the reason that at that time the submarine was not feasible. Neither had the storage battery been invented, and Jule Verne's idea of propelling a sub-sea boat by means of primary batteries alone, while feasible on paper, was not practical.

Another case in point is that of the planet Neptune, which had never been dreamed of until Le Verrier, the famous French mathematician, in 1846, by mathematical deductions, not only predicted that there *must* be another planet beyond Uranus, but he also predicted—on paper—just where in the heavens the planet might be found. His prediction proved correct, and the planet Neptune was indeed found almost exactly in the region where Le Verrier had deducted that it must gravitate. This was one of the most astounding scientific predictions ever made, but this instance, of course, was founded upon the exact science of mathematics.

Another case in point is that we know today that our list of elements is not quite complete. There are several gaps as yet of certain elements which have never been seen by man. Not only do we know that there must exist such elements, but we also know the *physical properties* of them, should they be discovered some day, which no doubt they will. When we therefore make the assertion that certain inventions are coming, we make it on a safe, scientific ground, because such discoveries will surely be made.

The subject of the article "*Television, or Seeing at a Distance,*" was about one of these inventions. Numerous inventors had busied themselves trying to invent an apparatus or machine whereby it would be possible for one person to see another while talking on the telephone, but in 1918 nothing practical had resulted. The future instrument on which the name "Telephot" (from the Greek *tele*-far, *photos*-light) has

Fig. 21. What the future Telephot will look like in order to be practical. Light R throws light on speaker's face and is reflected into lens L. Instead of a mouthpiece, the holes H of the sensitive transmitter inside of frame F pick up the speech. The picture of the distant person appears on screen S.

been settled, is supposedly an apparatus attachable to our present telephone system, so that when we speak to our distant friend, we may see his likeness not only as an immovable picture, but we will see his image exactly as we see our own image when looking into a mirror. In other words, the apparatus must faithfully follow every movement of our distant friend whether he is only five blocks away or one thousand miles. That such an invention is urgently required is needless to say. Everybody would wish to have such an instrument, and it is safe to say that such a device would revolutionize our present mode of living, just as much as the telephone revolutionized our former standard of living.

Most inventors who had been working in the past on this problem, failed to bear in mind a very important consideration.

A Telephone Telephot?

If the Telephot is ever to be a success, it must of course be possible to attach it to the present-day telephone lines. That means that the instrument must of necessity work in conjunction with the telephone without necessitating any more wires than there are now used. As everyone knows, the subscriber's telephone is connected with *two* wires to the central station. Each telephone instrument therefore requires *two* wires, or otherwise one metallic wire, and the ground for a return "wire," which is the same thing as two wires. Over these two wires today, we do not only speak, but "Central" also rings your bell. In the case of a "pay-station" telephone, quite a few more functions are accomplished over these two same wires. It is also possible today to telegraph and telephone *simultaneously* over two wires neither instrument being affected by the other instrument. Why then should it not be possible to also send *translated* light impulses over these two wires at the same time that the voice impulses are transmitted over them?

In most of the schemes offered by inventors heretofore, a plurality of wires was necessary; in some cases *several thousand pairs of wires*. No matter how well such an instrument might work, this alone would doom it to certain failure. Another point is that the future Telephot must not be a cumbersome machine requiring motors and all kinds of other complicated machinery, difficult to operate by the layman.

The future instrument must work the same as the telephone. In other words, all the subscriber has to do is to lift the receiver off the hook, and he will immediately see his friend just as if he were talking to him in the same room. All these requirements may seem hard on the inventor, but they are absolutely necessary as a simple reflection will show.

The writer also ventured to say that no Telephot will ever amount to anything that necessitates the use of selenium. As is well known in nearly all past suggested television schemes, the selenium cell in one form or another was used. The underlying idea of these schemes is that light rays of the object striking the selenium cell vary the resistance of the same, and these various impulses are then sent over the line to be translated into a picture by various means and manners at the receiving end. The trouble with the selenium cell is that it is not sensitive enough, and on account of its inertia, does not work fast enough. Also in most of the proposed television schemes, a multitude of selenium cells is required, which again means a plurality of wires, thereby dooming the scheme at once. There must be something else besides selenium that can translate light impulses into electric impulses. Indeed, such a scheme is already existent, nature having worked it out millions of years ago. And while it is not electrical, it illustrates what we are driving at.

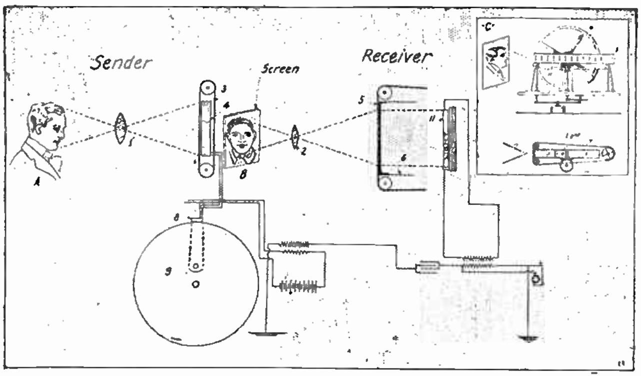


Fig. 23. This is the Rothschild telephot scheme which cuts up the light impulses by means of a slotted revolving belt 3 at the sender. Passing rapidly before the selenium cell 4 the impulses are sent over the line and influence a source of light 11 at the receiver where a similar revolving belt scheme reconstructs a picture as shown at E.

The Eye—A Television Phenomenon

The animal eye is the most marvelous television apparatus ever invented. Moreover, it is also probably electrical. If we look at an object, the latter is thrown into our eye, which is nothing but a marvelously efficient camera, but instead of a photographic plate, the impulses are thrown up on the *Retina* which records the object, not only in black and white as does the photographic plate, but the picture is recorded in its *natural colors* on the retina. From here numerous fine nerve strings interlocked in the retina connect with the optic nerve, which nerve in turn connects with the occipital lobes of the brain, *translating the various light impulses, (stimuli) with their component colors into a "picture,"* which is then "seen" in our mind. We say "seen" advisedly, because of course the picture is not actually seen in the mind, but the impulses which the retina has picked up *are translated into another form*, which we experience in turn as the sensation of seeing.*

Retention of Vision

As has been shown experimentally, the picture is retained on the retina for about one-thirty-second of a second. This is called the *persistence of vision*. It is this phenomenon which is made use of in moving pictures, each successive picture staying on the screen for perhaps slightly more than a thirty-second of a second before the next one is flashed on. The fact that the pictures follow each other so rapidly, gives the impression that the objects are moving on the screen, which of course they do not.

Actually sixteen pictures appear on the screen in a second but the shutter cuts down the time of their appearance.

Now, as we have shown that pictures can actually be transmitted at a distance† without the means of selenium cells, it is up to our inventors to devise something to do away with these cells entirely. It is safe to say that when the successful Telephot finally appears, it will be found to be a very simple apparatus, probably not much more complicated than the present-day telephone receiver.

When one considers how many different functions the diaphragm in a telephone receiver performs, it seems that it should be a simple matter to translate light impulses into electrical impulses. Just stop and consider that a single telephone diaphragm can pick up several hundred pure notes as well as several thousand distinct kinds of noises, which in turn are translated into electrical impulses. These impulses are then sent over the line only to be reproduced faithfully into the same notes and noises at the other end of the line, using nothing but a single diaphragm on another telephone receiver. Before the telephone was invented, it was thought that for each note, a diaphragm or vibrating reed was necessary. Strange to relate however, a single diaphragm records the human voice vibrations so faithfully that it is possible to readily recognize a friend's voice over the telephone as is done every day; th[illegible] is quite an amazing fact, if one stops t[illegible] think of it. For in order to recognize [illegible] friend's voice, it is not only necessary to transmit the various sounds, but also all the overtones as well as the *timber* of the voice. Fifty years ago [illegible]uld have been considered scientifica[illegible]ble if the proposition had been adv[illegible]at all this could be accomplished by means of a single circular disc of iron 2½ inches in diameter and 1/64 of an inch thick. Nevertheless, the telephone today bears witness that it is eminently possible.

So the question logically arises that if all this can be done [illegible] cannot light impulses be translate[illegible]ctrical impulses at one end, a[illegible]nslated at the other into lig[illegible]

Hugo [illegible]uggestion

Bearing [illegible]arious things in mind, we have tried to picture the Telephot as we imagined it would appear when invented. The front cover of the May, 1918 issue of the *Electrical Experimenter*, as well as the illustration herewith showed Mr. Gernsb[illegible]dea. He claimed that the future Te[illegible] would be an instrument attachab[illegible] our present telephone. The face of the distant speaker would probably be recorded on some sort of a fluorescent screen or [illegible]es, as here depicted. In order to show the [illegible]icture to advantage, the frame *F* must be more or less deep, otherwise the sun or other light at the receiving end would interfere with the "received" picture. In other words, the picture would set back an inch or more as shown in our illustration, Fig. 21.

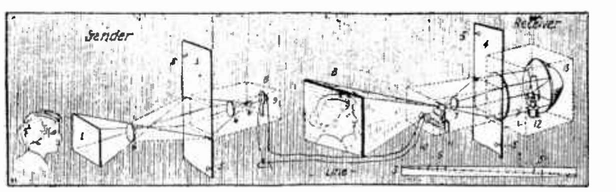


Fig. 24 shows the A. C. & L. S. Andersen Telephot, where use is also made of revolving belt 3, having perforations 5. This belt at the sender rapidly passes in front of the camera influencing a selenium cell 9. At the receiver a sensitive electro-magnetic arrangement, 10 and 11, acting as a shutter cuts off the light impulses; thus theoretically reconstructing the picture.

The holes *H* belong to a highly sensitive transmitter (microphone), as it will be im-

* Light entering the eye, influences the light-sensitive "rods and cones" of the retina, in some manner as yet not understood. The changes are supposed to be photochemical in their nature.

† The picture is actually transmitted at a distance. If the optic nerve is cut—the "wire" connecting the picture with the brain—we cannot "see" the picture, i. e., we will be blind.

practical for reasons which will be apparent to use the present day mouthpiece. All that the person at the other end need do is simply to talk in a medium low-pitched voice. The sound vibrations should be picked up by the sensitive transmitter, and should be heard sufficiently clear in the telephone receiver at the other station. In turn, the speaker's picture should be transmitted to his friend by means of the lens *L*, mounted in front of the Telephot. This lens is nothing but a photographic camera arrangement, and in the back of this "camera" *P*, the face or picture should be thrown just as a picture is formed on our eye's retina. Here the optical impulses are translated into electrical impulses which are now sent over the line along with the voice impulses.

In order that the distant person may *see* the speaker's face, it is of course necessary that the latter's face be illuminated. For it goes without saying that if the speaker was in the dark, his friend could not possibly see him on the other side because no light impulses would be thrown on the "sending" lens. For this reason it is necessary to provide a lamp *R* at the top of the Telephot, which lamp throws its rays on the speaker's face; from here the light rays are thrown onto the lens, thence to be transmitted to the distant station. It naturally goes without saying that the ideal Telephot should transmit the picture in its natural colors, although this may perhaps be asking a little too much of our inventors at first.

Quite a good many Telephots have been imagined and described as well as patented in the past. None of these, however, have ever appeared—most of them only existing on paper. One of the first of these was invented by the Frenchman, d'Ardres, in 1877. There was another one invented by Sawyer in 1880. Next we have the Bidwell machine of 1881; the one of Weiller in 1889; as well as those of Szczepanich and that of Dussaud of 1898. None of these, however, were of practical value. We may also mention the comparatively recent Telephots of Rothschild of 1907; Belin apparatus of 1907; Kruh of 1910; Hoglund of 1912; A. C. and L. S. Anderson of 1912; Stille of 1915; the Rosing apparatus of 1915, and the Sinding-Larsen instrument of 1916. The more important ones among this host of Telephots will be described in this article.

One of the earliest Telephots imagined by the Frenchman, Dussaud in 1898, is illustrated herewith, Fig. 22.

The Dussaud System

This ingenious apparatus at the sending end has a camera *A*, at the rear of which is a metal disc *B* perforated with certain holes. The disc is driven by clockwork contained in the case *E*. The ingenious part of this arrangement is that the disc *B* is perforated in a curious manner, the holes being disposed in the form of a helix or involute spiral. In other words, when the disc rotates the perforations cut off successive points of the picture formed in the camera *A*. Thus at each fraction of a second, a ray of light is allowed to fall on the selenium cell *C*, and when the disc has made one full rotation, every point of the picture will have been uncovered, as will be clear by a little reflection. It is apparent that the selenium cell *C* will receive various impulses due to the fact that more or less light reaches the cell. These impulses in turn are passed through a battery and a small transformer (induction coil) *D*, which is grounded at one end; the other wire goes to the receiving station. At the latter point, we receive more or less intense electrical impulses, and these impulses operate a very sensitive telephone receiver *T*, on which is hung an opaque plate, *E*, having very fine transparent lines engraved on its face.

The disposition of this black plate and the telephone receiver is shown in a separate detail sketch, *T* being the receiver, *D* the diaphragm, *E* the plate. At *A*, we have a source of light, as for instance an electric lamp, which emits parallel rays of light which are somewhat modified by the transparent plate in front of *E*. The disposition of the light rays is such that ordinarily the plate *E* cuts off all the light from *A*, but as soon as the telephone diaphragm vibrates the plate *E*, more or less light is made to pass through the latter, which light in turn is stopped by the revolving plate *G;* the latter has the same helical perforations as the disc *B* at the sending station. Theoretically therefore, the picture in motion should be formed in the camera at the receiving end, and this picture should correspond with the one sent out from the sender. This picture would then be thrown on the screen of the receiving station as shown. The two revolving discs *must work in synchronism*. It is also necessary that the discs be revolved *once in one-sixteenth of a second*, which is just the average time of the persistence of the luminous images on the retina of the human eye, and which is supposed to build up the transmitted picture, and in turn is observed on the screen. The lens *F* at the receiving end is used merely to enlarge the picture.

It seems that while most ideas look more or less practical on paper, it is quite impossible to tell if any of them would actually work in practice. At any rate the various proposed schemes here illustrated form interesting reading for the serious-minded experimenter, who is working on this more or less intricate problem.

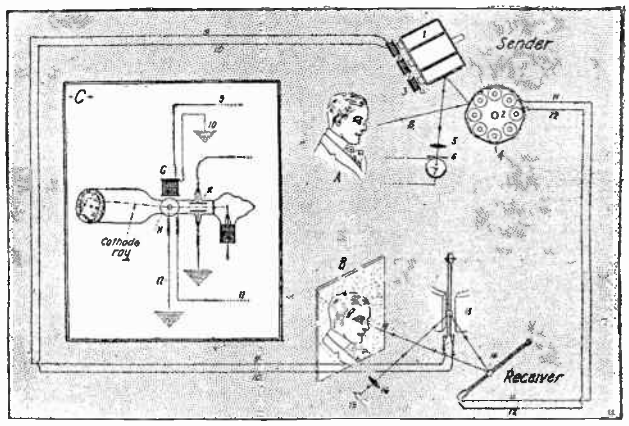


Fig. 26 shows the Rosing Telephot. Use is made of two sets of polyhedral revolving mirrors; 1 and 2, throwing a light ray on selenium cell 7. At the receiver two oscillographs reconstruct the picture shown at B.

Sidney Rothschild System

Figure 23 shows the telephot of Mr. Sidney Rothschild, of New York, on which patents have been issued. Briefly summarized, this invention consists in causing a light controlled composite background to vary the intensity of electrical currents flowing over a wire, and causing these currents to control the intensity of light at the receiving station, this light being caused by an appropriate mechanism to produce a moving luminous spot of varying intensity in such a manner as to reproduce a facsimile image disposed adjacent to the aforesaid background at the transmitting station. The outstanding features are indicated in the illustrations, and the more technical details have not been discussed. These can be readily looked up in the patent specifications by anyone sufficiently interested.

At the sending station we have a subject A, whose picture is transmitted through lens 1, the rays of which fall on the selenium cell 4, after passing through a belt 3, which is rotated at a high speed. This belt has a number of longitudinal slots disposed crosswise, the belt traveling in the direction indicated by the arrow. A revolving cylinder 9 is provided with a series of slots, each being adapted to register with one of the sections 8 of a further selenium cell. In this manner Mr. Rothschild expects to cut up the various points of the picture and transmit the impulses over the line as shown. At the receiving end, we find a revolving wheel 6 and another rapidly revolving belt 5 which also has longitudinal slots as shown in detailed drawing *C*. By means of a light source shown at 11, which may be an incandescent lamp, the light rays pass through the revolving wheel 6 and slotted belt 5. The light rays in this case being cut up exactly in the same manner as those of the transmitter. These light rays fall through lens 2 and thence are projected on to the screen *B*. Thus the picture is supposed to be reproduced. As in all other telephots, this one of necessity requires a synchronous movement as it is important that the sender and the receiver work synchronously. This is one of the difficult points of the telephot.

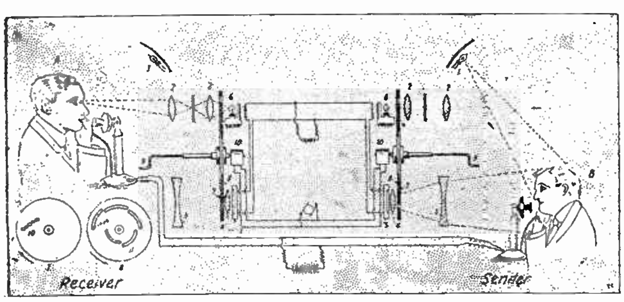


Fig. 25. The Hoglund Telephot makes use of two revolving shutters, 7 and 8, revolving in opposite directions. Selenium cell 5 is influenced by the light rays and the picture at the receiving station is reconstructed by means of the light variations of lamp 6.

The Andersen Brothers

A clever telephot which was patented by Messrs. A. C. & L. S. Andersen is shown in Fig. 24. The sending apparatus comprises a dark chamber shown in dotted lines, in which is placed a lens 6′ which receives the rays issuing from the dark chamber. These rays after being refracted meet a small selenium cell 8, placed behind the prism 6″. Screen 1 represents an object (in reality farther removed from the dark chamber than the drawing indicates). The light rays coming from the screen 1 after refraction in the lens 6 which is in front of the dark chamber form upon the endless ribbon 3, a real image reversed and reduced by the screen 1. This ribbon is flat continuous and opaque except at cer-

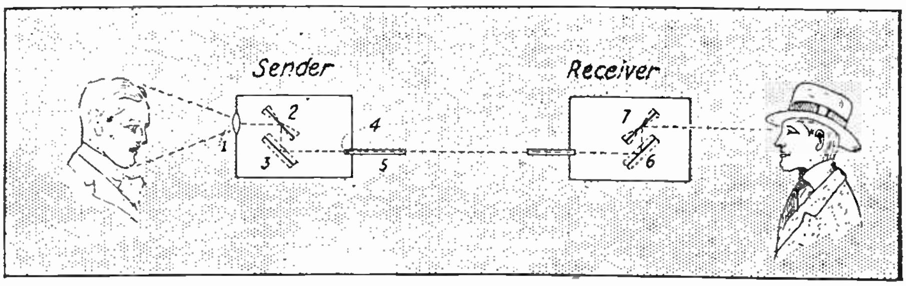


Fig. 27.—Depicts the Sinding-Larsen Telephot. Two mirrors vibrating at different frequencies cut up the light rays. These light rays are past through a metallic tube having strong reflecting inner surfaces. At the receiver, the light rays are past through a similar system as the sender and the picture is thus reconstructed.

tain perforated points, arranged according to a diagonal line as shown in the detail sketch *S*. The distance separating the holes 5 depend upon the size of the image in the dark chamber. The holes are spaced apart in such a manner that only one point can be located at each instant within the field of the image in the dark chamber. The ribbon 3 is displaced from above downwardly by means of an electric motor; it thus forms the end of the dark chamber; the luminous rays traversing the perforations of the ribbon fall upon the lens 6′. They are received by the selenium cell 8. Only one point comes at each instant within the field of the image as the illustration shows. When the ribbon has been displaced the whole of its length, each of the points of perforation has crossed the part of the image which is presented to view; thus, the entire picture is transmitted point by point.

At the receiving end we find the sender practically reversed. Here we have another moving ribbon 4 with perforated holes 5. In the dark chamber 13 we have a source of illumination which may be a kerosene lamp, or an electric lamp or any other kind of light 12. This lamp throws its rays through lens 7. Here we have also the electro-magnet 10 which is connected with the selenium cell, and a battery at the sending station. By means of an ingenious shutter arrangement 11, the light rays coming from the lamp 12 are more or less influenced, due to the fact that the electro-magnet is more or less energized by the selenium cell 8 of the sender. In other words when at the sending station, the selenium cell was energized at its maximum, in this case the electro-magnet 10 at the receiving end would also be energized at its maximum, and therefore the shutter would let the maximum amount of light pass. All providing of course that the ribbon 4 was working synchronously with the ribbon 3 at the sender. As the ribbon 4 revolves very rapidly and synchronously with the ribbon at the sender, the picture is thus reproduced point by point and is recomposed upon the screen shown at *B*. Messrs. Andersen have also incorporated into this invention an idea showing how the picture can be transmitted in its actual colors. This is a very ingenious arrangement, but is outside of the scope of this article.

The Method of Hoglund

The next telephot, Fig. 25, was imagined by Gustav E. Hoglund, of Chicago, Ill. This invention also has been patented, and relates to that class of devices for cutting up and dividing light rays emanating from an image and causing them to act upon a selenium cell capable of changing its electrical resistance under light rays of different degrees of intensity. These vibrations are sent over a line and act upon a luminous center at the other end thereof, which may be in the form of a speaking arc and cause a fluctuation in the brilliancy of said arc which will cause light rays to emanate therefrom, said rays being of varying intensity according to the strength of the current. These rays will follow each other in the same order, and will be of comparatively the same intensity as the light rays emanating from the object. Hence, when the rays from the lamp are projected onto the retina of the eye in rapid succession, they will cause an image to be built up before the eye, which will be composed of the varying light rays of the same strength and in the same order as those emanating from the original image.

The device shown in Fig. 25 has a receiver and a sender; each of the instruments comprises a selenium cell 5, positioned in front of which is the enlarging lens 4 and the reducing lens 3. Between these lenses is a double revolving shutter composed of discs 7 and 8. These are also shown in a detail sketch. Disc 7 has a series of square perforations 10, while disc 8 has a series of slots 11. It will be seen that as these discs revolve in opposite directions, each point of the picture is cut up successively and allowed to pass through the optical lens system. Each of the receiving instruments also comprises a lamp 1 and enlarging lenses 2, 2. Between these lenses a ground glass plate is placed, upon which the final picture appears. Both receiving and sending instruments are connected by electrical lines as shown. The oppositely revolving discs are ordinarily actuated by means of the synchronous motor 10.

An interesting part of this invention is that these revolving shutters can be corrected if they do not run synchronously by means of handle 9. It becomes apparent that the two shutters must be brought into proper relation to one another; it can be easily determined when such a relation is found by observing the image coming from the receiving instrument. If the shutters are not in proper relation, the image will be nothing more than a blur, and before it can be distinctly seen, the shutters will have to be in appropriate relation to bring the openings into the desired position. The inventor therefore provides handles 9 which extend from the shutters, and by turning these handles the shutters can be revolved until they are brought into proper relation with one another, the operator determining when such position has been reached by observing the completeness of the image reproduced by the receiving instrument. Once the shutters are in proper relation with one another, the motors are then supposed to operate them synchronously. By studying the illustration, it will be noted that the lamps 6 are varied into their proper luminosity due to the selenium cells 5 receiving more or less light.

While this scheme looks very feasible on paper, we are afraid that the lamps 6 will not respond instantaneously to the current variations in the selenium cells 5, and at best the picture formed would seem to us to be rather blurred.

Boris Rosing

The next telephot which has also been patented in several countries is shown in Fig. 26. The inventor of this telephot is Boris Rosing of Petrograd, Russia. In order to eliminate the synchronous motor arrangements which have been the failure of almost all telephot schemes, Mr. Rosing does away entirely with them, substituting therefore a system comprising two oscillographs with movable reflecting surfaces. This will be apparent further on. The optical system at the transmitting station comprises two polyhedral rotary mirrors, 1 and 2, the axis of rotation of which are at right angles to each other. They are driven at such speeds that the angular velocity of one of the mirrors is several times greater than the other; and an objective or lens 5, the focal plane of which coincides with the plane of the screen 6 and the photo-electric receiver 7. The objective 5 is arranged in such a manner that rays emitted from any point of the field of vision arrive in the photo-electric receiver only after successive reflections by the two mirrors. When the mirrors 1 and 2 are rotated, the end 8 of the optical axis thus deflected traverses the field of the picture in a zig-zag path, so that from every portion thereof light is transmitted in a certain determinate order through the opening of the screen 6 upon the photo-electric receiver 7. Permanent electro-magnets carried by the mirrors 1 and 2 and stationary bobbins 3 together form small generators producing in the corresponding bobbins pulsating currents, the periodicity of which per revolution of the mirror corresponds to the number of reflecting surfaces thereof. The currents which are produced in the conductors 9, 10, 11, 12 and transmitted through the receiving station are proportional to the components in the directions of the axes of a corresponding system of coordinates of angular movements which the optical axis 8 executes in the field of view.

At the receiving side we find two oscillographs provided with mirrors 13 and 14. The axis of both are arranged to correspond to the axis of rotation of the mirrors 1 and 2. Lens 16 directs the rays proceeding from the luminous signaling point 15 on to the small mirror 13. There will therefore be imparted to the deflected optical axis 17 at the receiving station, the same movements in space which the deflected optical axis 8 at the sending station executes at the transmitting station. The moving parts of the oscillographs naturally have much less inertia than do the revolving sets.

A different idea in Mr. Rosing's invention is shown in insert *C*, Fig. 26. Here instead of using oscillographs, the inventor makes use of a cathode tube, the wires 9 and 10 from the revolving mirror sender 1 being connected to wires 9 and 10 which in turn go to an electro-magnet *G*. Wires 11 and 12 from revolving-mirror sender 2 go to 11 and 12 which are also connected to another electro-magnet *H* placed at right angles to electro-magnet *G*. A pencil of cathode rays is thrown upon the screen in back of the tube, and this ray is influenced by the electro-magnets *H* and *G* synchronously to the revolving mirrors 1 and 2 of the sender. Consequently a picture should be traced out on the screen of the cathode tube point by point, and it is conceivable that a perfect picture could be readily obtained by this means. A condenser K is also arranged in the cathode tube to steady the cathode rays, and for certain other purposes which it is not necessary to delve into in this article. This is a particularly clever invention, but we do not have any information on hand showing if it has ever been tried in practise. It certainly looks more promising than any of the others, particularly as it requires only four wires.

The Alf Sinding-Larsen Optical System

We must also mention a certain other type of telephot which strictly speaking is not a telephot at all in the ordinary sense of the word because it does not transmit pictures by electricity, but optically. It shows how a picture can be transmitted practically *by means of a single light ray.* This idea was patented by Mr. Alf Sinding-Larsen of Christiania, Norway. The idea is to have two mirrors vibrating at a different frequency of vibrations, which mirrors cut up the light ray into its components. For transmitting the pictures directly, the inventor makes use of a narrow tube with strongly reflecting inner surfaces which tube is arranged with its rear opening behind the light orifice in the transmitter. The optical system forming the image is arranged in such a manner that the rays form the individual image points across one another at a very acute angle. By this the inventor is enabled to cause the light taken up in the mouth of the tube to be transmitted through the tube without being materially weakened in its passage to the other end of the tube and the image surface of the receiver.

The synchronous movement of the mirrors is effected by coupling them in series, the electro-magnets serving to keep the mirrors moving. Reference is made to Fig. 27, where the sender and the receiver are connected with the aforementioned reflection tube 5; 1 is an object lens of the receiving station camera in which are placed two mirrors 2 and 3. The mirror 2 oscillating very fast on an axis perpendicular to the plane of the drawing, while the mirror 3 oscillates more slowly on an axis lying on the same plane and is perpendicular to the axis of oscillation of mirror 2. By these means, the elements of the image formed by the lens 1 are in succession following a continuous zig-zag line transferred to the focus of a lens 4 placed in the opening of the reflection tube 5, said lens paralleling the rays which meet the image point. At the receiver two similar mirrors 6 and 7 oscillating synchronously with the mirrors 2 and 3 respectively, throw the train of rays emerging from the reflection tube to the eye of an observer as indicated. The synchronous vibration of the respective pairs of mirrors is accomplished by ingenious means outside the scope of this article. It becomes apparent from this invention that by substituting for the lens 4 some electrical means such as a combination of selenium cell with a revolving shutter, pictures may thus be transmitted electrically without using reflection tubes such as are shown in 27.

In fact, a system of this sort was tried many years ago by the Russian inventor Szcepanich.

Most of the television patents are very ingenious, and contain a good deal of information on television which has not so far appeared in print outside of the patent office records. Nevertheless the ultimate type of television system will be quite different and perhaps much simpler than any system thus far evolved. It is quite possible that a simplified system of synchronization will work wonders in the television field.

Again in the July, 1920, issue of *Radio News* Mr. H. Gernsback, the editor of that magazine, touched upon his pet dream. Because of the pregnant possibilities in the editorial we are reproducing it verbatim. It will be seen that some of the events predicted have already come to pass. Banks of photo-electric cells, as pointed out in the first article in 1909, are impractical for several reasons, but one can never foretell what the future may bring. The editorial "Radio in 1945," follows:

We are slowly ascending the steep hill of progress. However, we have still an enormous mountain to climb as far as the radio art is concerned. Compared to the ultimate goal, our present achievements are like the smallest pebble in comparison with the Himalayas. Standing on this little pebble, we do not get much of a vantage point, but we can, at least, look back upon the road we travel, and we can also, figuratively speaking, soar toward the peak of the towering mountain above our heads.

Everything in life is comparative. So is progress of the arts and sciences. What appears fantastic and wholly visionary today has a knack of coming true on the morrow. Consequently on looking back only over the microscopically small stretch of time of twenty-five years, we find the art of radio just born. We then had our spark coil connected to a ponderous aerial, and as a receiver we had a tremendously complicated conglomeration of apparatus, comprising coherers, relays, tappers, choke coils, batteries and various other paraphernalia.

Of course, we smile on this today in our very superior manner; particularly when we look at our compact little sets with which, strictly speaking, we need no longer even use an aerial, nor a ground.

We use a little loop of wire three feet square; we have a small vacuum tube and a pair of receivers all encompassed into a box that fits into your suitcase, and lo and behold! We can set up this box, and within the radius of hundreds of miles receive radio music to which we dance. Had we suggested such a thing twenty years ago we would have been most severely condemned as visionaries and dreamers.

If radio has made such tremendous progress in only twenty-five years, what will it be in twenty-five years hence? The imagination fairly staggers at the contemplation of the progress that is coming. But certain things may be prophesied with relative safety. Many scientific prophecies are as certain as the rising of the sun. If you are correct on your premises, you can make certain deductions that we know in advance must come true.

It is therefore safe to say that in twenty-five years hence there will be no such thing as a big ponderous aerial mast even for the powerful radio stations sending messages all around the globe. Probably no aerial will be used at all. Perhaps no ground either. Before we reach that stage someone will go and bore a shaft into the earth, possibly a thousand feet deep, and hang an insulated wire into this shaft. He will probably astound the world by finding that by means of this arrangement messages can be sent and received all over the globe just as easily as having a huge mast towering a thousand feet into the clouds. It is also a safe bet that twenty-five years from now our long-distance stations will be operating with comparatively small power. Bearing our past progress in mind, it should be possible in 1945 to telegraph 12,000 miles, which is half way around the globe, with a power which does not exceed ½ k.w.! Perhaps even this figure is high, and the day is surely coming when it will be possible to detect the waves of a small induction coil all over the globe.

And, one of these days we will wake up and find that some genius has made it possible for us to *see* actual radio waves. And why not? Arguments may be brought against this prophecy by stating that the length of radio waves is such that they can never be perceived by the eye, which is built to perceive light waves only, which have an entirely different wave length. This argument, however, does not in the least influence us for the simple reason that we have already photographed sound waves, although we cannot see these either. Just how it will be brought about we have, of course, no means of knowing at present.

It is safe to say that twenty-five years hence we will not use telephone receivers with which to receive our message. What the method will be at that time to receive messages we cannot even guess at. It may be by visual means; it may be by acoustics, or perhaps in a totally unsuspected manner. We venture to say that it might even be accomplished physiologically. Who dares say that we will not at some future date pick up two metallic handles and "feel" the dots and dashes come in—that is, if we are still using dots and dashes at the time?

Lee de Forest has shown us that a vacuum tube can be used as an *audible* receiver. Who, therefore, dares to deny that some day we will be able to hear telephone messages simply by using a special vacuum tube, which not only will receive messages but will *also reproduce them acoustically?* This, in an experimental way, is already possible today.

One of the coming wonders without doubt is radio movies. Imagine a bank of several hundred special vacuum tubes upon which the light and dark variations of a film are thrown by means of projecting apparatus. Each individual tube will be affected in a different manner. Some tubes will be strongly exposed to the light, while others will be kept in the dark. These tubes will be light-sensitive similar to the Rubidium Cells in use today. Each tube will send out an impulse by undamped radio waves, and as the wave length of each tube differs by a small fraction of one per cent, there will be no interference between the different tubes. At the receiving end the process is reversed, and a similar bank of tubes reconstructs the picture and throws it upon the screen by some intermediary apparatus. Imagine then a central point of the country, such as Denver, which sends out nightly moving pictures by radio. These are then received in every house all over the country without any difficulty; and, of course, it will be no far cry to combine these movies with voices or music as well. All of this may sound wild and woolly and impossible now, but the reader who picks up this magazine in 1945 will smile at the utter simplicity of this editorial because at that time many more wonderful things than the ones mentioned here surely will have come to pass.

The Radiophot

In still another article by Mr. Hugo Gernsback, called the "Radiophot," he advanced the suggestion of applying television to the radio field. It will probably only take a few more years until this, another "dream," will be realized. But in 1922 when this suggestion was advanced, it was just as remote an idea as the wireless transmission of power is even to this day. The plan was illustrated in the July issue of *Science and Invention* Magazine of that year.

Schemes on television were not new even in 1922. Inventors busied themselves for several generations with this invention, but up to that time nothing of note had been produced. Mr. Hugo Gernsback, in the May and June, 1918, issues of the *Electrical Experimenter* discussed various ideas on television and showed what had been proposed by inventors heretofore. There are many patents in existence referring to the *telephot* (*tele-far; photos-light*), but at this time there had been no inventor who actually was able to electrically demonstrate a continuous view of a moving object at a distance. At that time, viz., July, 1922, Hugo Gernsback, writing in *Science and Invention* magazine, said—

It is not impossible to do this, but the great cost of such an apparatus has been prohibitive. Furthermore, one of the greatest stumbling blocks is that in nearly all schemes shown in the past, it was necessary to have hundreds and even thousands of wires between the sender and the receiver. If, for instance, we wish to talk to our friends five hundred miles away over the wire all we need is a single wire, or two at the most, if we do not wish to use a ground or return circuit. If with the schemes proposed heretofore, we wish to see our friend at a distance, it means that we would have to string several hundred wires between the two points and the idea for this reason becomes at once impractical.

The author in this article proposes a somewhat more ambitious scheme of television not only over wire, but by radio. He wishes to state in advance that no apparatus has been as yet constructed along this line, but it is believed that the scheme here shown has possibilities that would seem inviting to our constructors who wish to take the time and trouble to build such an apparatus. Engineers are of the opinion that an apparatus of this kind will actually do the work with perhaps a few minor improvements.

The stumbling block with former telephots or television schemes usually was found in the selenium cell. This was so for the following reason: When we desire to project a picture at a distance, it is first necessary that we have some instrumentality which changes the intensity of the electric current in the same ratio as the intensity of the light that falls upon the instrument changes. A picture, as is well known, is made up of various points. Pick out any half-tone illustration in this journal, view it under a magnifying glass, and you will see that it is made up of light and dark dots. The dark dots give the picture its dark tones and the light dots give the half-tones and the white paper shades into unison with the dots.

The selenium cell has long been thought the best instrument to translate changes in the intensity of light into electrical current impulses. Imagine a screen made up of several thousand selenium cells. A picture falling upon this screen will thereby resolve itself into the various components of the picture itself. Then some selenium cells will receive more light, others less, etc.

The electrical impulses are then sent out over the wires to be reconstructed later into a picture at the receiver. The trouble with the selenium cell is, however, that it is sluggish. In other words, the selenium cell takes a large fraction of a second in which to change its resistance. Light is instantaneous, and all reconstructed selenium pictures are always lagging behind; if we actually could obtain a reconstructed picture, it would be imperfect.

This trouble is done away with in the author's radio television scheme whereby instead of the selenium cell, we make use of photo-electric cells. There have been lately developed a number of such cells, which are available and which are highly light-sensitive. Moreover, there are not sluggish in action as are selenium cells. In other words, *they vary their resistance almost instantly* as the light falls upon them, or as it is removed.

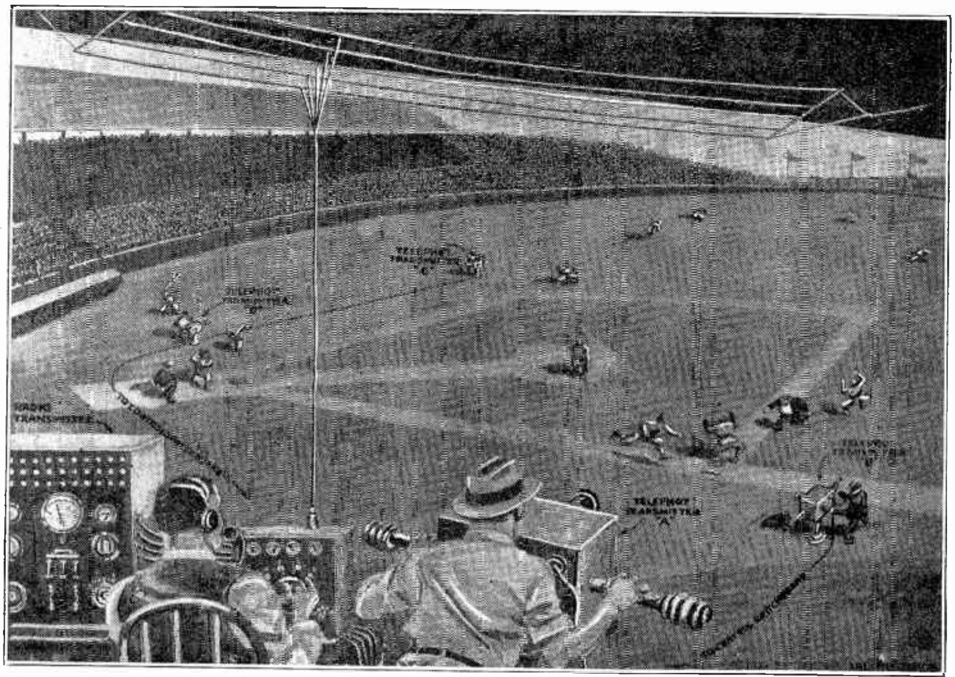


Fig. 28. In this illustration we behold how future audiences will see a baseball game thousands of miles away. Here we see a common radio transmitter to which are connected several telephot transmitters. The operators of the telephot transmitters A, B, C and D "shoot" the interesting parts of the game, but they do not do this simultaneously. They merely point the telephot transmitter into focus while the radio operator at his instrument switches from one to the other in order to get those close-ups which he wishes. The distant audience then will see whatever close-ups are selected by the radio operator. It naturally would not do to have just one telephot transmitter for the reason that at times, the operator would be either too far, or otherwise too close to the scene. By having a multiplicity of telephots, this is avoided.

