ABC of TELEVISION

SHORT WAVE AND TELEVISION

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THE ABC of TELEVISION

Including

Fundamentals of Scanning
Mechanical Systems
Cathode Ray Systems
Transmitter Operation
When Will We Have Television?
List of Stations

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PREFACE

THE question, "When will we have television?" is heard more and more frequently these days, particularly since television is again coming into the newspaper headlines through demonstrations by Philco, Farnsworth, RCA, and others. While it is emphasized by all these interests that television will not be ready for the public for some time to come, still public interest has been aroused and there appears to be a general desire among those who are well based in radio but who have not kept abreast of television to learn more of what will undoubtedly be a great future industry. It is quite possible to build a television receiver which will intercept the present broadcasts, and while it is beyond the scope of this book to detail such equipment, we have endeavored to cover the principles as well as possible in the hope that the builder's interest will be stirred to such a degree that he will look for more detailed knowledge on the subject and will seek to enter the field actively.

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TELEVISION FOR THE BEGINNER

CHAPTER 1

The following constitutes a simple review of the operation of the simplest television equipment, and gives the analogy between television scanning and the eye.

• WHEN considering the subject of television, we must remember that not all television equipment is complicated. The common telescope is the simplest and most well known of all television "machines". Here we have an apparatus which will pick up a distant scene and bring it up to the eyepiece with the utmost clarity. No transmitter is required, the object being viewed acting as the transmitter.

But of course, the telescope has its limitations. The conditions between the "transmitter" and the "receiver" (telescope) must be perfect—there can be no objects or poor atmospheric conditions to hinder the passage of the light rays. And too, the telescope only makes the distant scene available to the human eye; it does not reproduce the image, for the eye must do this.

When the first serious idea of the transmission of sight to a distance was conceived, more than fifty years ago, the human eye formed the natural basis of the design. Until now it has been impossible to rival the product of Nature, because of her unlimited ability to disregard expense; but a consideration of her methods may still afford useful hints to the inventor.

When George Corey published the first television design, he proposed a lens, as in the eye, projecting an image on a sensitive surface, also as in the eye. The only light-responsive means then known was selenium connected to an external source of current; but there has since been devised the photoelectric cell, which, like the eye itself, actually produces a minute electric current.

The eye is merely a specialization of the skin to obtain extremely great response to light. Skin, unless calloused, has greater sensitivity than is popularly realized. In the lowest forms of life, the whole surface is light-sensitive, as well as capable of absorbing food. In oysters or scallops, there are rows of sensitive spots, which advise the creature when to close its shell. In lobsters, etc., and insects, the sensitive spots are collected together; so that their separate sensations make up more or less clear vision.

In still higher animals, and man, the sensitive spots are collected under a projecting lens, in a place where they are protected by bone; and equipped with muscular focusing and adjusting apparatus, to increase their efficiency. The retina, or light-sensitive rear wall of the eye, has millions of spots, each connected to the brain by a separate channel or nerve fiber corresponding to a telegraph line.

There is more or less sensitivity to light in the whole retina, except at the "blind spot" where the optic nerve enters. But the accurate determination of form and color is confined to the "yellow spot" (Macula Lutea), indicated in our illustration, which receives the image of whatever we are examining most closely.

This spot, about 1/6" wide and half as high, receives an image about as large as two faces side by side at 20 feet; it contains somewhere in the order of a hundred thousand separate sensitive spots; and sees about 1/5000 of the whole sphere around us. The eyes, however, very quickly and involuntarily change the direction of their attention; in fact, it is almost impossible to hold their gaze steady, upon the same point, for an appreciable length of time (try it!)

We may imagine, therefore, that a scanning system of 100,000 points would be equal to steady vision on the object of interest; but the instant the eyes of the observer are taken off it, the limitation of the image must be perceived. A television camera might be made to "wobble" slightly, to relieve this staring effect.

For its sensitivity, it is now agreed, the eye depends on a substance called "visual purple," which it produces, which is decomposed by light, to cause the sensation in the optic nerves we associate with "seeing". It is always active, even in the dark; a bright light on a spot in the eye will temporarily exhaust its seeing power until new "purple" can be obtained.

So we may image a television camera, built like the eye, with an electrolyte flowing around numerous photovoltaic couples each generating a small current falling into an amplifier. The problem of scanning is not essential to the pickup, but has

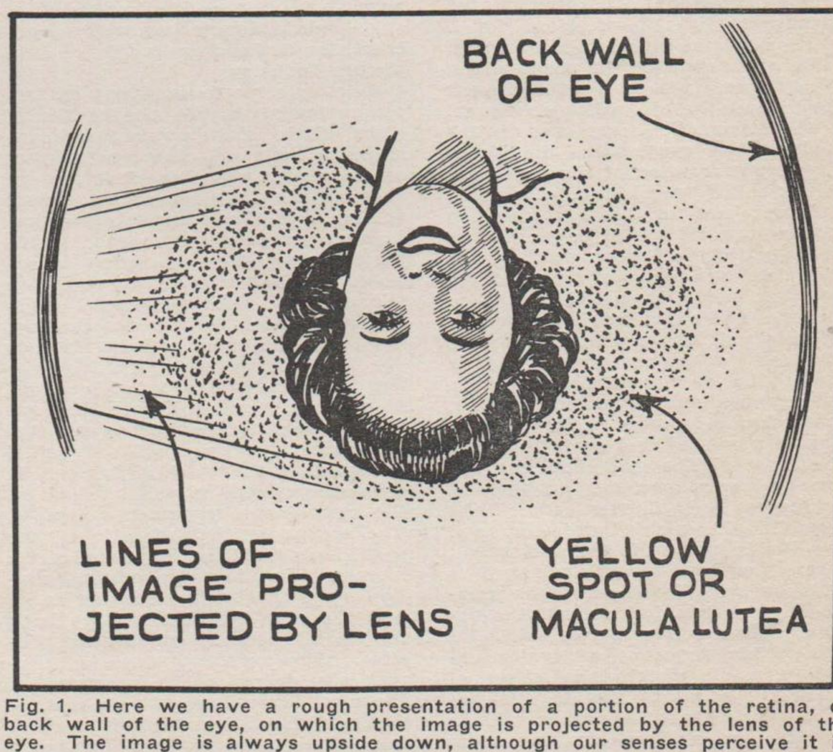


Fig. 1. Here we have a rough presentation of a portion of the retina, or back wall of the eye, on which the image is projected by the lens of the eye. The image is always upside down, although our senses perceive it in the proper position.

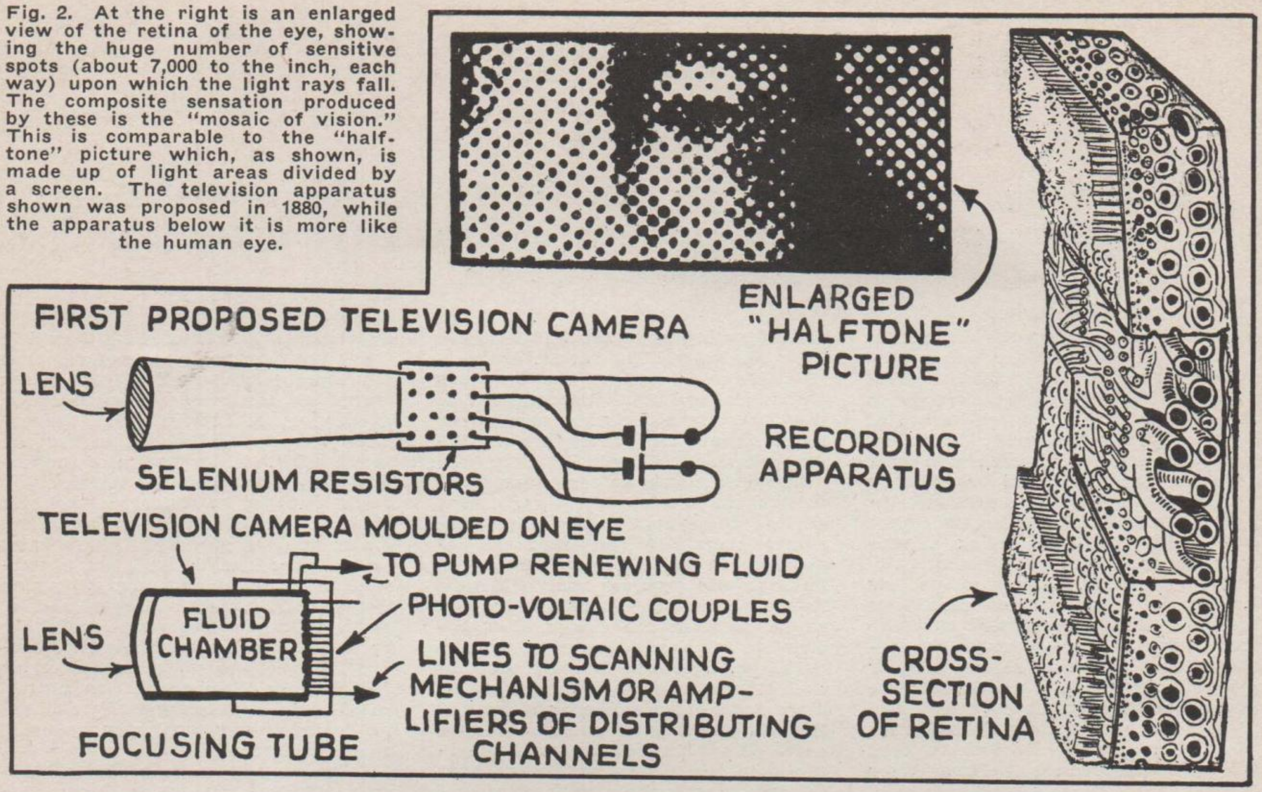


Fig. 2. At the right is an enlarged view of the retina of the eye, showing the huge number of sensitive spots (about 7,000 to the inch, each way) upon which the light rays fall. The composite sensation produced by these is the "mosaic of vision." This is comparable to the "half-tone" picture which, as shown, is made up of light areas divided by a screen. The television apparatus shown was proposed in 1880, while the apparatus below it is more like the human eye.

been forced on us by the problems of transmitting—since a million telegraph wires, to correspond to the fibers of the optic nerve, will cost real money to string and operate.

This brings up also problems of storing up light impressions for a fraction of a second, as the eye does.

We all know that the scene which the eye perceives does not disappear the instant the eye shifts elsewhere, or the instant the scene becomes invisible. The eye retains the image for a short fraction of a second, and this is called "persistence of vision". If it were not for this fact, common movies would have to be worked in some entirely different manner, for it is this persistence of vision of the eye that makes it possible for us to perceive and enjoy movie scenes. It is quite well known that the various "frames" or separate scenes of a movie film do not run through the camera in a smooth continuous flow. Each frame is stopped for a fraction of a second and projected upon the screen. The eye notes the image and retains it for an instant, during which a shutter cuts off the light in the movie projector, and the film is jumped to the next scene, when the light is again allowed to pass through. By this time the previous image has faded from the retina, and the new image takes its place, this sequence of cycles enabling us to obtain the effect of smooth continuous motion. It has been found that the motion will be satisfactory and without apparent flicker if the film passes through the projector at the rate of about 24 frames per second and this is the standard speed of movie machines. It is also the average speed of most television systems, although some may be faster and others slower, since this industry has not as yet been standardized as has the motion picture industry.

We now come to another very important point in the phenomena of sight. This is the subject of scanning. A little reflection on the part of the reader will show that the eye does not view any complete scene all at once, but that it travels over the scene in irregular movements, building the image upon the retina in sections. To make our analogy between the eye and television more easily understood, let us consider reading, since this is a more orderly procedure for the eye than the more or less haphazard viewing of a scene. In reading a printed page the eye travels from left to right over a line comparatively slowly while the mind is digesting the subject matter. It then snaps back to the left end of the next line to repeat the process. The return to the left side of the page, however, is accomplished much more rapidly than the original motion since there is no reading to do and the only object is to get back to the left side as quickly as possible. Also note that the eye automatically drops to the beginning of the next lower line rather than return to the beginning of the original line, and it thus follows a rather regular zigzag path. This is the theory of television scanning and every practical system now in use is based upon this zigzag movement.

There are many experts who believe that this scanning system is all wrong and that some method could be discovered and made practical whereby the whole scene could be sent out at once. If this is so, a great deal of the present complication of television could be removed, since most of the trouble is now had with the so-called synchronization of the transmitter and receiver. It will be easily seen by the most uninitiated that if the transmitter scanner is at the upper left corner of a scene, while at the same instant, the spot of light in the receiving scanner is at the lower left corner of the picture it is building on the screen, a conglomeration will result which will be totally unlike the original scene. The transmitter and the receiver must be in exact step all the time, or as the engineers say, they must be synchronized. The equipment needed to bring about this result is highly complicated, as will be seen from later chapters.

The many various "systems" of television now in development differ most widely in the method of obtaining the scanning, and while there have been a large number of schemes proposed to bring about the desired result, only a few have been found practical, although most any of the systems can be successfully operated in the laboratory by trained technicians.

CHAPTER 2

A consideration of the Nipkow disc as related to television, as well as its shortcomings and a brief description of some other mechanical systems.

• THE development of television, up to the present time, is not far enough advanced to permit the transmission either by wire or by radio of a complete "still picture" at one time. We have to divide the picture up into many small areas and, by means of an equivalent electrical signal, transmit these small areas one after the other. This process of breaking up a picture or scene into elementary areas is known as **scanning**. We shall learn that the speed with which we reproduce these small areas determines whether we shall have a still or a moving picture.