Referring to our illustration, Fig. 28, the author's scheme resolves itself into the following: At the transmitter we have an ordinary camera-like box in the back of which we have a great number of tiny photo-electric cells. Each cell responds according to the strength of light and shade. The lens in front of the camera picks up the view and throws it inverted upon the group of photo-electric cells in the rear. All dark parts of the picture, as for instance, the shoes of the baseball player will, therefore, *not* affect the light sensitive cells *and these remain inactive*. The other parts of his body, as for instance the white uniform, will affect only those cells upon which rays of light from the white fall. These cells then send their impulses into a vacuum tube modulator and synthetizer. This vacuum tube modulator is a regulation radio transmitter such as is used in all broadcasting stations today. Each photo-electric cell is made to operate a separate vacuum tube, and each of these vacuum tubes sends out its own wave. For instance, photo-electric cell number one will send out on a wave, let us say of 500 meters; photo-electric cell number two transmits on a wave of 500¼ meters; photo-electric cell number three sends out on a wave of 500½ meters, and so on down the line.

From the radio transmitter all of these waves are sent out from one and the same aerial, which is quite feasible, for it has been demonstrated years ago that one aerial can be used to send out many messages, each on a different wave length, and there is no trouble in doing this very thing today. To resume, what have we done in our transmitter? We have transformed light impulses into electrical ones. These in turn are being shot out into space at different wave lengths each retaining its own identity.

Now let us see what happens at the receiver. The distant aerial picks up all the different waves on a regulation radio receiving outfit, which, of course, must be able to tune very sharply; otherwise, it will not be possible for us to receive a clear picture.

In our television receiving box proper, we have the following: There is a bank of inductances with their respective condensers, together called the wave analyzer, these inductances and condensers are lined circuits, and each picks out its own wave length and responds. In the circuit of each inductance and condenser, we have also an audio frequency amplifier, which operates an electro-magnet, similar to a telephone receiver. This wave analyzer is already in use today and is not a new development at all. Any owner of a vacuum tube set knows that he can tune in or out almost any wave length, within reason.

Coming back to our wave analyzer, let us see what happens now. Inductance number one, condenser number one, and audio frequency amplifier number one, are tuned to a wave length of 500 meters. This circuit, therefore, will respond only to 500 meters wave length, and to no other wave. Consequently, when at the distant sender, photo-electric cell number one is energized, it sends out a wave at 500 meters, which wave is received in our wave analyzer, and will only affect inductance number one, condenser number one, and audio frequency amplifier number one.

We shall now see how the picture is reconstructed. The electro-magnets connected with each of the many audio frequency amplifiers are equipped with pivoted diaphragms in the center of which are mounted vertical strips of mirror, which are very narrow. These mirrors may be 1/16th of an inch wide, or thereabouts. The best width will probably be found by experimenting. From a common source of light also shown in our illustration a single ray of light falls just outside of each mirror. See Fig. 29. The common source of light may be a powerful tungsten lamp enclosed in a box perforated with many holes. Each hole lets a ray of light pass and each hole sends a ray of light upon a different diaphragm.

The instant that the audio frequency amplifier energizes the electro magnet the diaphragm in front of it begins to turn on its axis, and the ray of light normally at rest begins to vibrate back and forth. This ray of light falls upon a ground-glass plate in the rear of the receiver.

At this point, we wish to call the readers' attention to the fact that the diaphragm in front of the electro-magnet is not the ordinary telephone diaphragm but is one that is pivoted. In other words, the more current flows in the electro-magnet, the more the diaphragm will turn. Of course, this diaphragm is attached in such a manner that it will not turn through a great angle. A small fraction of a degree is sufficient. It can be readily understood that we have here to do with a lever action, and if the mirror turns only a minute angular measurement or less, the beam of light that plays on the ground glass will move for quite a distance.

If the diaphragm vibrates violently, the flat pencil of light will illuminate a square upon the screen which is predetermined by experimentation. If the diaphragm does not vibrate at all, the light pencil is not visible at all because, as we stated before, the light ray can only be reflected when the narrow mirror begins to vibrate. At rest there can be no reflection of the light ray, because the latter does not then fall upon the mirror at all. The more the mirror vibrates, the wider the light band becomes, as is shown in our separate insert illustration. In other words, if at the sender photo-electric cell number one is fully illuminated, it will send out a strong impulse, which strong impulse is received at the receiving end exactly as if at the present time a broadcasting station was sending out a loud note, you would loudly hear it in the telephone receiver. If it was sending a weak note, you would receive it weakly in the phones. Just so in the author's television scheme. The more light there falls upon the photo-electric cells, the more the tiny mirror in front of the receiver electro-magnet will swing back and forth. Therefore, the entire imaginary small square upon the ground glass will be illuminated.

If, on the other hand, a black object falls upon photo-electric cell number one it will not send out an impulse and for that the receiver will not energize the tiny mirror and, consequently, the square of the unit number one on the ground glass will remain black. It will be seen from this that any shade from either darkest black to lightest white will be transmitted instantaneously.

The entire picture is made up by such impulses and is thus reconstructed upon the screen where we can view any picture, whether it be at rest or animated. In other words, it makes no difference, if we turn the sender on a scene that is at rest, or whether we turn it at a horse race; the effect will be of the same degree of perfection.

There is no doubt that this scheme can be made to work, and we would be very much surprised if television by radio were not an accomplished fact during the next two or three years. The author wishes it distinctly understood that the proposal has not been worked out and exists only in theory so far, but there is no point in it which is not sound, and which cannot be turned into practice today. It is simply a matter of building the device, and making minor improvements as would be found necessary in actual practice. It should also be understood that this idea is not only applicable to radio, but it is possible to use the same instruments on wire lines with equal facility

This television scheme would then resolve itself into wired wireless with which we are all familiar. One may ask if the voice currents and the radio currents will not mix up and distort the picture at the other end. This, however, is not the case at all, since we can use such widely different lengths of waves.

The Jenkins Radio Television

Then, even before the ink of the presses was dry, announcement of the discovery of radio television found space in all the metropolitan newspapers.

Science and Invention, always the first to give to the scientific world news of all the important steps in the progress of this field of research, carried the article on this important step in the Aug., 1922, issue. It was written by S. R. Winters.

This arresting title when seriously employed by any individual other than the accredited originator and inventor of the motion-picture machine would smack of sensationalism and the claim would be considered visionary. However, when C. Francis Jenkins of Washington, D. C., possessor of the Elliott Cresson gold medal, awarded by the Franklin Institute of America for his original contribution to motion-picture mechanics, announces that he has discovered a means for transmitting photographs and motion pictures through space, the public lends an attentive ear. The revolutionary character of the

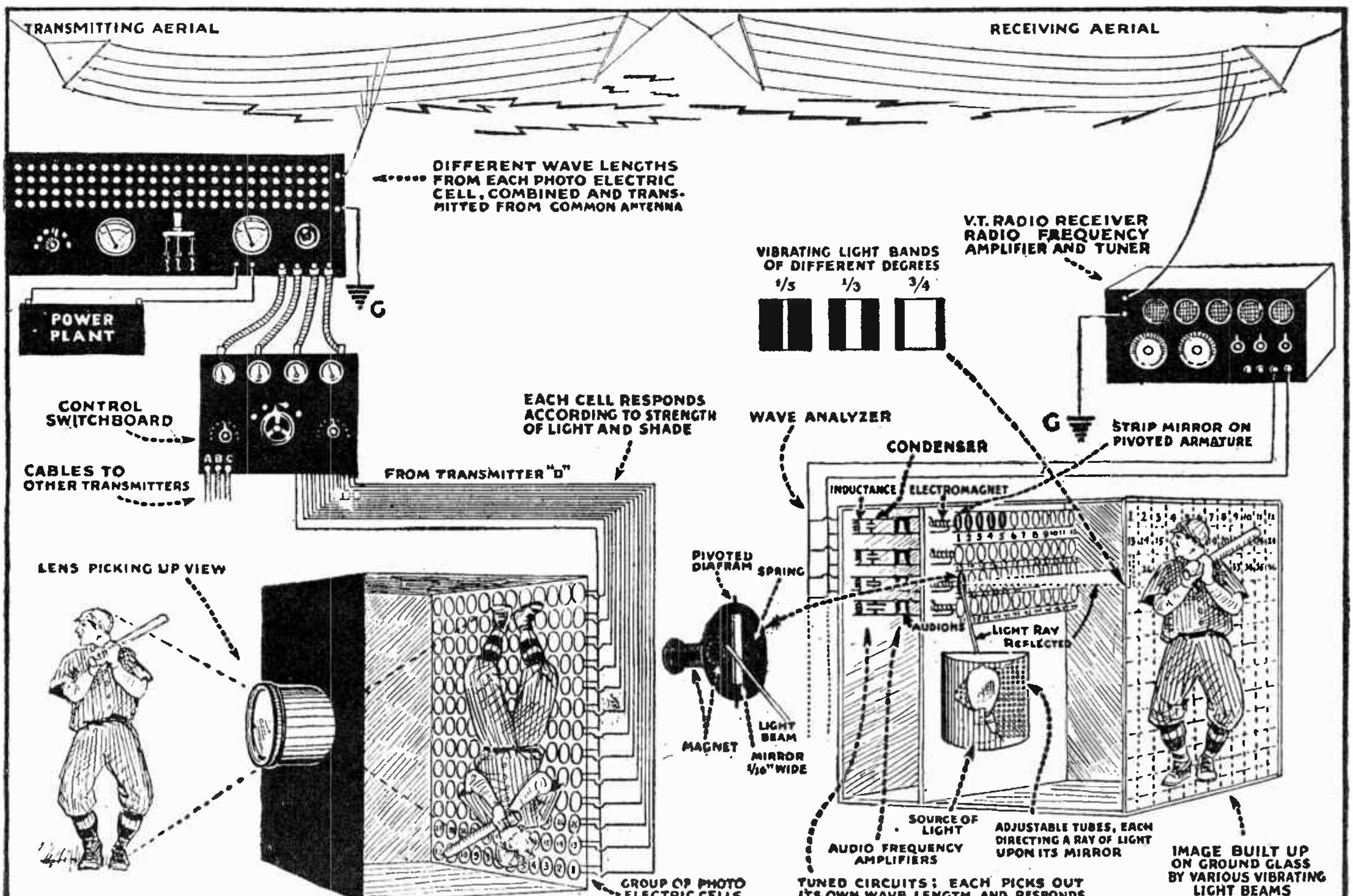


Fig. 29. This shows the modus operandi of Hugo Gernsback's Telephot scheme. First we employ a group of photo-electric cells which are light-sensitive, and which transmit light impulses into the radio transmitter. Whenever light falls upon the photo-electric cells, these cells transmit an impulse. Where no light falls, as for instance the socks of the baseball player, such a photo-electric cell remains dark, and consequently sends out no impulse. All the cells send out impulses which are transmitted at different wave lengths from a common transmitting antenna. These are picked up at a distant receiving aerial, where we have also an instrument which consists of a great number of inductances, condensers, audio frequency amplifiers, and electro-magnets. Each such unit responds to a certain wave length. In front of the electro-magnet, which is energized, we have a pivoted diaphragm. On the diaphragm we have a narrow mirror. When the diaphragm is at rest, the light beam falls upon it, and just misses the mirror. The smallest vibration of the mirror, however, intercepts a light beam from a common source, which light beam plays upon the ground glass. The combination of all of these diaphragms in reflecting each one a light beam, reconstructs a picture on the ground glass, as shown.

discovery, however, gives cause for doubt in the popular mind as to the success of the enterprise, irrespective of the prestige of the inventor.

With this introductory paragraph, not in the form of an apology, but as a shock-absorber in view of the startling nature of

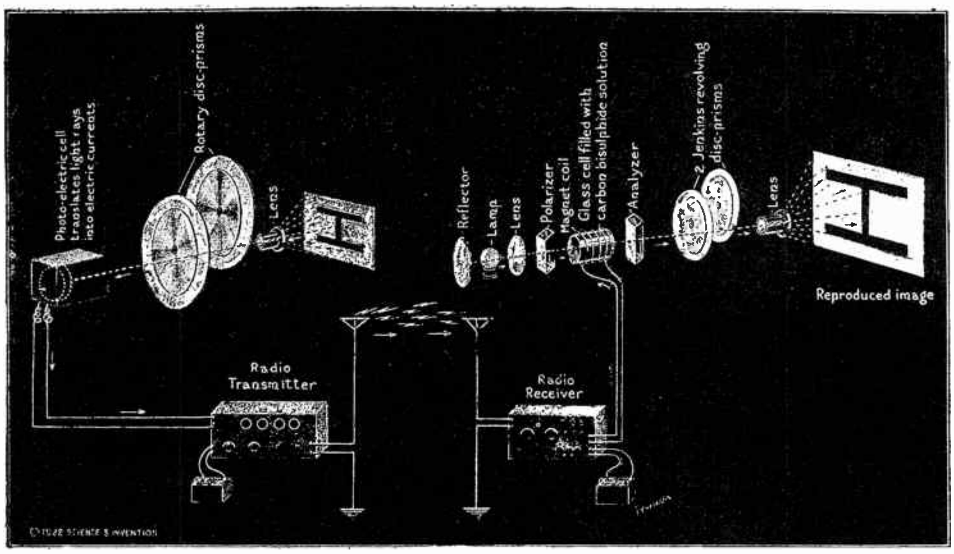


Fig. 30. The apparatus used by Mr. C. F. Jenkins of Washington, D. C., in actually transmitting an image by means of a motion picture camera transmitter and a radio receiver, coupled to a special projector mechanism, is here shown in diagram form, so as to be easily understood. The image of the letter H at the transmitter (at left), which may be moving or stationary, is flashed through the lens and two revolving disc prisms onto a photo-electric cell. This cell changes its resistance in proportion to the amount of light falling on it, and consequently various light and shade values cause corresponding fluctuations in the transmitted radio current. These pulsating electric waves are picked up by a radio receiving set in the usual manner, and the amplified current pulsations, corresponding to the light and shade values of the transmitted image, pass around a coil inside of which is a glass cell filled with a carbon disulphide solution. Certain polarizing effects set up in the optical system of lenses and prisms, as well as the carbon disulphide cell and the magnet coil, together with two more revolving disc prisms, cause a duplicate of the original image to be flashed on the screen.

the subject, the claim of C. Francis Jenkins, distinguished exponent of the inventive mind, is presented without further ado: "The broadcasting of motion pictures has been made possible by use of a prismatic ring, a new optical shape in glass, which has recently been brought to a rather high state of perfection. It has already been applied in extreme high-speed photography (1,600 pictures per second): continuous motion-picture projection machines; direct-reading ground-speed meters for airplanes; etc."

The transmission of photographs from one room to another, only a few steps intervening, at his laboratory in Washington, D. C., in 1922, had been accomplished by use of these prismatic rings, which are protected by patents. The principle involved in the transmission of photographic objects through ether is that electromagnetic or wireless waves are susceptible to the impression of picture characteristics just as at present electrical waves may be translated into speech if voice characteristics are impressed thereon. Accepting the logic of this theory, it is then only a matter of combining with these new ring prisms certain well-known elements in operative relation—elements to be found in any modern physics text-book.

A circular ring of glass, unpretentious in appearance, is the vital unit upon which the claim was based that photographs and motion pictures were transmitted through space over short distances. The warped contour of this ring of transparent substances, when rotated across a beam of light, produces an effect on the latter comparable to that of a glass prism which changes the angle between its faces. Or, putting it differently, there is a constant change in its refracting angle.

The effect on a ray of light passing through this glass ring, having a fixed axis on one side of the latter, is to give to the ray of light on the other side of the glass prism an oscillation or hinged action in the plane of the diameter of the ring. Consequently, a ray of light passing through this prism and spending its force on a picture surface at the top will travel across the picture surface to the bottom as the prismatic ring rotates. By the same token, the identical ray of light passing through a second prismatic ring, with its diameter, set at right angles to the first, will embrace the picture surface from left to right. If then one of the prismatic rings is rotated one hundred times faster than the other, it will be seen that the picture surface would be covered, horizontally, in one hundred parallel stripes by the pointed beam of light.

Such is the behavior of these prismatic rings in conjunction with instruments developed in contemplation of a broadcasting service of motion pictures, not altogether dissimilar from the prevailing system of distributing vocal speech and music by means of the radio-telephone. The equipment for the transmission of pictures is composed of a pair of prismatic rings and a sensitive photo-electric cell.

The outfit for the contemplated *reception* of motion pictures consists of another pair of these circular prismatic rings of glass and a light valve. The latter unit is a glass tube filled with carbon disulphide solution, the tube being wound with wire somewhat similar to the winding formation of the tuning coil used in radio-telephony and telegraphy. Current given passage through the photo-electric cell of the transmitting apparatus fluctuates under the influence of variations in light values of different parts of the picture. This fluctuating current is impressed on electromagnetic waves, and is "picked up" by wireless receiving sets equipped with the prismatic rings. The current values, subsequently, are translated into picture values on the screen. The result is a duplicate of the scene broadcasted.

How do the amplified radio currents coming from the vacuum tube receiver influence the carbon bisulphide within the tube in such a manner as to act on the ray of light passing through it?

In answer to the above question Mr. Jenkins said:

"The construction of the light valve is based on phenomena described in most modern text-books on physics, that is, it is a well-known fact that polarized light passing through carbon disulphide (a liquid) is rotated if this bisulphide lies in a magnetic field. Also, the polarized light is rotated proportional to the current strength creating the magnetic field.

"The construction of the cell is such that light from a fixed source, passing through a polarizer and then through a solenoid surrounding a tube of disulphide of carbon impinges on an analyzer set crossed with respect to the polarizer. Such an arrangement will give total extinction of the light at the analyzer, if no current passes through the solenoid.

"However, when the current passes through the solenoid (creating a magnetic field within it), the plane of the polarized light will be rotated and will, therefore, pass out through the analyzer and on to

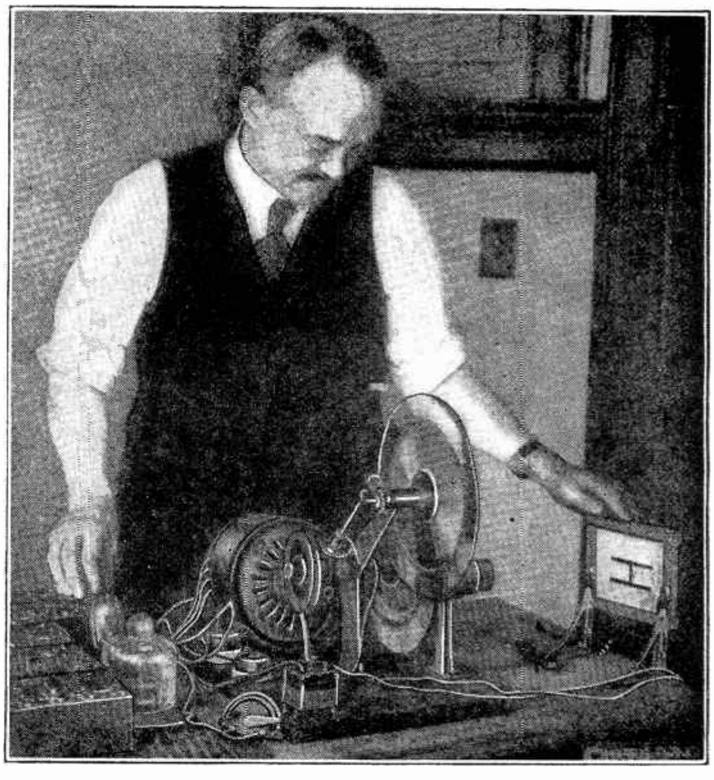


Fig. 31. Mr. C. F. Jenkins, original inventor of the motion picture machine, is here shown at work in his laboratory, together with the apparatus which transmits stationary or moving pictures via radio or wire, as desired. The underlying principles are fully explained in the accompanying text. Note the two prismatic glass discs rotated by the motor.

the photographic plate. As the light is rotated in proportion to the current strength in the solenoid, the light intensity which reaches the photographic plate is also in proportion to the current strength. Therefore, the half tones of the picture sent from the broadcasting stations are reproduced as half tones at the receiving stations. That is, the reproduced picture at the receiving instrument is a faithful reproduction of the picture sent out from the broadcasting station in shadows, half tones, and high lights.

"Again, as this disulphide cell acts as a weightless shutter, there is practically no limit to the speed with which it can respond to modulated current

"The motion picture simply consists of a series of successive lantern slides thrown on the screen at a speed of sixteen a second, that is, at a speed which, by reason of persistence of vision, deceives the eye into the belief that it is looking at a continuous picture on the screen. There is no difference between photographs, *i. e.*, 'stills,' and motion pictures, except in the speed."

The Belin Radio Television System

In the April, 1923, issue of *Science and Invention* Robert E. Lacault described the apparatus of the well-known French engineer, Mr. E. Belin, famous for his telestereograph, by means of which pictures and documents can be sent by wire or by radio. Belin delivered a lecture on television at the Sorbonne in Paris and demonstrated an experimental apparatus which proved that it was entirely practical to send animated pictures to a distance by wire or by radio. Mr. Belin actually worked such an apparatus and obtained very gratifying results: he expected to have his machines completed and to give a demonstration of television before the end of the year.

During the lecture delivered before an audience of distinguished scientists, Mr. Belin used a simplified set to illustrate the principle. Our illustrations show the transmitter and receiver which were installed in the same room, loop aerials being used as the range was so short.

By means of this apparatus, it was possible to transmit by radio, luminous bands varying in tint from black to full white passing through various values of gray which are found in any photograph or moving picture film. The sketch, Fig. 33 shows the arrangement of the instruments. A source of light, 1, composed of a Pointolite lamp, providing an intensely luminous spot of very small area, was placed in front of a lens concentrating the light upon the edge of a disc having drilled near its circumference, a series of small holes following the line of a spiral as shown in 2. When revolving, this disc allows the light to pass through each hole in turn, thus covering a horizontal strip, as shown by the dotted lines, which corresponds exactly with a small screen colored with all values of grays from black to white. The light passes through one hole of the disc at a time but the speed of the disc exceeded ten revolutions per second, making it impossible for the eye to perceive the interruptions.

On account of the spiral shape of the row of holes, each ray of light strikes on the screen, a different grade of gray which, therefore, increases the light from zero to its full value at every turn of the disc. The rays are concentrated through another lens upon a very sensitive photo-electric cell connected through an amplifier to a radiophone transmitter of the usual type. The variations of light acting upon the photo-electric cell modulate the current of the radiophone in the same manner as if a microphone were connected to the input side in place of the photo-electric cell.

Radio waves were emitted from the radiophone set, modulated to the contour of those shown in 3; since the variations produced were identical at every turn of the disc. The increase from nothing when no light was impressed upon the cell, to maximum value when the light passed through the white part of the screen, produced in the photo-electric cell a progressive variation. At the receiving end, a loop antenna connected to a tuner and amplifier collected the waves and transformed them into audio frequency variations of the same shape as that of the modulated waves. The output current from the amplifier was passed through the movable coil of an oscillograph, this coil being composed of a loop of silver wire, one thousandth of an inch thick, supporting a small mirror about 1/32 of an inch square.

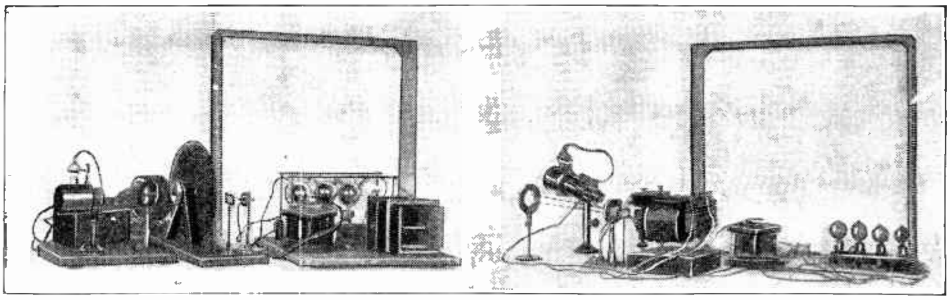


Fig. 32. Above are two photographs showing the transmitting (Left) and receiving (Right) apparatus for the demonstration of television. The transmitter is composed of a special optical device combined with a screen and a perforated disc projecting a beam of light through the screen upon a photo-electric cell. The current of a radio telephone transmitter is modulated, the photo-electric cell replacing the microphone. At the receiving end, the current after being amplified, acts upon an oscillograph, the mirror of which reflects a beam of light through a similar screen to the one used at the transmitter and projects it upon a screen.

Since this movable coil is acted upon by a strong magnetic field, it tends to turn whenever a current passes through the wire, the deflection being proportional to the intensity of the current. This variation causes the tiny mirror upon which a powerful beam of light is concentrated to produce a deflection of the beam which is reflected upon a screen similar to the one used at the transmitter. Behind this screen is placed another lens projecting upon a white screen, the light received which is reproduced in the shape of a luminous strip varying in color from black to white.

Another experiment carried out during the lecture was the transmission of a little black square moved by hand in front of the screen. At the receiving apparatus, the audience could see on the screen the little square moving at the same speed as it was displaced in front of the transmitting screen.

The photo-electric cell used in these experiments is of a new type recently invented, having a grid made of fine platinum wires and a cathode made of an alkali metal. (See 4.) When a luminous ray strikes the cathode, electrons are emitted changing considerably the electric resistance between the electrodes.

In another system which Mr. Belin used in his laboratories, moving pictures may be displaced rapidly in front of the transmitting apparatus. Each picture of the film may be resolved into about 10,000 points, being explored over all its surface at such a speed that every part of the picture is reproduced at the receiver exactly as it is and with all the accuracy necessary to give perfect reproduction upon a screen when the picture is enlarged.

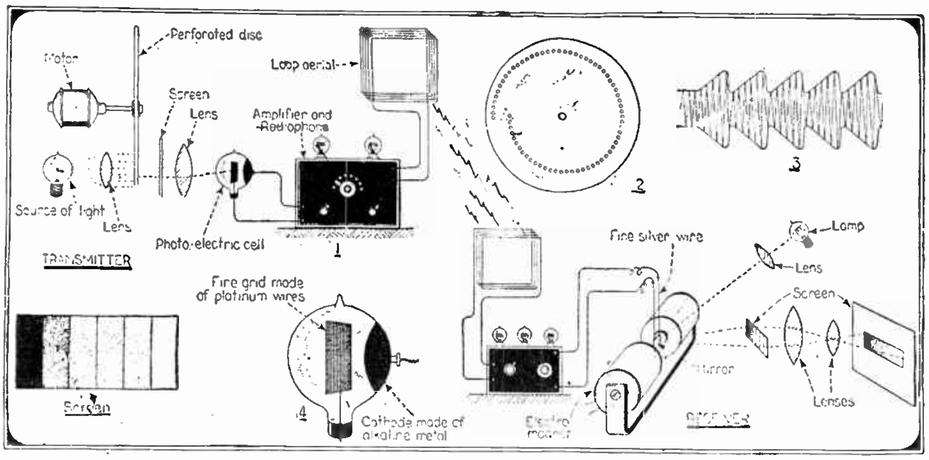


Fig. 33. The diagram, 1, shows how the transmitter operates. 2 shows how the disc, rotated in front of the screen, is perforated so as to permit a beam of light to cover the whole length of the screen at every revolution. 3 illustrates modulation of the radio waves produced by the radiophone transmitted every time the ray of light passes through the screen from black to white. 4 is a detail of the construction of the photo-electric cell which modulates the oscillating current of the radiophone transmitter. The diagram of the receiver clearly shows how a beam of light produced by a lamp and concentrated upon the mirror of the oscillograph reproduces upon a white screen, the shaded screen which varies in colors from black to white, passing through all grades of gray interposed between.

Jenkins' Improved System

Mr. H. Gernsback in September, 1923, visited the laboratory of C. Francis Jenkins, of Washington, D. C. He was still under the influence of what he considered to be the most marvelous invention of the age when he wrote an article on the subject in the December, 1923, issue of *Radio News*. The demonstration took place before a general of the army, his staff, and Mr. Gernsback. The latter writes:

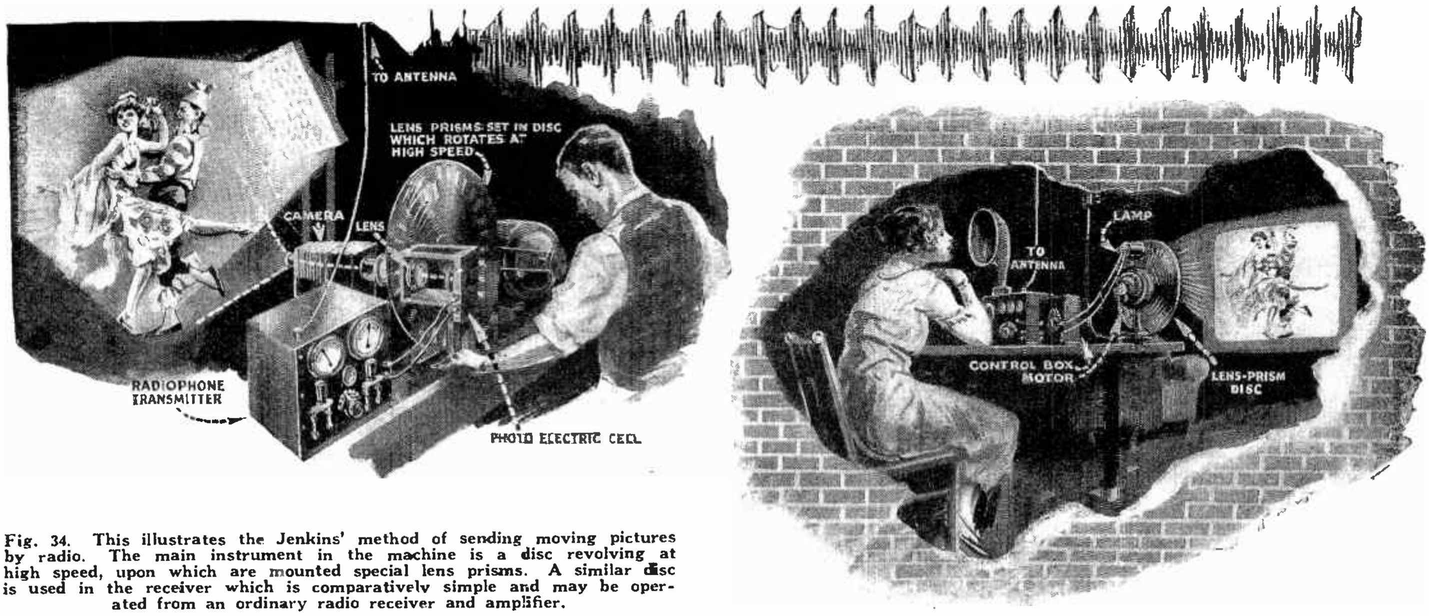


Fig. 34. This illustrates the Jenkins' method of sending moving pictures by radio. The main instrument in the machine is a disc revolving at high speed, upon which are mounted special lens prisms. A similar disc is used in the receiver which is comparatively simple and may be operated from an ordinary radio receiver and amplifier.

Although the machine is not yet perfected, I had been able to see my hand projected by radio and being received by radio. In one of the illustrations, you will observe several small objects in the foreground of the transmitter, such as a key, cross, clamp, etc. By placing these in the path of the light, the picture was transmitted by radio and was received again at the other side by a radio receiving apparatus. It was possible to wave these small objects in the path of the light ray of the transmitter and one could amuse oneself by seeing how these objects were actually being transmitted by radio.

While of course the apparatus used by Mr. Jenkins today may appear cumbersome and complicated, it should be remembered that the first telephone and the first radio outfit were no less complicated, and perhaps more so. It is not necessary to go into the technicalities, as we have described the important parts of Mr. Jenkins' invention. The former articles, however, dealt exclusively with the transmission of pictures by radio and it is easily understood that there is a vast difference between transmitting a photograph and transmitting a baseball game while it is being played. The underlying principle of the two machines, however, is practically the same. Roughly, Mr. Jenkins, by means of revolving prisms, cuts up the light rays which vary the resistance of a light sensitive cell, such as, for instance, the well known Case Thalofide cell. The fluctuating currents after passing this cell are fed to a regular vacuum tube sending outfit where the variations of the light impressions affect the modulation of a lamp, as the voice does. Radio waves are then sent out into space and are received on a regulation radio outfit. The receiving apparatus is very simple. One of the illustrations shows the receiver. It consists of only three parts, namely: A revolving disk with prism and lenses, a motor and a special lamp. The special lamp is used in place of a telephone receiver or loud speaker and this is what happens: The waves as they come in light and extinguish the small pin lamp thousands of times per second. Looking at the lamp with your eyes, you would think it was fully lit. This is, however, not the case. The lighting and extinguishing take place so rapidly that one cannot follow them with the eye. After the light ray passes through the revolving prism lenses, the picture is automatically recomposed on a screen. There is very little complication here.

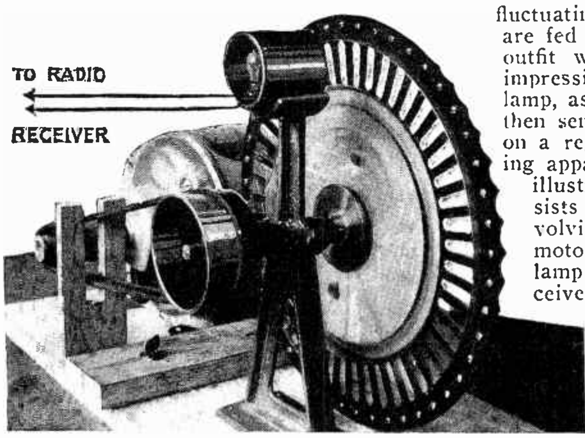
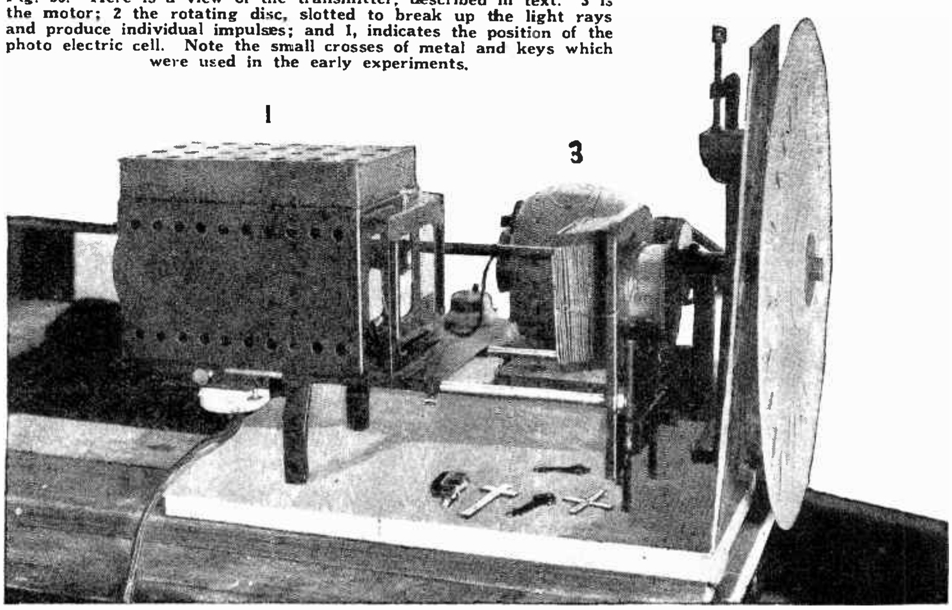


Fig. 35. Above is a back view of the receiver apparatus which projects on a screen pictures of moving objects displaced between the lens and the bellows of the transmitter shown below.

The day will come when you will be able to sit at home and witness a baseball game as it is being played five thousand miles away or you will be able to sit at home and not only listen to, but also actually see an opera as it is being sung and acted. In other words, not only the music but the action will be broadcast simultaneously. In future wars, it will be possible for an Admiral to witness a naval battle and follow it with his own eyes, although his battleship squadron may be thousands of miles away.

Fig. 36. Here is a view of the transmitter, described in text. 3 is the motor; 2 the rotating disc, slotted to break up the light rays and produce individual impulses; and 1, indicates the position of the photo electric cell. Note the small crosses of metal and keys which were used in the early experiments.



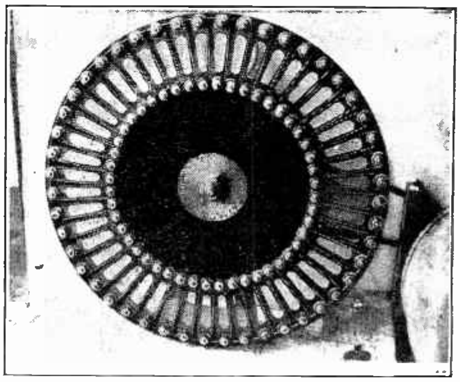


Fig. 37. Front view of the receiver disc showing how the lens prisms are mounted.

The Mihaly Telehor Machine

In an article by Nicholas Langer, an experimenter on television systems, we find one of the finest accounts of the Telehor machine, invented by Dionys Mihaly. This appeared in the May, 1924, issue of *Radio News*. Mr. Langer writes:

About five years ago I conducted many experiments along these lines. Later, through interest and knowledge of these experiments, I became acquainted with the Hungarian engineer, Dionys Mihaly, who was at that time making very rapid progress in experiments along practically the same lines as those in which I was engaged. I accepted his kind offer to become his assistant and it is through this relation that I am able to make public this article which is the first detailed account of his experiments to be published in America. I am sure the American public will be greatly interested in the following description of Mihaly's apparatus.