Of vital importance in the process of scanning is the area or space to which the television pick-up system (the photo-cell) responds, and within which the subject or scene to be televised is confined. The area is defined as **the field of view**. In the present status of the art, the field of view is very limited.

We have said that it is necessary to transmit in rapid succession a series of elementary areas; which are then assembled at the receiving end, to form an image of the scene which is being televised. It is essential therefore that the light reflected from these elementary areas which are picked up by the photo-cell, deliver to the cell the maximum amount of light possible. We shall see that this is done by utilizing a series of **square** (or round) holes in the form of a spiral at the outer edge of a thin metal disc, known as a **scanning disc**.

Let us consider for a moment Fig. 3, which represents a picture area which has been broken up into many horizontal strips. Let us go one step further and choose a particular horizontal strip, such as No. 3 for discussion. You will notice that we have divided this particular strip into 24 squares.

If we were to take a piece of cardboard and cut into it a small square hole (slightly larger than the area of square No. 1, for example) and slide it over the picture horizontally along one particular strip, we would see through the hole a series of light and dark portions, such as squares Nos. 1, 7, 12 and 16. Square No. 1 is white, and its position is at the left-hand side of the picture. As we slide the strip along toward the right we begin to notice various shades of black and white, corresponding to the shades of the photograph. No. 7 is partly shaded, No. 12 is the darkest part of our picture and is entirely black. Having passed over the picture with our scanning hole (if we may call it that), we find the remainder of the photograph is perfectly white.

If we are able, therefore, to produce varying amounts of electric current, corresponding to the various shades which we observe as we slide along this horizontal strip, we will be able to transmit our picture by means of radio waves. The photo-electric cell is the device which changes varying light intensities into corresponding electrical impulses.

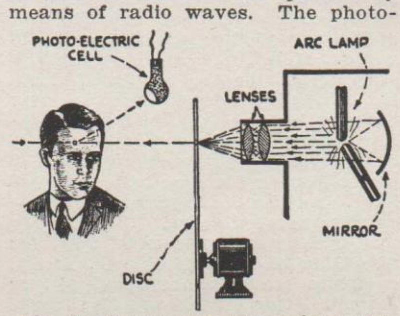


Fig. 4. Set-up of transmitter for scanning human face with disc.

Different objects reflect different amounts of light; it is this fact which has enabled engineers to develop television successfully. Let us look for a moment at Fig. 4, which represents a light source behind a lens for focusing the rays of light from the lamp to a small point, as shown in the diagram. At this particular moment the little spot of light is focused on the man's forehead, which will reflect a considerable amount of light. If we were to focus a spot of light toward the top of the man's head, not so much light would be reflected, because of the color of the man's hair. In the same way, the white collar would reflect a large amount of light, while the coat would reflect hardly any. Our problem, then, is to use a device which will cause a spot of light to pass back and forth, from left to right and from top to bottom, in a series of strips across the man's face. The scanning disc projects the light from the arc lamp upon the subject being televised. It is interesting to note that, in order to have a clear image of the object which we are scanning, we must divide up the picture into from 2,500 to 3,500 spots to one square inch of picture.

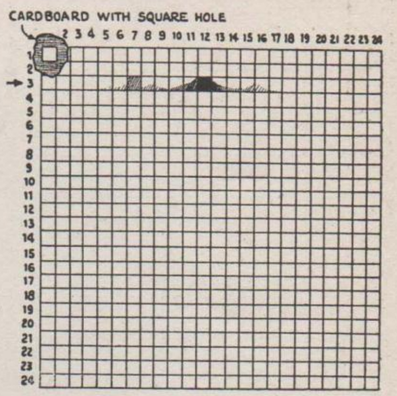


Fig. 3. A graphical reproduction of Nipkow disc scanning.

Fig. 6 illustrates what we have been talking about. (Naturally, our spot of light is magnified for the sake of illustration; for in actual practice the scanning spot is only about 1/32 of an inch in diameter. You will see from Fig. 6 that the

Fig. A Fig. B Fig. C Fig. D Fig. E

Fig. 5. A comparison of a picture as made up originally, as made up with lines similar to the way television pictures are formed, and as made up of dots, formed by the screen used in all printed cuts. At A we have the original line cut illustration; B shows the same formed with 120 dots per inch; C, same with 120 lines per inch; D, 60 lines per inch; E, 60 dots per inch. The coarseness of D and E is apparent upon close examination.

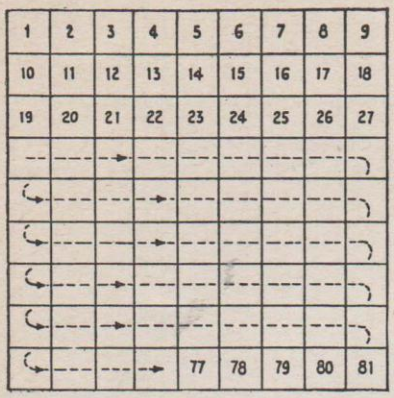


Fig. 6. The path taken by the spot of light over the subject.

spot or square of light moves from left to right, drops down a line, and moves from left to right again; in much the same way that we "scan" or read pages of a book.

The photo-cell is the eye of the television system, and scanning is the method by which this eye picks up and reproduces an image of the action taking place before it. The human eye observes a rather broad field of view. Unfortunately, the eye of television, the photo-cell, is limited to an extremely small field of view. However, a television pick-up device can render a distinctly useful service if a well-chosen field of view is selected. Furthermore, the eye will make up for the minute details which present-day systems lack.

If a comparison is made between a scene as depicted in a newspaper and an actual photograph of that scene, we can see that the latter has much greater detail. The newspaper picture is an attempt to show a photograph on the printed page. The clarity of the newspaper print is determined by the size of the screen used in making it. Figs. 5, A, B and E, represent, respectively, the original; a newspaper print in which a 120-mesh screen was used; and a print in which a 60-mesh screen was used. Just what is the connection between Figs. 5B and 5E, and

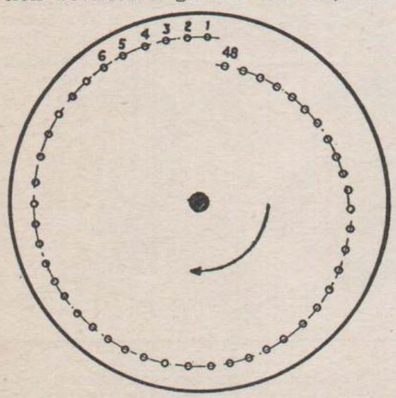


Fig. 7. Layout of a 48-line disc. Note spiral line arrangement.

scanning? Simply this: in Fig. 5B we have divided one picture into 14,400 elementary areas, while in Fig. 5E we have divided it into 3,600 elementary areas. It is customary to consider the detail of a picture such as Fig. 5A in terms of **elements per square inch.** Figs. 5C and 5D show relative appearance of same illustration as seen in a television receiver.

Therefore our detail would be 14,400 elements or dots per square inch. As an experiment, look at these pictures: first one foot away; then three feet away; and finally five feet away. The farther away the picture is, the less noticeable are the elementary areas. This is an important factor in television for, as we stated previously, television systems are capable of reproducing a detail of at least 2,500 to 3,500 impressions per square inch. For a square picture, therefore, we should have our scene to be televised divided into 50 squares per row and 50 rows.

Let us consider the action of a scanning disc when rotated slowly. Fig. 7 represents the disc and we shall rotate it in a clockwise direction. Since the disc consists of 48 holes, one revolution of the disc will divide our picture or scene into 48 strips. Hole No. 1 would produce a strip across the top of Fig. 3. Hole No. 2 would produce a picture strip one row lower. It is evident, therefore, that with one revolution of the disc we have completely covered the man's face with one little spot of light. As the disc rotates, this process is repeated again.

It is interesting to note that, for television of moving objects, fifteen complete pictures are required per second. Our scanning disc must cover the man's face fifteen times per second, if we are to have what is called a continuous picture. With a 48-hole disc, therefore, we would have 48 x 48 x 15, or 34,560 impressions per second to be picked up by the photo-cell. Since the number of lines into which the scene is divided is determined by the number of holes in the disc, television systems are classified as 24-, 48-, 50-, and higher-line systems. It is evident that, the larger the number of lines, the clearer the picture will be. It is also true that the greater the detail, the higher the **picture frequency,** and the more difficult, therefore, it becomes to construct apparatus which will pass this wide band of frequencies.

In a 48-line system, the highest frequency which we must pass is $\frac{48 \times 48 \times 15,}{2}$ or 17,280 cycles per second; this is for a square picture of 2,304 picture elements. It might be well to consider the picture frequency of the 72-line system, since the picture detail in a 72-line system shows considerable improvement over the other three mentioned systems. As before, the maximum frequency would be $\frac{72 \times 72 \times 15,}{2}$ or 38,880 cycles per second.

Let us study for a moment persistence of vision. Imagine that the eye is substituted for the photo-cell, and that we observe a scene through the aperture, or hole in the scanning disc. If the disc is slowly revolved and we confine our observation entirely to what we perceive through the small aperture, it will be difficult to piece together the scene before us. As the speed of rotation of the disc is increased, the number of our elementary impressions is increased; and it becomes easier to see the scene before us. Apparently the eye has the power to store up these elementary scenes, or areas, and build up the composite scene. This property of the eye is known as **persistence of vision.**

Before we enter into the study of television we must become acquainted with certain apparatus and certain effects peculiar to the art. The photo-tube, in particular, is of interest because of its remarkable possibilities and because of its romantic past. Heinrich Rudolph Hertz

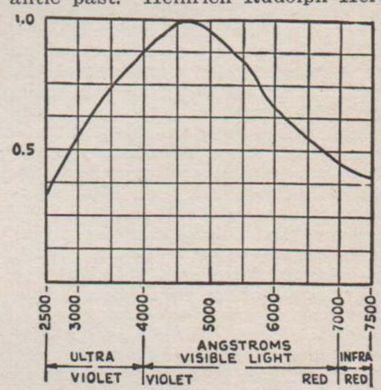


Fig. 8. Response curve of a photo cell, voltage against light units.

(who gave his name to the waves which later became known as Radio) was one of the first physicists to note the effect which light had upon certain substances and phenomena. Hertz, although his name is not connected with the subsequent development of the photo-tube, discovered the fact that certain substances when subjected to the influence of light rays gave off electricity. The degree of this electron emission is proportional to the intensity of the light falling upon the surface, and also upon the character of that light. That is to say, certain substances are more sensitive to one color range of light than another—light being defined as to wavelength in much the same manner as radio waves, except for the fact that the light waves are much shorter. The meter would be an unwieldy unit in this case and we measure the wavelength of light in "Angstroms". The Angstrom is a unit one ten-billionth of a meter in length (taking "billion" in the American sense of one thousand million, and not one million million as it is defined in Europe).

The color-sensitivity curves of photo-tubes are not unlike the curves of audio-frequency transformers, as you may see from Fig. 8, where the relative sensitivity of a particular photo-tube is plotted against wavelength of light. In constructing photo-tubes, a thin layer of caesium oxide is deposited on the wall of a glass bulb. This layer constitutes the cathode or electron emitting element. The other electrode—the anode—is usually a piece of mesh-wire mounted in the center of the tube, directly between the sensitive wall or cathode and a transparent window in the coating of the bulb.

When light is caused to fall upon the cathode, a stream of electrons is given off; this is accelerated toward the anode because of the fact that the latter is maintained at a high positive voltage with respect to the cathode. (The electrons are accelerated toward a positively-biased point in all electronic devices.) The path between the two electrodes becomes conductive, in a degree depending upon the number of electrons leaving the cathode; this factor is, in turn, dependent upon the intensity of the light flux incident upon the sensitive surface. This light flux is measured in "lumens"; the lumen is—simply stated—the amount of light falling upon a surface of one square foot from a one-candle power source at a distance of one foot.

In designing a photo-tube, the choice of the elements depends upon the service in which the tube is to be used. In those cells used for photo-metric work in motion-picture studios, the cells have the same color-response characteristic as the film employed in making the pictures. Owing to the inability of ordinary glass to transmit the ultra-violet rays, the tubes used to make measurements in this range are often constructed from fused quartz.

After the sensitive surface has been formed on the wall of the tube

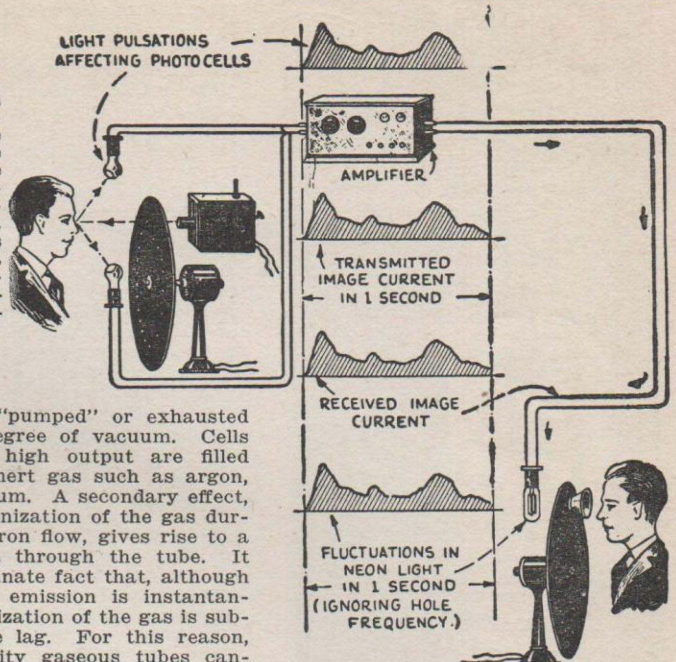


Fig. 10. Here is a simple representation of a complete television system. The wires on the right take the place of the usual radio transmission channel. The two discs must, of course, be exactly synchronized to enable transmission.

it must be "pumped" or exhausted to a high degree of vacuum. Cells requiring a high output are filled with some inert gas such as argon, neon, or helium. A secondary effect, due to the ionization of the gas during the electron flow, gives rise to a high current through the tube. It is an unfortunate fact that, although the electron emission is instantaneous, the ionization of the gas is subject to some lag. For this reason, high-sensitivity gaseous tubes cannot be used in services where great rapidity of action is required. Some gas-filled cells will operate at the frequencies required in talking motion-picture work, but so far none have been developed for television.