Disregarding coloring, a photograph of any object, whether stationary or in motion, can be considered as consisting of many small areas of different shading. For the sake of simplicity we shall call these minute areas "picture elements." This system of reproduction of photographs has long been in use in the half-tone method of printing, in which each of the small areas is reproduced in the printing plate as a larger or smaller dot, depending upon the shading of the area it represents in the original picture. If the element is made sufficiently small, each one will have a uniform shading over its entire surface. This fact is of cardinal importance.

By dividing the picture being reproduced into these small elements, it is a comparatively easy matter to transform the degree of shading of each area into an electric current. This transformation is effected usually, through the agency of a photoelectric cell. There are a number of such agencies, one of the most important of which is the selenium cell.

Selenium cells are based on the fact first observed by the English cable engineer, Smith, that the electrical resistance of selenium was reduced when light fell upon it. It was found that the resistance of the substance decreased as the light increased, within certain limits.

Present selenium cells are constructed with large cross section and small length which results in decreasing the very high specific resistance of the substance itself. One of the principal types in use at present consists of two thin parallel wires wound about a porcelain plate so that the distance separating the two wires is about .5 millimeter. A coating of amorphic selenium is then placed over the wires. A heat treatment to which the cell is then subjected carries the selenium into its gray-crystalline form which has been found to be most sensitive to light variations. An average cell made in this fashion has an electrical resistance varying between 60,000 and 100,000 ohms. By illuminating this cell with a 16-candle power incandescent lamp placed at a distance of one meter, its resistance

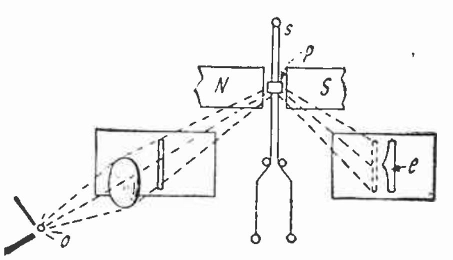


Fig. 38. The oscillograph arrangement which converts the variable current into picture elements at the receiving apparatus.

drops to approximately 30,000 or 40,000 ohms, which is about half of the "dark resistance."

One of the chief difficulties encountered in all selenium cells is the low current which they pass, due to their high resistance. This current is usually on the order of one mico-ampere. A more important defect than this is the lag in the restoration of the "dark resistance" after the removal of the illumination from the cell. Several different methods have been worked out as a means of compensation for this lag.

The first step in television is always the division of the pictures to be transmitted into the small picture elements. Each element is of the same size, but may vary as to brightness. Each of these is then projected upon a light-sensitive cell which transforms the degree of brightness of the element into a correspondingly weak or strong electric current. This current is transmitted either by wire or radio to the receiving station. Here a method is arranged through which the strength of each individual current produces a light in direct proportion to the current strength. Through this method, each of the small elements is reconstructed at the receiving end so that when they are collected in their proper relation, a picture is formed which is very similar to the original.

The problems of television may be briefly stated as follows:

In dividing the picture to be transmitted into the small elements.

Converting the variations of brightness between the elements into an electric current of proportional amplitude.

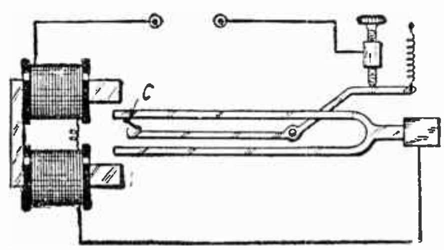


Fig. 39. The tuning fork interrupter which is kept vibrating with an electro magnet.

Transmitting these differences in amplitude by wire or radio.

Rearranging the fluctuations representing the picture elements with their corresponding degrees of brightness.

Projecting the elements on a screen in the same order as that in which they originated.

Each of these is a very difficult problem within itself. The most serious one of the lot, however, is probably that of converting the extremely small differences of brightness into an exactly proportional current. This, as has been said, is done through the aid of a selenium cell. The very small current fluctuations caused in such a cell by the variation of light falling upon it, have been so small as to be hardly measurable. By means of electronic valve amplifiers, however, we are today in a position to magnify these minute currents to an extent which makes television possible.

The Telehor

The chief feature of the Telehor, Mr. Mihaly's television apparatus, is the system of very small oscillating mirrors, of an area of one millimeter or less, which convert the fluctuating currents into picture elements of correspondingly illuminated spots on the screen.

The small mirror P in Fig. 38, is fixed to a loop of extremely fine platinum wire S.

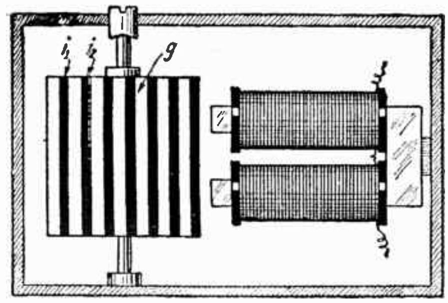


Fig. 40. The phonic drum used to synchronize the telehor.

This wire support is approximately .01 millimeter in diameter and is stretched between the poles of a powerful electromagnet, NS. This arrangement is a well-known Siemens oscillograph.

The Phonic Drum

Another great difficulty encountered in all television apparatus is the synchronization of the sending and receiving instruments. Two special devices have been made use of in the Telehor to perform the service. One is the tuning-fork interrupter and the other is the La Cour phonic drum. Since these devices play a most important part in the instrument described here, it might be well to give a short account of both. The tuning-fork interrupter, as illustrated in Fig. 39, is very similar in operation to the ordinary buzzer. The fork is placed between the poles of an electromagnet so that, as current passes through the coils, the two arms of the fork are attracted to the pole pieces. But immediately the prongs of the fork are separated, the current is broken and they return to their former position, making a new contact and being separated again. This process is continued as long as current is connected to the instrument. By this means, a pulsating current may be produced which has an exceptionally constant frequency.

The phonic drum illustrated in Fig. 40 represents the simplest possible synchronous motor. It is composed of a hollow drum made of wood or some non-magnetic metal and is partly filled with mercury. On the periphery are mounted thin iron strips I_1, I_2, etc., at equal distances. The drum is pivoted near the pole pieces of an electromagnet. If the magnet is connected to an alternating current or a direct interrupted current supply, and the drum is caused to rotate at such a speed that the number of bars passing the pole pieces per second is equal to the frequency or interruptions of the current passing through the magnet, the drum will remain in phase, i. e., it will rotate at a speed depending upon the exact frequency of the current.

Synchronizing Stations

This synchronous motor is used in connection with the tuning-fork interrupter. By installing a synchronous motor which operates in phase with a tuning-fork interrupter at both sending and receiving station, and carefully tuning the forks at each station to exactly the same pitch, the two drums may be rotated at a high speed and yet in exact synchronism for hours without attention. This arrangement has also been used for high speed telegraphy.

In the transmitting apparatus illustrated in Fig. 41, the lenses A and B reduce the picture, which is to be transmitted, in area and project it in the small oscillating mirrors D which form the oscillograph C. The mirror D is caused to oscillate at a rate of 500 vibrations per second by supplying the small platinum suspension wire with a 500-cycle alternating current. The mirror also vibrates at a much slower rate in another

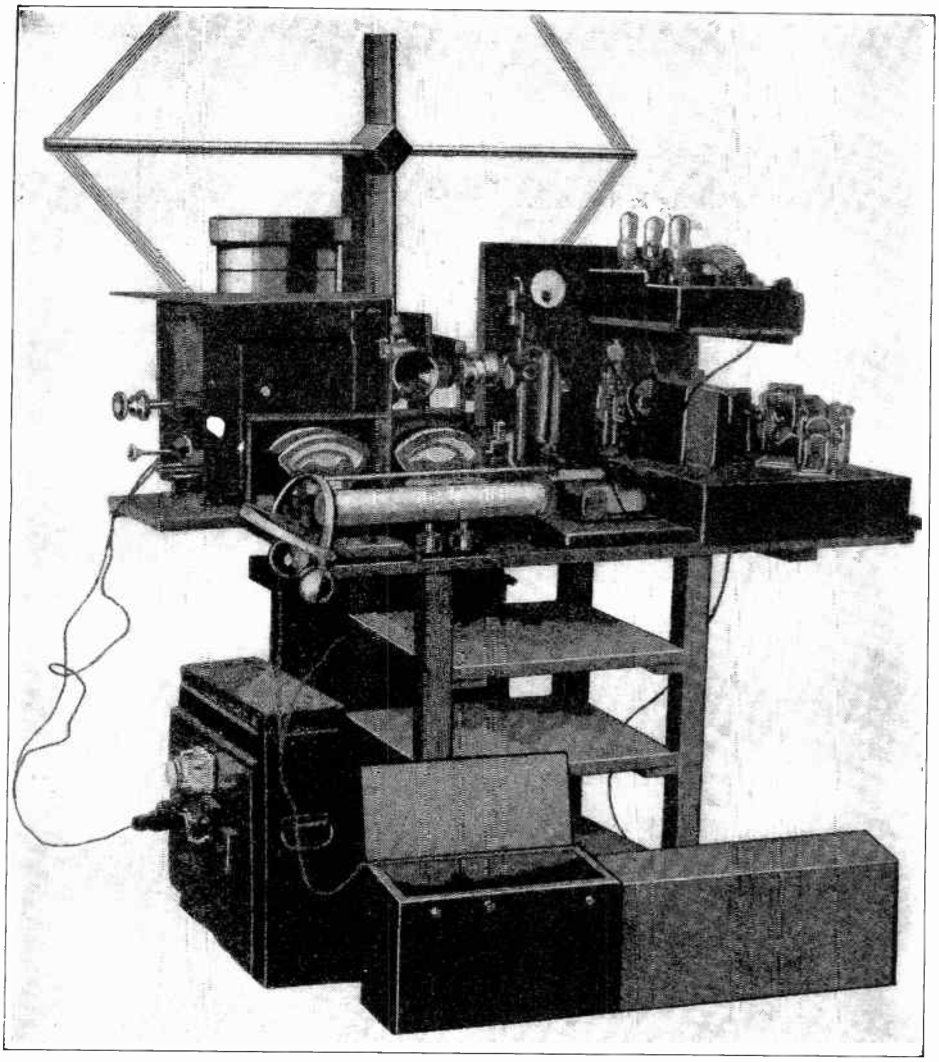


Fig. 43. The Mihaly Telehor machine. 1 is the arc lamp, 2 the light relay oscillograph, 3 the tuning fork, 4 the screen, 5 the diaphragm, 6 the oscillograph, 7 electro-magnet of phonic drum, and 8 the brush.

plane, which is at right angles to the plane of the 500 per second oscillations. These vibrations are produced by attaching the platinum wire to a lever which bears on an eccentric which is fixed to the phonic drum.

The drum is caused to rotate through the electromagnet—which is connected to the tuning-fork interrupter I. The tuning-fork is pitched to 100 vibrations per second. There are 20 of the iron strips attached to the periphery of the drum which revolves five times per second.

The alternating current supply to feed the platinum wire is obtained by interrupting a current from the battery by means of a small 100-segment commutator, which is attached to the shaft of the phonic drum. This produces an intermittent direct current which is supplied to the primary of a transformer, the secondary of which is connected to the platinum suspension wire.

The picture is broken into its small elements in the following manner: The image from the lenses falls on the oscillating mirror and is reflected upon the diaphragm e. This reflection is practically the same size as the original, on account of the divergence of the light rays caused by the mirror. The selenium cell is placed behind an aperture approximately one square millimeter per second up and down across the aperture. But the mirror also vibrates in a horizontal plane at five vibrations per second which means that during 1/10 of a second, while the mirror makes 50 vibrations per second in a vertical plane, half an oscillation is made in a horizontal plane, thus through the double oscillation of the mirror, the picture is broken up into the small elemental areas. The complete decomposition of the picture requires only 1/10 of a second. At Fig. 45 an idea of the order of this decomposition is given.

Picture Currents

The selenium cell Se is connected in series with the battery. The small current changes caused in this circuit through the change in the conductivity in the selenium cell caused by the difference in the amount of the light falling upon it, as the mirror reflecting the image vibrates, is amplified through an ordinary vacuum tube amplifier working at audio frequencies. This amplified current is passed directly to the transmission line or to the radio sending apparatus.

The receiving apparatus, as illustrated in Figs. 42 and 44, is, in its chief features, very similar in its construction to the transmitter. The tuning-fork interrupter and phonic drum represented by I and G and the oscillograph, C, will at once be recognized as being of the same form as the corresponding pieces of apparatus in the transmitter. The most important part of the receiver, of course, is the so-called "light-relay," the device which converts the current fluctuations supplied to it into light, the intensity of which varies in direct relation to the intensity of the supplied current. The light-relay consists of a very sensitive bifilar oscillograph of special design. The arc lamp O casts a narrow but very intensive beam of light on the mirror P of the oscillograph. The received pulsating current from the transmitter is led into the wire supporting the small mirror, causing it to be deflected in direct proportion to the strength of the current originating at the sending station. This deflection causes more or less of the light beam to fall on the aperture depending on the strength of the received current, all the beam being used at maximum current which represents a light spot on the original and little of it falling on the aperture for small currents which represent dark picture elements.

When no current is passing into the loop, the narrow beam of light reflecting from the mirror is projected close to the diaphragm aperture E so that no light can pass through it. At a deflection, however, caused by the passage of current from the transmitter, the light beam passes through the diaphragm and falls upon the mirror of the oscillograph which corresponds to the same arrangement as the transmitter. This mirror, of course, through the agency of the synchronized motor and the tuning-fork interrupter, oscillates in exactly the same manner as its counterpart in the transmitter. Thus, by means of the reflected light, falling upon the vibrated mirror and being reflected on the screen R, the picture is reproduced.

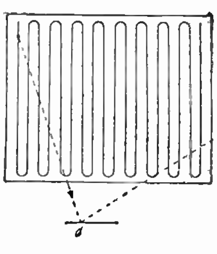


Fig. 45. The waved line shows the path followed by the beam of light to cover the picture being sent.

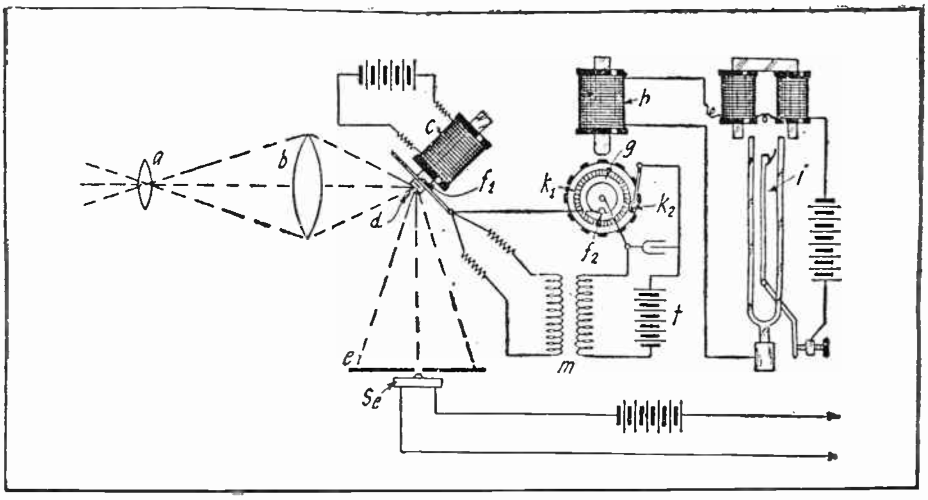


Fig. 41. The transmitting apparatus of the telehor. The object to be seen at the receiver is placed in front of the lens.

Moving Pictures

Since the reproduction of a single picture requires but 1/10 second and since 10 of them may be transmitted per second, the constancy of vision, or the lag in the eye (the same principle which makes moving pictures possible), gives the effect of a moving image on the screen. Of course, only movements which are of medium swiftness may be reproduced through this process.

The success of this apparatus depends entirely upon the synchronism of the two mirrors of the oscillograph. The very smallest deviation at this point causes the screen to show a meaningless conglomeration of light and dark spots instead of the photograph. If the tuning-forks at the transmitting and receiving stations are set into vibration simultaneously, the operation of the two stations will remain in perfect phase for hours. Frequently, through a difference in temperature or other natural causes, the tuning-forks are caused to change their rate of vibration which will ordinarily necessitate adjustment of the apparatus.

In order to make corrections for such changes, Mr. Mihaly has provided a very ingenious automatic arrangement. At the transmitting station a glass plate, which has three opaque spots at its edge, X, Y and Z, Fig. 46 is interposed before the lens B in the path of the light rays. This causes three similar spots to appear in the reproduced picture. These spots must, while the transmission is correct, fall always at the same place. If three selenium cells are placed in these spots at the receiving station, their resistance will be very great while the transmission is perfect. When the synchronism is disturbed, however, light will fall upon the cells decreasing their resistance. Sensitive relays, magnetic coupling apparatus and brakes may be connected to these cells, and may be made to operate through them in such a way as to restore synchronism.

A simple calculation shows that by increasing the size of the picture to be transmitted, the number of picture elements is also greatly increased and the difficulties of the transmission also increase very considerably. If we are working with picture elements of 1 square millimeter, as in the experiment described, which makes only a very rough reproduction of the object possible, we have in the case of a picture 10×10 cm.=10,000 picture elements to

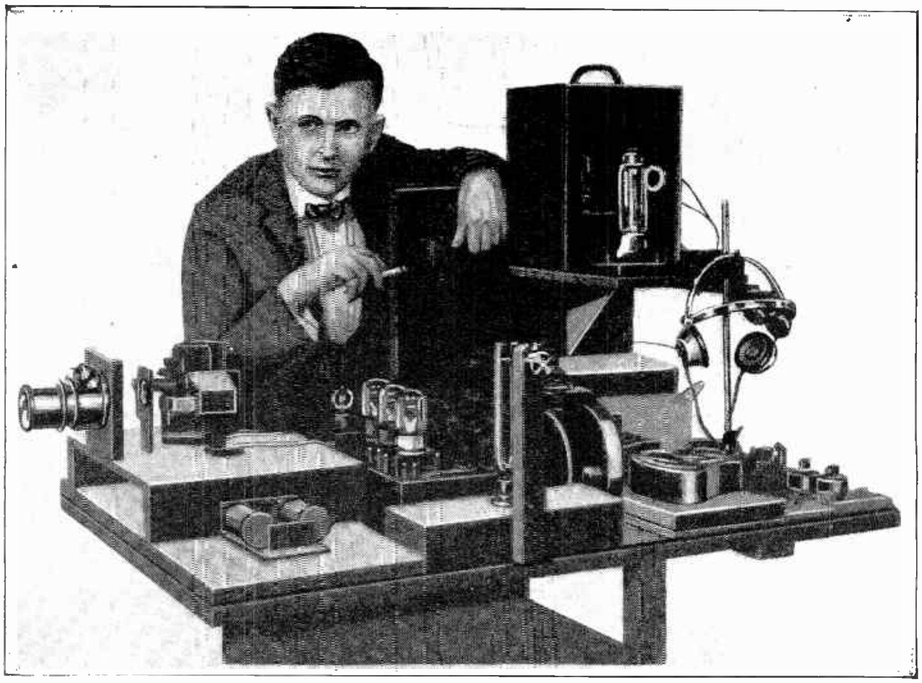


Fig. 44. Another view of the telehor machine with its inventor, Mr. Dionys Mihaly. The numbers refer to 1 tuning fork interrupter, 2 selenium cell, 3 mirror of oscillograph, 4 lenses, 5 phonic drum, 6 armature, 7 electromagnet of phonic drum, 8 diaphragm, 9 oscillograph.

transmit 10 times a second, i. e., a frequency of the "picture currents" must be 100,000 cycles a second. Fortunately the neighboring picture elements are generally of similar brightness, so that the frequency of the picture currents increases at a more moderate rate than the number of picture elements. The number of oscillations the decomposing mirror has to perform depends also upon the size of the picture to be transmitted. As stated, this was, at the experiments described, 500 oscillations a second, but through its very small inertia it can easily produce oscillations up to 5,000 or 10,000 a second.

Experiments were also carried out on wireless television with about the same success as by wire. In consequence of the high frequency of the picture currents themselves, the use of very short waves for radio transmission is to be preferred.

The experiments were conducted partly under very difficult conditions, especially during the great war and in some of the subsequent years. The materials of many kinds necessary for experimental purposes were scarcely obtainable then, so much so that at times, the experimenters were obliged to undertake the making of their own amplifier-valves. Material difficulties interrupted the experimenters in the middle of 1923, but it is hoped to be able to continue them in the future and by using more elaborate arrangements and some innovations to obtain more perfect results.

An Airplane Which Sees

In the November, 1924, issue of *The Experimenter*, Mr. Gernsback, commenting on the future possibilities of Television, suggested a raidio controlled airplane. His futuristic idea follows in his own style:

Last year on a visit to Washington the writer visited the laboratories of C. Francis Jenkins, the well known experimenter of international reputation. It was Mr. Jenkins who perfected the shutter that made our present day motion pictures possible. He was paid over $1,000,000 for this invention.

Of late he has been experimenting with television and has already obtained astonishing results. At the time of the writer's visit Mr. Jenkins demonstrated his television machine before a number of Government representatives, including the General of the Signal Corps. At that time the writer actually saw his waving hand projected by radio over a distance of some 30 feet, the shadow of the waving hand being transmitted to a screen at that distance. Every motion made by the writer's hand

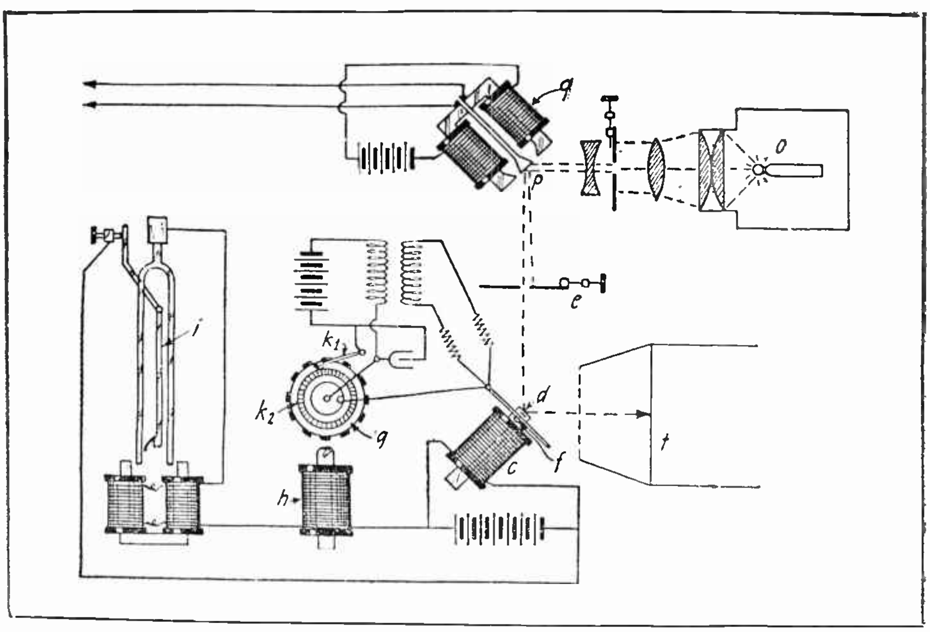


Fig. 42. Diagram of the receiving apparatus through which the current from the transmitter is transformed into a picture which may be seen on the screen.

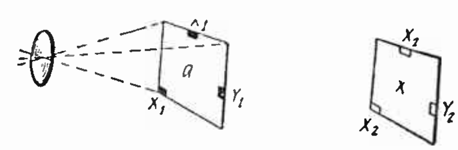


Fig. 46. By means of three dots placed at some point on the screen the synchronism between the transmitter and receiver may be checked.

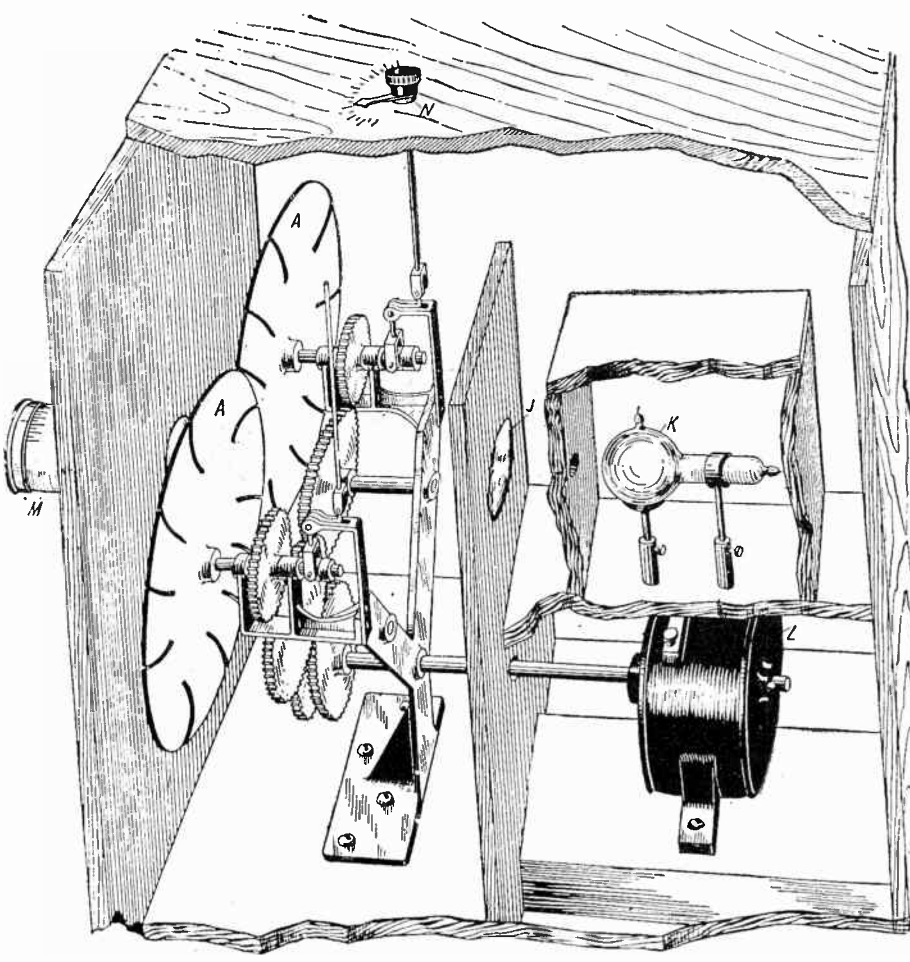


Fig. 48. Above is a plan in perspective of the new television transmitter. Note the position of the lens, M, and the light sensitive cell, K.

was faithfully reproduced on the distant screen. Opaque substances, such as a cross, knife, pencil, etc., were also successfully transmitted and projected by the Jenkins Television machine. While admittedly in a crude state, the machine will no doubt be developed and it is the writer's opinion that within two or three years it will be possible for a man in New York to listen over his radio to a ball game 500 miles away and *see* the players on a screen before him at the same time. Whether it will be the Jenkins machine or some other machine that will achieve this result is of little consequence. The main thing is that experimenters all over the world are working frantically on television and sooner or later the problem will be solved.

An entirely new age will then be opened up and it is not necessary for the writer to expatiate at length on this phase as it has been exploited by him in his past writings and by others for some time.

In this article we concern ourselves with the radio controlled television plane which will come into being the minute the television problem is put on a practical basis. It should not be construed that the radio television plane is merely a monstrous war machine, but it also has its uses during peace time, as will be explained. At the present time it costs much effort, time and aviators' lives in order to train our perfect flyers.

A radio controlled airplane has already been demonstrated by the French Government, and it flew for a lengthy period without anyone on board. The entire control was from the ground while the machine was aloft. The plane arose, cut figure eight's, volplaned, ascended, descended and went through all the ordinary evolutions, the control being entirely and solely by radio. The same kind of a machine is also being experimented with successfully by our own Government and it may be said therefore that the radio controlled airplane has passed the experimental stages and has become practical.

But the great trouble with radio-controlled airplanes is that the operator must see the plane. If his machine were to make a landing at a great distance he might land the airplane on top of a building or in a river, or it might collide with a mountain.

Imagine now a radio controlled airplane also being equipped with electrical eyes, which eyes transmit the impulses—or rather what these eyes see by radio—to the distant control operator on the ground. Illustration Fig. 47 shows a war machine depicting this phase. Here we have a radio controlled airplane equipped with a number of lenses which gather in the light from six different directions, namely, north, south, east, west, up and down. The impulses are sent to the operator on the ground who has in front of him six screens labeled north, south, east, west, up and down. Each screen corresponds to one of the electric eyes attached firmly to the body of the airplane as shown in the illustration.

Let us now see what happens. The airplane is started from the ground and is sent over the enemy territory. During every second of its flight the control operator, although 50, 100 or 500 miles away *will see exactly what goes on around the plane just the same as if he himself were seated in the cockpit,* with the further advantage that sitting before a screen he can take in six directions all at once which no aviator can do. If for instance an enemy airplane suddenly comes out of a cloud and starts dropping bombs on our machine below, the control operator sees this enemy machine quicker 500 miles away, than if an aviator sat in the cockpit one-quarter of a mile away from the enemy bomber. The control operator will immediately disengage a smoke screen from his radio television machine, hiding his craft in smoke. He can also make it turn about if such operation should be necessary, or he can increase its speed if it is desired to escape.

If he outdistances, or otherwise eludes the enemy, the radio controlled television airplane can then be directed to the spot where it is supposed to drop its bombs. Moreover the distant control operator can see *exactly* when his machine arrives over the given spot. A sighting arrangement can be attached to the plane in such a manner that when the object to be bombed comes over the cross wires, the bomb or bombs are dropped at the exact moment. Suppose that the enemy becomes too strong and that a great number of machines attack the radio controlled plane and that there is no escape from the enemy. In that case the control operator will simply press another key which will immediately set the radio television plane on fire, bringing it down in flames. Thus it would be useless to the enemy and no lives will have been risked or taken—it being cheaper to destroy a machine than the valuable life of an aviator.

In the future such radio controlled television planes may be used not only singly but in squadrons as well. They can be used for attacking the enemy if necessary. They can be used in pursuit of the enemy, for taking aerial photographs, and for any other military operation, just the same as a present-day plane conducted by an aviator. Suppose the enemy has the same kind of machines, which, of course, he will have. It then becomes a matter of "playing chess" the same as if the machines contained live aviators. The battle, of course, would not be bloody, but practically the same results would be achieved as far as the military result is concerned.

For peace purposes the advantages of such a mechanical and almost human plane are unlimited. It will be possible in the future to send mail planes from one end of the country to the other without a human being on board. Every second of the flight would be watched by the Post Office Department operator and the plane would, of course, be able to defend itself against attack. It could readily be equipped with electrically operated guns if such should be necessary. Particularly for transporting mail and the like, the radio controlled television planes will be invaluable.

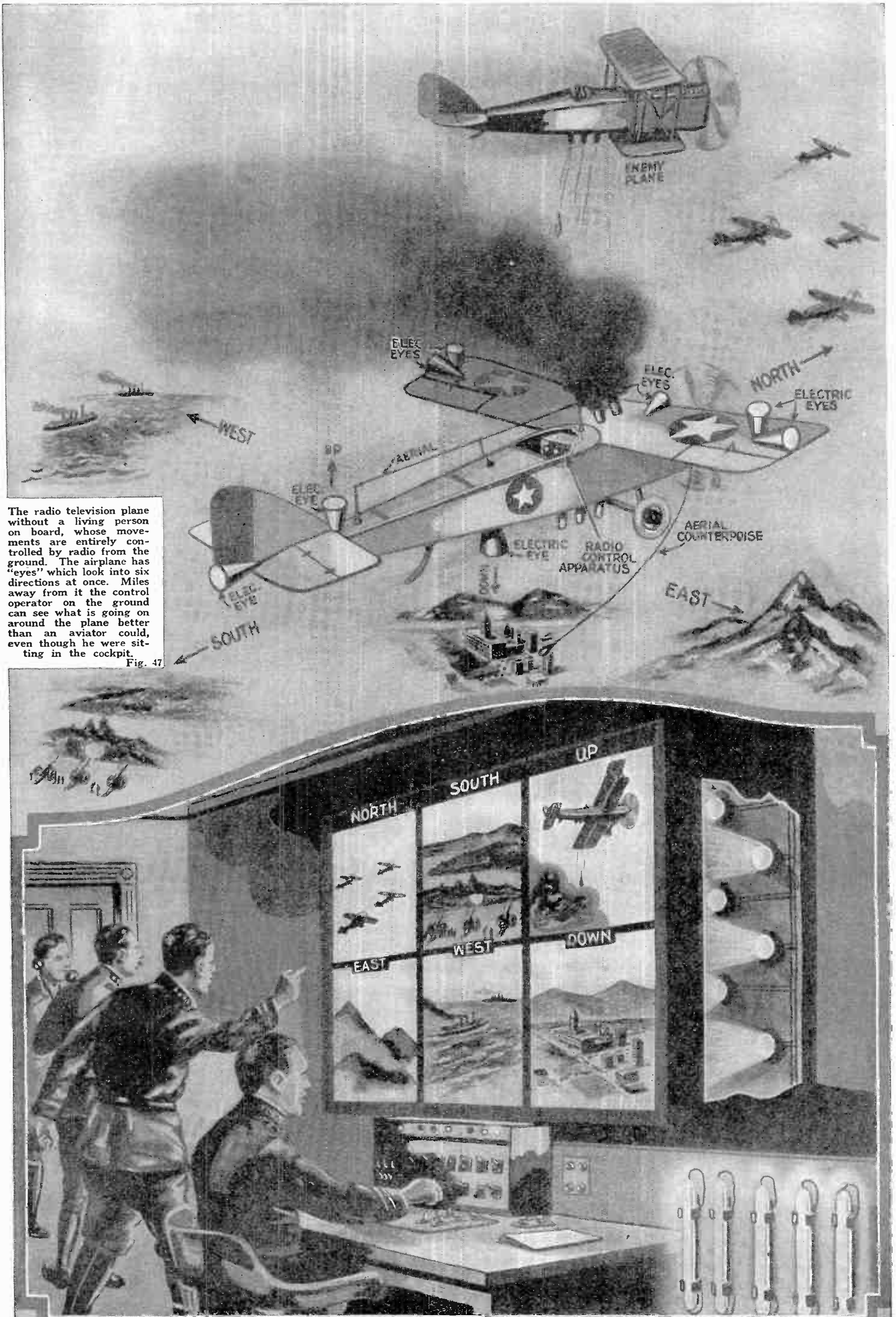
There are, of course, hundreds of other applications of the idea which readily suggest themselves to anyone.

The Process Used by Stephenson and Walton

Mr. W. G. Walton, in the interest of scientific progress, kindly gave an interview for *Radio News* in which he explained the great difficulties in accomplishing the "Radio Movie," the ultimate object of his research. Both he and Mr. W. S. Stephenson, of the General Radio Company, London, have done a great deal of research work in the matter of the transmission of pictures by radio, and have made some highly interesting discoveries. The original material was published in the April, 1925, issue of that magazine.

"For a matter of 30 or 40 years attempts to transmit pictures by electrical means have been made, and the advent of the motion picture led to dreams of transmitting pictures at such a speed that a motion picture effect could be produced.

"The light sensitive device has been, and still is, the greatest source of our troubles.



The radio television plane without a living person on board, whose movements are entirely controlled by radio from the ground. The airplane has "eyes" which look into six directions at once. Miles away from it the control operator on the ground can see what is going on around the plane better than an aviator could, even though he were sitting in the cockpit.
Fig. 47

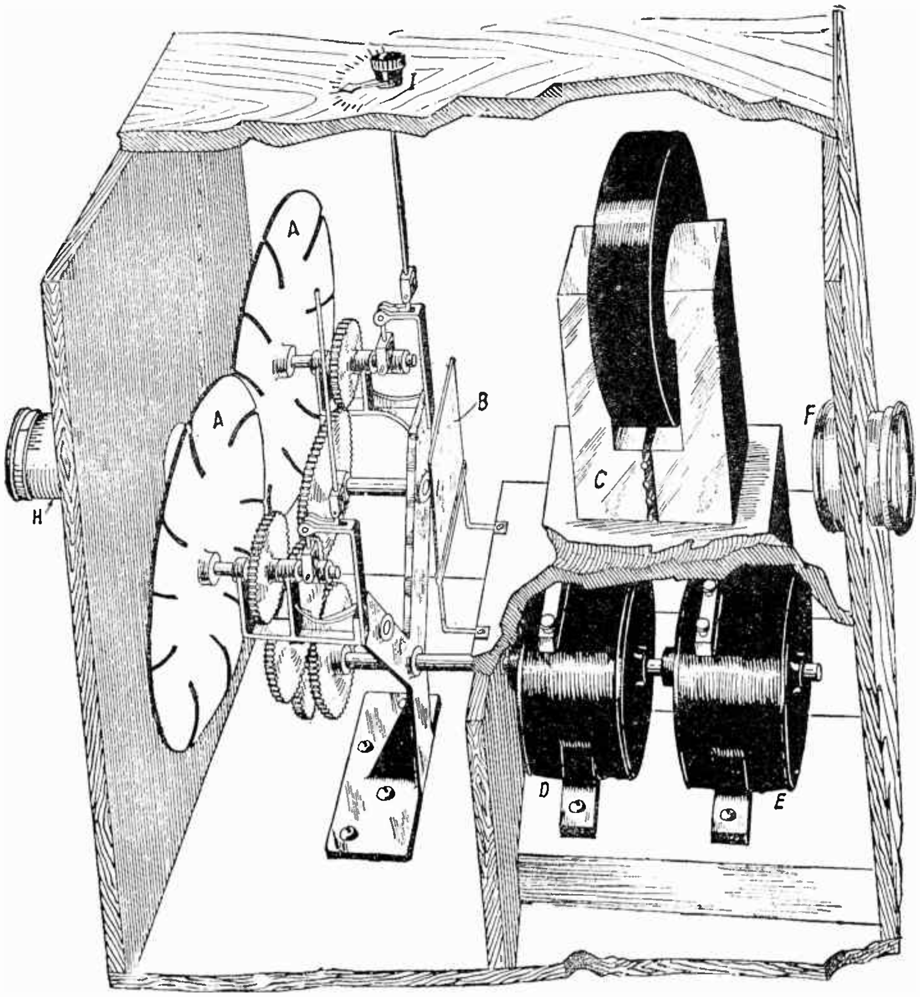


Fig. 49. The reproducing apparatus which recreates the image transmitted to it by the sender.

Selenium cells have the disadvantage of slow action and lag, while photo-electric cells, though faster, give only very minute currents which need amplifying by many stages of resistance coupled vacuum tube amplifiers. Neither of these devices is a desirable feature of commercial apparatus. The time required by the fastest apparatus is too long. To be an entire success, apparatus must be faster and such that it can be used at a moment's notice without many adjustments, and the reception of a reasonable picture must be a certainty.