This peculiar effect of producing variations in electrical impulses for corresponding variations in light and shade, was observed many years ago, with the advent of **selenium** cells. Quite by accident, it was discovered that the resistance of selenium changed with variations in light. Immediately the questions arose, "How can we utilize this phenomenon?" Unfortunately, the selenium cell is too slow in its response for present television requirements, and the problem was unsolved for many years. It remained for the advent of the photo-cell to give us the beginning of television as we know it today.

The process of producing this cell is rather interesting. One method is to release the caesium (an element of the "alkaline" group) which is introduced into the tube as a pellet, by heating the tube after it is sealed. The photo-sensitive substance condenses on a silver cathode plate which has been oxidized. Baking the cell causes a reaction between the alkaline metal and the oxygen which, ultimately, results in the formation of caesium oxide with a monatomic layer of caesium over all. The use of the photo-tube which is most interesting to us is as a generator of alternating current; this is the mode in which the tube is operated in television and in sound motion picture work. An amplifier suitable for use in this case is shown in Fig. 9; it was intended primarily for television service, but is exceptionally good for use in any experimental set-up where the cell is operated by rapid changes in light intensity.

An interesting feature of the photo-cell, and that which makes it valuable to us for television, is that "photo-emission" takes place almost instantaneously. With the countless experiments which have been performed on the photo-cell, none have shown a lag between the incidence of the light and the issuance of the photo-electrons. In the ordinary high-vacuum cell, a fluctuating light causes the number of emitted electrons to vary in exact correspondence to its instantaneous intensity.

The neon tube consists of two electrodes in an atmosphere of gas. This gas ionizes and glows when an electrical current is passed through it. Over a certain range, this glow

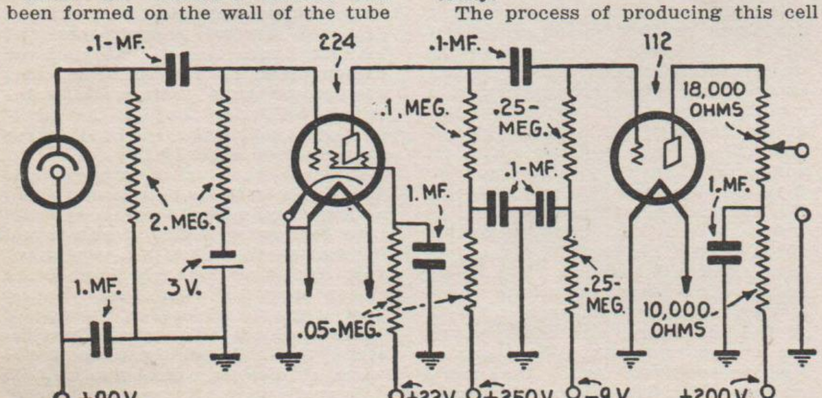


Fig. 9. Here is a simple amplifier for use with a photo-cell. Any other type tubes, such as 6J7 and 6C5, which will give equivalent gain may be used.

Fig. 10A. New Westinghouse mercury lamp which produces as much light as conventional 200 W. lamp.

varies in its intensity in direct proportion to the current flowing through it. This is the exact counterpart of the operation of the phototube, where the emitted current varies in proportion to the intensity of the light.

If we place in the output of a television receiver a neon tube with its elements designed so that one is in the shape of a flat plate, of the same size as the image to be formed on our receiving scanner or disc, we will upon looking through the disc, see a square field of light of even intensity. The light visible to the eye at any one instant is that passing through one of the apertures in the scanning disc.

Now, if the transmitting equipment consisting of scanning disc, phototube and amplifier is set in operation, the light emitted by the neon lamp will at all times be proportional to that falling on the surface of the photo-tube. If, then, we rotate the two discs in exact relation to one another—that is if they are "synchronous"—the light variations in the neon tube will construct a replica of the scene scanned by the disc at the transmitter. That is, if the transmitting disc is traversing a bright spot in the scene, the brightness of the neon lamp will increase. In the same manner the neon tube will lose in brilliancy when the light at the transmitting disc is at a minimum, corresponding to the current through the photo-tube.

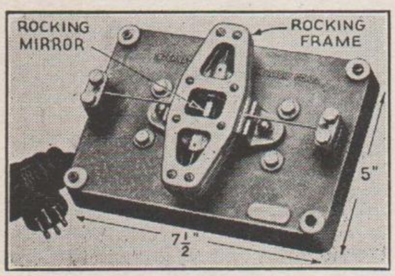


Fig. 11. Priess rocking mirror or vibrator type of mechanical scanner. Mirror can move on 2 axes.

One of the greatest disadvantages of the earlier television systems operating on the principles just covered was the dimness of the image and also its small size. The latter difficulty was first partially remedied by the use of a large optical lens placed in front of the spinning disc so that the original received image of an inch square or so was increased to 3 or 4 inches in size. However, the lens had to be optically perfect, or the enlarged image would be badly distorted, and a large lens of high quality is expensive. Therefore various means were tried to produce a more intense neon light source, the so-called crater lamp, which provides an intense small area source of light being one of the best produced. This enabled the image to be projected upon a screen in front of the disc so that it could be readily viewed.

Most promising in its division now appears to be the high-intensity, high-pressure quartz capillary mercury vapor lamp on which Philips Company of Holland has been at work for some years. In this country the General Electric and Westinghouse Cos. are each developing this type of high-pressure mercury vapor lamp with every promise that this source shortly will be available for television purposes.

In the air-cooled variety the intensity of the capillary vapor stream is approximately that of the electric arc crater or 85,000 candlepower per sq. in. But where the capillary is water-cooled by being encased in an outer glass tube through which a rapid stream of cold water is maintained flowing, high mercury pressures (20 atmospheres) are obtained; and a light intensity value **equal to that of the sun's disc,** or some 250,000 candlepower per sq. in.!

The lamp (Fig. 10A) measures about 5⅝x1¼ ins. overall, the actual light element being only 1½ x ½-in. in dia.. It is operated from a transformer which delivers around 250 V. at the secondary, and the mercury arc is approximately ½-ins. long, a striking contrast with the usual mercury- (or Hg-) vapor lamps in which the arc is of varying lengths from 5 ins., up. Thus the ideal "point source" is approached more closely than ever before in this type which fact makes its use in television of the greatest interest. As with other lamps of the mercury-vapor type, the starting time is 3 to 4 minutes, before full brilliance is attained. Many other, larger sizes are made, that shown being the smallest at present.