"Television or the radio movie, is the transmission and reception of pictures by electricity in such rapid succession that a motion picture effect is obtained. Apparatus for this purpose is generally the same as that used in the transmission of photographs, but operating at a much greater speed."

One of the methods is to traverse the picture in lines by optical arrangements and transmitting impulses, the strength of which depends on the intensity of the small sections of these lines as they are shown in succession on a light sensitive device.

At the receiving end a beam of light varied in intensity by a shutter actuated by the impulses received from the transmitting end is traversed over a screen by an optical arrangement similar to that used at the transmitting end. Everything depends upon the rate at which the light sensitive device can respond and also the light controlled shutter at the receiving end. This refers to schemes using one cell.

Before difficulties in the way of television can be appreciated, the number of dots necessary to produce a reasonable picture must be known. Television to be a complete success must have almost as good a definition as the standard motion picture. With a picture of one square foot consisting of a million dots and held a foot away from the eye, an average person will be able to distinguish the dots. Such a picture will give good detail of a town or landscape view.

Motion pictures are shown at the rate of 16 per second. Taking this as the rate of which complete pictures must be repeated by television apparatus, our light sensitive device in single cell methods has to respond to 18,000,000 different impulses per second, and so must the light control shutters. This is, of course, putting the problem at its worst. Some investigators have stated that 300,000 (an enormous difference) will suffice. Allowing that the number of complete pictures is 10 per second, our picture consists of 30,000 dots, 150 lines of 200 dots each. Take any magazine or newspaper picture and mark off 30,000, the picture within this area can hardly be said to have good detail, certainly not in a landscape or incident picture.

We are striving to produce something as good as the motion picture, and though 18,000,000 per second is high, it is a good ideal to aim at. Light sensitive devices as used up to the present time have not been able to respond to anything like such a speed.

"Mr. W. S. Stephenson and I," Mr. Walton said, "have done a considerable amount of research work. In an endeavor to discover something much faster, we tried the possibilities of vacuum tubes to see if light would affect a stream of electrons by bending the stream or otherwise producing some action. Results were doubtful, masked by other things such as light from the filaments.

"Although we have not abandoned this idea, we are trying another line of investigation which shows great possibilities. We have hopes of producing a light sensitive arrangement with a reverse effect, so that an extremely rapid shutter will not be required at the receiving end."

Heterodyning Wave-Lengths

Light waves are electro-magnetic in nature, differing from radio waves only as regards wave-length, though the difference is great. Our endeavor is to convert light frequencies into radio frequencies by an action similar to heterodyning (super imposing one wave-length on another) in several steps. The radio frequency thus produced is, after amplification, transmitted direct without modulating a carrier wave. The possibility is now apparent. A picture consisting of light waves is converted into an invisible picture of radio waves which, after

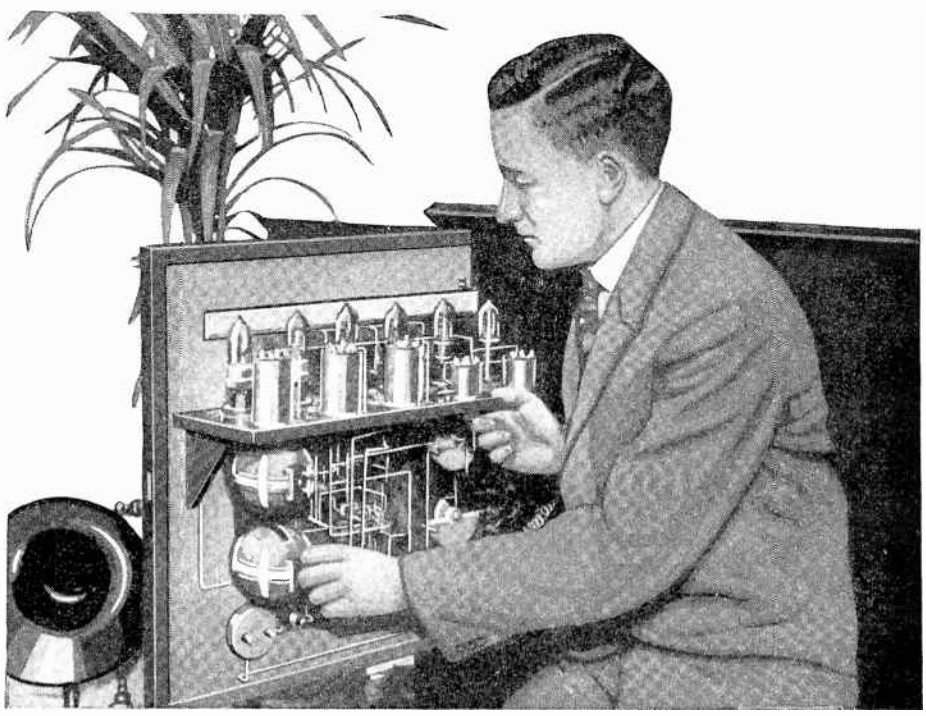


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Fig. 50. Mr. W. S. Stephenson, the co-inventor of the machine for the transmission of pictures by radio described in the accompanying artic'e.

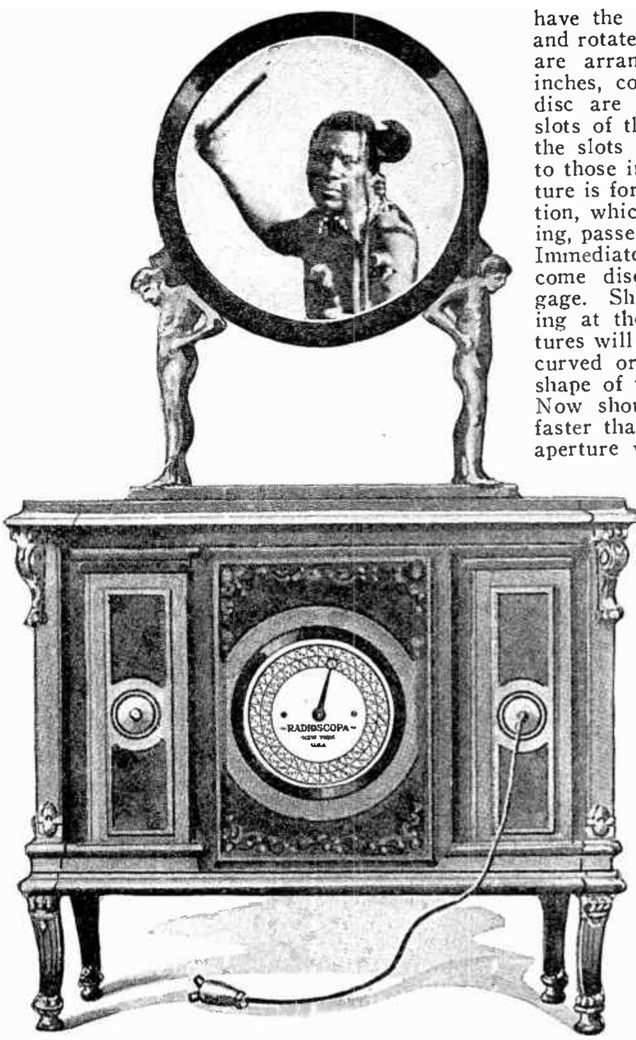


Fig. 51. Above is shown the tentative radio set of 1935. Here we have radio television combined with radio broadcast. Instead of using a number of dials as we do today, the user of the future radio set will have a small pear, as shown. Pressing one of the buttons revolves the pointer slowly until you get the station you desire. Releasing the pressure on the button puts the station on the loud speaker and a television apparatus begins to function at the same time. Pressing the other button will bring in foreign stations located on the inside circle, using the same pointer, the operation being identical in all cases. Separate loud speakers can, of course, be used in this set, or the screen itself upon which the television picture shows may become the diaphragm for the loud speaker.

amplification and reconversion at the receiving end, produces a visible image on the screen. As just described, the trouble is in sorting out the waves and putting them in their respective positions at the receiving end. But if the picture at the sending end is split into sections, and each section has a frequency of its own, then the rearrangement at the receiving end is only a matter of reversing the operations which took place at the transmitter.

The transmission of the pictures would mean the use of a band of wave-lengths, but, after all, radio telephony has the same difficulty. The speed of operation need not be considered with such an arrangement and natural colors mean little further complication.

"I have explained," Mr. W. G. Walton told *Radio News*, "the difficulty in breaking up the picture into dots at a sufficiently high speed to produce an illusion of motion. I will now tell you how Mr. Stephenson and myself tackle the problem with our apparatus. The method used is by causing apertures formed by the intersection of slots arranged around the periphery of two discs to traverse the picture. These discs may be rotated in the same or in opposite directions, according to the number and disposition of slots used and the relative speeds of the two discs. In Figs. 48 and 49 the discs (A) are of the same diameter, have the same number of slots each, and rotate in the same direction. They are arranged to overlap about $1\frac{1}{2}$ inches, consequently the slots of one disc are moving downward and the slots of the second disc upwards. As the slots of one disc are at an angle to those in the second, a minute aperture is formed at the point of intersection, which, when the discs are rotating, passes from one side to the other. Immediately one pair of slots has become disengaged, the next pair engage. Should the two discs be rotating at the same speed, all the apertures will follow the same path, a line, curved or straight, depending on the shape of the slots, from right to left. Now should one disc rotate a little faster than the other, each successive aperture will traverse a line a little above or below the line traversed by the last aperture.

"The effect of all this," continued Mr. Walton, "is equivalent to causing the pinhole to traverse an area in successive lines from right to left, each line just above the last, until the whole area has been covered, when the same process is repeated, starting at the bottom. The great advantages of this method are that there is no waste time, some part of the area is always covered by the pinhole, the pinhole is always open and not arranged for a series of rapid flashes and lastly, speed of traverse is practically the same over the whole area.

"The transmitting instrument is arranged somewhat similar to a camera," explained Mr. Walton. "A lens (M) (on the sketch) throws an inverted image about one inch square in a plane parallel to and just between the overlapping discs (A, A). The slots in the discs are about .002 of an inch wide, therefore the pinhole formed by intersecting slots is about the same diameter. As I explained, the pinhole traverses the whole of the inverted image, allowing a small area of light at a time to pass through. This light is then focussed by a lens marked (J) onto a light sensitive cell (K). The varying electric currents from the cell and a speed control current are then transmitted by radio or other means to the receiving station

"It is obvious that similar sets of discs must be used both at the transmitting and receiving stations," Mr. Walton continued. "At the receiving station a source of intense white light such as an electric arc is placed behind the lens marked (F), which concentrates the beam on a light control shutter (C), shown diagrammatically as a fourstring Einthoven galvanometer. The light having been controlled by the shutter is then thrown on a white diffusing screen (B). An area of this screen throws light through the aperture formed by the slots of the discs onto the lens (H), which focusses the light in a spot on an ordinary projection screen. The received electric current, i. e., current corresponding to the current from the light sensitive cell at the transmitting end, and the speed control current, are applied, the first to the light control shutter (C), and the second to maintain synchronism between the transmitting and receiving machines.

"It is possible when the two machines have just been started and synchronized that the spot of light shown on the screen is not in its correct position, in which case by means of the 'advance' or 'retard' control (I) can be rectified even while the machine is operating at full speed.

"I have mentioned the spot of light shown on the screen, but actually this spot would be moving at such a speed that a continuous image would be seen much the same as the motion picture image.

"This is the type of machine which was evolved after careful consideration of many ways of accomplishing the results. Quite the most important point is the amount of light passing through the shutters onto the light sensitive cell, and at the receiving end onto the screen. With the above method the focussing of the beam of light at the receiving end into a narrow pencil of light is unnecessary. The amount of definition available is purely a question of the width of the slots and the gearing of the discs. We use slots .002 inch wide, and one disc does 1,000 revolutions while the other does 999, consequently our picture consists of 1,000 lines with 50 per cent. overlap between lines. The number of dots in each line—if such a term may be used—depends on the speed of the light sensitive cell and the light control shutter. Should the cell be slow, it will respond only to an average effect beyond its speed of response; in other words, the reproduction would be blurred.

"Another interesting arrangement we have brought out is for natural color reproductions. This is a three-color method similar to that used in photography. At the transmitting end there are three light sensitive cells, each of which respond only to one color and at the receiving end there are three light control shutters, each actuated by currents from one light sensitive cell only. The shutters pass light only of one of the three colors which are mixed and then shown on the screen. The shutter in this case could be a three-string Einthoven, each string independently operated.

Again we must come to an article by Mr. Hugo Gernsback appearing in the May, 1925, issue of *Radio News*. This editor

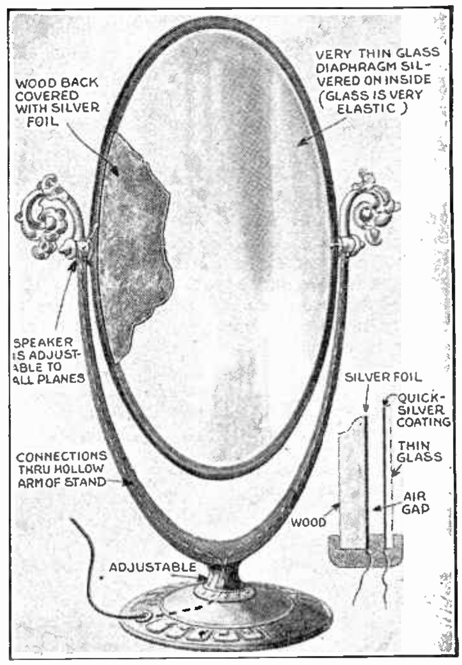


Fig. 52. It has always been Mr. Gernsback's contention that the present loud speaker with a small diaphragm, operated on the telephone principle, is all wrong. Pictured above is theory of an electrostatic loud speaker whereby a large surface is made to vibrate on the electrostatic principle. Mr. Gernsback has himself been working on a speaker of this kind for some time and has obtained fair results. The loud speaker of 1935, in our opinion, will have a large vibrating surface instead of the small $2\frac{1}{2}$ to 3 inch surface in use today.

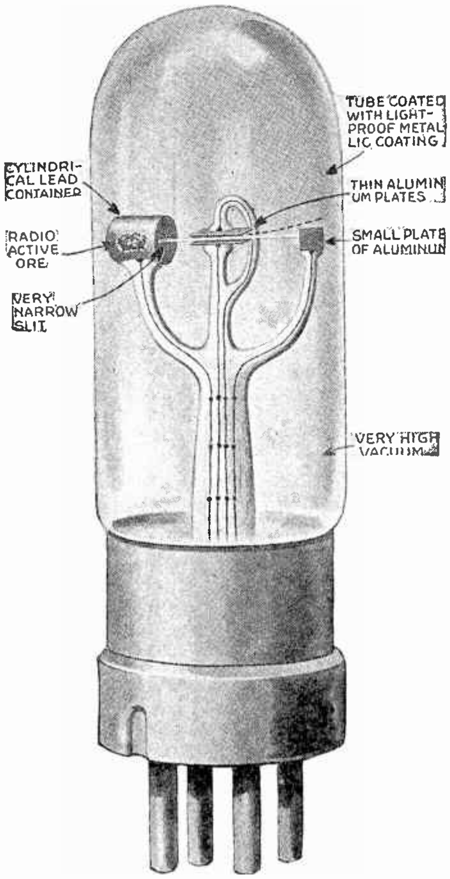


Fig. 53. The theoretical cold vacuum tube of the future. Some experiments by a number of scientists have been made along these lines, and it is now thought possible that within the next ten years we shall have a tube that will not require an "A" battery at all, the electrons of the tube being supplied, not by a hot filament as at present, but by a radio-active substance, or perhaps in some other similar way to obtain the same result. No such tube has, of course, as yet been produced, the above illustration representing the artist's conception of the tube.

has been classed by many as the Jules Verne of the scientific world. His keen insight into future developments, his predictions for the radio and scientific world, have had the remarkable property of coming true even before the date or time limit set by him. The article is reproduced in part herewith and is presented primarily because of its very nature. It was headed, "Radio In 1935." Mr. Gernsback writes:

"There is today a science which may be termed the Science of Prediction. In former years one had to be a prophet to make predictions, whereas in these enlightened days it would appear that even the best historical prophets of antiquity were in reality but good scientists themselves. In other words, these worthy individuals had mastered the science of prediction themselves and by putting two and two together they often achieved remarkable results which, to the superstitious populace, seemed supernatural.

"Any good astronomer today can predict with exactitude the solar and lunar eclipses for the year 1935 down to a small fraction of a minute. The mean average temperature for the United States can now be calculated six months ahead, due to recent studies of solar activity.

"When it comes to predicting what radio will be in 1935, it is not necessary to make wild and improbable guesses, but by following certain laws and by building upon what has been accomplished for some years back, we can readily arrive at a result that will be fairly accurate."

"When the writer compiled his book on the radio telephone, in 1910, the first of its kind to be published anywhere, entitled, "The Wireless Telephone," he made certain statements therein, which he believed sound in view, of the then prevailing wireless art. The preface of this book is printed on this page. The writer was criticized quite a good deal, and called visionary and a dreamer by many at that time; the predictions, nevertheless, not only came true, but proved far too tame, and not visionary enough to compete with the events that actually took place later on.

"So when the writer sets himself the task of predicting the advance in radio in the year 1935, he no doubt will be ridiculed again. Nevertheless, the statements that follow hereafter are probably entirely too conservative, and within 10 years, far more impossible things will have come about than those mentioned in this article.

"At the present time there are nearly 600 broadcast stations operating in this country, but we have only 150 channels in which to operate them. That means that some of the stations have to share time with others, to give them all a chance to get on the air, while some must be so far removed as not to interfere with the others.

"This is a very unsatisfactory state of affairs, and the writer has pointed out a number of times before that the only solution is to reduce the wave-length for all broadcast stations. It is the writer's firm belief that in 1935 all broadcast stations will operate below 50 meters, possibly below 10 meters. At such low wave-lengths the frequency increases so rapidly that 10,000 stations can be separated 20 and more kilocycles without interfering with each other. The word "wave-length" will not be used in 1935. Rather, stations will all be known to operate under so many kilocycles, or perhaps, myriacycles (kilo meaning 1,000—myria, 10,000). Operating at 25 meters or below, we could immediately accommodate, even today, thousands of extra broadcast stations, which would not interfere with each other in any way whatsoever. The reasons why it is not done at the present time are various.

Losses

"Suppose one of our popular broadcast stations were to suddenly drop to 25 meters? No broadcast receiver made today could receive at such a low wave-length, because modern receivers are made to operate on a wave-length between 200 and 600 meters, or thereabouts. The writer makes the prediction that during the next few years the popular broadcast receivers will be those which will be able to tune down lower and lower. Already broadcast stations are beginning to go down in the wave band. Of course, this movement is gradual, as it should be. Such changes take time, which is a good thing, because if the changes were made overnight, all present broadcast receiving sets would be obsolete. By building better receivers to operate at lower and lower wave-lengths, each year will show an improvement over the past one, and soon we shall have nothing but low wave receivers.

"At the same time the sensitivity of our sets will keep on increasing, as it has during the past 10 years. The greater amount of losses having been done away with, the efficiency having been increased, it stands to reason that the sensitivity of the set will be increased as well.

"While the writer believes in the present cycle of super power, he does not believe that it will prevail in 1935, for the following simple reasons:

"When Marconi first started sending across the Atlantic Ocean, it took 50 kilowatts or 67 horsepower to accomplish the feat. Most of this energy was wasted, and only a very small fraction arrived at the other side of the ocean. Here we had wireless receiving instruments with fearful losses and the small amount of energy that came in was barely audible. On the other hand, the amateurs of today are sending messages across the ocean regularly with an energy of 10 watts, which is exactly two-hundredths of one per cent. of the energy that it took Marconi to do the same thing 24 years ago. In other words, with the energy inherent in a few small batteries that can be easily put into a small suitcase, and which can be readily carried about, it is now possible to transmit radio intelligence across the Atlantic ocean. Again, if conditions are right, and the transmission and reception are efficient, there is no need for super power. In 1935 a 10-watt station will be heard around the entire world. Under such conditions, with ultra-sensitive apparatus, the super power system would create havoc with receiving apparatus within a distance of a few miles, and for that reason it probably will not be used at that time.

Preface

The present little volume is intended for the experimenter doing research work in wireless telephony and the student who wishes to keep abreast with the youngest branch of the wireless art.

The author realizes that the future use of the wireless telephone will be confined to the low power or battery system, as the present instruments, necessitating 220 and 550 volts for their successful operation, are not desirable nor practical enough for every day use.

The wireless telephone of the future must be as flexible as the wire telephone of to-day.

Every farmer will be able to operate his wireless telephone, when the sending and receiving instruments will be housed in a box a foot square, without depending on the lighting current for its operation.

The author predicts that in less than 10 years this stage will have been reached as it is bound to come sooner or later.

Quite a little new matter will be found in these pages and while some old matter has necessarily appeared for the sake of completeness of the book, the author trusts that the necessity of reviewing such matter will be apparent.

The author shall feel happy if this little volume will be the cause to advance the new art if ever so little, and he will be pleased to bear honest criticism and suggestions as to the contents of the book.

H. GERNSBACK.

New York,
February, 1910.

Fig. 54. A prediction made in 1910 by Mr. Gernsback in the original book, "The Wireless Telephone," which was the first of its kind published anywhere. The predictions shown in this book have already come true.

Television

"In 1935 we shall have radio television. It will be possible to see, as well as to hear, by radio. An explorer will take along with him a portable radio station and he will be able to give a lecture right on the spot in the jungle in darkest Africa or up in the unexplored regions—if such there be at that time—of the Amazon. He will explain everything he sees, and his projector will also be turned in every direction so that the listeners 10,000 or 12,000 miles away will be able to see at the same time. This television apparatus, by the way, is almost within our grasp now, thanks to the wonderful work done by C. Francis Jenkins, of Washington, D. C., and Edouard Belin, of Paris, France. The actual transmission over short distances has already been accomplished, and it remains only to put on the finishing touches.

Tubes

"What tubes shall we use in 1935? The development of the vacuum tube since 1906 has been slow but steady. Since DeForest invented the Audion, much improvement has been made. We are still using the same tube with a number of refinements. At the present time all tubes are run by batteries, or, if operated from the 110-volt house-lighting current, an intermediate circuit is used to step down the current to the right voltage. Within the next few years we shall have a 110-volt tube, which will operate directly from the electric lighting mains, without any resistances whatever. This will be a great step forward, but to the writer's mind this is not the final solution. Engineers are working towards a further goal, and that is a cold electronic tube; in other words, namely, no more heated filaments and no more "A" batteries. It is already possible to make an electrolytic "tube" such as was invented in Germany recently, where a colloidal liquid was used, and there is, of course, no heat in this. The electronic action is between plates and grids.

"A 'cold' tube will probably be used by 1935, this tube containing certain gases which may become luminous under the action of the current. These tubes will probably be used on either batteries or 110-volt current, but there will be no heating current, and such tubes, therefore, will be most economical. Even if five or six tubes should be used, the consumption of current would be so small that it would not even be registered on the house current meter.

Controls

"The control of the radio receiving outfit of 1935 will be simplicity itself. We are getting away from too many controls, knobs and other handles, which long before 1935 will be obsolete. It was the writer, by the way, who, in an editorial in the February, 1923, issue of *Radio News*, was the first to advocate single control sets. It will have been noted that a few of these made themselves noticeable late in 1924, while 1925 will surely witness the advent of a great many single control sets, which seem to gain greater and greater favor with the public. The outfit shown on our cover illustration, as will be noted, has a single control, with a remote control added. At the present time it is necessary to jump up whenever you wish to tune in another station or whenever an adjustment has to be made. This ties down the listener to the set, which is not always desirable. The writer shows the remedy for this by having a pear-shaped control, as shown. The lady on the cover, by pressing a button, closes a circuit which automatically rotates the tuning controls very slowly or swiftly, depending upon the amount of pressure on the button. The pointer on the dial revolves very slowly in the manner of a vernier until the station desired comes in loud and clear, at which the control is stopped. American stations will be found at the outer circumference, while foreign and trans-Atlantic stations are just below, in the red inner circle. By touching the second button on the pear-shaped control, the operator can, at will, bring in either foreign stations, or the stations of her own country. The single control will operate both the sounds from the station to be received and the television elements, both working in unison and automatically."

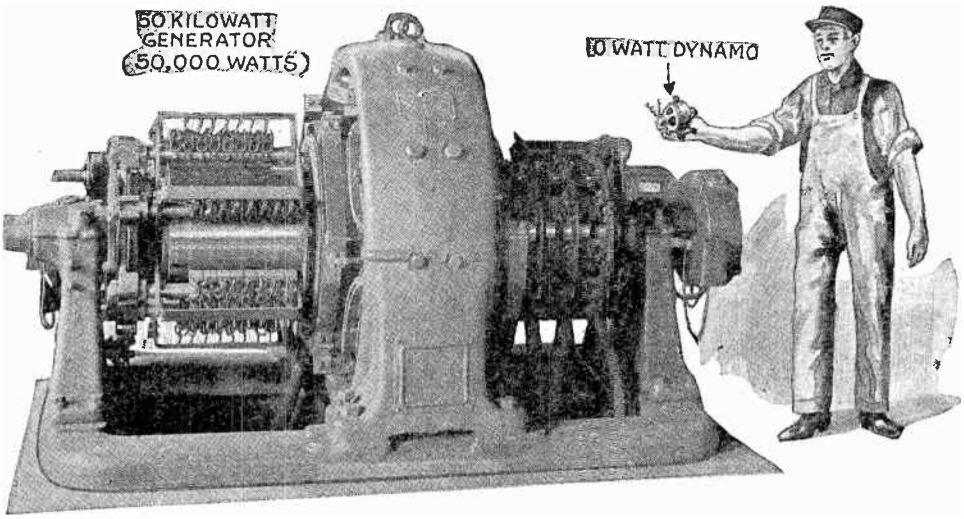


Fig. 55. When Marconi, 24 years ago, sent his first message across the ocean, it required 50,000 watts. The radio amateur today accomplishes the same results in a much better way by using 10 watts only; in other words, the merest fraction of the power necessary to accomplish the same thing 24 years ago. The chances are that in 1935 no broadcast station will require more than 10 watts in order to supply entertainment to listeners within a radius of several hundred miles.

The Jenkins-Moore Machine,

The last week in June, 1925, seven men stood in a laboratory in Washington, D. C., watching the arms of a miniature windmill revolving on a small screen of white blotting paper. The real wind-mill was five miles away in Anacostia. The picture on the laboratory screen was being transmitted by radio through the intervening space.

It was the first time in history that real television had been demonstrated or motion pictures had been transmitted by radio and an announcement of the demonstration was carried by *Radio News* for September, 1925, in an article by W. B. Arvin.

The men present at the demonstration were Mr. D. MacFarlan Moore, inventor of the lamp upon which the receiver depends; Mr. C. Francis Jenkins, inventor of the prismatic disc used in the transmitter; representatives of the Navy Department; Mr. Burgess, Director of the United States Bureau of Standards, and Judge Taylor, advocate of the Department of Commerce, who presides over radio under Secretary Hoover.

After the demonstration, everyone was unanimous in the opinion that this long-sought-for goal is at last actually in sight. In a more or less perfect form it will be a common thing within a year. The main difficulties in the problem have been successfully worked out.

No few pages have been written on this subject. Indeed, it is a barren month which does not find the radio press carrying some sort of scheme for the transmission of pictures by radio. But the point with most of them is that they are usually very plausible on paper but hold little promise of practicability when reduced to practice. The present scheme is practical. It works. This is the real point.

Probably the most outstanding characteristic about the whole scheme is its simplicity. Great inventions are usually simple, however. The success of their makers is primarily a matter of removing the complexities. With the Jenkins and Moore machine, simplicity is noticeable from the first.

As to the technical description, it can be made plain enough for the man in the street to understand.

The first of the two prerequisites of any picture transmitting apparatus is a photo-electric cell which will take the blacks and whites of the photograph or picture to be transmitted and turn them into electric current in direct proportion to their shading. The whites must transmit a heavy current when it is focussed on the cell, while the intermediate grays and the blacks must transmit little or no current in accordance with their approach to dead black.

With electric energy in direct proportion to the shading of the picture, the transmission of this energy to a distant point is a comparatively simple matter. We may use radio or fall back upon the land-line.

Then the second point of importance is a lighting device at the receiver which will take the currents after they have been amplified, and turn them again into light and shadow in exact step with the transmitter and in exact synchronism with the shade changes in the picture at the transmitter.

Practically, these two problems have been solved very well. The light at the receiver is one developed by Mr. Moore. It depends upon the glow about the negative pole of a lamp in an inert gas, such as neon. The characteristics of this little tube are such as to make it excellent for television—or telerama, as Mr. Moore chooses to call it.

Tests in the laboratory have shown that the lamp may be lighted or extinguished at the rate of more than a hundred thousand times a second. The superiority of the lamp in this direction may be appreciated when one calls to mind that with the ordinary hot filament type of light, more than one-tenth of a second is often required for the hot filament to radiate sufficiently for the glow to cease. Its second point of superiority is its ability to follow exactly in illumination the current fed to it.

In one stroke, this little lamp, which is shown in an illustration, eliminates two very complicated and bulky pieces of apparatus which have heretofore been in-

Fig. 56. D. MacFarlan Moore, inventor of the lamp for the Jenkins-Moore machine.

corporated in television receivers. Previously, in order to get comparative light and dark, it has been necessary to install and use some sort of magnetic shutter to govern the amount of light passed to the screen. The Moore lamp remains in exact step and does away with the quantitative shutter.

At the transmitter, the photo-electric cell which turns the light and darkness of the photo or scene into electrical energy is a commercial product. It seems that there is a great deal of misinformation afloat concerning the effectiveness of present-day photo-electric cells. Two large manufacturers have in the open market at the present time two designs of these instruments which will fulfill almost any conditions which might be imposed upon them. One of these cells is employed in the Moore-Jenkins apparatus.

With a capable method of converting the light into electric energy and back again into light, the only other important consideration for the operation of the machine, is that some method be employed for breaking the picture up into small signals. This simply means that the picture must be transmitted in dots, or that it must be broken up in some fashion so that a large number of impulses are employed to transmit the picture. In the last analysis, it simply amounts to telegraphing at high speed.

This breaking-up process in the Moore-Jenkins machine is accomplished so simply that it is almost absurd. With the aid of the prismatic disc spoken of before and a second ring containing a number of lenses, the process is done with the least possible complication and with the greatest clarity and ease. The lenses—there are forty-eight of them—are focussed so that they draw a fine line across the face of the picture. Each of them would follow the same path were it not for the prismatic disc. The forty-eight of them cover a picture about four inches long. That is, each one covers approximately one-twelfth of an inch of the picture. The prismatic disc moves these line struck out by the lenses from the top to the bottom of the picture, giving the complete break-up process.

Thus we have the breaking of the picture into its component parts. The superiority of the present machine lies mostly in this process, which is made possible by the Moore light. The picture, instead of being broken up into dots, as has been done before, is broken into *lines*. Each of the lenses sweep out a line across the photograph. As was explained, each of the lines is just beneath the previous one. The Moore lamp makes this possible by its characteristic, as explained above.

A more detailed description of this little instrument might not be amiss. It uses the conductivity of the gas and the heating of the atoms by the passage of current. When a difference of potential is established across the two terminals—the outside sheath is the negative while the inside one is the positive—the gas becomes luminescent, giving off light. Immediately the current is cut off, the light stops. "Immediately" is used advisedly.

The construction of the light is such that the illumination is all from the point in the center of the center electrode. This allows perfect focussing and the better use of the lenses.

Then there has always before been the question of keeping the transmitter and the receiver in synchronism. This problem has been solved with a degree of simplicity in keeping with the remainder of the apparatus. By employing synchronous motors to revolve the discs and lenses at the two stations, and using a hand adjustment to

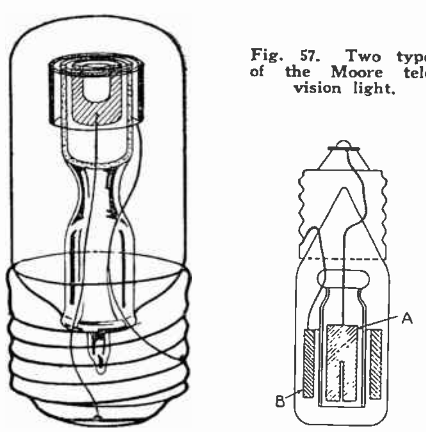


Fig. 57. Two types of the Moore television light.

set the machines after they are started, the problem becomes simple. The synchronous motors *must* run in step, and the adjustment is so simple that a child might easily handle it. From the large manufacturers of alternating current generators comes the word that in all their large installations they can guarantee that the difference in frequency between any two plants is less than one-half of one per cent. This guarantees the perfect operation of the machine in many localities where alternating current is available.

The actual transmission of the impulses from the transmitter to the receiver is a very simple problem. When it is to be by radio, the impulses from the photo-electric cell are amplified, just as they come from it, led to a radio transmitter similar to that used in a broadcast station or by amateurs, where the picture current modulates the carrier wave just as the voice of the artist usually does. At the receiving station it is picked up and detected in the usual manner, and sent to the Moore light after amplification. On account of the great simplicity in the remainder of the apparatus, only the light current is transmitted through space.

One of the most important points in connection with the use of the set is that it may at the same time be used for the transmission of voice. Just this was done in the demonstration in Washington. In Bellevue, the operator would change the position of the electric fan which was used as the motive power for the toy wind-mill, and while doing it speak into the microphone of the transmitter, telling the listeners at the laboratory in Washington that he was making the change. The voice would be heard from the loud speaker and immediately a change of the speed of the silhouette on the screen would be noted.

As to the origin and design of the machine, a few details might be interesting. Mr. Moore, as far back as 1899, had been granted patents covering certain elementary principles of television design. Since that time, he has been constantly thinking about the solution of the problem. Mr. Jenkins' connection with this line of research is of long standing. It was he who deduced the idea of the prismatic ring. One of the peculiar things is that the lens disc used in the present design is incorporated in one of the old Moore patents. Of course, the use of it is no longer protected because the time limit on the patent has expired.

One often wonders whether synchronism will be required in future devices and also whether that synchronism will not be accomplished by means of the light beam itself when translated into electric current, the same as the telephone receiver responds to voice currents. But that is just another thought.

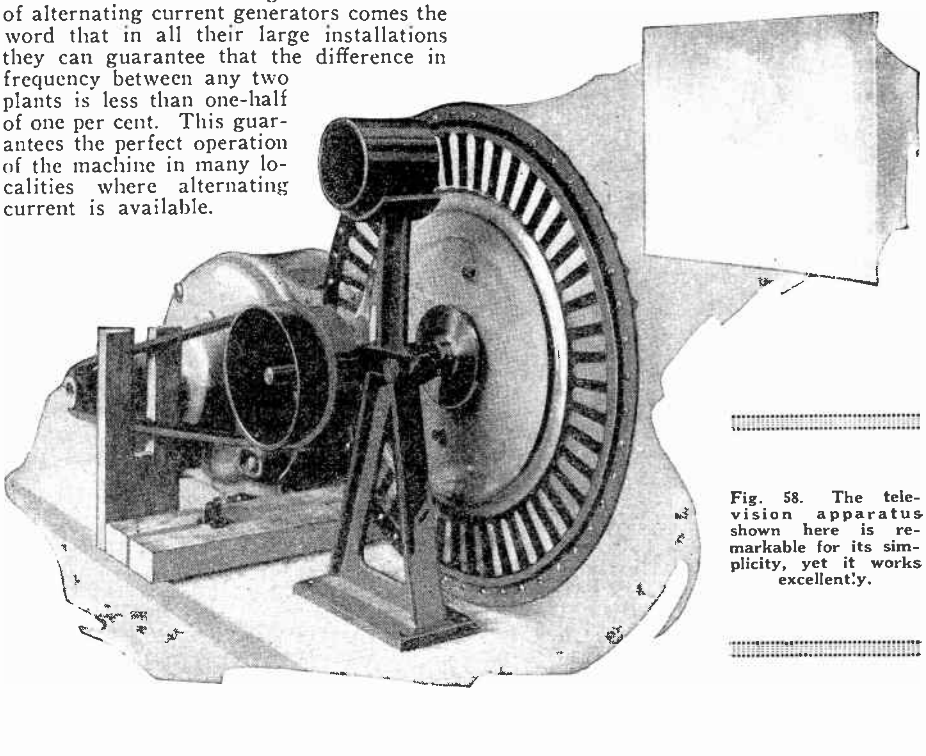


Fig. 58. The television apparatus shown here is remarkable for its simplicity, yet it works excellently.