While the most obvious use of this new mercury vapor lamp would be as a fixed source with light valve modulation, it is not at all uncertain that the brilliancy of this source can not be directly modulated at television frequencies by means of a suitable power amplifier. If so, this latter arrangement will afford many advantages over the fixed source with Kerr cell and polarizing devices.

There seem to be as yet untried possibilities in the future development of the so-called **crater lamp**

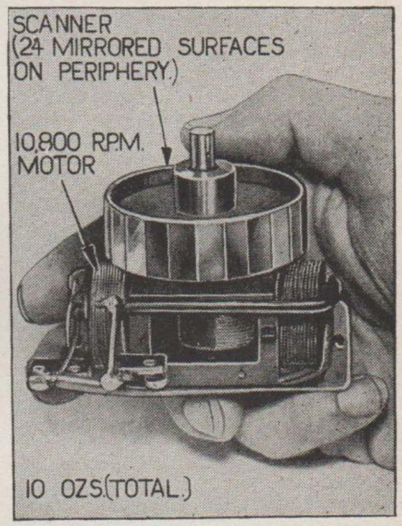


Fig. 12. Peck mirror scanner which is very compact and is capable of high definition reproduction.

source. The ultimate in a high-intensity, long-life crater lamp, either with a hot or a cold cathode, **has not yet been reached** at this writing. Although several investigators and manufacturers are still at work on the problem, it is doubtful whether any crater lamp will equal in intrinsic brilliancy that of the capillary quartz mercury- (Hg-) vapor source above described.

Akin to the crater lamp is the fixed-beam cathode of a source using a long, cylindrical, cathode beam tube containing sufficient gas to aid in focusing the beam to a very small spot and directing this fixed beam either upon a fluorescent coating upon a quartz window at the end of the tube which will successfully withstand the highly intense bombardment, or directing the beam at a 45 deg. angle upon a fluorescent, coated metal plate and viewing the spot through the side of the tube. In either construction it is obvious that the fluorescent surface must have no appreciable time lag, nor can the quartz or metal surface on which it is deposited become heat luminous. It is not difficult to construct air-cooled tubes of this nature which remain sufficiently cool to avoid redness of the bombarded surface.

The small number of milliamperes involved in this cathode-beam light source and the ease with which the beam can be modulated at television frequencies are arguments in favor of this type of light source for home television.

The following paragraphs are taken from an article in "Radio-Craft" and written by an advocate of the mechanical system. Many interesting comparisons are given.

"There is a great deal going on in television that is new even to the workers who have been long immersed in the problems of the laboratory. These new developments are mainly in the theoretical state; such for example, as the flying spark, the oscillating crystal and the multicellular systems. It is reasonable to say that they add ideas to the television art, which had borrowed much of its thought and equipment from many other arts, but nevertheless it is also reasonable to say that as we view the picture today, the race is to be run and **the winner is to come from one of two schools.**

"These two schools are represented by the advocates of (1) **the Braun cathode-ray** and the advocates of (2) **the mechanical systems.** In particularizing the reference to the cathode ray, the reference is to its inventor Braun, who dates back almost as far in the art as does Nipkow, pioneer among the devisers of mechanical systems. So little attention is given to this German scientist Braun that many television engineers seem unaware of his vital contribution.

"Whichever system — the Braun cathode-ray or the mechanical system — proves the best commercial answer to the problem, this system will be ultimately adopted, because television inherently is, and must be, built on a single pattern; a single type, that is, insofar as the technical equipment is concerned. That there will be considerable waste of investment in order to make this choice, seems to be inevitable. Whoever buys a receiver based on the cathode-ray principle will be left holding the bag should the mechanical system become triumphant. Likewise will this be true in the case of all who buy receivers built on the mechanical principle should they at a later date find that the cathode-ray system is adopted.

"As far as the investment in transmitting equipment is concerned, no tears need be shed in either case, because transmitter installations will be of sufficient flexibility to enable them to be altered to another form of system at a comparatively minor expense.

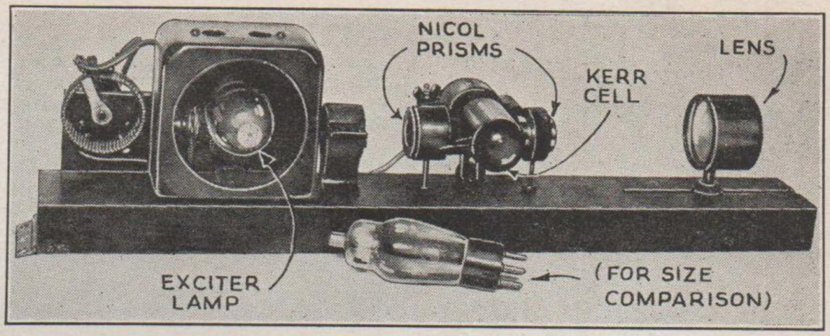


Fig. 13. A modern Kerr cell set-up as used in the Peck mechanical system. Note the compactness of this equipment, which is used with a compact mirror drum (see Fig. 12). The exciter lamp is an ordinary auto headlamp and has rheostat control.

"Fundamentally all television sets have many parts and functions in common. They are primarily differentiated by the way in which they scan or sub-divide an object at the transmitter, and the form of scanning they employ at the receiver to reassemble the picture from the received electrical pulses. Therefore our first point of inquiry should be directed at the comparison of the two types of scanners.

"The **cathode-ray** system employs a large evacuated glass tube on the end of which is a fluorescent screen, and upon this screen a fine cathode-ray "pencil" paints a picture. The illumination comes directly from the power of the cathode-ray beam. The beam travels over a predetermined geometrical pattern under the influence of two spaced pairs of scanning electrodes. A number of large radio and electrical companies in the United States have been working on the cathode-ray system for the past 6 years and have spent vast sums on its development.

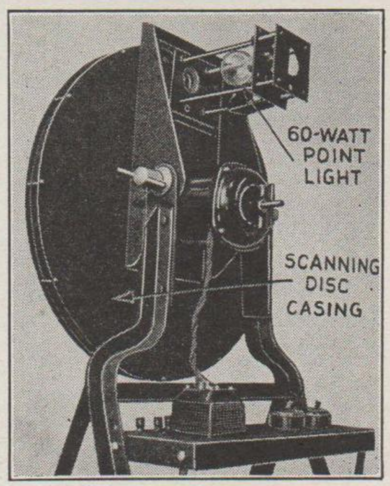


Fig. 14. A modern French disc scanner using a point light source. This equipment is used at the transmitting end of the system in conjunction with the usual photo cells.

"In the **mechanical** systems there is a physical motion of one or more parts. The light from a steady source modulated by a Kerr cell, see Fig. 13, is projected from a moving optical element to a screen. The mechanical motions used are either rotary or oscillatory. The former has been generally abandoned because of the multiplicity of optical systems it requires and the resulting high cost, leaving for practical consideration only the oscillatory or **vibrating** type. The scanner shown in Fig. 11 is the Priess scanner and is of the vibrating-mechanical type."

Another advocate of mechanical scanning writes as follows:

"Proponents of the cathode-ray receivers generally consider only the light source and scanner; they do not consider the 6 or more additional tubes which are required to maintain the "sweep circuit" which controls the motion of the electronic beam. Nor do they mention that each of these extra tubes must have its own oscillator coils, condensers and so forth; in addition to a separate power pack, including rectifier, chokes, condensers and resistors, to supply the fearsomely high voltage which the cathode-ray-tube requires.

"On the other hand, the mechanical system requires no more tubes than are found in the average radio receiver—it uses no extra circuits. It consists merely of a light source (an ordinary automobile headlight bulb), a light modulator tube and a tiny disk driven by a motor as small and dependable as that used in an electric clock. This motor is driven by the signal received over the air, and thus automatically synchronizes the disc for any transmission, regardless of number of lines per image or images per second.

"The only elements needing replacement in this system are the auto headlight bulb, which costs 10 cents, and the light-modulator tube, which will sell for a dollar or less. Both these elements will last for 5,000 hours or more. The scanning disc and motor need never be re-

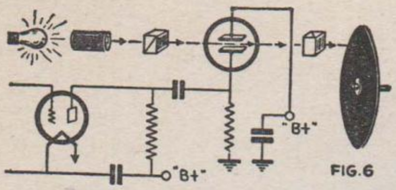


Fig. 15. The light passes through the lens to the prism, then to the Kerr cell, through another prism and to the disc. The Kerr cell is filled with a liquid which, in conjunction with the 2 special prisms, controls the flow of light through the system as the current from the amplifier tube varies. This arrangement is usually used at the receiving end.

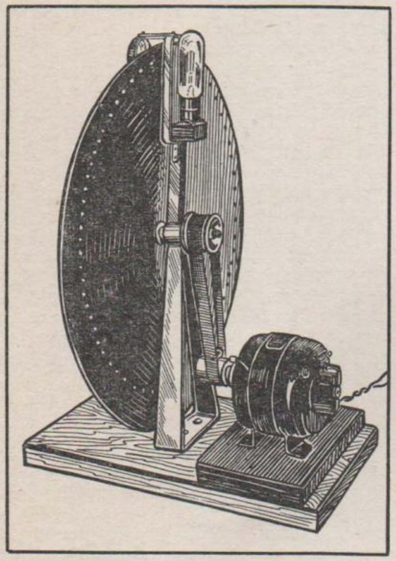


Fig. 16. The receiving disc used in early television sets. Note the neon tube on one side (the rear) and the magnifying glass on the other.

placed. The system uses only normal radio receiver voltages — less than a tenth the voltage required by the cathode-ray type. Its fewer tubes and lower "wattage" will also result in saving current and consequently lower electric bills, for the 1/100th horse-power motor uses far less current than one ordinary electric light bulb!

"There is only one more control on this set than on ordinary broadcast receivers, for a component of the signal is used to maintain synchronism. The additional control is to be used for framing the picture when first tuned in. This control makes the receiver far more flexible than the cathode-ray type, for it is doubtful whether they will be able to receive programs sent out by transmitters using any type of scanning other than that to which they have been set at the factory, while these sets will receive any number of lines, from 180 to 405, whether straight or interlaced scanning is used. It does not seem practical that a set should be as limited as the cathode-ray type, any more than that a radio receiver should be limited to one of the two major networks, and be incapable of receiving the other chain, or the independent stations.

"With the cathode-ray tubes thus far demonstrated, the picture has been limited to a square inscribed upon the circular end of the tube, and the length of each cathode-ray tube must be approximately 3 times its diameter, which creates the problem of building a cabinet big enough to house the tube if a large picture is desired. Newer cathode-ray tubes may be sufficiently brilliant to project a picture upon a screen, but these would probably use even higher voltages and have shorter life, due to the greater activity of their radioactive end screens. Using this mechanical system it is now possible to project a 14 x 16 in. picture on a screen built into a small console cabinet.

"Most mechanical scanners have hitherto produced pictures of only 60 lines, while the cathode-ray tubes are stressing images of more than 300 lines. The new model will project 180-line images, or 9 times the detail formerly secured with a disc, and more than half the lines used in cathode-ray work. In other words, it is theoretically possible to view a cathode-ray image at 5 ft., while the same effective detail would be had at 10 ft. with any system. However, it is necessary that a cathode-ray scanner use twice as many lines as a mechanical scanner in order to get equally good images, for the flying spot remains uniform in size in this system, while it decreases in size when modulated downward on a cathode-ray tube, resulting in black spots which must be filled in by closer scanning.

"Furthermore the usual cathode-ray image is "peasoup"-green and black, while the images this system provides are black and white. Although experiments are being conducted to secure black and white images with the cathode-ray tubes, to the best of available information very uneven results have been thus far secured. Let us again stress the brilliance of an automobile headlight bulb, 90 per cent of the light of which actually reaches the screen used in this system, as compared with the fluorescence of the end-screen of the cathode-ray tube. This is like a comparison between a powerful electric light and a kerosene lamp.

"Both systems will probably use 24 effective frames per second, being thus enabled to transmit programs composed of standard motion-picture film in addition to direct pick-up of studio and outdoor programs.

"Both the cathode-ray scanner and the Priess mechanical scanner can be built to the upper limit of the amplifier range and beyond.

"There is no real upper limit to the rate at which a cathode-ray tube can be made to scan, but this property is of little value because its practicability is blocked by the amplifier. Such a claim as "1,000 lines" is misleading, for the amplifier to which the tube must necessarily be connected will not pass more than about 500 lines! And again, if such an amplifier could be built, the side-bands required would be so great that the Federal Communications Commission would hesitate about the allocation of such a huge slice of the ether to a single station.

"As a practical matter therefore, the detail or quality of both systems is the same. Other systems which cannot meet this standard of quality, fixed only by the amplifier limitations, have no place in home television."

It must be realized that this brief description of the various mechanical systems of television is by no means complete. What we have endeavored to do in the space available is to give a general idea of the many possible variations of the conception of scanning as originally brought out by Nipkow.

A few comparisons between the mechanical and the electronic scanning systems have been given for completeness, but the latter system will be covered in much greater detail in later chapters. The electronic or so-called "cathode-ray" system is at present getting the bulk of the publicity, since it is being exploited in various forms by several of the country's largest radio corporations. The mechanical system are not lagging however, and it is possible that the final form to be offered to the public will be a combination of the two, with mechanical at one end and electronic at the other.