Simplified Radio Television

Here is a new system which employs a colloidal photo-electric cell. It will be observed that there is a lens disk as well as a serrated disk, rotating at different speeds in front of the photo-electric or colloidal cell. The impulses of the cell are then transmitted by a radio apparatus and picked up at the receiving end, amplified and made to operate a lamp which varies its brilliancy. The reconstructed image at the receiving end, although not perfect, permits of hopeful improvements. The original article appeared in Science and Invention Magazine for June 1925

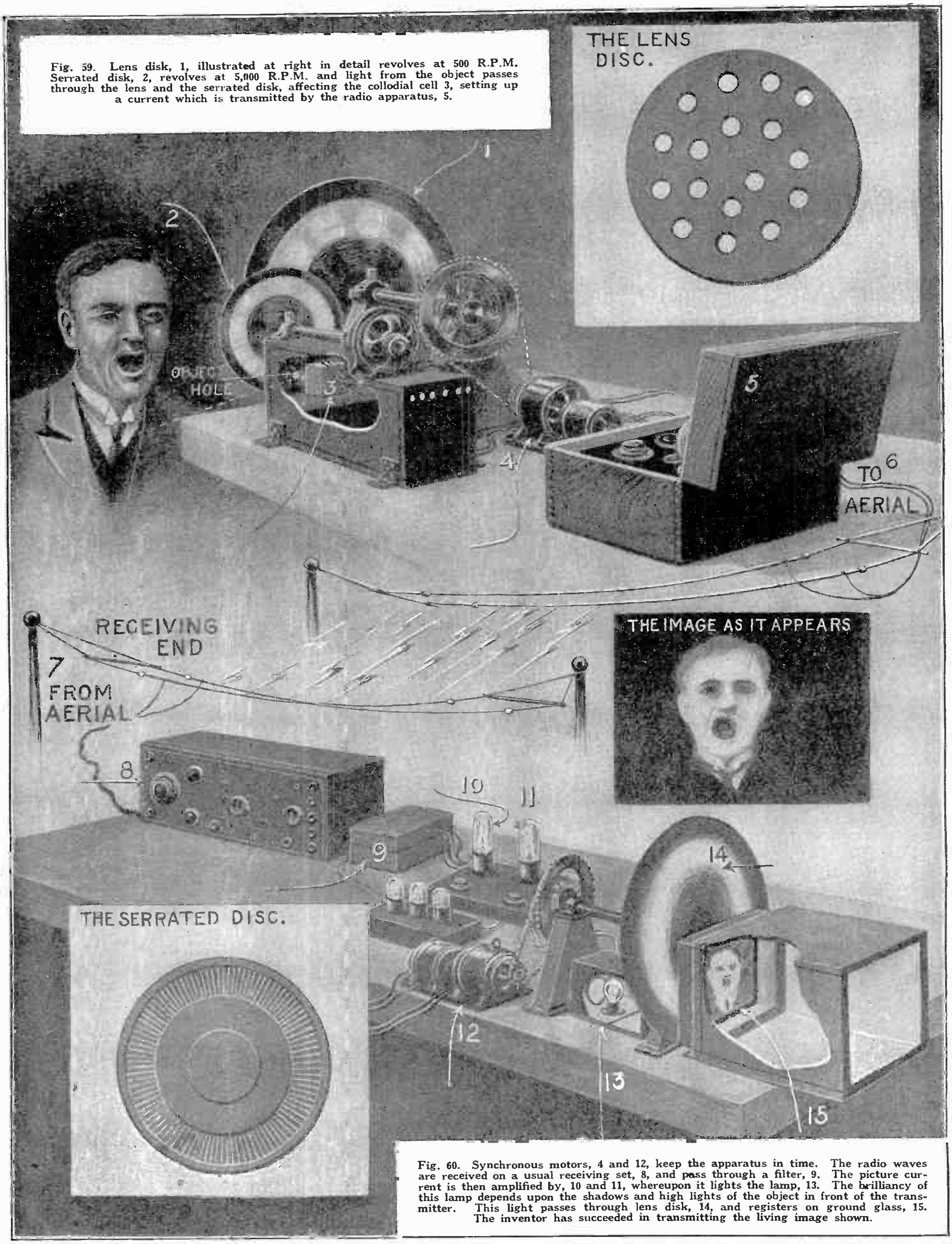


Fig. 59. Lens disk, 1, illustrated at right in detail revolves at 500 R.P.M. Serrated disk, 2, revolves at 5,000 R.P.M. and light from the object passes through the lens and the serrated disk, affecting the collodial cell 3, setting up a current which is transmitted by the radio apparatus, 5.

Fig. 60. Synchronous motors, 4 and 12, keep the apparatus in time. The radio waves are received on a usual receiving set, 8, and pass through a filter, 9. The picture current is then amplified by, 10 and 11, whereupon it lights the lamp, 13. The brilliancy of this lamp depends upon the shadows and high lights of the object in front of the transmitter. This light passes through lens disk, 14, and registers on ground glass, 15. The inventor has succeeded in transmitting the living image shown.

In the May, 1926, issue of *Radio News*, the following Editorial by the Editor-in-chief of that periodical, appeared. The front cover illustration of that issue showed a lad proposing to his loved one. Nothing unusual in this last remark, but in this case, the television apparatus comes into its own. A picture of the lad's loved one is reflected in the television screen. The Editorial follows:

A Television Proposal?

"I am frequently asked this question: "What, in your opinion, will be the next great development in Radio?" And to this question I always answer that, in my opinion, the next most logical step in Radio will be the establishment of "Television," or the power to see objects at any distance, through the same medium by which we are now enabled to hear sounds by radio from all over the world.

"Radio receiving sets have been developed to such a high degree that we need not expect any revolutionary improvements to be made in them for some years to come. The radio receiver is now at the stage of development such as the automobile reached ten years ago. The improvements made since then in the automobile have been only in the refinement of its various parts; and it will prove exactly so with radio.

"So, when I speak of television, I do not predict a novel type of radio set *per se*, but rather the creation of a device which can be attached to your radio set. It will be similar, in its relation to the present radio set, to the loud speaker, which can be connected to your set, regardless of whether the latter is of the vintage of 1923, or the latest 1927 model.

"This may seem to be a rash, offhand statement, but a moment's consideration will show you that it is not. For instance, you can listen to a full orchestra with your radio set and (providing you have good transformers and your loud speaker will take both the upper and the lower ranges) you will find no trouble in distinguishing the notes of the bass drum from those of the piccolo, even though both are playing at the same time. In other words, you hear simultaneously a number of different instruments without their interfering with each other.

"Through the future application of television, it is quite logical that while a station is broadcasting a song, you will be able to see the face of the singer at the same time, through a transmission on the same wave to which you are tuned in, for the following simple reason.

"The range of acoustical frequencies is really very narrow, and does not take in a wide band; the human ear responds to no vibrations above a frequency of 23,000 per second. That is the reason why the so-called radio "carrier" is inaudible. To the non-technical reader it may be explained that the "carrier" is the fundamental wave emitted by a broadcast station, which is on the air at all times when the station is transmitting. When no one is speaking or singing at the broadcast studio, you hear nothing but a faint rushing sound in your receiving instrument. The vibrations of this carrier run into millions per second, and that is why we cannot hear them directly.

"If, however, television is perfected (as it almost surely will be during the next two years, or perhaps sooner) it will be possible to impress the television impulses upon this same "carrier" which brings the sound impulses to your set. The television impulses, being of a frequency too high to be audible, will not interfere with your loud speaker; and the television picture for the same reason, will not be mixed up with the speech, any more than a violin or a piano, both of which you can readily distinguish with your ear. This is an inadequate comparison, because the separation between the acoustical band or audio frequencies and the radio frequency band is enormously wider than that between any two audible notes of music; and it will therefore be practically impossible for the "sight" waves and sound waves to interfere with each other.

"I have pointed this out to bring home the point that, when television is finally brought about, it is quite probable that today's radio sets will be adapted to this new purpose; and that it will be possible to connect a television attachment right to your present set and thereby see what is going on all over the country while you are enjoying the program. Not only will it be possible to see the entertainers at the broadcast station to which you tune in, but everything that is broadcast for sound only, today, will be broadcast by "remote control" for television as well.

"Radio television, it must be said, is nearer at hand than most of us realize. The inventors of the entire world are racing frantically for the goal, because they realize that in television they will have created a great new emancipator, much greater than the telephone or radio communication itself.

"In this country C. Francis Jenkins has been in the foreground in television experiments; and he has achieved success in making it possible to transmit and receive the outlines of moving objects by radio at the present time. In England, it is reported, John L. Baird, who has been on the same track, has accomplished a great deal; in France, Professor Edouard Belin has also produced results, and similar work has been done in many other countries. Television is now "in the air," and I shall be very much surprised if this great new art does not step out of the laboratory into every-day use, some time in the next two years, or less.

"Back in 1915, and again in 1918, I wrote a series of articles on television which were the first, I believe, published in the technical press. At that time we had only the selenium cell as a "photo-electric" or light-sensitive substance; but it is sluggish and does not follow changes of light with sufficient quickness. It has been superseded recently by some very excellent light-sensitive cells, which react to changes in less than one ten-thousandth of a second; and this improvement makes television an assured possibility today.

"We should not be surprised, also, when the final apparatus is evolved, to note with what simple instruments television can be accomplished. It is my belief that the successful device will be simpler and of fewer parts than our radio receivers are today, and it is quite possible that within the next ten years $50 will purchase a complete television attachment which will perform well.

"To be sure, for a long time to come, transmission will be only in black and white, giving an effect similar to that seen in motion pictures now. Color transmission will come later.

"At this point I desire to correct an erroneous idea about television, which is much in vogue now. Many people think of television as "radio motion pictures." Of course there will be no motion picture equipment of any kind in the radio television apparatus. Television does not concern itself with such methods at all. *In reality you will see at a distance*, just as if you had a telescope through which you could observe anything going on in any part of the country.

"Television between broadcast stations and the broadcast public will become very popular. If the telephone companies wish, they can make simple attachments for the present-day telephone, so that you can see the person at the other end with whom you are conversing. A lot of people will throw up their hands in horror at this idea, because the idea of television added to the telephone will suggest a reduction of their privacy to the minimum enjoyed by a gold fish. This need not be feared, however, because a pushbutton in the telephone mounting will insure that the party calling cannot see you unless you wish it. This is a very simple detail.

"As to radio television between parties, as depicted on the front cover of May, 1926, *Radio News*, I must admit that this lies much further in the future—perhaps twenty-five years or more, for there are not enough wave-bands available to make it possible for thousands to talk to each other at the same time. On the other hand, the same illustration could readily represent two radio amateurs, who can converse by radio telephone even today; and if, in the next two years, they are enabled to place television attachments on their radio sets, there might easily result such a situation as shown on the cover. But the individual application of television, to every one's personal convenience, will not be practical for many more years."

Edouard Belin's New Advances

Then along in the July, 1926, issue of *Radio News* we find an article by Lucien Fournier devoted to an explanation of more recent experiments made by Edouard Belin for the purpose of determining the influence upon the "persistence of vision," of the length of time during which light is emitted. These experiments present a new point of departure in the attempt to solve the problem of practical television—which must be *radio* vision, because the lag caused by electrical conductors prevents the transmission by wire to great distances of modulated currents which are produced by extremely rapid variation in the luminous intensity of a point.

The art of invention may be compared to that of a prospector for gold, who drives his pickaxe everywhere, until he uncovers the vein of gold of whose existence he has been certain. This is the present procedure in the endeavor to establish television. Our readers have doubtless heard how Edouard Belin succeeded, after patient and laborious research, in transmitting between two radio-telegraph stations, first the changes in a luminous point, and then a circle which was complete or broken in accordance with the variations at the transmitting station. This was the first positive result obtained, and was a direct accomplishment of radio vision.

In viewing an ordinary moving picture, the impression on the retina lasts less than one sixteenth of a second. But, when we transmit the image of an entire scene, the whole of it cannot be covered at once by a ray of light. The scene or picture must be separated into distinct points; as if it were composed of a fine screen, over which a sharp brush would pass, covering one vertical line after another, parallel and extremely close, until every point has been covered.

(We repeat, an examination of the illustrations, or "halftones," used to reproduce photographs in this and other publications, will illustrate this idea. They are composed of points of varying size obtained by reproducing the photograph through a very fine screen. The effect of light or shade is obtained by the use of very small or very large dots in the various areas of the illustration. It will be seen that by transmitting impulses in any regular order, each corresponding in its magnitude to that of one of the points between the white lines of the screen, it is possible to reproduce any picture in all its details at any distance. This is the fundamental principle of the transmission of pictures, first by land telegraphy and then by radio, which has so lately been placed on a regular commercial basis.)

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 result? So long as the first mirror B remains stationary, the image which it projects upon the screen H is motionless; but slightly different angle, comes into line, 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.

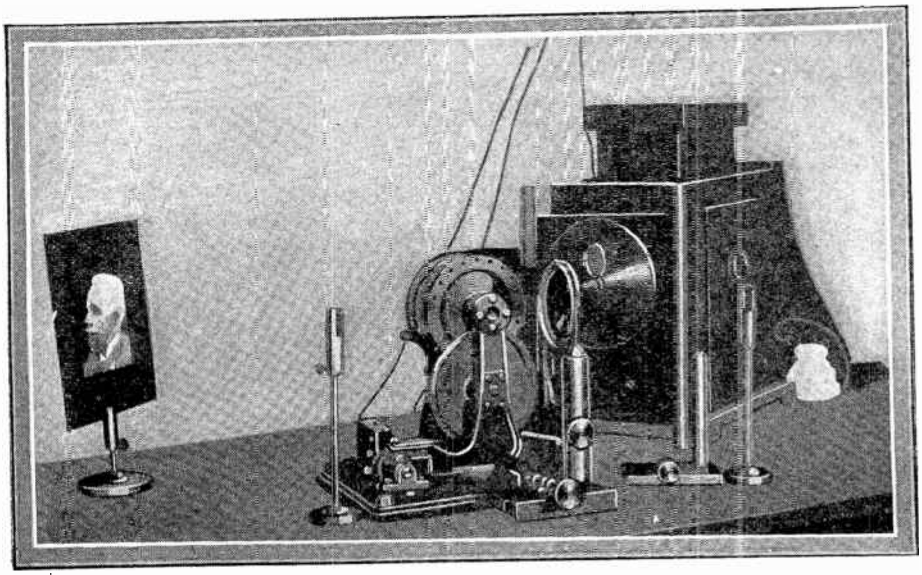


Fig. 61. This apparatus is diagrammed below; the projecting lantern at the right; the drum of mirrors, center; and the adjusting stands for diaphragm and fixed mirrors in front. At the left a continuous image appears on the screen, although only 1/25,000 of it is actually projected at any instant.

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

The luminous ray of the television apparatus moves in a similar manner; but, instead of leaving ink upon the image at the receiving end, as does the apparatus used to reproduce pictures, it only sweeps over the screen in vertical lines, each almost touching the next, at such a tremendous speed that it must cover the whole field in one-tenth of a second, or less.

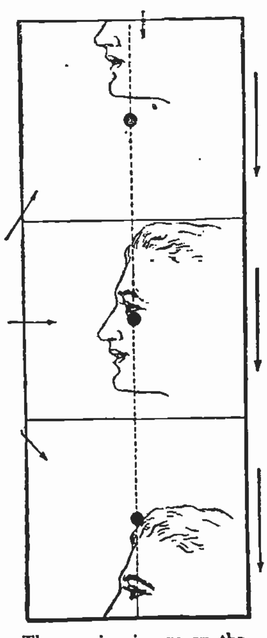
An image whose surface, is, for instance, 18x25 millimeters (about the size of a postage stamp) composed of points divided by five lines to the millimeter (1/125 of an inch apart, about the fineness of the photo-engraving illustrations used in *Radio News*) will contain 11,250 points. All this must be transmitted in one-tenth of a second to produce in the eye the effect of a continuous image. To transmit a complete scene, in detail, perhaps double the number of points will be required; each of which must be recorded in 1/225,000 of a second.

The effectiveness of so short an impression upon the retina might be doubted. It seems hard to believe that it would be perceptible by the optic nerve, and even more so that the effect should persist for a tenth of a second. The apparatus which we shall proceed to describe was especially devised with this end in view.

The Belin Apparatus of 1926

The diagram, Fig. 62, is a schematic view of the mechanism illustrated on these pages. 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



The moving image on the fixed diaphragm (C).

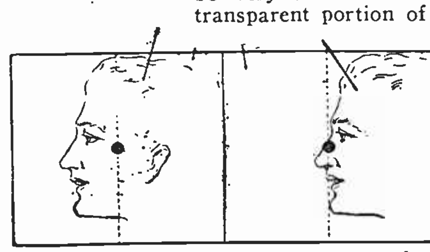
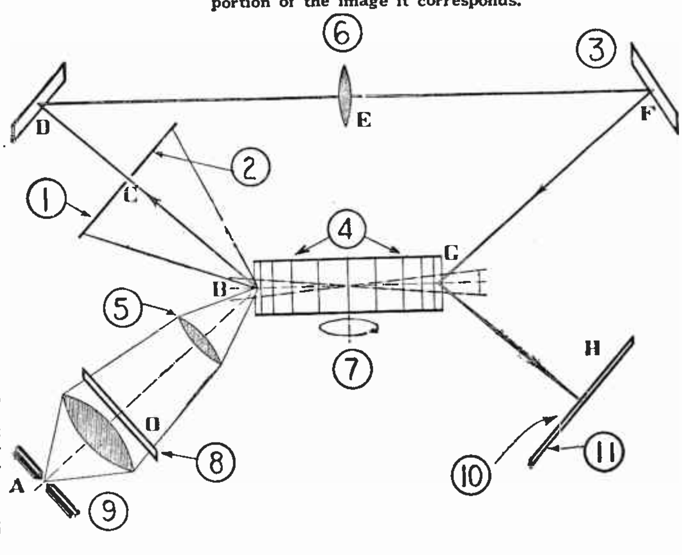


Fig. 63. This shows, in a similar manner, the effect on the image of the oscillation from side to side of the mirrors. It is swung from side to side on the perforated screen or diaphragm, until every part of it has been covered by the vertical lines traced by its movement over the central opening. These 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.

Fig. 64. 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 what portion of the image it corresponds.

Fig. 62. 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.



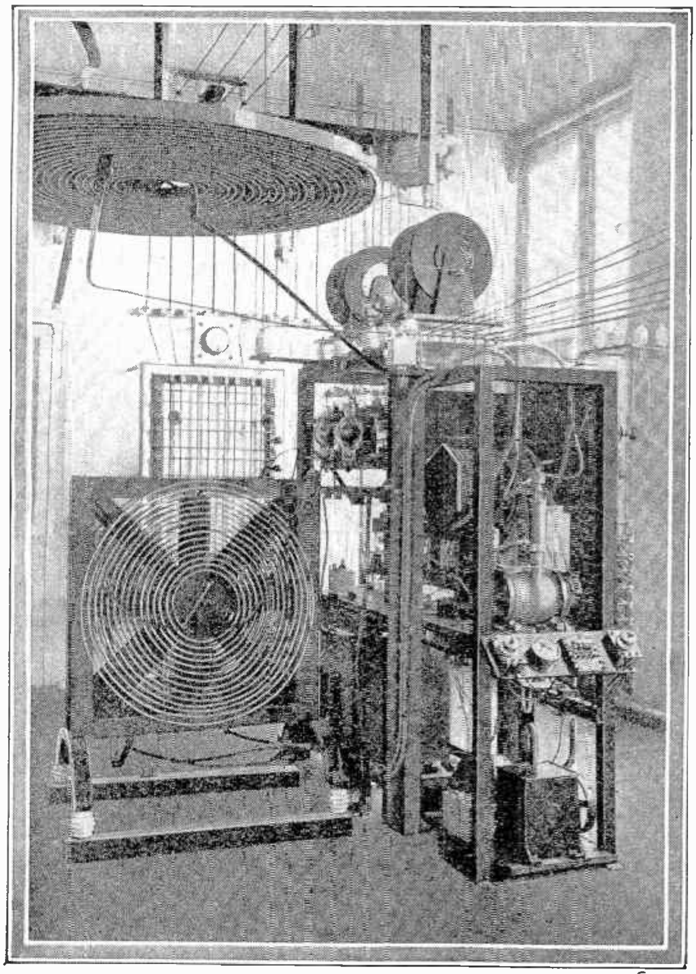


Fig. 65. The illustration at the left shows the interior of the T. S. F. "wireless transmission" station at Malmaison, near Paris, which has been utilized by Prof. Belin in television experiments. Overhead is the large antenna coil; and the grid coil is beneath, in a vertical position. Above the frame at the right are choke coils; and just below them the modulating tubes. The screen for the reproduction of the image is just above the grid coil. In the center of the frame at the right is a reel of rubber tubing, through which cold water flows to cool the "Holweck tube," shown in a vertical position, connected to a cylindrical "molecular" air pump just below. In the lower right is an oil-operated "forepump" to which the molecular pump is connected; and between this and the grid coil, a case containing the antenna condenser.

more obscure when it passes through a part representing a darker portion of the image.

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 closely 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. These 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 reflection 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.

To transmit the image by radio waves, we have only to replace the mirror D by a photo-electric tube, such as have already been described to our readers. 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

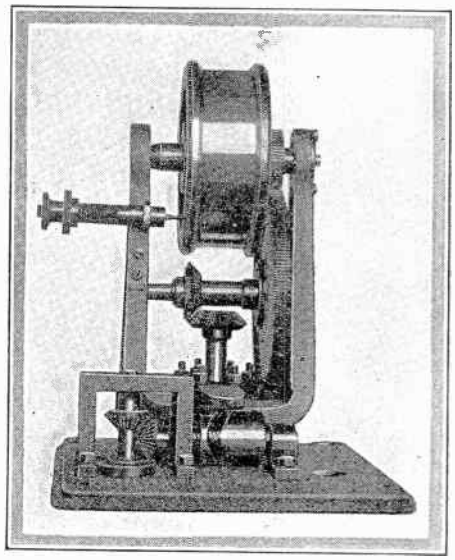


Fig. 66. This is a front view of the cylinder or drum of mirrors. It is turned by an electric motor, and at the same time swung from side to side by the gear at its base.

be reproduced and projected in the same order upon a screen corresponding to H, producing the phenomena 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,

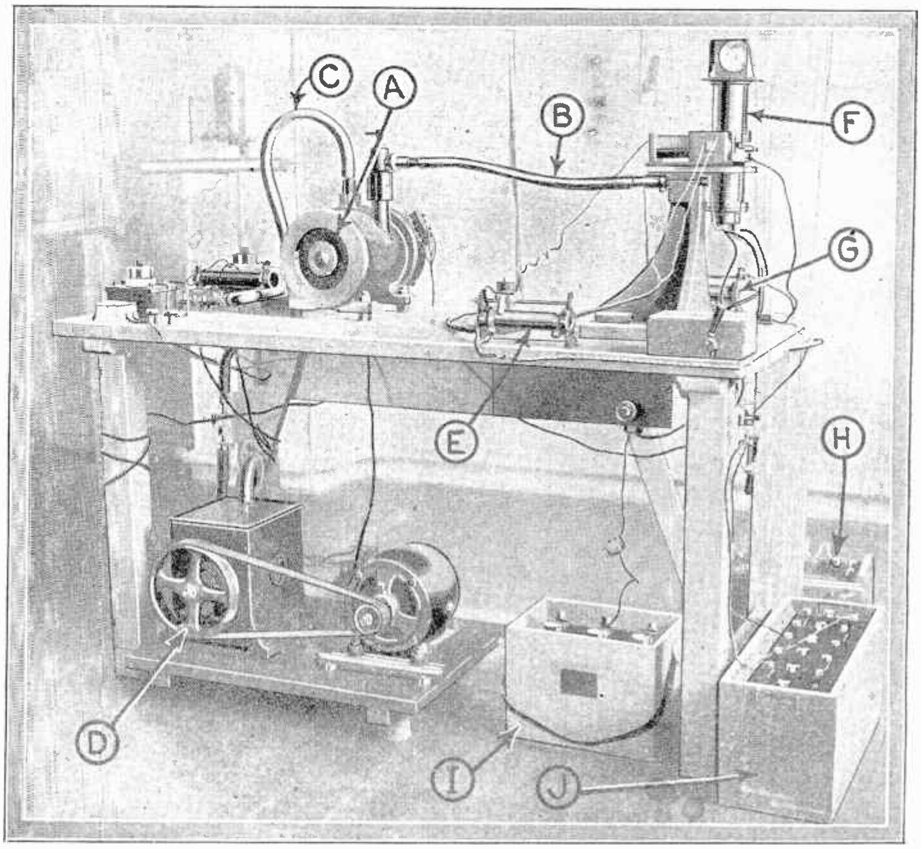


Fig. 67. The receiving apparatus: A is the Holweck molecular pump; B, tube connecting with oscillograph; C, tube connecting pumps; D, preparatory or "fore" pump; E and G, rheostats; F, oscillograph; H, I and J, batteries for concentrating coil, filament and low-frequency coil.

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.

Developments by Messrs. Belin and Holweck

This new apparatus is based on the modulation of a light beam exploring a photographic plate. It was explained by L. Fournier in the December, 1926, number of *Radio News*.

The system of transmission is represented essentially by two little oscillating mirrors (see Fig. 68), one placed above the other. The lower mirror, of very narrow width, oscillates vertically at a frequency of 500 cycles per second; the upper mirror, somewhat larger, oscillates horizontally at about 10 oscillations per second. The lower mirror, receiving the luminous beam, traverses one or another of these tints; it will therefore experience, as it leaves the plate, a modulation such that its intensity will change in value at every instant. As this light, varying as above, is projected on a photo-electric cell, the cell will pass a very feeble current, the intensity of which will depend on that of the light which reaches the cell. But so far, the actual experiments have not been made with the photographic plate. A plate was used without any half-tones, carrying only black and white portions.

The reader's attention is recalled to the fact that the photo-electric cell contains two electrodes, the cathode being composed of an interior layer of metallic potassium and the anode of a very light ring of nickel or platinum. The anode and cathode are connected in a circuit with a battery. When a ray of light reaches the cell, the circuit is instantly closed and the current passes. Naturally, the stronger the light, the more current passes. It is thus, by the action of this apparatus, that it is hoped to transfer light modulations into modulations of an electric current, which is connected finally to a vacuum tube amplifier before being sent to the receiving station. In practice, this amplified current will be

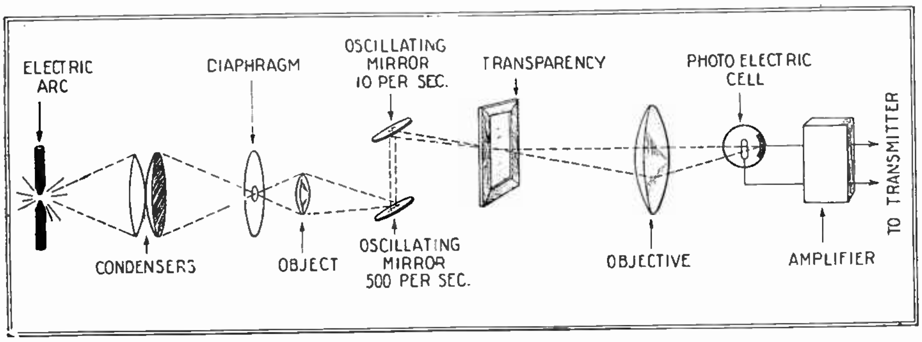


Fig. 68. After the light from the arc has been concentrated by the condenser lenses it is caused to pass in a wavy line over the transparency (See Fig. 69) and the variations of the transmitted light are registered on the cell.

impresses on it as reflected 500 oscillations per second. As this beam is also received by the upper mirror, which oscillates in a line perpendicular to that of the lower mirror, the projected beam will be resolved into two sets of different oscillations, each with its own frequency and its own direction.

Suppose now that this beam is received on a screen placed in front of it. Let us follow its course.

The oscillations of the 500-cycle mirror makes it traverse the screen uninterruptedly from right to left and left to right, but the beam at the same time answers to the oscillations of the 10-cycle mirror, which moves in a direction perpendicular to that of the first. It, therefore, is acted upon by two forces. The resultant is traced upon the screen as a luminous line of the form shown in Fig. 69; that is to say, the screen is swept over by the ray alternately from right to left and vice versa and then from above downwards and back again.

However, if we watch the screen, our eyes will see no sign of the oscillations, because the ray takes only one-tenth of a second to cover the entire surface. The persistence of vision does not permit us to see movements of such rapidity.

We have alluded to a screen to explain how the ray would traverse such a surface. In the actual apparatus this screen is replaced by a photographic plate, which the light traverses. This plate is composed of transparent and opaque sections and also has a whole scale of tints varying from intense black to absolute transparency. The pencil of light is then greatly affected in its intensity, according to whether it sent into the radio transmitting station and transmitted by radio to the receiver.

After what we have said, it is easy to understand that if a reproduction on a reduced scale is desired, such as an image of the moving picture film, about 1 x ¾ inches the points will be much closer together and more numerous per unit of surface than on a screen of 6 x 9 feet area. Now, coming back to the film, a point less than .001 of an inch will be enough to reproduce an image under good conditions. The analysis

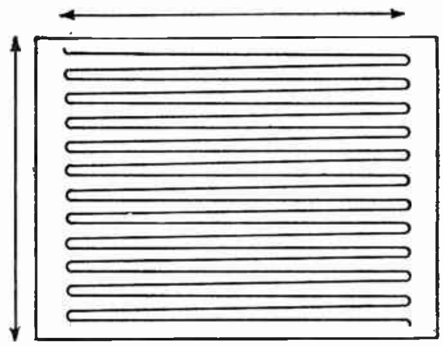


Fig. 69. Due to the oscillations of the two mirrors, the beam of light follows a zig-zag path across the screen as indicated above. It oscillates horizontally 500 times per second, and vertically 10 times per second.

of the image to be transmitted will come down, therefore, to the production of 10,800 points. As all the surface of this image is swept over in 1/10 of a second, each point of the plate has only 1/108,000 second to act.

The transparent parts of the photographic negative will pass enough light to enable the cell to carry out its functions, but the semi-opaque parts will require probably a light beam of the luminous intensity of an arc-light to properly affect the cell. However, if the photographic plate is larger, the dimensions of the pencil of light should be increased. Under these conditions, we may ask if the photo-electric cell, with increased light pencil, will respond sufficiently to the changes in light?

The Synchronizing Device

The movement of the oscillating mirrors gives us a curious mechanical problem to solve, for we must not forget that the transmission apparatus must be synchronized with the receiving apparatus. The oscillating mirrors are acted on by a little alternator, which sends current of a frequency of 500 cycles per second either over a wire or by radio-transmission to the receiving stations and which acts like a motor for keeping the mirrors in motion. It is necessary to send not only the current of 500 cycles, but also another one of 10 cycles that drives the upper mirror. In the experimental arrangement the upper mirror was connected to an ordinary microphone by a light metallic bar, whose end rested upon the microphonic membrane (see Fig. 70). At the end of each oscilla-

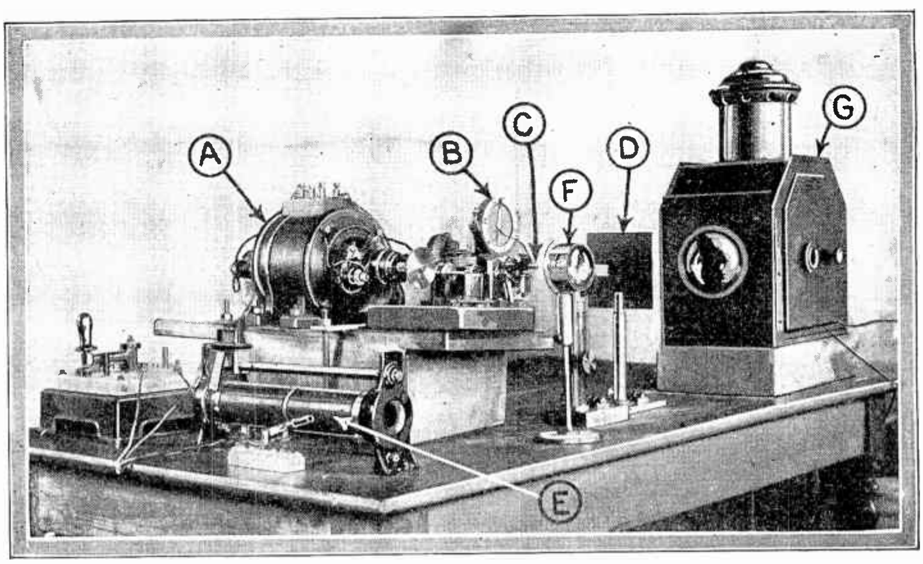


Fig. 70. The Belin transmitter: A is the 500-cycle alternator used as a motor for the moving mirrors; B, microphone of low-frequency mirror; C, "transparency" (photo film) support; D, diaphragm; E, alternator rheostat; F, objective lens; G, arc lamp.

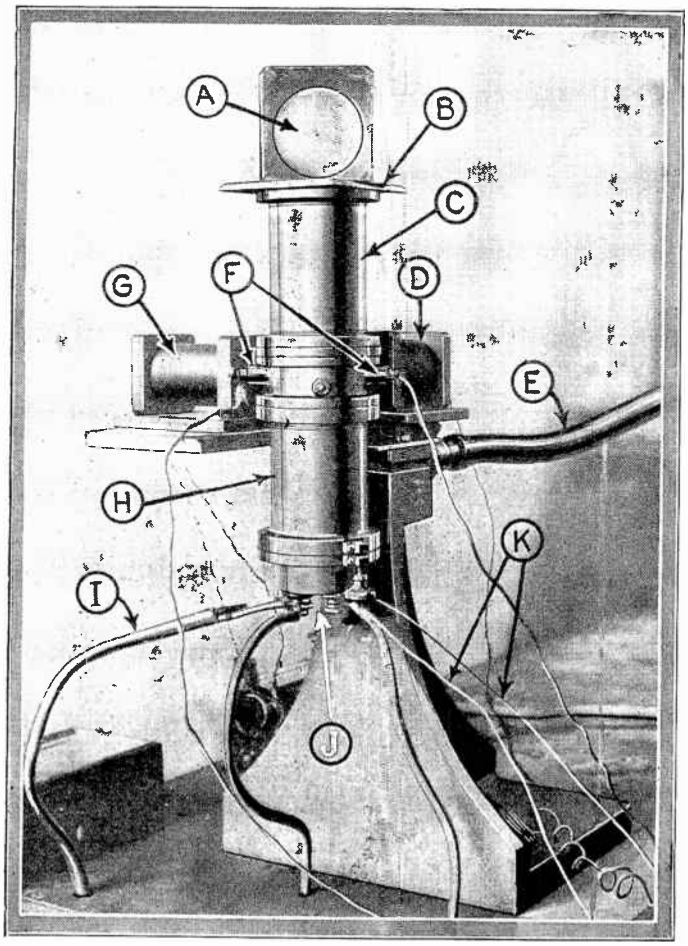


Fig. 72. The Holweck oscillograph: A is a prism on which the visible images form; B, fluorescent screen of calcium tungstate; C and H, oscillograph tube; D, low-speed electric motor; E, tube from molecular vacuum pump; F, terminals of the concentrating coil; G, high speed motor; I, p'ate connection, (1500 volts); J, filament connection; K, grid filament lead.

tion of the 10-cycle mirror, the rod, by its pressure on the membrane sent a current each .1 of a second, which was received by the receiving station; and in conjunction with the 500-cycle current, acted to synchronize the sending and receiving apparatus.

It is hoped to dispense ultimately with the microphone. It is not necessary to transmit two different currents at different frequencies; it is enough to transmit a current of 500 cycles to insure the synchronism of the two stations. This is because the movements of the two mirrors are mechanically conjugate, being actuated by the same motor. At the receiver a frequency-changing apparatus may be used for lowering the frequency from 500 cycles to 10 cycles, a part of the original current at 500 cycles, being utilized directly.

Holweck Cathode Oscillograph

Here comes in the art of Mr. Holweck, expressed in his cathode oscillograph. This is simply a modification of the three-electrode tube used in radio-telephony. Above the filament, Fig. 71, is placed the grid, a circular plate with a hole in its center, above which a disc of similar form acts as the plate, which is also pierced by a central hole with a little copper tube above it. The filament requires a potential of about two volts. The varying potential in the modulated circuit is applied between grid and filament. Finally, the plate is kept at a constant potential of 1,500 volts by a special battery.

The apparatus thus formed being in action, there is produced between filament and plate, a stream of electrons which is "canalized" in the vertical tube surrounded by a little coil. The action of this is to concentrate in a very fine ray the invisible shaft of electrons. Their bombardment is made visible by their reception on a fluorescent screen placed in the upper part of the oscillograph. We must add that the oscillograph tube is evacuated, by a Holweck molecular pump (Fig. 67).

The current, modulated at the transmitter, and picked up by the receiver reaches the filament and the grid of the oscillograph tube. This current will introduce a disturbance in the normal emission of electrons, a disturbance which corresponds exactly with the variations of the modulated current at the transmitter. The luminous point produced on the fluorescent screen of the oscillograph tube varies in intensity in accordance with the passage of the luminous pencil at the transmitting station, as it traverses light and dark portions of the photographic plate. This phenomenon is very apparent when the point is kept fixed upon the fluorescent screen. It gives a little blue speck of light, comparable to a star on a beautiful winter night.

But this only gives us a fixed point on the screen. This is far from the reproduction of the image! What are we going to do? Our readers know that an emission of electrons is very sensitive to the presence of a magnetic field. The presence of a small coil surrounding the tube of the oscillograph, which "canalizes" the electrons, shows its sensitiveness very clearly. When it is not excited the stream of electrons fills the little tube. When a current passes, the stream is contracted and the trace, which it produces on the screen, shrinks up until it is only a brilliant point.

Putting aside the question of television, we are here face to face with some very curious electrical phenomena. The stream of electrons, in fact, is displaced in any direction whatever, merely by bringing a bar magnet near the oscillograph; the luminous trace will be seen to describe a circle on the screen. Remove the magnet and the point returns to the center. This extreme sensitiveness has been utilized for making this point of light repeat the movements that the mirrors give to the pencil of light, at the transmitting station.

Two ordinary coils are placed near the oscillograph at an angle of 90°. Through one is passed the 500-cycle current and through the other the 10-cycle current. After what we have said it will be seen that each of the magnetic fields which they produce will have the effect of displacing the stream of electrons in exactly the same way that the luminous ray is displaced by the oscillating mirrors at the transmitter. As these movements of the receiving spot of light are performed under the direct control of transmitting apparatus (alternator and microphone), synchronism is secured in a rigorous degree and the reproduction of the picture at the transmitting station can be obtained on the screen of the oscillograph. The illustration, Fig. 72, shows that this screen, which is placed horizontally upon the oscillograph, has been adjusted there so that a prism reflecting the beam gives a slightly inclined image which is easier to observe.

The Television System of Dr. E. F. W. Alexanderson

Since the transmission of music and speech by radio has come into its own, many scientific experimenters have been looking for new fields to conquer, in this same realm of radio. Photographs have been transmitted across the Atlantic Ocean by radio in twenty minutes, and now that this is an accomplished fact, improvements on the method are being sought.

Dr. E. F. W. Alexanderson, one of the foremost radio engineers in the world, has been working for the past few months on the improvements mentioned above. 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," his theory of accomplishing which he outlines in the accompanying article. An ar-

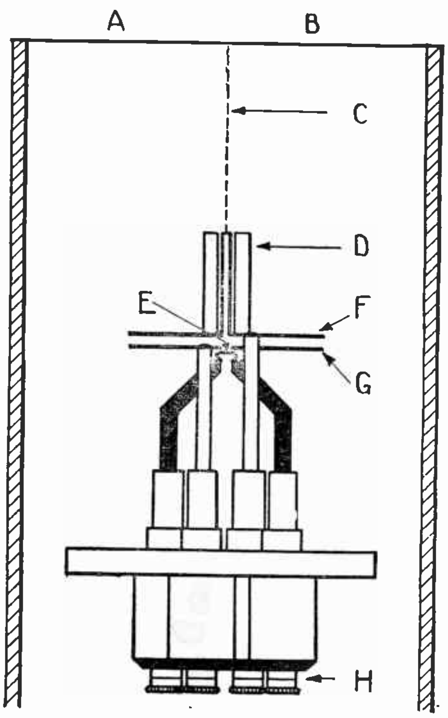


Fig. 71. The Holweck apparatus: A-B is the fluorescent screen on which the electron stream, C, traces a line of light; D is the concentrating coil; E, the filament; F, the plate; G, the grid; H, terminals for the supply circuit.

ticle on his system written by him appeared in the February, 1927, issue of *Radio News.* Dr. Alexanderson writes:

In the well known play by George Bernard Shaw, "Back to Methuselah," is described a scene which is supposed to take place in the year 2170. The head of the British Government holds conferences with his various cabinet ministers several hundred miles away. He has at his desk a switchboard and in the background of the room is a silver screen. When he selects the right key at the switchboard, a life-sized image of the person with whom he is speaking is flashed on the screen at the same time that he hears the voice. The fact that one of his ministers is a lady lends some dramatic color to the incident, but this is beside the point.

A passage of this sort from the pen of a great writer is significant. The new things that civilization brings in to our lives *are not created or invented by anybody in particular;* it seems to be predestined by a combination of circumstances that certain things are going to happen at certain times. Great writers and great statesmen seem to have the first presentiment of what is coming next. Then the inventors and engineers take hold of the same ideas and dress them up in practical form. It is now several years since Mr. Owen D. Young, at a banquet, expressed his hope that radio would soon give us visual means of communication. The idea seemed at the time absurd to many of the technical men present; but work was promptly started and we have at least gone so far that a commercial radio picture service is in operation across the Atlantic Ocean.

It takes at present twenty minutes to send one of these pictures, whereas the imagination of Bernard Shaw forecasts a *direct* vision of distant moving objects.

From moving-picture practice we know that the realization of this idea would require the transmission of a series of pictures at the rate of sixteen per second. It is a long way from twenty minutes to one-sixteenth of a second. It means that we must work almost twenty thousand times faster than we do now. However, we have tackled this problem; and I shall attempt to show what prospects we have of realizing practical television. In doing so we shall think of the scene described by Bernard Shaw as the ultimate goal.

Fig. 73. These three copies of the same photo were transmitted at different speeds. They were sent in two, four, and eight minutes, reading from left to right, as explained in the article.

Telephotography

The principle of picture transmission over wires or radio was worked out about fifty years ago, and all work done at the present time is based on the same principle. The work of fifty years ago, though described in many books and patents, fell into neglect; but the development of radio has renewed interest in the subject. We have also some new tools to work with, such as the vacuum-tube amplifier and the photo-electric cell. Radio photography has thus become an established fact. A practical realization of television, or the art of seeing moving objects by radio, involves some difficulties which have heretofore seemed almost insurmountable.

Fig. 74. At the right is shown the receiving mechanism of Dr. Alexanderson's apparatus. The cylinder, in which is enclosed the negative, is being removed from the motor attachment that rotates it.

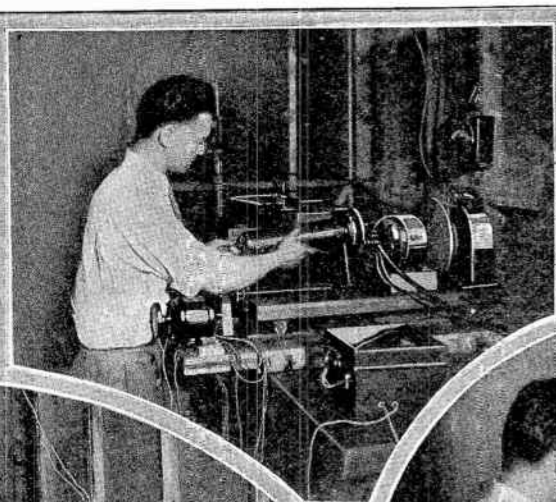


Fig. 75. Below is shown the transmitter. The revolving shutter for interrupting the light source is seen under the man's elbow. The impulses are amplified before they are transmitted.

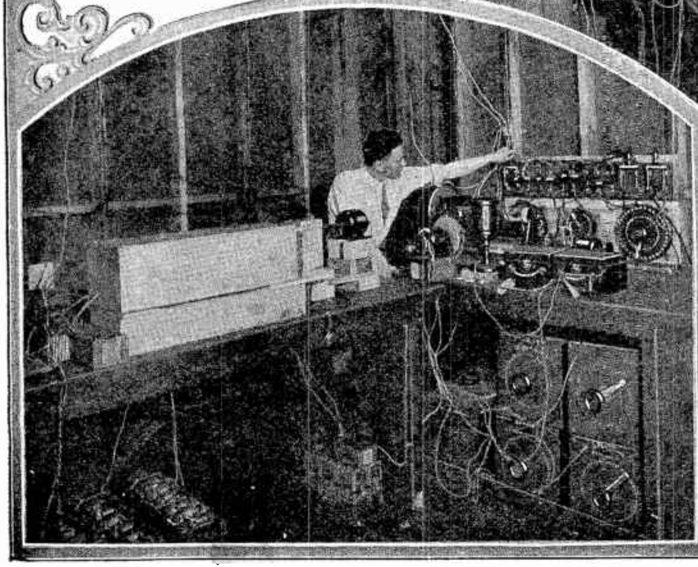


Fig. 76. Below is a closer view of Dr. Alexanderson's apparatus for transmitting photographs by radio. The photo to be sent is placed on the revolving cylinder, which is synchronized with the cylinder at the receiving end.

Photo by Courtesy of General Electric Company

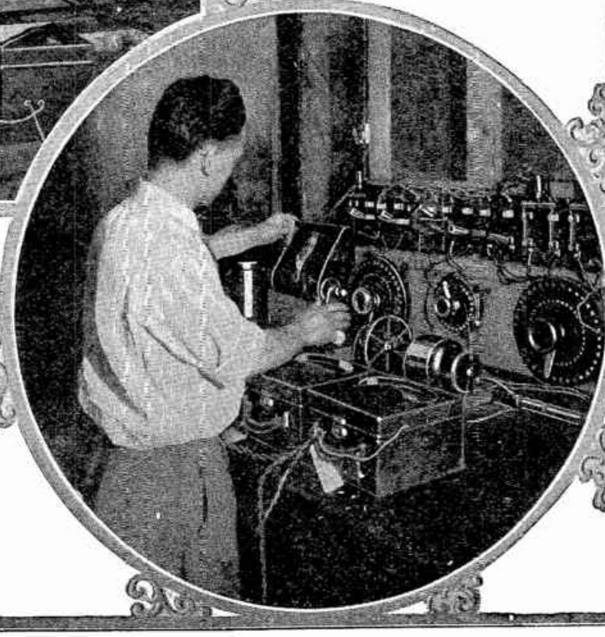


Fig. 77. This distorted picture was made from a newspaper reproduction of a steel engraving of "Washington's Family" by E. Savage. The distortion is due to the improper adjustment of the receiver apparatus. This picture may serve to give a visual idea of the audible distortion sometimes experienced by broadcast listeners.

However, before dealing with the problems of the future, I shall give a brief picture of the contemporary art of telephotography. So much has already been published on this subject that I need give only a few references. Since the interest in telephotography revived, the work has been taken up simultaneously in America, France, England, and Germany, and the names of a number of engineers, Korn, Belin, Jenkins, Ranger, Ives, Karolus, Petersen and Baird among others, have become familiar. I hesitate in giving these names, because there are surely some equally important ones that I have left out.

The accompanying illustrations show some telephotographs made in Schenectady. The originals were made at a rate of sixteen square inches per minute, and thus were produced in two minutes. They were made as a preliminary study of commercial transmission of pictures and facsimile messages over long distances. The recording instrument used in making these originals is a standard General Electric oscillograph, with some adaptations the availability of this highly developed instrument having made it possible for us to enjoy rapid progress in the development of a practical technique in telephotography. Our energies can now be devoted largely to the main problem, which is the adaptation of the radio art to this new use, and particularly to devise ways of dealing with our old enemies—static and fading—when we wish to transmit pictures over long distances.

Static and Fading

The radio art has, up to the present, developed two distinct methods of signalling: by modulation and by interruption. The first is usually associated with broadcasting and the second with telegraphy. Both of these methods of signalling may be adapted to radio photography, and each will have its distinct field. The effective range of a broadcast station is very much shorter than that of a telegraph station of the same power; but within this range it gives a service of excellent quality. The accompanying samples of pictures were made with a modulation-frequency of 3000 cycles, which can easily be transmitted by the ordinary broadcast stations. It is therefore possible that a picture service may be given by these stations, which will be of the same standard of quality as their musical entertainments.

Freedom from disturbances is insured by having a large number of stations interlinked by a wire system, so that a good selection of entertainment is available in all parts of the country. This method of dealing with static and fading may be characterized as "brute force"; but after all it is this mode of operation that has developed radio into the great industry that it is now. This whole broadcasting machinery is now available, should the public become interested in radio photography for entertainment or otherwise.

For long-distance communication we have, fortunately, another method of using the radio wave, which is much more sensitive and economical. The most striking illustrations of this are the feats of amateur operations in communicating with their friends on the other side of the earth with small home-made sets adjusted to short wave-lengths. So far this method of signalling has been limited to dots and dashes; but ahead of us are the possibilities of using this wonderful medium of communication to transmit pictures, facsimiles of letters or printed pages and moving picture films. These fascinating possibilities have induced so many investigators to work on this problem.

In our research work on the development of radio photography and television, we have looked upon the adaptation of the telegraphic method of communication to picture transmission as one of the essential problems. A system has been worked out for transmitting half-tone pictures in a way which takes advantage of the more efficient methods used in radiotelegraphy. The underlying principle which makes this possible is the use of a system of signalling in which the results are independent of the signal strength. Thus, if the signal is strong enough to be recorded at all, it gives the same kind of records at the maximum as at the minimum signal intensity. This makes the recording independent of fading. If, furthermore, the signals are stronger than the prevailing static, it is possible to eliminate the effects of static by introducing a *threshold value* of signal strength in the receiver, so that nothing is received unless the signal exceeds this value.

The Multi-shade Process

"Half-tone" effects are produced by dividing up the picture into five or more separate shades such as white, light gray, medium gray, dark gray and black. The transmitting and receiving machines analyze and reassemble these shades automatically. Various methods may be worked out for translating light intensities into radio signals. One method would be to use five wavelengths, one for each shade. The pictures that are shown here have, however, been made by a process utilizing a single wavelength.

The transmitting machine is made in such a way that it automatically, at every moment, selects the shade that comes nearest to one of the five shades, and sends out a telegraphic signal which selects the corresponding shade in the receiving machine. This sounds more complicated than it really is, because the telegraphic code by which different shades are selected depends upon the synchronization of the two machines, which is necessary under all circumstances. Thus black in the picture is produced by exposure of the sensitive paper to the recording light spot during four successive revolutions; whereas light gray is produced by a single exposure during one of the four revolutions and no exposure for the three succeeding revolutions. The overlapping exposure is progressive and the thing is a continuous process.

When we embark on such an ambitious program as television, it behooves us to reason out, so far as it is possible, whether the results we expect to get are going to be worth while, even if our most sanguine hopes are fulfilled. We have before us a struggle with imperfections of our technique, with problems which are difficult, but which may be solved. In every branch of engineering there are, however, limitations which are not within our control. There is the question whether the medium with which we are dealing is capable of functioning in accordance with our expectations and desires.

We are dealing with the photoelectric cell, the amplifier, the antenna and the radio wave. The photoelectric cell and the amplifier employ the medium of electron, which is exeremely fast; but the use of the radio wave itself imposes certain speed limitations on account of the limited scale of available wavelengths. The question therefore remains: what quality of reproduction may we ultimately expect in a television system if we succeed in taking full advantage of the ultimate working speed of the radio wave? An experimental study of the problem and the conclusions may be illustrated by the comparison of some pictures made at different speeds.

These three pictures shown in Fig. 73, were made with the selective-shade process, under conditions which reproduce the characteristics of one of our long-wave transatlantic transmitting stations with a wavelength of 12,000 meters, or a wave-frequency of 25,000 cycles. The picture at the left is the result we get if the time of transmission is two minutes. For the middle picture the transmission time is four minutes and for the picture to the right eight minutes. Everything else in the three cases is identical. Relatively, these pictures represent the effect of the sluggishness of the tuned antenna upon the sharpness in the reproductions. The two-minute picture is not as sharp as the eight-minute picture. With this particular subject we may be satisfied with a two-minute picture; but with other subjects containing more details it would pay to use eight-minute transmission time.

However, if we wish to draw conclusions regarding the practicability of television, we may say that if we are speaking with a friend across the ocean and if we can see his features as clearly as we do in this two-minute picture, we will be satisfied, and probably quite pleased. This picture has been produced, as accurately as we can determine by laboratory equivalents, with a wave of 25,000-cycle frequency.

Now (if we let our imagination loose) we will use a wavelength of twelve meters instead of 12,000 meters, and a frequency of 25 million cycles instead of 25,000 cycles. If the photoelectric cell and the amplifier and the light control can keep up with this pace, the radio wave will do its part and transmit a picture, such as seen here, in 1/1000th part of two minutes; *i. e.*, in one-eighth of a second. We are thus able to predict that it will be possible to transmit a good picture in a space of time which is of the order of magnitude of the time required for moving picture operations, the exact figure being one-sixteenth of a second.

Alexanderson's Television Projector

But Bernard Shaw's specification has one more requirement. He wants the television picture shown, life-size, on a large screen. In this lies one of the fundamental difficulties.

Fig. 78 shows a model 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 parallel paths, and that it should be capable of making 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 signalling, 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. Offhand, 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 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.

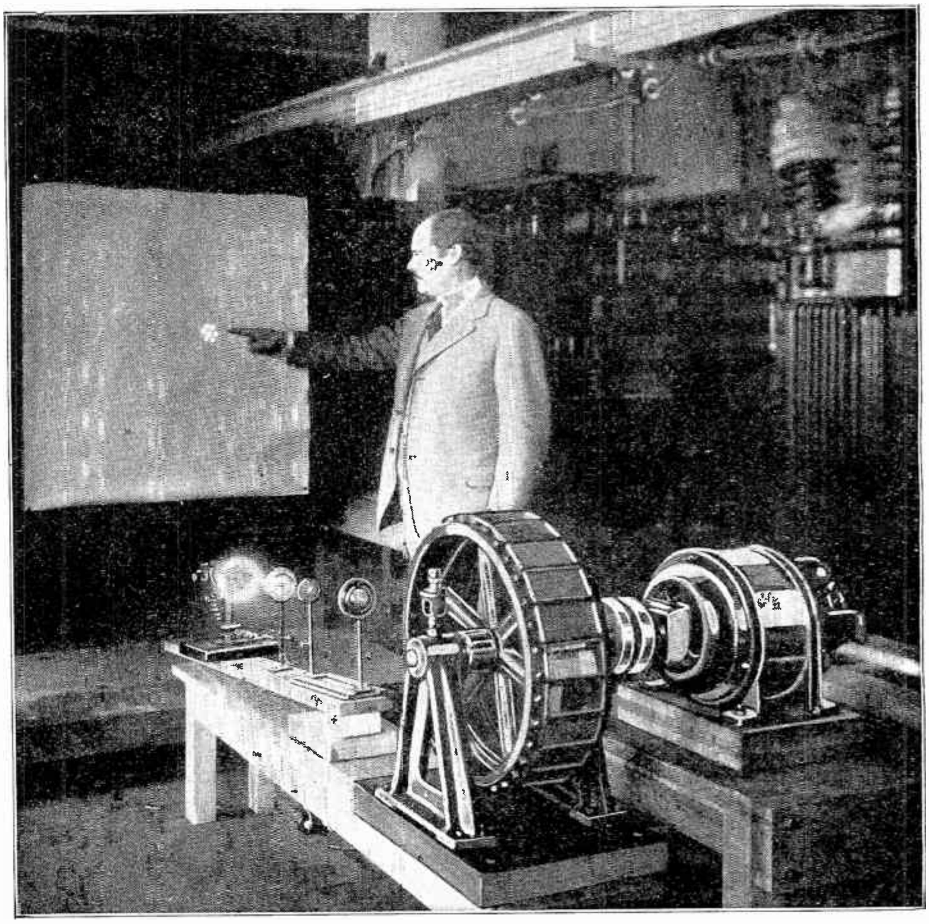


Fig. 78. Dr. Alexanderson in his laboratory indicating the seven light-spots, which are used in the method proposed by him for television. In the foreground is the drum on which are mounted the mirrors, with the motor for rotating it. A system of lenses may be seen, together with an arc light.

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.

If we knew of any way of sweeping a ray of light back and forth without the use of mechanical motion, the answer might be different. Perhaps some such way will be discovered, but we are not willing to wait for a discovery that may never come. A cathode ray can be deflected by purely electromagnetic means, and the use of the cathode-ray oscillograph for television has been suggested. If, however, we confine our attention to the problem as first stated, of projecting a picture on a fair-sized screen, we know of no way except by the use of mechanical motion. If we also insist upon a good image, we find that we must speed up the process seven times and, in doing so, we must reduce the dimensions so that we will have only one-forty-ninth as much light.

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. A Hammond multiplex system may be used with seven intermediate carrier waves, which are "scrambled" and sent out by a

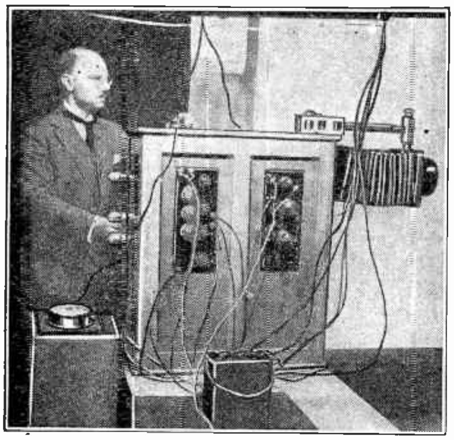


Fig. 79. Exterior view of the Dauvillier television transmission apparatus and the inventor at its side.

single transmitter, and then unscrambled at the receiving station so that each controls one of the seven light beams.

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.

How long it will take to attain this end I do not venture to say. Our work has, however, already proven that the expectation of television is not unreasonable and that it may be accomplished with means that are in our possession at the present day.

The Dauvillier System

We are going to speak now of the apparatus of Dauvillier, a young scientist, chief of the physical research laboratory for X-rays, founded by M. de Broglie, and described by Lucien Fournier in the March, 1927, issue of *Science and Invention.* To explore the image, M. Dauvillier utilizes two tuning forks kept in vibration by electricity, and producing induced currents. One of the tuning forks vibrates eight hundred times a second, and the other ten times a second. The induced currents are synchronic, which are conducted by wires to electrostatic fields in the cathodic oscillograph receiver which is a Braun tube. The author of these investigations proposes a direct solution of the problem of television. He tries to have two correspondents in telephonic communication see each other mutually, and this is why he calls the apparatus the telephot.

The image given by the objective strikes the mirror carried by one of the legs of the tuning fork of eight hundred vibrations per second. It is supported horizontally and

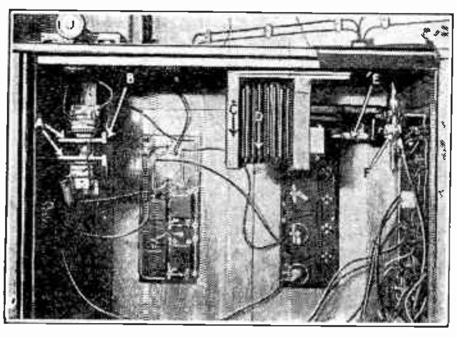


Fig. 80. A, the two legs of the electric tuning fork of 10 cycles; B, mirror; C, screen; D, governing rheostat; E, the electric tuning fork of 800 cycles; F, photo-electric tube.

the mirror is moved from right to left, and back again at the rate of eight hundred times per second. The image is transmitted in "horizontal vibrations" to a second mirror on the other tuning fork of 10-cycle periodicity. This is so arranged that the legs vibrate up and down. The image reflected by the two mirrors then has a rapid horizontal movement and a much slower vertical movement, as it is received on an opaque screen pierced by a hole. Each of the points which constitute it will pass through this hole and will pass in succession one after the other. Thus the image will be completely explored or traced.

As our diagram shows the point of light passing through the screen as it falls upon a photo-electric cell, familiar to all our readers, and the currents issuing from the photo-electric cell and produced by the ray of light are directed to the receiving station with the intermediation of an amplifier and two conducting wires. We said at the beginning that the electric tuning fork produced induced currents which became synchronized currents.

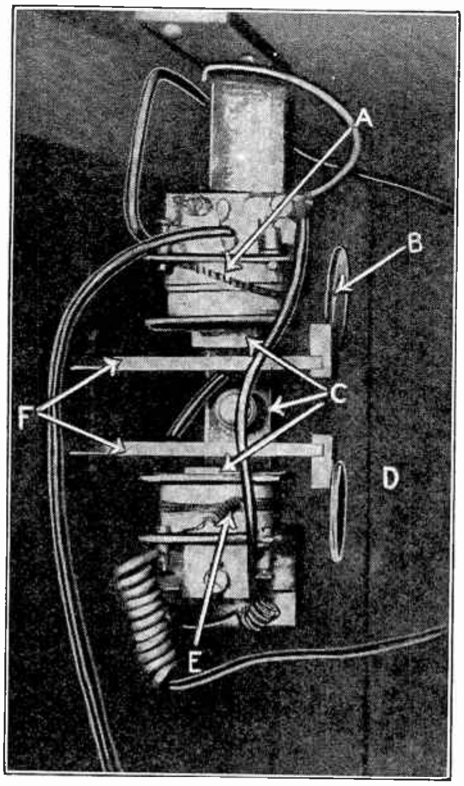


Fig. 81. A, coil producing alternating current of ten cycles; B, mirror; C, permanent magnetic circuit; D, frame; E, receiving coil of the tuning fork connected to the triode tubes; F, legs of the tuning fork (oscillating armature of the alternator).

These are produced in the coils shown in our diagram respectively of 800 cycles and of ten cycles, and after amplification reach the receiving station by three wires. The Dauvillier system includes then really five line wires.

The receiving station includes a Braun photo-electric tube which operates as follows. The current modulated by the luminous intensity varying for each point of the image passing through the hole in the diaphragm, is received by the grid-filament circuit of the Braun cathodic oscillograph.

It modifies the cathodic emission in exact correspondence with the variations of luminous intensity received by the transmitting vacuum tube. This is the first point to be noted. As regards the synchronic currents, they act upon the oscillograph by two electrostatic fields (see the Fig. 84), which are simply due to two condensers placed at right angles to each

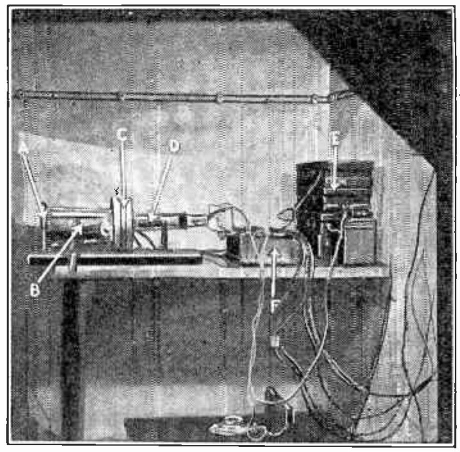


Fig. 82. Receiving apparatus: A, fluorescent screen; B, calcium tube for producing a vacuum in the oscillograph; C, concentrating coil; D, cathodic oscillograph; E, plate batteries, 300 volts; F, potentiometer box.

other. These condensers perform the same functions as the coils of the Holweck oscillograph in the Belin apparatus.

By their action the synchronic currents act upon the cathodic beam causing it to vibrate exactly in the same conditions as due to the image to be transmitted after its reflection on the two mirrors of the electric tuning forks.

The cathodic beam now has to cover all of the fluorescent screen in its path determined by the Braun tube and then the image will appear. It will be seen that the Dauvillier system is very simple. There is no other mechanical part than the two electric tuning forks, which is a considerable advantage. The inventor has told us that he hopes very soon to solve the problem of television by using new special amplifying tubes.

The same members of the British Royal Institute who saw, in 1926, the first demonstration of television of human faces were recently allowed an opportunity to judge improvements in the process made in the course of twelve months by the inventor, J. L. Baird.

Mr. Baird proved a year ago that it was possible to combine sight and sound, but faces transmitted were under a light of such intense brilliance as to cause great discomfort to their possessors. Mr. Baird at the new demonstration showed that he could transmit faces of human beings sitting in a room of inky blackness to a screen fixed in another room in which the watchers were in total darkness.

The inventor accomplishes this seeming miracle by using invisible infra-red rays. Such rays will pierce fog. By means of them it will be possible for a General in future wars to see every movement, even in the darkness, enemy troops, and an airplane can be watched without the aviator realizing that his presence is detected. In a fog at sea a beam of invisible light sweeping the water in front of a vessel will pick up any object ahead of it, such as another vessel or land.

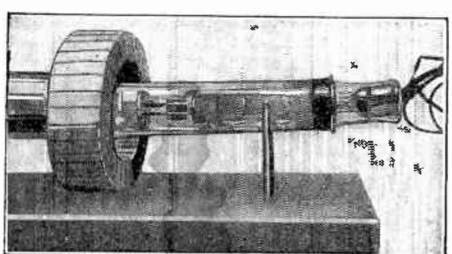


Fig. 83. Close-up view of the Dauvillier special vacuum tube used to reproduce image by virtue of cathode beam oscillated or controlled by the electro-static fields.

At Last Practical Television

And then—the first really practical television machine was demonstrated. To those who may pick up this book in the future we would say that the present day mechanism is not the ultimate television machine. Many changes will be wrought and much simplification will be effected. On this point we would like to quote Mr. Hugo Gernsback, from an editorial in the June, 1927, issue of *Radio News*. He writes:

With the official recognition of Television by the Radio Commission, as well as the actual successful demonstration early in April by the American Telegraph and Telephone Co., it may be said that television has finally arrived. The Commission, in setting apart the waveband of 150 to 200 meters for television, and particularly television for experimental purposes, recognized that one of the greatest, long-awaited and predicted inventions of modern times has at last come to the front.

It is interesting to note, in passing, that *Radio News'* sister magazine, *Science and Invention* (then called *The Electrical Experimenter*), was the first to use the term "Television," in many articles on this subject which it has been publishing for some fifteen years.

I have said many times before, that there exists some confusion in the public mind because there has appeared in the press the unfortunate term of "radio movies," which is a totally different thing from television. The "radio movie" is to television what the phonograph record is to the telephone. The telephone transmits and receives a conversation while it is being held; the phonograph *records* the conversation or the music, and it is then laid aside until it can be reproduced at a later date. Radio movies are in this class, in that an event is filmed or otherwise recorded and then transmitted at a distance by wire or by radio. I hold the opinion, however, that most likely radio movies will not be very popular in the future when once we have television—which indeed we already have.

When the term "television" is used nowadays, it means television coupled with radio, although there is, of course, no necessity for such a view; because if you have television by radio you can have television by wire, and *vice versa*. If television apparatus is perfected to such a degree that it becomes a commercially practical instrument, the telephone companies will not hesitate to make an attachment that can be used on your desk or home telephone. In that case you will be able to converse with your friend and see him at the same time, if this is desirable.

But, if, for instance, you are not dressed or otherwise do not make a presentable appearance, a button located in the telephone stand which starts transmission may be left unpressed; in which case you will be able to see your friend, but he may not see you.

Television, as far as radio is concerned, will extend the present benefits of radio tremendously. It is recognized by every one that, inasmuch as radio is "blind," an entirely new world will be opened to the radio listener if he can see as well as hear. It will then be possible not only to hear the President of the United States, when he speaks, but to see him as well. And the same thing will be true of Lopez and his orchestra, as well as of all the performers when grand opera is broadcast direct from the stage.

The race for television has been on for twenty-five years, but it may be said that television became practical only during the past few years, since the invention of a light-sensitive photo-electric tube. Heretofore it was necessary to use selenium as a light-sensitive instrumentality, which translated the light impulses into electrical ones. It was found that selenium is too slow because of its inertia, and television apparatus constructed with selenium cells gave no practical results. The photo-electric cells, of which there are now a number of excellent types, have no inertia or lag, and work practically with the same speed as the variations of light.

The race for television is at the present at its maximum of effort. All the big technical research organizations, the world over, are frantically working on the problem, and it may be said that the organization or inventor who solves the problem in the most practical way will have an invention that will far outrank radio as we know it today. Even as late as five years ago it was thought that a television attachment would probably be a most cumbersome apparatus. We no longer think so today, and I am quite certain, for one, that the final television apparatus on your radio set will take up no more room than your present cone speaker.

And, while I am delighted with the decision of the Radio Commission to set aside a special band for television experiments, actual television as applied to radio, *will not need an extra waveband*. The reason for this is very simple, in that the television impulses can be sent out by the present broadcast transmitters without any trouble. They will be sent out on exactly the same wave at a frequency (of modulating vibrations) so high that the human ear can no longer hear the result. The process will be then reversed at the receiver, where the inaudible signals will be fed through a system of intermediate and step-down transformers, where they will be used for the regular television reception methods.

And continuing along the same line of thought, Mr. Gernsback has this to say in the corresponding issue of *Science and Invention* in an editorial entitled "After Television—What?" While not dealing exclusively with the subject of television, we are sure that our readers will agree with us, when we say "The thought expressed therein were well worth the time and effort expended." Perhaps some of us will be interested in other "Tele" phenomena. If so the outline here given might deter the inventor and set his thoughts along the right road.

Television, which has been in the making for the last twenty-five years, and the perfecting of which has been freely predicted in many technical articles by many writers, as well as by myself, is now a reality. No longer need we look into the future for it. Although not perfected so that it can be attached to every telephone or to every radio set, television is, today, in a state comparable to that of radio when its principles were first laid down by Heinrich Hertz, in 1888, and to that of Bell's crude telephone, in 1876. It will take a few years to develop the television apparatus out of the laboratory stage, and much work as yet remains to be done. This is always the case when bringing the laboratory product to the final and practical everyday use with any instrument or technical appliance. It may take two years and even five years before every telephone and every radio set is finally equipped with its television attachment, but you may rest assured that this generation will soon personally witness the appearance of this stage of the art. There can be no doubt about it. But, and we may ask this question soberly,—"After television, what next?"

It is now possible to hear and see a person over a wire line, or over the radio. We have, therefore, made it possible to *transport two senses*, so to speak, to a distance, the two senses being sight and hearing.

In these days of wonder and achievement, we should ask ourselves the question, "What other of our senses is it possible to transport to a distance, and, from our present-day knowledge of science, is it possible to transport any of them at all?"

The remaining senses are smell, taste and touch. Now, then, of course nothing can be said to be impossible, although some things are highly improbable. Thus, the next of the senses on the list being smell, is it possible to smell at a distance? I might say that this is not impossible, although highly improbable. From a tech-

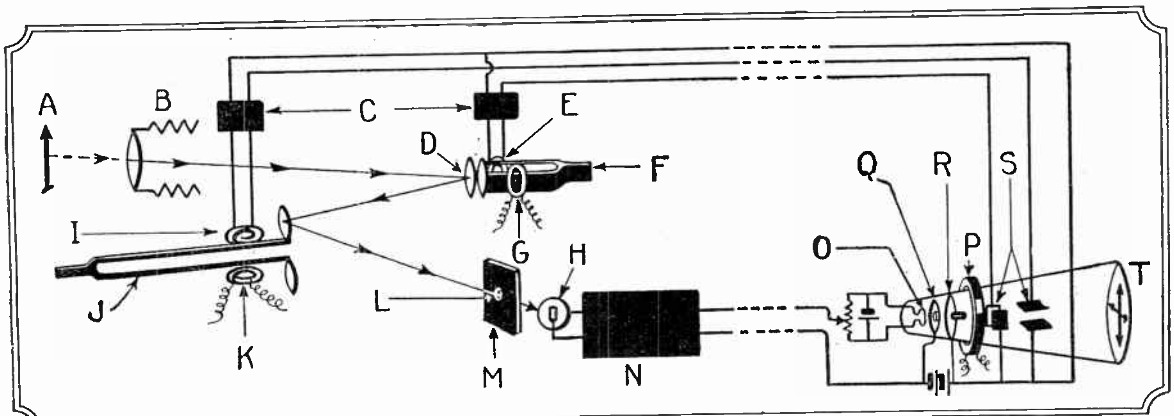


Fig. 84. Diagram of the Dauvillier apparatus: A, object; B, objective; C, amplifier; D, mirror; E, coil generating synchronic currents; F, 800 cycle tuning fork; G, exciting current; H, photo-electric cell; I, coil generating synchronous currents; J, 10 cycle tuning fork; K, exciting current; L, hole determining the point of the image; M, optical screen; N, amplifier; O, filament; P, concentrating coil; Q, grid; R, plate; S, condensers producing electrostatic fields; T, fluorescent screen.

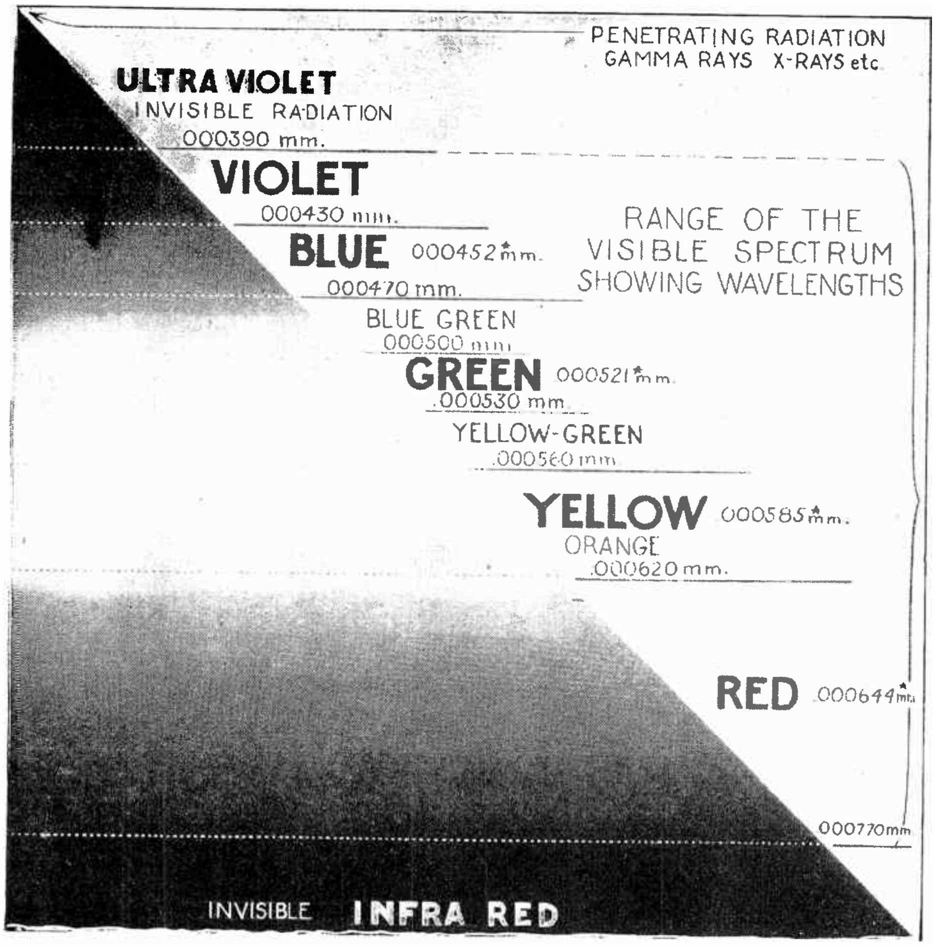


Fig. 85. The electromagnetic rays of the "visible spectrum," one billionth as long as those used in broadcasting, produce on the eye the effect of color (the stars indicate the wavelengths of the primary colors). Beyond its limits, at either end, no sensation of sight is caused. However, photo-electric 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.

nical standpoint, it may be quite possible to build an instrument highly sensitive to odors, which instrument would be able to distinguish between the most subtle variations of various smells or odors. The next step would then be to amplify these, which presumably could be done by means of vacuum tube amplifiers. After that, transmission could be effected electrically by many ways now known.

At the receiving side the impulses would be stepped up and some means would have to be provided to unscramble the odors. We can imagine, for instance, 5,000 small tanks at the receiving end, each of which would release, upon a contact being made, an amount of odor depending upon how much was wanted, as indicated by the impressed signal. Thus it would be possible to *recreate* at the receiving end, odors or smells similar to those sent out from the transmitter. All perfectly possible, but, and here comes the big question mark, why would any one want to do it? It would cost a million dollars or more to build such an apparatus, and to what good? So that is why I said, "Not impossible, but highly improbable."

The next sense to be transmitted would be touch. Again I say, "Not impossible, but somewhat improbable." It should be a simple thing to construct an electrical apparatus operated at a distance, to transport the sense of touch, in some ways. For instance, it is possible, today, to build an apparatus that, by means of television, would enable mechanical fingers to open the combination of a safe. You would watch by television a mechanical hand, of which you would operate a duplicate at the sending end, and you could thus open or close the combination of the safe without much trouble. This is not impossible, nor is it improbable, but, as with the transportation of the sense of smell, there would not be many uses for such a device.

We have with us today the science of *telemechanics*, which means, operating either by wire or by radio an apparatus at a distance. Some years ago, before television was invented, I described the radio-controlled television plane, which will make it possible, in a not-far-distant future, to operate an airplane without a human being on board, and which, being provided with television apparatus, will enable a distant operator to see and guide the plane over enemy territory and drop bombs at any desired instant, although no one be on board the airplane. We may call this "touch at a distance" and, in fact, it is just that. This is not only quite possible, but will be done in the next few years.

But, when it comes, for instance, to actually *feeling* the texture of a piece of cloth, at a distance of a thousand miles, this would seem highly improbable, at least for practical purposes.

The remaining sense, namely, taste, may be classed with the transportation of the sense of smell. It is not impossible, but highly improbable. A machine can be invented whereby, just like the one explained under odors, certain impression are made upon certain media, when certain foods or liquids are placed upon it. The tongue, by dissolving certain of the ingredients of the foods or liquids, gives the sensation of taste. The counterpart of an electrical tongue would present no insurmountable difficulties to a clever physicist, and it is possible to transmit such impressions, in the form of electrical impulses, to a distance. Here, at the receiving apparatus, the impulses could release from tanks or some such other apparatus liquids to simulate the transmitted taste impulses. This is not impossible, but the whole thing would be the height of foolishness, because no one would want to do it, as the expense would be entirely too high.

It might be possible for a New York merchant in this way to taste the quality of Chinese tea 6,000 miles from New York, but why would he wish to do it after all? And certainly, if he had to pay the cost of doing it, he probably would think twice before attempting it. Coming back to television, what application this interesting invention will take in the future can only be dimly guessed at. There was a time when we were talking first about radio telephony, when it was conceded by practically all of us who had a hand in the shaping of its destinies, that the logical thing would be talking by radio to our friends. Thus in the first book ever written on the subject: "The Wireless Telephone," published by me in 1908, before there was a Radiotelephone, I could see only one use for the coming invention and that was a parallel to the wire telephone. I did not dream of broadcasting, nor did any one else.

The same may be said of television. Right now we are glibly talking about television attachments on our telephones, and radio sets. We may be all wrong, and the new art of television may turn into entirely different directions, undreamt of today. Science has the habit of doing the unforseen, and often throws our best and most logical predictions on the scrap heap.

Baird's Developments

At a demonstration of John L. Baird's system in 1926, 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.

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

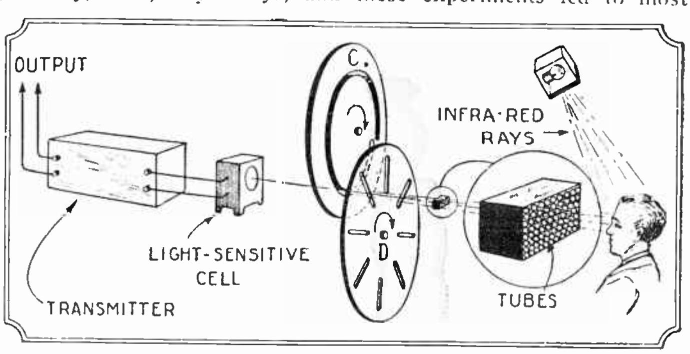


Fig. 86. The infra-red rays are reflected from the object, through the tubes, and the revolving slotted discs C and D, where they are broken up, as explained in the text. They are then transformed into electrical energy by the cell, and are fed to the transmitter. At the receiving station they may be recorded on a phonograph, and reproduced at any future time.

important results, says A. Dinsdale in an article in June, 1927, issue of *Radio News*. In order to understand clearly exactly what has been done, let us consider briefly the spectrum.

Beneath the range of the shortest wireless waves are other wavelengths 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, 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. (A description of its exploration will be found on page 218 of the September issue of *Radio News*, previously mentioned.)

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 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 more dangerous, for they had a bad effect upon the eyes of 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.

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; as I discovered for myself recently when I was privileged to witness 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.

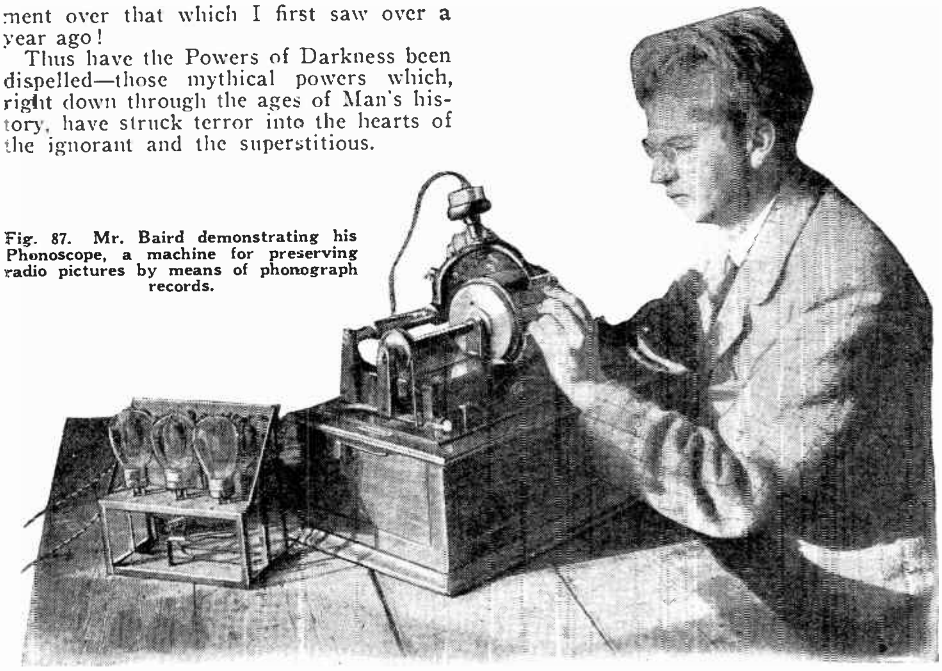


Fig. 87. Mr. Baird demonstrating his Phonoscope, a machine for preserving radio pictures by means of phonograph records.

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

Attacking aircraft, approaching under cover of the night, will be disclosed to the defending headquarters by the electric eye of a 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 gunfire.

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-penetrating properties are of importance. This new application of television renders possible the use of infra-red rays with their still greater 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 to actually *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 searchlight, 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

Since his apparatus was last described in these pages, 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 subdivided into minute horizontal portions, or flashes, by the two other rotating discs, and each flash was, in turn, thrown upon

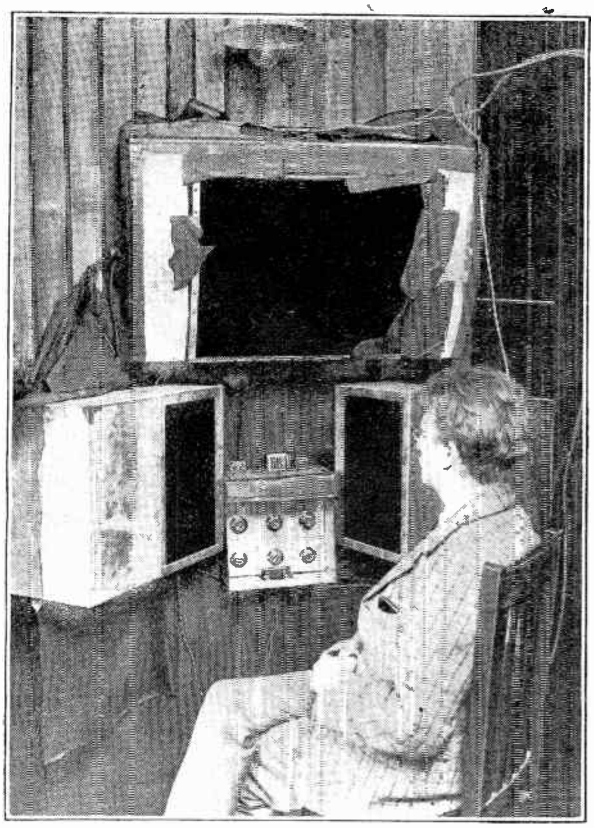


Fig. 88. Mr. Baird seated before his television transmitter. The three black-faced boxes are the sources of the infra-red rays.

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.

Projection Tubes a Solution

This apparatus is illustrated in Fig. 86. 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 Fig. 89, 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 living reproduction of the original, complete with even gradations of light and shade, and showing the movements of the sitter.

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

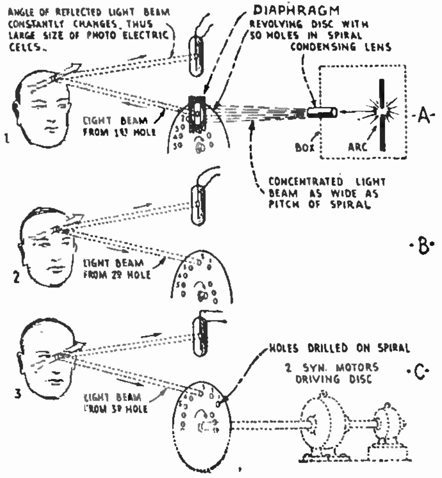


Fig. 90. Successive light beams issuing from the holes in the whirling disk at the transmitter sweep over the object; their movement is exaggerated here. A lens is also used in front of the disc.

mechanical imperfection. 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. We are not yet at liberty 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

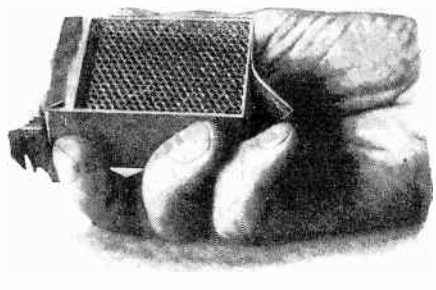


Fig. 89. The cellular structure of the image-projection tubes used in Baird's television apparatus.

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 reproductions 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 cinematograph 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.

There would appear to be no limit to the remarkable inventive genius of John L. Baird, and the enormous possibilities of television stir the imagination, conjuring up visions of marvelous inventions before which even Sam Weller's magic opera glasses pale into insignificance.

Modern Practical Television

And so we arrive at last at the close of this chapter on television. Here is a complete informative description of the Bell Telephone Lab. system of television as rendered by H. Winfield Secor, the Managing Editor of *Science and Invention* Magazine and the co-author of this work. This description appeared in June, 1927 issue of the aforesaid publication and also a corresponding article appeared in a similar issue of *Radio News* Magazine. Because the subject matter overlaps, the article from *Radio News* has been given preference in this work to the one in *Science and Invention.*

April 7, 1927, will always be a memorable day in the annals of science, for on that day, before a group of invited guests, the experts of the Bell Telephone Laboratories demonstrated in New York the first, practically perfect reproductions of the living image of Mr. Herbert Hoover and other speakers at the Washington end of a telephone circuit; and secondly, similar images transmitted by radio from Whippany, N. J., thirty miles away.

To make the subject more interesting, it is well to state at the outset that at the transmitting end of the circuit the image of the moving object was reproduced in two forms. In the smaller receiving instrument the size of the image is about 2½x2 inches, and here the likeness was very perfect; Mr. Hoover's face appearing in a photographic reproduction against a rose-pink background. This color is due to the use of neon gas in the glow-tube, which is placed behind a revolving disk in the small machine. The larger reproduction apparatus, used to show the built-up image before the assembled guests, had a screen approximately 24 inches wide by 36 high. Here also the general color of the background was pink, due to a grid of evacuated glass tubing containing neon gas, which formed a surface on which the picture was built up by means of 45,000 light-flashes sweeping over the screen every second.

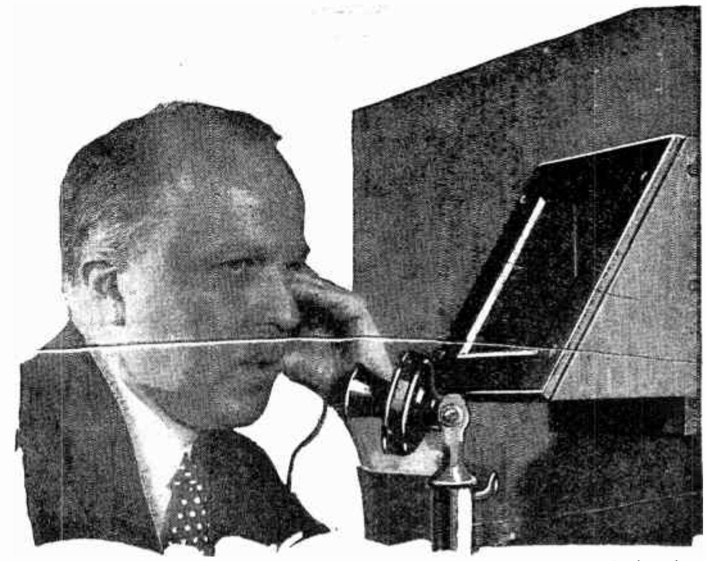


Fig. 91. At right Mr. Walter S. Gifford, President of the American Telephone and Telegraph Company, speaking in front of the small television receiving screen.

How Image Is Transmitted

Referring to the diagram (Fig. 90, A, B and C), we shall first consider how a concentrated light-beam from an arc lamp is caused to sweep across the object, a human face for example, in a series of small spots and at the rate of 900 light-flashes per second. The light from the arc is concentrated through a condensing lens upon the back of the rotating perforated disk shown in the figure. There are 50 small holes drilled through this disk, these being laid out in a spiral; it rotates eighteen times per second, or 1080 revolutions per minute. As the three stages of the process (Figs. 90A, B and C) demonstrate, and thanks to the slit or diaphragm placed behind the disk, one hole only is permitted to pass a light beam at a time. Look at Fig. 90A; then note that at B the second hole in the spiral has reached the vertical position and a small beam of light passes through and sweeps across the image in the second lower position. Look at Fig. 90C, and it becomes evident that No. 3 hole has reached the vertical position, and the third pencil of the beam sweeps across the image in the third position from the top of the face or other object at the transmitter.

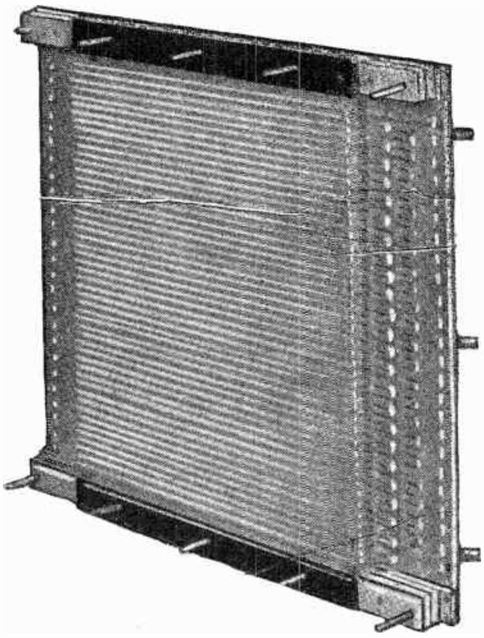
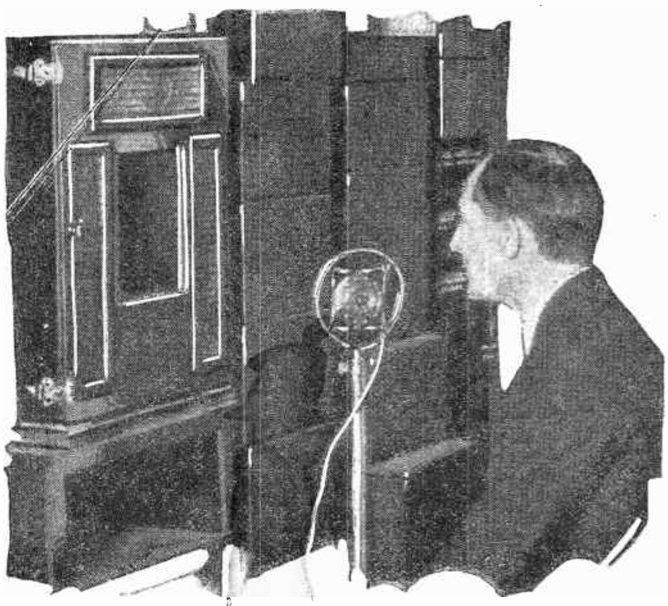


Fig. 92. The large 24 by 36-inch glass tube screen on which the television image was reproduced at the demonstration in the Bell Telephone Laboratories in New York City.

This action is repeated, as becomes clear, so that when the 50th or innermost hole of the spiral on the disk comes into position before the diaphragm, a pencil of light passes through, sweeping the bottom of the image. This is clear on inspection of Fig. 95. A second lens is used in front of the disc.

It is well known that the motion picture of today is possible only because of the *retention of vision* by the human eye. That is, sixteen slightly-different pictures are jerked, one after another, in front of the lens and flashed on the theatre screen every second. Due to the "lag" of the human eye, the individual pictures overlap and give the illusion of a perfect moving image. The same thing occurs in this television system; but instead of flashing each light across the face sixteen times per second, the engineers who developed this system of television in the Bell Telephone Laboratories cause the light-beams to travel across the image at a speed of eighteen times per second. As there are fifty light-beams, due to the fifty perforations in the rotating disk at the transmitter, we have 18 times 50, or 900 light-targets traveling across the image every second!

It might be thought that such a strong concentrated pencil of light, when it traveled across the eyes, for instance, would prove unbearable; but such is not the case. The effect when looking toward the opening in the transmitting machine is like looking into a camera lens with a fairly strong light behind it. The light beams change place so fast that the final result is a slightly flickering bluish light which seems to bathe the face or other object at the transmitter.



Photos courtesy Bell Telephone Laboratories.

Fig. 93. Photo at left shows subject at Television transmitter with microphone which picks up the voice. Behind the three grille doors are placed the large photo-electric cells, which pick up the reflected light images from subject's face, as the rapidly moving pencils of light coming out of the square opening shown explore it. The apparatus in the background comprises amplifiers and other devices used in the transmission.

The next very important point to note is that, as the light-beam (at Fig. 90A for instance), moves across the top of the man's face, a ray of light with a constantly changing angle of incidence is reflected from the face and impinges on some part of the three large photo-electric cells used in this perfected system of television.

Looking at Fig. 95 we see how the three large photo-electric cells of new design are arranged in front of the image. In the pictures you will note that these three photo-electric cells, each of which measures about 14 inches long and 4 inches in diameter, are placed inside three metal boxes provided with wire-grille doors to protect them from electric fields. The doors are shut, even when the machine is in operation. These photo-electric cells, which were devised under the direction of Dr. Herbert E. Ives of the Bell Telephone Laboratory

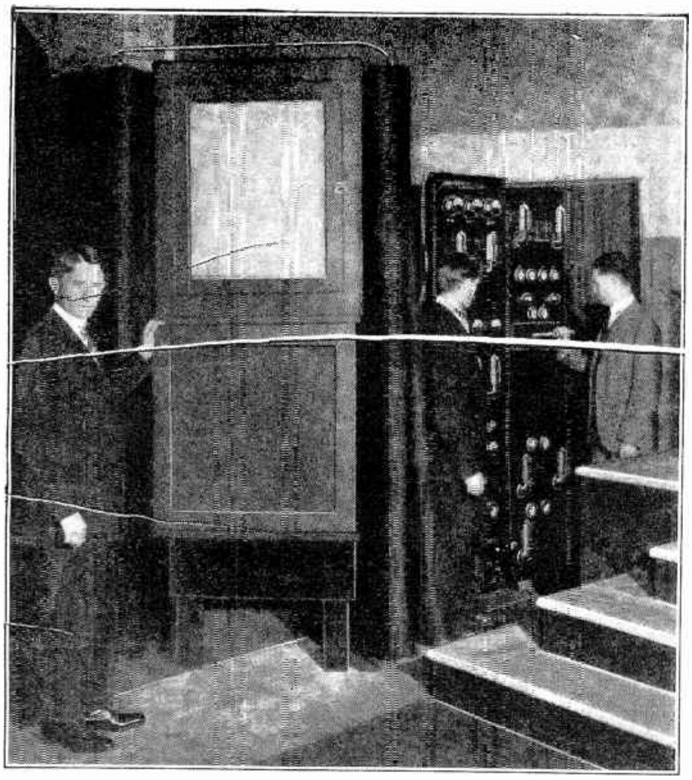


Fig. 94. The glass screen and front of the loud-speaker horn used. The large image reproduced appeared on the screen at the top. Vacuum-tube amplifier at right.

staff, comprise a central electrode running the length of the tube, while the rear inside half of the tube all the way up is coated with a metallic deposit. The tubes are then exhausted and the proper gas introduced.

As Fig. 95 shows, there is a constant *solid angle* of vision, filled with a constantly-moving series of light-beams. As becomes evident, the angles of the reflected beams will be constantly changing as the initial beams shoot forth from the apertures in the rotating disk. This is one of the main reasons why such large photoelectric cells are required. These are undoubtedly the largest ever used. The terminals of the cells are connected in parallel, so that their action is all concentrated in one circuit, as becomes clear from an inspection of the diagram, Fig. 97.

Instead of using three telephone circuits, in the radio transmission three different wavelengths were utilized, as indicated in Fig. 97. Looking at this we see how a concentrated light beam from the arc shoots through one of the holes in the revolving disk which is driven by two synchronous motors; thence to the face, from which the light beams are reflected progressively upon one of the three large photo-electric cells. By the instantaneous action of the photo-electric cells, every gradation of tone or color upon the face or other image encountered by the spot of light as it sweeps across the face is transmitted to the receiver. For this reason the spots of light, as they build up the image at the receiving instrument, give a very faithful reproduction of the image at the transmitter.

A special vacuum-tube amplifier of several stages serves to magnify the very minute fluctuating currents coming from the photo-electric cells five thousand, thousand, million (5,000,000,000,000) times. It is interesting to note that this vacuum-tube amplifier had to be designed to amplify all frequencies from ten up to twenty thousand cycles. The *image-currents* then enter a 5-kilowatt standard radio transmitter of the vacuum-tube type, and leap across the thirty-mile gap between Whippany and New York City on a wavelength of 191 meters.

In New York a standard receiving set picks up the 191-meter image-signal, and after amplifying it sufficiently, passes it into a neon tube, placed directly behind a second revolving disk having the same speed and number of perforations as the disk at the transmitter station. The person at the receiver simply looks through a small aperture at the swiftly-moving pulses of light as they become visible through the whirling holes in the spinning disk. He sees the real image build up apparently at the position of the disk, while the virtual image is of course considerably behind the disk, as the drawing shows.

How Synchronism is Established

It required much special research work and clever designing of the synchronizing circuit and motors used for this perfected television scheme; and to Mr. H. M. Stoller is due the credit for the special synchronizing means finally adopted.

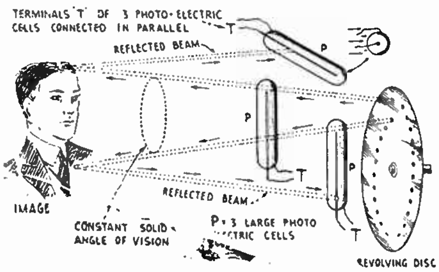


Fig. 95. How the extreme positions of the succeeding pencils of light exploring the object at the transmitter are enabled to pick up the whole image. The solid angle of vision is made up of rapidly moving beams of light.

This very important part of the system of television has several new aspects. Due to the high speed of the light-image transmission and reception, quite necessary to produce a practically perfect image at the receiving end of the line, it was soon found that ordinary 60-cycle synchronous motors would not do. Synchronous motors, as is well known, have the habit of *hunting;* that is, they will swing a little below or a little above their true normal speed at times. To reduce the degree of this variation resulting from hunting, a second synchronous A.C. motor was placed on the same shaft that drives the rotating disk, at both the transmitter and receiver, this motor being designed for a frequency of 2,000 cycles per second. As will be seen, a slight variation at this frequency is much less noticeable than it would be at 60 cycles; and so, between the two motors, the synchronous speed is maintained practically uniform at all times.

Note particularly how the 2,000-cycle alternating current supply is connected in parallel to the 60-cycle A.C. supply circuit. Suitable filters made up of inductances, resistances and condensers are placed in each pair of leads running to the synchronous motors, as Fig 97 shows. Where television takes place over three telephone circuits, the action is quite simple; while with radio transmission the insertion of a standard transmitter of the vacuum-tube type is necessary to transmit the synchronizing signals to the receiving instrument.

In the demonstration recently conducted, these synchronizing signals were transmitted to the receiving station by a one-kilowatt transmitter, on a wavelength of 1,600 meters. It should be noted at this point that no such high power is necessary, and all of the units were operated at considerably less than normal capacity. The reason that these particular transmitters were used is the fact that they happened to be available and handy at the experimental station.

In radio transmission of the television image, the synchronizing signals were picked up on a standard receiving set fitted with suitable inductances and condensers for tuning at 1,600 meters; and the amplified synchronizing signals were then fed into the circuit supplying the 60-cycle and 2,000-cycle A.C. to the two synchronous motors driving the revolving disk in the receiving instrument.

How Voice Was Transmitted

Referring to Fig. 97, we see that the voice of the subject before the television transmitter at the receiving station was picked up by a standard microphone, fed into a standard radiophone transmitter (a 50-kw. set was here used at greatly reduced power), from whence it leaped across the 30-mile gap to New York on a wavelength of 207 meters.

The wavelengths used were purely arbitrary and chosen because of their freedom from interference at this time. Any wavelengths available can be used, so long as the three are sufficiently separated to be tuned in clearly and without any overlapping at the receiving station.

The radio waves carrying the voice were picked up on a third and independent antenna amplified by means of a standard receiving set, and then passed into a loud speaker placed alongside of the picture-reproduction mechanism.

Reproduction of Image

Sufficient has been said to give an insight as to how the image is reconstructed or built up by light pulses, rapidly following one another at the receiving instrument. Referring to Fig. 97 once more, we note that the neon glow-tube, placed behind the revolving perforated disk, is about the size of

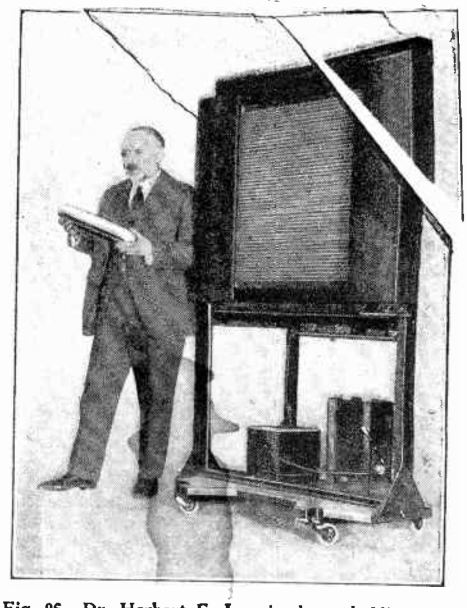


Fig. 96. Dr. Herbert E. Ives is shown holding one of the giant photo-electric tubes. At his left, the screen on which the large television image was reproduced.

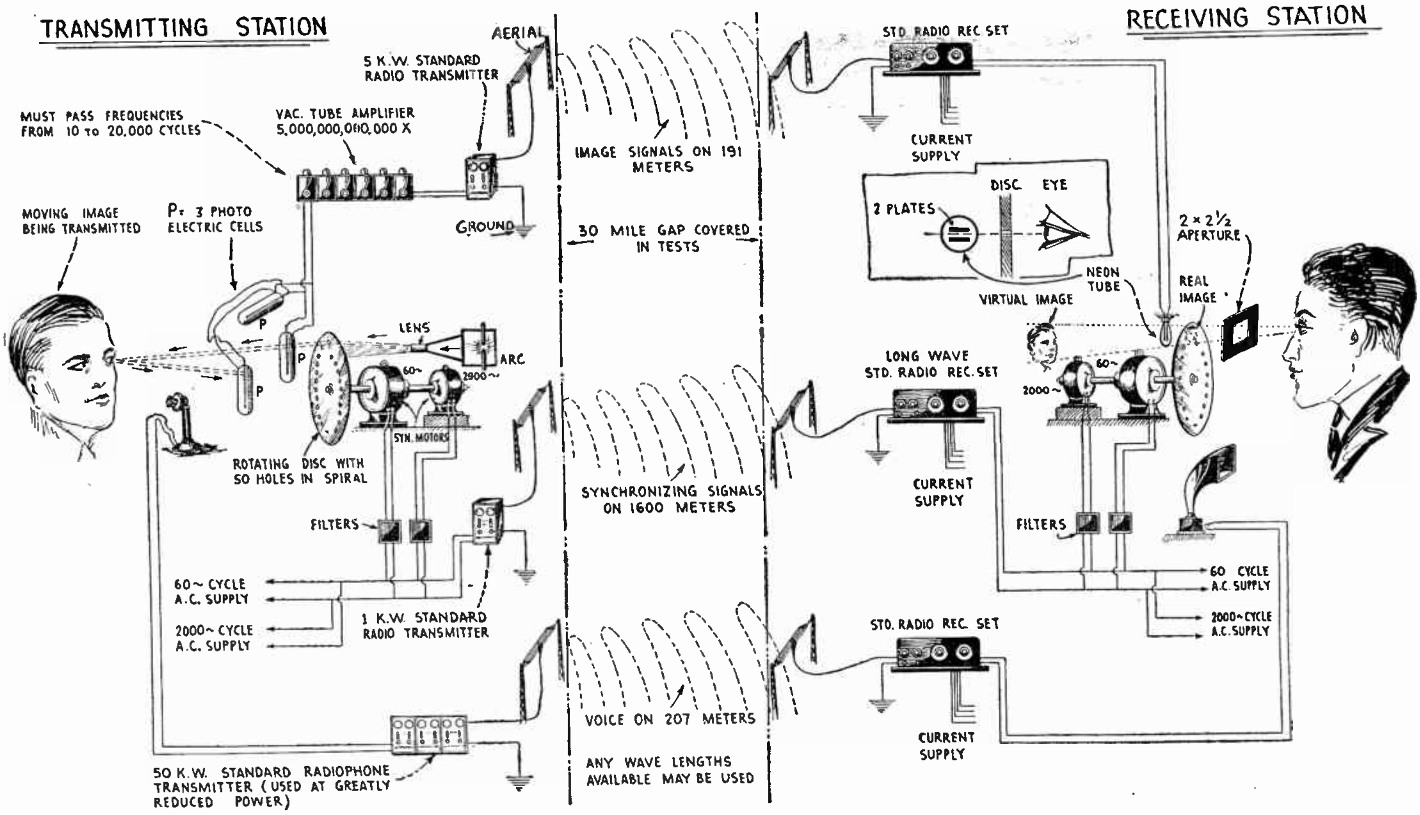


Fig. 97. A comprehensive diagram of the entire radio television apparatus; the subject, an image of whose face is being transmitted by radio, appears at the left, while the person observing the transmitted and reproduced image appears at the right. The perforated disk causes rapidly moving targets of 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 disk, 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 disk. The voice is transmitted and received in usual manner; while a third radio wave transmits synchronizing signals for the motors. A lens between the rotating disc of the receiver and the aperture has been omitted.

a 75-watt electric light bulb; it contains two flat metal plates a short distance apart. The detail sketch in the upper right-hand corner of Fig. 97 shows the relative position of the eye, the perforated disk and the neon glow-tube when viewed from the top. Usually a curtain is drawn around the person looking through the aperture. The remarkable thing is that no screen of any kind is here used, and we might say the person at the receiving instrument sees the likeness of the person at the transmitter actually reconstructed in the air.

The image at the receiving instrument is built up by reproducing the same number of light pulses per second, as those flashed across the face or other object at the transmitter. That is, the eyes of the person gazing through the aperture at the receiver witness 900 flashes of light per second, each of which carries the proper tone of some part of the image. The revolving perforated disk at the receiver rotates at the same speed as that at the transmitter, and like it has also fifty perforations. One of the wonderful things accomplished at this juncture is the perfection of the synchronization between the two revolving disks. Another very important contribution to the science of television is of course the special photoelectric cells used at the transmitting instrument.

Simplified Radio Transmission

Where the picture is transmitted and received over telephone circuits, four circuits would ordinarily be required; but, thanks to the ingenuity of the scientists who worked on this problem in the Bell Telephone Laboratories, this has been reduced to three circuits by combining the 60-cycle and 2,000-cycle alternating current circuits feeding the synchronous motors. Where regular wire circuits are to be used, there can be a still further reduction to one full-metallic circuit of two wires; as it is perfectly feasible now to transmit the three distinct currents for the image, for synchronism, and for the voice, by utilizing three carrier-frequencies. These must have a value above an audible frequency, in order not to interfere with the voice transmission. With voice transmission over special telephone circuits, the engineers have for several years been able to transmit six telephone currents over one circuit simultaneously, by using carrier-currents of different frequencies; in the case of multiplex telegraphy they are now transmitting ten different signals over a two-wire circuit simultaneously by the use of suitably graduated carrier-currents.

Looking at Fig. 99 we see how it is pos-

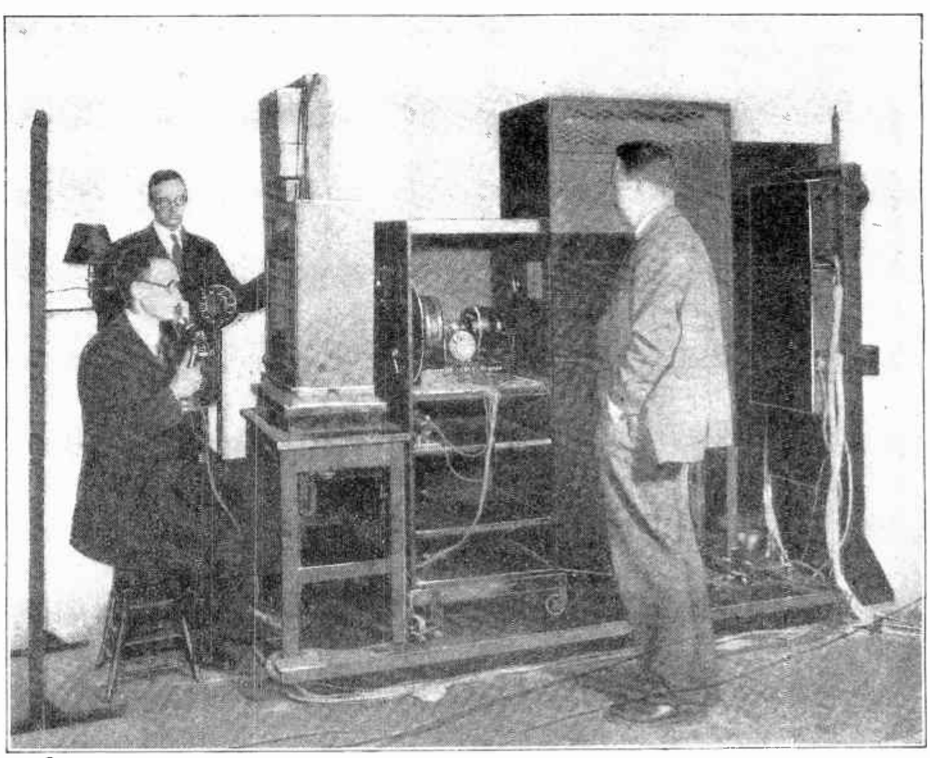


Fig. 98. A subject sitting before the transmitting mechanism. In the center cabinet are the 60-cycle and 2,000-cycle A.C. motors which drive the perforated disk. The light from an arc in the cabinet at the rear passes through the holes in the revolving perforated disk and falls on the face of the subject.

[Photos courtesy of Bell Telephone Laboratories.

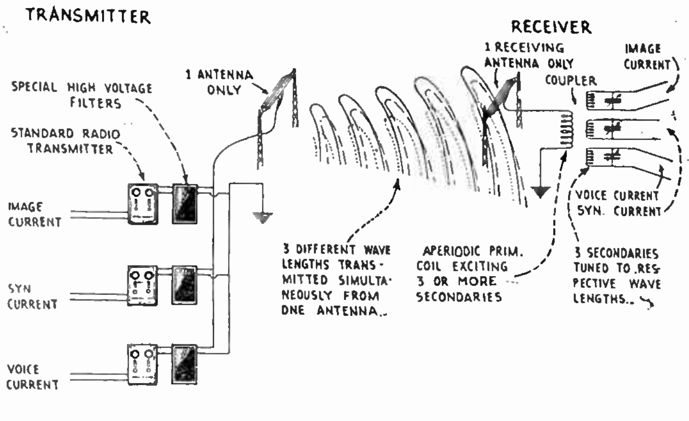


Fig. 99. Simplified system, whereby three transmitters, tuned to different wave-lengths, are joined to a common antenna through suitable filters.

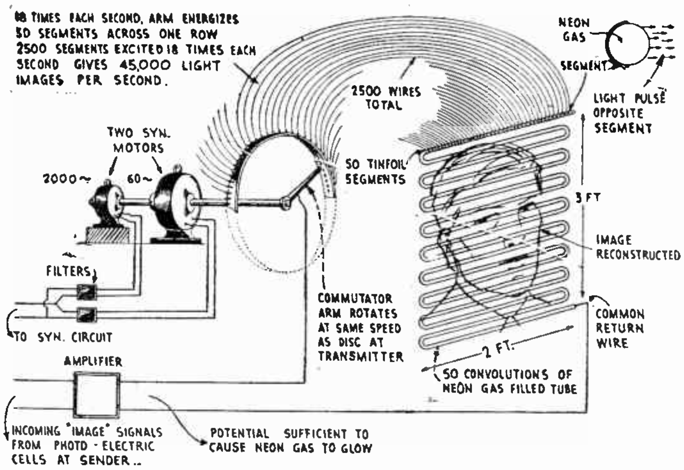


Fig. 100. The large exhibition screen, built up of a continuous length of glass tubing, along the rear walls of which are cemented 2,500 tin-foil segments. The tube is filled with neon gas; light spots appear opposite each segment when electrically energized.

sible to simplify the radio transmission of picture images by this or any other system, and where three different wavelengths have to be transmitted simultaneously for the image, synchronism and voice transmission. As pointed out in an interview of the writer with one of the scientists of the Bell Telephone Laboratories, who is familiar with this remarkable achievement by their engineers, it is possible, if occasion required it, to connect the three standard radio transmitters shown in Fig. 97 to a single antenna as shown in Fig. 99. This can be accomplished by connecting special, high-voltage filters comprising suitable inductances, condensers and resistances, in series with the respective radio transmitters and the common aerial and ground. In the recent demonstration and tests leading to it, it was found much cheaper and more convenient to use three separate transmission antennas and also three separate and independent receiving antennas. These special filters required where three radio transmitters are to be connected to one antenna, are quite expensive, and ordinarily it does not pay to use them.

There are several ways in which the three wavelengths being transmitted simultaneously can be picked up and passed into the three independent circuits, for the image, synchronism and voice circuits. One of the simplest ways of picking up and sharply tuning the three desired wavelengths is shown in diagram at Fig. 99. Here an aperiodic primary winding on a special coupler transfers the aerial energy to three or more independently tuned secondary windings. All the operator has to do is to tune the respective secondary circuits to the desired wavelengths. This is the system used for reception of transatlantic radio telegraph messages. The more elaborate system of Dr. A. Hoyt Taylor of the Navy can be used; as well as numerous others which have been patented and described in the technical press.

Details of Large-Image Screen

These details have probably made fairly comprehensible how at last it has become possible for a person at one end of a telephone or radio circuit, to actually see the moving image of the person at the other end, but the mind fairly staggers at the results obtained in reproducing a larger television image on a screen measuring two by three feet, such as that demonstrated before the audience which attended the introduction of this system of television.

Imagine for a moment what a problem the engineers had to solve, when it became evident that to properly build up the image of a face for example, on a screen as large as two by three feet, that not less than 45,000 light images or pulses per second, must occur. This meant, for one thing, that the synchronism between the two rotating elements at the transmitter and receiver must not be out of step by more than one ninety-thousandth of a second. As one of the scientists connected with this work pointed out to the writer, if either one of the revolving elements slipped out of synchronism by one-half a cycle, it would result in a *negative* image being received instead of a *positive*. In other words, you would see a white man with a black face and white hair. This problem, therefore, was one of the hardest ever placed before electrical engineers.

The Large Neon Lamp

Other phases of the research problem were encountered in the development, by Dr. F. Gray, of the large neon tube used for the production of an image large enough to be viewed by a considerable audience. The development and use of such a tube, with its present total of 2,500 external electrodes, required the construction of a current-distributor from which 2,500 wires, like a gigantic optic nerve, extended to the tube. When the front of this tube is observed, its

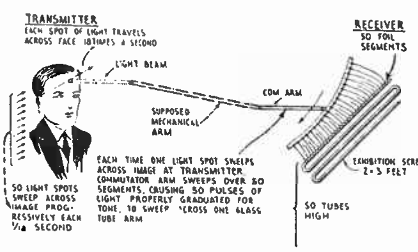


Fig. 101. How the image on the large receiving screen is built up. 45,000 light pulses flash across it every second.

whole area appears to glow at once; so rapidly does the instantaneous spot travel from one electrode to another that the eye does not appreciate its successive positions.

Referring to Fig. 100 we see that, instead of the revolving disk previously used for reproducing the image, we here use the two synchronous motors on a common shaft to rotate a commutator arm, and this arm passes over no less than 2,500 compactly-arranged metal segments, cemented along the rear walls of the 50 convolutions of the neon tube. These are correctly and progressively energized. Note that the incoming image signals, instead of passing into a single glow-tube, as in the simple apparatus for the small image, are now amplified to a sufficiently high potential to cause the neon gas in the large grid-tube to glow at the spot corresponding to any one of the 2,500 tinfoil electrodes.

The man who built the commutator needed lots of patience, a good hot soldering iron, and also plenty of time. He had to connect the 2,500 insulated wires running from as many tinfoil segments, cemented on the back of the neon tube, in exact order to their respective segments around the stationary commutator frame. When he had connected 50 wires from the 50 segments along the top glass arm for example, he then repeated this with the 50 wires coming from the 50 tinfoil segments along the second leg of the neon tube, etc. The action taking place in the magnified image on this large exhibition screen is made a little clearer perhaps by looking at the mechanically analogous diagram in Fig. 101.

How Neon Lamp Works

Referring to Fig. 101 for the moment, let us note that as one of the fifty pencils of light at the transmitter sweeps across the face for example, it, by analogy, causes a mechanical arm, corresponding to the commutator brush, to sweep across the fifty metal segments, and has therefore caused fifty spots of light of varying intensity or tone to sweep across this top leg of the glass neon tube. As the commutator has 2,500 segments, it will be seen that, while the fifty light beams passing through the transmitter disc cause 900 spots of light to traverse the face or other object each second, the number of light pulses, all properly graduated, reproduced on the large glass tube screen will be 45,000. In other words, 2500 light pulses appear 18 times every second on the 2 x 3-foot exhibition screen; this is sufficient to give a satisfactory image, owing to the retention of vision by the human eye, as described in the first part of this article.

CHAPTER VIII

Experimental Information

As early as September, 1919, Leroy J. Leishman described the construction of a television machine in the *Electrical Experimenter* of that issue. The second part of the article appeared in the October, 1919, issue of the same publication. Both portions are reproduced herewith because some readers will undoubtedly be interested in securing this simplified explanation.

It is a very simple matter to *telegraph pictures*. A crude machine for this purpose was suggested seventy years ago. The idea is therefore not entirely new to students of electricity.

How little the general public knows of *telephotography* is shown by the fact that when two of my machines were exhibited on the Orpheum and Pantage's vaudeville circuits two years ago, the demonstration was fascinating, baffling and uncanny to the audiences everywhere. Even most of the newspapers had never heard of such a thing previous to these demonstrations.

Even to this day a person with an electric picture transmission machine may entertain and baffle his friends and townspeople, besides conducting a great deal of experimenting which will be instructive and highly beneficial to himself.

At the time this article appeared, popular interest in telephotography was heightened by the use of telegraphed pictures by many of America's leading newspapers. Several papers published "news pictures" periodically, *and pictures had been telegraphed across the continent at regular intervals and displayed on bulletins.* The practicability of the scheme as shown by the fact that excellent pictures had been transmitted 4,856 miles! Many newspapers had subscribed for a service that supplied one hundred and fifty news pictures a year, making it possible for them to publish a picture of an event the day it happens, regardless of geographical location or distance!

The person with the necessary apparatus to telegraph pictures will find himself the center of interest everywhere.

It has often seemed puzzling to me why more electrical students have not experimented with telephotography. Many letters which I have received lead me to believe it may be due to a popular misconception that such experiments are too costly. I therefore designed some *Picture Telegraphing Instruments* which are lowpriced enough to suit every experimenter who may be interested. To further interest the readers in this fascinating and instructive field, I am explaining in this article how a simple telephotographic set can easily be made. However, the chief fascination and instruction is in the operation of the finished machines and in the various experiments that can be made with them.

No exact dimensions will be given for any of the various parts, as the material at one's disposal sometimes makes it advisable to change some of them; and then the others must be altered accordingly.

General Design Features of Apparatus

Let us first get an idea of the general appearance of the device we are going to make. A glance at figures 1 and 2 will show that the machine resembles very much an old style cylinder phonograph. The cylinder of the picture transmitting machine holds the pictures to be telegraphed in the same manner that the phonograph cylinder holds the record to be played. The sending and receiving carriage corresponds with the phonograph reproducer, and it passes slowly from one end of the cylinder to the other on a threaded shaft as the cylinder revolves. In this manner the carriage needle finally touches every part of the picture. The threaded shaft on which the carriage travels *must* be absolutely parallel to the cylinder. The reproducer on a cylinder phonograph has a half nut that rests against the threaded shaft, so that the reproducer may be lifted up and moved to the other end of the cylinder. This necessitates another shaft, parallel to the threaded one, on which the reproducer pivots. A picture transmitting machine is similarly equipped.

The size of the complete apparatus depends upon the dimensions of the pictures to be telegraphed, as this determines the size of the cylinder; and the shafts and

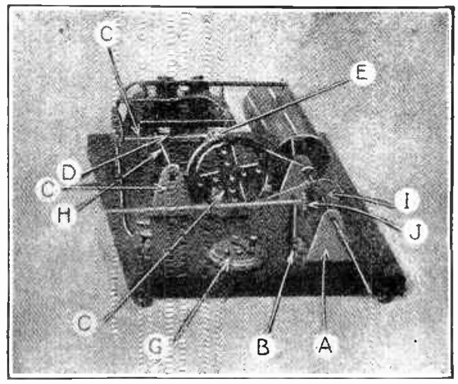


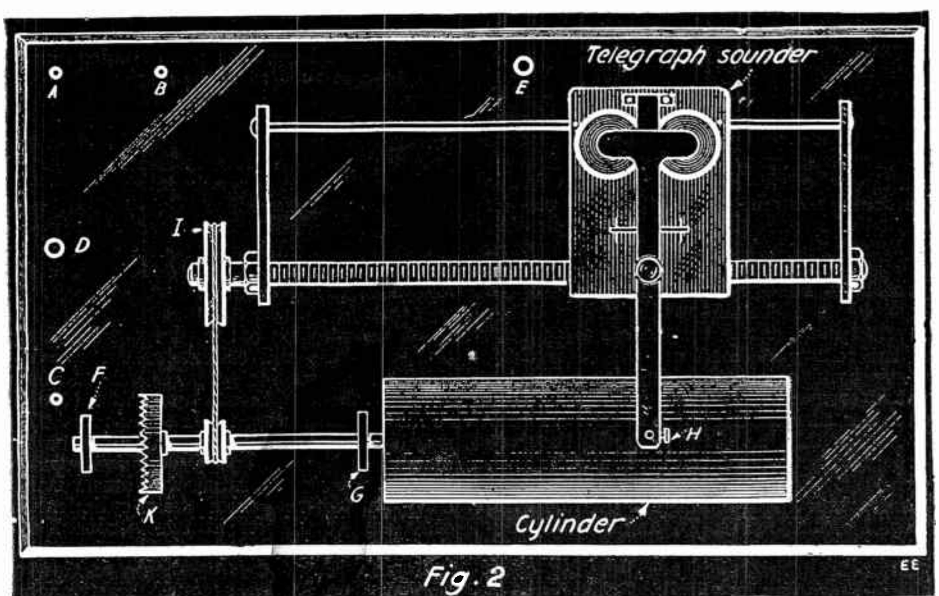
Fig. 1. The telephotographic machine here described. It opens up an era in scientific experiments for the electro-mechanical student and provides a stepping stone to this newest branch of applied science.

base must be proportioned accordingly. A convenient size for the picture is about 5 by 6 inches. As plenty of margin must be allowed, this necessitates a cylinder about 2 inches in diameter and 5½ inches or 6 inches long. Electrical contact must be made with the rolled copper plate which is slipped on the cylinder, so it is most convenient to make the cylinder from metal tubing. Ordinary pipe will not do; as the cylinder must be very true and perfectly uniform thruout. Brass or nickel-plated fixture tubing is excellent. A metal bar or disc must be soldered in each end, and holes accurately drilled in the exact centers to fit the shaft. As the cylinder is light and supports no great weight, the shaft may have a small diameter, so a rod can be selected for this purpose which will fit the gears available. Erector, Meccano or other rods are satisfactory, and can easily be fitted with gears which are obtainable in the regular sets or at any hardware store. The cylinder rod should be 3 or 4 inches longer than the cylinder and must be *perfectly straight.* Place it thru the holes in the cylinder ends and solder it so that one end is flush with one end of the cylinder.

After the cylinders have been made, the length of the base can be decided upon, as this dimension should exceed that from one end of the cylinder to the other end of its shaft by about 4 inches. The width of the base should be 8 or 9 inches. It is inadvisable to make these bases from metal, as short-circuits are too liable to occur. Wood is good enough.

Five holes are to be bored in each base as indicated in Fig. 2. A and B are for binding posts. C should be a small hole to accommodate a piece of annunciator or magnet wire. D and E should be large enough for two flexible cords such as that used for light drops. Do not bore E until the machine is practically completed for reasons that will be apparent later.

The uprights A (Fig. 1) that support the cylinders must be made of metal. They can be triangular shaped, and should have half an inch of the lower edge turned up to a right angle for affixing to the base (see B, Fig. 1). From this angle to the hole which is to be bored at the top for the cylinder shaft the distance must be at least a half inch more than the radius of the cylinder. The holes in these must be bored exactly the same distance from the bottom, *so that the cylinder will be supported absolutely level.*



Top view of telephotographic machine here described in detail. The parts required in building it are few and simple, but should be made with as great an accuracy as possible.

The cylinder should be mounted close to the opposite edge of the base to that near which the holes were bored for the binding posts. The binding posts are at the back of the machine, and the cylinder at the front. Mount the cylinder and shaft so that the cylinder comes about 3 inches from the end of the base, leaving about 1 inch between the end of the rod and the other end of the base. One support should be placed against the cylinder and the other about 1 inch from the end of the shaft (see F and G, Fig. 2). Screw the supports in place so that the cylinder is parallel to the edges of the base, and then place the cylinder rod through the holes provided for the purpose. If Meccano or Erector material is used, collars can be obtained for keeping the cylinder and other parts in place.

Now get a cold-rolled steel rod about 3 inches longer than the cylinder and about ¼ inch in diameter. Have this threaded within a half inch of one end and an inch of the other. No particular pitch is essential, as the progress of the carriage can be governed by other means. The unthreaded ends must now be turned down to the same size as the cylinder rod, so that the same make of gears or pulleys will fit. Then secure a rod about a half inch shorter than the threaded shaft. This rod can be of the same diameter and material as the cylinder shaft.

The height of the supports for these will vary with the material at your disposal for the carriages, which can be made from ordinary telegraph sounders by soldering an extra piece on the end of the arm where the spring is attached. This piece can be the same width and thickness as the original arm of the sounder, but must be at least 3/16 inch square. The length will be dependent upon the diameter of your cylinder and the way the sounder is mounted on its own base. Hold the sounder level and at the same height as the cylinder rod, keeping the end of the sounder with which we are concerned toward the cylinder and the base of the sounder at least ½ inch behind the cylinder. The addition to the arm must be long enough to extend about ⅛ inch beyond an imaginary line perpendicular to the base of the whole machine and extending through the center of the cylinder when the carriage is held in this position. The phonograph needle, to be placed in the end of this extension arm, will then touch the cylinder right at the top. Drill a hole the size of a steel graphophone needle down through this extension arm about ¼ inch from the end, when measured from the top, and slightly less than 3/16 when measured from the bottom, so that the needle will set at an angle of thirty or forty degrees. As the needles must be changed, a thumb screw (H, Fig. 2) should be placed in the right side of this arm to hold the needle in place. A Victor or Columbia graphophone thumb screw is satisfactory, and most phonograph repair shops have taps to thread holes to fit.

If you do not have two sounders—one for each machine—the essentials for making the carriage are merely the needle arm, the fulcrum, a pair of electro-magnets, a bar for the magnets to attract, a coiled spring, and a stop to prevent the arm from moving too far up or down.

Under the front of the carriage, near each side, some sort of threaded half-nut arrangement must be provided. It is satisfactory to use a couple of pieces of tin with the edges turned down and slotted approximately to fit the screw or threaded shaft. Place one at each side. Under the back of the carriage two screw eyes can be used for the guide rod to pass through.

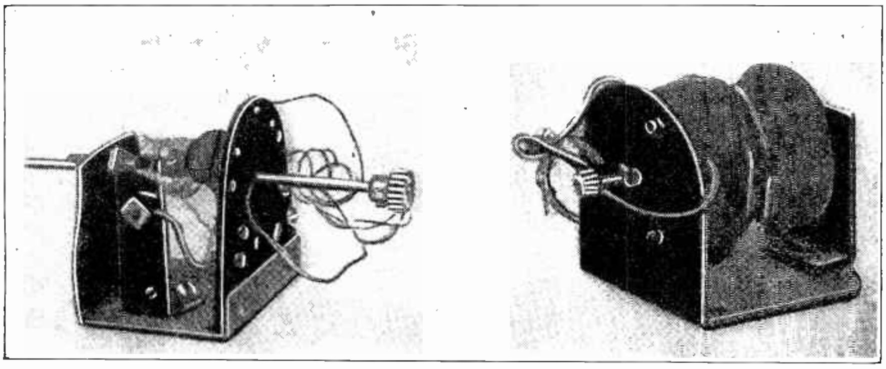


Fig. 3. A simple electrical synchronizer apparatus for operating two telephotographic machines. The commutator of the motor is used at the transmitter and the motor at the receiver.

The height of the uprights or supports C (Fig. 1) for the guide rod D and threaded shaft E can now be determined. They should hold these rods at a height which will support the carriage so that the end of the phonograph needle in the end of the arm will touch the cylinder when the arm is in its downward position. These supports can be made of metal, like those for the cylinders, or else from wood. Separate supports can be made for the screw and rod, or else double supports with two holes. The screw and rod must be absolutely parallel, otherwise the carriage will catch or bind. They must also be parallel to the cylinder, but not necessarily in the same plane. This means that great care must be taken in boring the holes in the uprights so that the screw and rod will be not only the proper distance from each other, but absolutely the same distance from the base throughout. Be sure, therefore, that the rod and threaded shaft are straight. Mount these so that the rods extend the same distance beyond each end of the cylinder, and so that the front of the mounted carriage comes about ¼ inch behind the cylinder with the needle at the top of the cylinder directly above its center.

The only place in the whole set of machines where pulleys can be used instead of gears is in connecting the threaded shaft and the cylinder. The pulley I (Fig. 2) for the screw must be larger than the one on the cylinder rod, the exact size depending on the pitch of the threads and how dark or light you may desire the telegraphed pictures to be. The cylinder should make from 60 to 120 turns while the carriage travels 1 inch. After the pulleys are placed on the rods and lined up, put on a cord, elastic band or spiral spring for a belt.

It is essential that the cylinders of both machines turn as true as possible. If they do not do this, bend the rods till they are as perfect as you can make them.

Hole E (Fig. 2) should now be bored about a half inch behind the guide rod D (Fig. 1) and J (Fig. 2), and midway between its two ends.

After both machines are this far completed, they may be wired. Get a piece of flexible fixture cord and cut two pieces about 2 feet long. Peel the ends and scrape the strands of wire till they shine. Inasmuch as it is difficult to tell which one of the wires you want after they are drawn through the base, it is best to twist both ends of one of the wires in such a way that it will be recognized from the other. Put a pair of these wires through the hole E in the base of one machine, and use the other pair in like manner for the other instrument. Attach one wire to the terminal of the magnet windings on the carriage, and also ground it so that it is electrically connected to the metal arm bearing the phonograph needle. Connect the other end of the same wire to one of the binding posts. The other wire should be connected to the other side of the carriage magnet windings, so that a current in both wires will energize the magnets and lift up the needle. The remaining unconnected end of these wires should be drawn through hole D (Fig. 2), where it is to be connected to the right side of a two-way battery switch G (Fig. 1). The slack in this wire should be pulled above the base to give the carriage plenty of play. A piece of magnet or annunciator wire should lead from the left contact of this switch through hole C, and be grounded to the support of the cylinder rod. The main terminal of the battery switch must be connected to the other binding post at the back of the base. Both machines must be connected the same way.

Now suppose we examine these circuits. First turn the battery switch to the contact at the left—the position used when "sending." The current now comes from the binding post to the switch, through the right contact to the upright and through the rod to the cylinder, thence through the needle down one of the flexible wires to the other binding post. When the switch is thrown to the right or "receiving" position, the current passes to the carriage magnets.

Excepting for the gear connections, the machines themselves are now completed, but as no picture can be transmitted unless the cylinders run in synchronism, I shall first explain three ways to synchronize them before showing how to prepare and transmit a picture.

We can use a rod connection, or one of several different electrical schemes which permit the machines to be operated at long distances away from each other. However, only two electrical synchronizers will be explained. The simplest and least fascinating way to synchronize the machines is by a rod connection H (Fig. 1), with the instruments only a few feet apart. A few rods, such as those used for shafts, can be connected with couplings and one machine placed at each end with the cylinder rods toward you. Make two or more supports for this connecting rod to hold it at the same height as the cylinder shafts, to which it runs at right angles. Place a crown gear I (Fig. 1) or K (Fig. 2) on each cylinder rod, with the teeth turned toward you on one machine and away from you on the other. Now slip an upright on both ends of the synchronizing rod and place a small gear J (Fig. 1) flush with each end to mesh with the crown gears.

Fix the uprights or supports in place so that the proper connection is maintained and so that both machines run together, regardless of which cylinder is turned. The machines may be operated by a crank attached to the end of one of the cylinder rods, or by a motor properly geared down.

The cylinders themselves must turn at about one revolution in three seconds. This may seem quite slow: but it must be remembered that this is a very inexpensive home-made set, and that T. Thorne Baker and Dr. Korn operate their cylinders at only one revolution in two seconds, and that the most delicate sets for one of my systems utilize drums operating as slow as a revolution in one second. Faster work can be done with some of my latest appa-

(Continued on page 109)

TELEVISION

Tubes

For Amateurs and Experts

Actual Size

PHOTO ELECTRIC CELL
VISITRON-5
LIGHT WAVES TO ELECTRIC WAVES

THE *Visitron* and *Neotron* Tubes are the last word in television equipment. They are finished, perfected and thoroughly tested in our own extensive laboratories by television experts who understand the science. They know the needs of amateurs and also those of scientists.

These tubes may be used either in telephoto work (recording of illustrations upon sensitized plates) or for television—the transmission of motion pictures.

The *Visitron* is practically instantaneous in response to every visible light impulse. It is the unit used to transform light variations or pulsations into corresponding electric impulses which are amplified by regular radio amplifiers (either resistance or transformer coupled). From these amplifiers the current is passed through the light valve or *Neotron* and thereby converted into light impulses.

The *Neotron* is a highly efficient light source which may be easily modulated. It operates at moderate voltage from ordinary radio amplifiers.

These tubes are being used commercially every day in connection with television work and the concerns using them report that they are serving very satisfactorily; in fact, they are very enthusiastic in their praise of the *Visitron* and *Neotron*.

Visitron 5. A standard size photoelectric cell of very high sensitivity. Used in television systems where light at transmitting end can be focused to enter the one inch window of the cell. Bulb about 1½ inches in diameter. Bakelite base is standard X-type with four prongs, two for support only. Anode and cathode (positive and negative connections) are clearly marked on base. Price prepaid, $18.00.

Visitron 15. Exceptionally sensitive photoelectric cell. Three inch bulb with two inch window. Suited for television transmission where light received by cell is over wide range. Pairs well with *Neotron 35.* Price prepaid $35.00

Visitron 21. Very small, for use where high speed and low capacity of cell circuit are desired. Less than 1 inch in diameter. Mounted complete in standard X201A radio tube base. Sensitized cathode less than 1 centimeter in diameter having very low electrostatic capacity. Price prepaid $22.00

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ELECTRIC WAVES TO LIGHT WAVES

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G-M SCIENTIFIC INSTRUMENT CO.

URBANA, ILLINOIS

Chapter V. The Korn System

(Continued from page 27)

tween the light and the selenium cell. Consequently, there will be a varying current of electricity passing through it, and this current will vary in strict accordance with the lights and darks of the picture. Since the spot of light passes over every part of the picture in the same way that the sharp stylus traverses the tinfoil image in Meyer's apparatus, we will have our whole picture translated into a varying electric current that flows to the receiving station.

Now for the receiving apparatus whose purpose it is to accomplish this translation we again have, of course, the inevitable rotating cylinder. We have also an electric light as before and a lens to focus that light into a very small spot on the cylinder. Over the cylinder is wrapped a piece of sensitized photographic paper.

But before the light can reach the paper it goes through a very small window, which window is normally closed by a very fine wire stretched between the two poles of a powerful electro-magnet. When a current flows through this wire it moves sidewise between the poles of the electro-magnet, and in doing so uncovers the window, allowing light to pass through to the photographic paper. If only a small current passes, the wire will not move very far, and not much light will get through, but if a large current comes in over the line the window will be entirely uncovered and all the light will get through to the sensitive paper.

The Jenkins System

(Continued from page 42)

light to sweep across the picture in adjacent parallel lines, until the whole surface of the picture negative is covered."

This newly designed optical shape in glass, for which a patent has been granted, is the heart of this invention. By use of these revolving glass rings, the lights and shadows that constitute a photograph are built up, line by line. The dense areas make highlights; less opaque parts of the surface, the half-tones; and extremely thin areas, the shadows of a picture.

From these revolving plates of glass the light beam goes to a dark box, containing a so-called photo-electric cell (selenium or other chemical sensitive to light). A "chopper" in the pathway of the light beam, located between the optical rings and the photo-electric cell, causes the light beam to shoot up and down about 500 times a second. An oscillating device would also serve this purpose. The light characteristics are then converted into electric current characteristics by passing through a transformer. At this point two stages of amplification are introduced in a conventional wireless sending set, after which electro-magnetic waves become the vehicle for broadcasting pictures just as music and speech are now universally disseminated. An antenna, extending fifteen feet above the three-story building in which the Jenkins laboratory is housed, completes the equipment both for sending and receiving photographs by wireless. He also maintains transmitting and receiving outfits at his laboratory in his home on Sixteenth street.

When these modulated wireless waves arrive at the receiving point, whether it be in an adjoining room or seven miles away, as in the case of the sending of the pictures of the Government officials, the electric characteristics are re-converted into picture characteristics. This is accomplished by duplicating the apparatus at the transmitting station, namely, by use of two pairs of the newly shaped optical glass rings. Two methods of receiving pictures have been devised by Mr. Jenkins, both of which employ an ordinary radio-telephone receiving outfit.

Certain additions, however, are made to the wireless receiving set. On the metal diaphragm of the receiver is mounted a tiny mirror, which vibrates in accordance with the diaphragm as the wireless oscillations are recorded. Focused on this mirror is a strong ray of light, which is reflected through a shutter when the mirror is stationary. As the electric impulses are set up by the transmitting station, this mirror oscillates with the metal diaphragm on the receiver and the reflected ray likewise oscillates across the shutter hole. Consequently, when this diaphragm is vibrating widely more light from the ray filters through the aperture than when the vibrations are narrow. The electric current variations received by wireless are accordingly transformed back to light variations. The latter are impressed on a sensitized photographic plate, and the final product is a faithful reproduction of the picture broadcast from the radio-transmitting station.

However, these light variations must be reproduced in perpendicular "strips" or "slices" across the area of the photographic plate just as they were originally transmitted from the sending station. Here, again, the new formation of optical glass —or prismatic ring, if you please—are indispensable. These unpretentious chunks of glass, to tell more of them, are circular in appearance and about 10″ in diameter. The rim of each of these glass rings is beveled so as to form a prism of spiral shape and of gradually increasing thickness at the edge. As the beam of light or picture characteristics from the reflecting mirror strikes these revolving prisms, a pair being used because of slight error in one unit, it is bent along a perpendicular path downward across the photographic plate. The procedure is repeated until, line by line or section by section, the original photograph is in complete form.

The second method for the reception of broadcast pictures, and the one more recently applied by Mr. Jenkins, involves the sending of the electric current as amplified by radio apparatus through a specially designed incandescent eletric-light bulb. The filament of same is surrounded with hydrogen. Approximately two volts of electric energy from a storage battery are conveyed constantly through this filament so as to produce a red glow in the bulb. As the electric or amplified radio current varies in intensity it is reflected by this filament—thus lighting up or being dimmed as half-tones, shades or other picture characteristics are reflected directly on the photographic plate.

Not only does the Jenkins invention permit of the broadcasting of camera studies by that popular vehicle, radio, but prints and plates may be eliminated and the likeness of a subject sent out through space offhand. In fact, this wonderful feat has already been achieved. In the laboratory of the inventor, a girl placed her face against a window as a means of steadying herself and her likeness was transmitted on electro-magnetic waves to the laboratory of Mr. Jenkins, on Sixteenth street, about five miles distant. The image of the subject was illuminated by daylight.

Telephotographic Apparatus

(*Continued from page 106*)

ratus; but the system is far different from the one for which these machines are used, and the machines are too costly and complex for the average experimenter to build. So let us be content with one revolution in three seconds.

A Simple Electrical Synchronizer

A simple electrical means for synchronizing the two machines utilizes a motor for one machine and its commutator for the other. (See Fig. 3.) The armature of the motor is separately excited and has but two poles; while the field has three poles connected in series, with the connections tapped between the magnets for the three wires which extend to the three segments of the commutator of the other machine. Two diametrically opposite brushes rotate against this commutator and cause the field to rotate in synchronism. The current can be supplied to the brushes by collector rings. As before mentioned, the armature of the motor is separately excited.

The shaft supporting the brushes must be geared (nothing but gearing will do) to the sending machine, and the motor must be geared in exactly the same manner to the receiving machine. The sending machine can be operated by hand or by a motor as desired, and the receiving machine will then operate in exact synchronism.

An Automatic Electrical Synchronizer

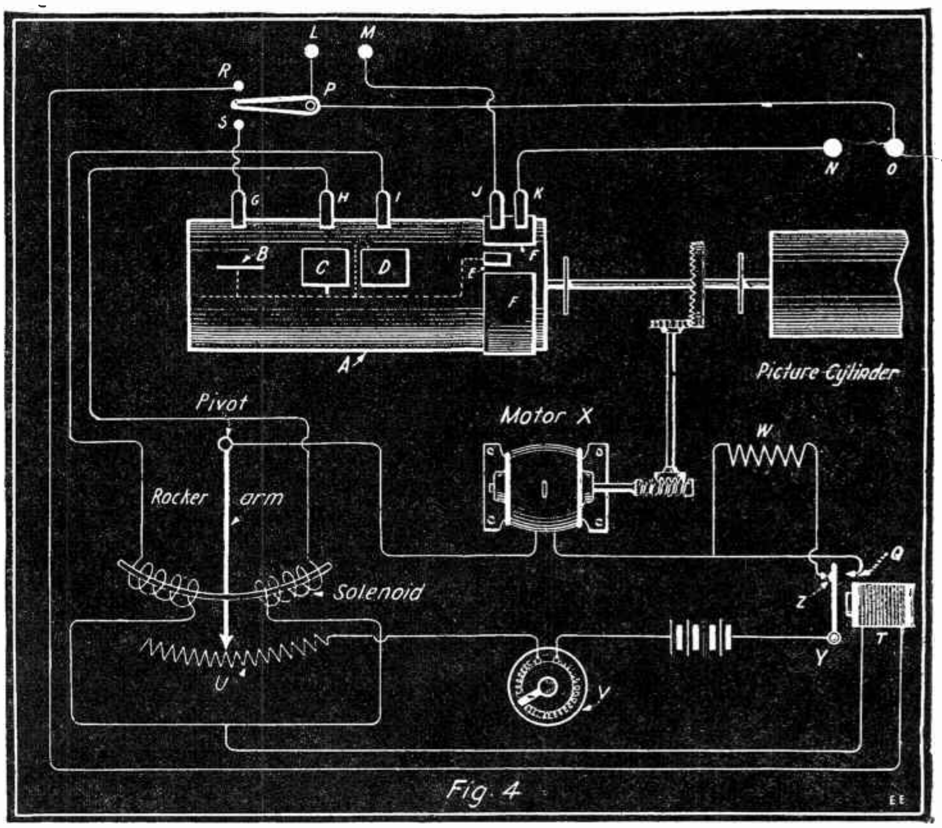
The most interesting and ideal synchronizer of all requires no extra wires whatsoever. The principal part is a wooden or other non-conducting drum A (Fig. 4), the shaft of which is connected to the shaft of the cylinder upon which the pictures are sent and received. B is the edge of a piece of metal electrically connected with the shaft. C and D are pieces of graphite connected on opposite sides to metal strips or wires which are in turn connected with the shaft. E is a narrow piece of metal also connected with the shaft. F is a metal band much wider than E which extends around the cylinder from one side of E to the other, but does not touch E, as E and F must be insulated from each other. G, H, I, J and K are brushes. J touches both E and F as the cylinder revolves, but K touches F only. L and M are binding posts to which the wires are attached that come from the distant machine. N and O are the binding posts of the particular picture transmitting machine to which the synchronizer is attached. H and I are connected to two solenoids into which the horns of an iron rocker arm protrude. There is sufficient friction in the pivot of this rocker arm to keep it from turning excepting when the solenoids are energized. U is a rheostat with which a brush on the rocker arm makes contact. V is also a rheostat, and W is resistance in series with the motor. T represents the electro-magnets of a gravity relay, the arm of which rests against the stationary contact Z until T is energized, after which it rests against the contact Q. R. S. P is a two-way battery switch. X is a motor that is geared down to operate the picture transmission machine proper. The electrical connections are all shown in the diagram.

If this type of synchronizer is to be used, one must be made for both machines. The particular advantage of this type over all others which require no additional line wires lies in the fact that the cylinders are permitted to revolve continuously and are not stopped momentarily each time a revolution is made.

Now let us see how this synchronizer operates. With the arm of relay T against Q, we adjust the rheostat V so that the motors X of the sending and receiving machines run as nearly as possible in synchronism when the contact of the rocker arm is in the center of U. The synchronizer is now ready to operate.

Of course, we have not yet explained how a picture is prepared or transmitted, but you know that the needles on the carriage arms must be in contact with the cylinders. Until the machines are running in synchronism, we therefore do not let speed of the motor on the sending apparatus.

The accurate synchronizing now goes on automatically. You will remember that the current to the resistance pieces C and D comes from metal strips on opposite sides. When the synchronizing impulse comes in, when H and I are in the exact centers of C and D, the currents in H and I are therefore equal. The solenoids also receive equal current and keep the rocker arm in the center of U, supplying the motor with a uniform amperage. If the receiving machine gets slightly behind or ahead of the sending machine, the brushes H and I will be slightly above or below center, and one brush will be nearer the metal strip which



Layout for improved electrical synchronizer to be used for operating telephotographic transmitting and receiving apparatus here described.

the needles rest on the pictures, as everything transmitted before synchronism is established would be distorted beyond recognition.

On the sending outfit put the arm of the gravity relay against Q, and put the two-way battery switch on S. The motor of the sending machine is now started, and by studying the diagram you will see that a circuit is completed every time B and E come in contact with G and J, respectively, causing an impulse to be sent over the wire once every revolution. Start the motor of the receiving machine with the relay arm against Z, and throw the battery switch to R. This motor is now going slightly slower than that of the other machine, because it is in series with the resistance W. The motor of the sender is not in series with its resistance, as its relay is against Q instead of Z. On account of the slower motion of the receiving cylinder, the brushes are on a different part of the circumference of the drum A each time the once-every-revolution impulse comes from the sending machine. The brushes H and I are therefore finally on C and D when this synchronizing impulse comes. This causes the current to go through the solenoids and the relay T, the arm of which is pulled from Z to Q, thereby cutting out the motor resistance so that the motor will of its own accord run at the approximate supplies the current to the resistance, and the other brush will be further away. One brush, therefore, carries more current than the other, and one solenoid will pull harder than its companion, causing the rocker arm to change its position on the rheostat U, thereby correcting the speed of the motor. The function of E, F and K is to distribute the current alternately to the synchronizer and the picture machine proper.

If this synchronizer seems too difficult or costly to make, the other synchronizer may be used or else the rod connection employed. In the latter case, your picture transmitting set will have been very easily and inexpensively constructed, and the degree of excellence of the received pictures will not be lessened in the least.

The machines are now ready to be adjusted. When sending, the needle in the carriage arm may have a play of as much as a quarter inch. It must at all times touch the cylinder and should there be any sort of bulge in the rolled transmitting plate, this much play is necessary so that the bulge will not raise the needle beyond its play and throw the half nut on the bottom of the carriage out of mesh with the threads on the shaft. For receiving, the needle must be very delicately adjusted. It must rest on the cylinder when the magnets are not energized, and when raised up it should be just high enough to clear the cylinder at all points on its circumference. The less upward and downward motion the needle has the faster it will operate and the better the pictures will be.

Extend a wire from one of the binding posts of one instrument to one of the binding posts of the other. The remaining posts must be connected to the batteries—preferably two dry cells. If the last explained synchronizer is used, these wiring directions may be considered to apply to the synchronizer binding posts instead.

Transmitting Pictures

Before transmitting half-tones, you can write or draw with shellac upon a thin metal plate and transmit this. After the shellac is dry, roll the plate into a cylinder and slip it over the cylinder of the machine you are going to use for transmitting. Place the edges at the top of the cylinder with the overlapping part of the cylinder toward the carriage, and if the plate is put on as explained the overlapping edge will not strike the needle and cause trouble. Put heavy rubber bands around the ends of the plate to hold it firmly against the cylinder.

Receiving the Pictures

To receive the picture, you will need a sheet of ordinary white paper and a piece of pen carbon paper. The carbon sheet goes on the cylinder face down around the white paper. If the rod connection or the first explained electric synchronizer is being used, be sure that the edges of the paper are placed at the top. If you are using the synchronizer which requires the extra cylinder or drum, the edges of the paper when placed on the picture cylinder should be in a straight line with the resistance pieces and the copper strip. This also applies to the copper sending cylinder. Overlap the ends of the paper toward the carriage, the same as you did with the plate. If you should carelessly overlap it the other way, the needle will catch the edge of the paper and tear it off. Be sure that the carbon sheet fits *tightly* against the white paper. Secure these to the cylinder with rubber bands.

Put the carriage at one end of the cylinders with the needle in contact with the same. Now place the switch on your sending instrument at the right and on your receiver at the left. Start your motors, or else turn the cylinders with a crank. As before mentioned, the speed should be about one revolution in three seconds.

By the time your carriages have advanced to the other side of the cylinders the picture is finished. As long as the needle of the transmitting instrument is on bare copper, the current flows, energizing the electric magnets of the receiving carriage and causing the needle to be raised out of contact with the carbon paper. Whenever the shellac comes under the needle the current is broken and the spring holds the receiving needle against the carbon paper, thereby making a mark. In this way the transmitting of the entire picture is accomplished.

In the inexpensive sets that I mentioned having designed for the market, half-tone pictures were supplied already prepared on copper for transmission; but there is some satisfaction in having them prepared yourself. Any photo-engraver can do it. You should have a photograph without too much detail and with considerable contrast—that is, black and white. Better results are possible if the photograph has a glazed finish. Obtain a sheet of thin polished copper of a size that will roll to fit the cylinders. Tell the engraver that you want him to proceed as if he were going to make a half-tone on this copper plate, but that he must stop after he has cooked his gelatine to a dark chocolate color. *It must not be etched.* Tell him you want the screen to be no finer than 25 or 30. He undoubtedly will have no screen this coarse, so instruct him to make a small zinc half-tone cut of 40 or 65 screen, and to make a print from this. Then have him make an enlargement of this print, without his screen, until he has the 25 or 30 mesh which you desire.

This plate is rolled and the picture transmitted just the same as the shellac drawing.

Pictures do not have to be received with carbon paper. Your apparatus will permit the use of a few other methods. Smoked paper or wax-coated paper will do. If the former is used, however, the received picture will be a negative unless a negative is used for transmitting. Various other plans of receiving may be experimented with and will be found very interesting to the experimenter.

Pictures may be received without any carbon paper by turning the switch of the receiving machine to the right or sending position and utilizing a sheet of paper soaked in a solution of the following proportions:

Nitrate of ammonia, 4 pounds; ferricyanid of potassium, 1 ounce; gum tragacanth, 4 ounces; glycerine, 4 ounces; water, 1 gallon.

The paper should be kept moist while the picture is being received. Like the smoked paper, this produces a negative when a positive is being used for transmission, and a positive when a negative is being sent. These visible ways of recording make a much more interesting demonstration, although the picture is not as good.

Of course, there are ways to telegraph pictures which are radically different from those explained here, but only the simpler ways are given so that the apparatus can be constructed easily and cheaply.

The experimenter will find telephotography a very interesting, instructive and fascinating field.

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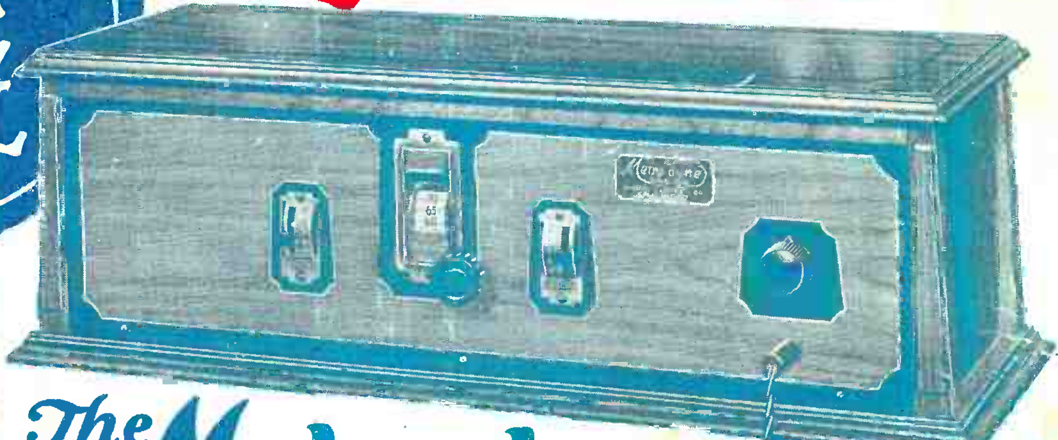

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