It is quite certain now that, in the mechanical line, the original Nipkow disc has served its usefulness and will be completely replaced by other forms which are much more compact, such as the various mirror systems, the lens drum, and others. Again, however, only time can tell.

Whatever the system finally used, the reader is urged to study up on them all, since the general problems faced are the same, regardless of system. We certainly advise the reader against taking too seriously, the claims of advocates of either system that their respective "brain child" is the only one that can possibly survive, since at the present stage of the art it is certain that both types have distinct disadvantages along with their more obvious advantages. Not only must the technical side of the story be taken into consideration, but we must also consider problems of replacement of parts and attendent cost, adaptability to operation by the novice and many other angles. So study them all and be prepared for whatever may finally win out!

CHAPTER 3

The need for a large number of lines per inch is explained. We also see why it is necessary to have a broad channel on the air for high fidelity transmission.

• THE quality of a television picture is dependent directly upon the number of areas into which the subject is broken, providing that the pictures are repeated with sufficient rapidity to give a smooth continuity. Other than the scanner itself there are 2 factors that limit the detail or the dot frequency. The first is the width of sideband that the Federal Communications Commission is likely to permit, and the second one is a technical limitation imposed by the amplifier in the receiver. This latter limitation is serious and for an amplifier of high gain within the low-cost class we might set its upper range at about 2 megacycles. Of course with time this range will be extended.

Many students of television have misinterpreted the word "lines," in defining image definition, having confused it with the "lines-per-inch" expression used in the printing trade to designate the "screen" required for reproduction of certain illustrations. This confusion probably would not have arisen, had the designation not been contracted from the original — "lines-per-image."

From this explanation it will be seen that the number of lines, then, is a function of the **size of the image area as a whole,** rather than of any particular, marked-off area (for instance, a 1-in. area) within that boundary. (See Fig. 17.)

By reference to Fig. 18 it will be noted that, regardless of the size of the image area, there are substantially only 80 (for example) lines, total, over the entire surface of the image or picture area. Thus, we have a choice of getting close to a small image having, let us say, 80 lines, or of getting further away from the image and then enlarging the image until the fidelity of reproduction equals that of the smaller image. The image will not then appear more "clear" to us, because there has been no change in the **number of lines per image area** (this figure is entirely dependent upon the design of the scanning mechanism—if a disc is used, the total number of holes in the spiral determines the number of lines-per-image; if a cathode-ray tube, the adjustment of the sweep-circuit oscillator), but a greater number of people can now view the screen. (The light intensity is less on a large screen, for a given scanner light-output, than it is on a small screen, tending to fade to a large extent if a weak light-source is used and the image projected to a very large screen—because the reduction in light intensity is in proportion to the square of the distance from the light source; another factor in reducing the light-intensity of the image is the proportion of image light to incident (room) light on the screen.)

This ability of the eye to define the image is affected by the low intensities of illumination (except, if you will, the strong light secured by some "projection" systems, as for instance the intermediate-film process whereby a weak light affects a photographic film which, a minute or so later, is used to modulate the intense light of an electric arc), and by the intermittent character of the light which we ordinarily must employ in television.

Low intensity of illumination reduces the ability to distinguish details because the iris of the eye expands in poor light to allow a maximum of illumination to enter the eye—light rays from a given point passing through different parts of the optic lens do not all focus together (thus, points now very close together become indistinguishable).

Intermittent light and low illumination intensity result in poor focusing power.

With this explanation the relation between picture "definition" (the amount of detail that can be discerned in the image—eyebrows, eyelashes, wrinkles, nose, etc., on a face, for example), lines-per-image, and lines-per-inch, and the size and distance of the screen may now be visualized by reference to Fig. 19.

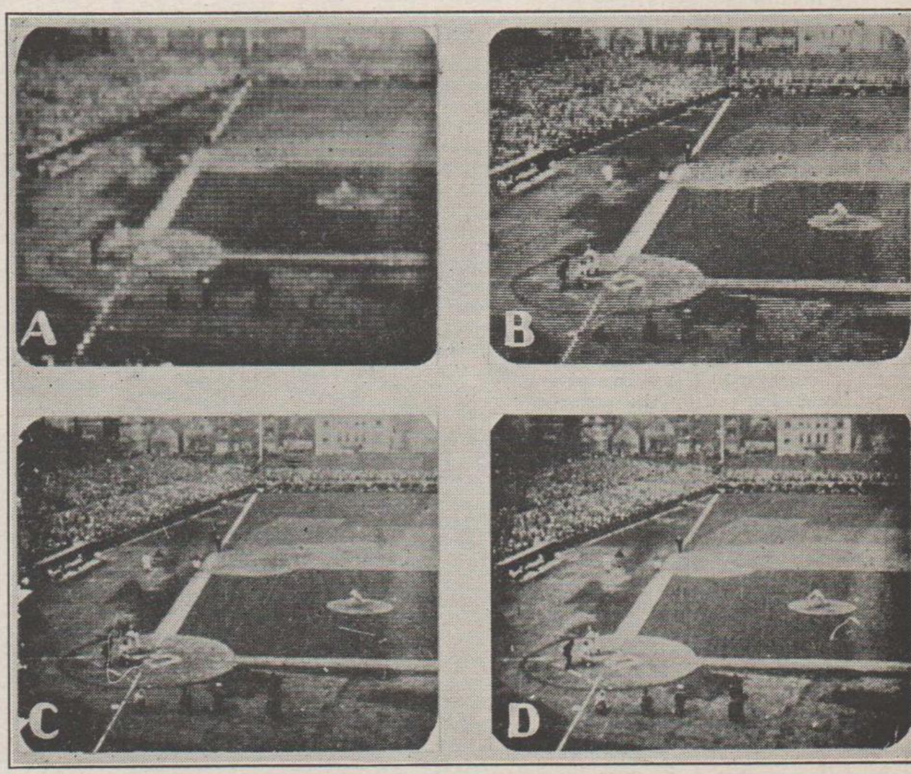


Fig. 17. A comparison of various standard numbers of lines per inch as applied to the same picture. A is 60 lines, B is 120 lines, C 180 lines and D shows the appearance of 240 lines.

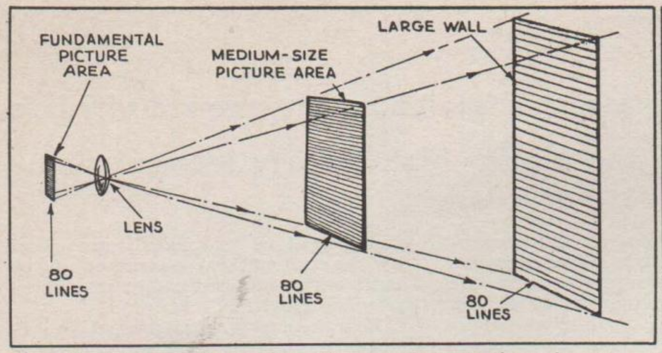


Fig. 18. We see here that the number of lines is the same regardless of the size of the image. The lines per inch varies.

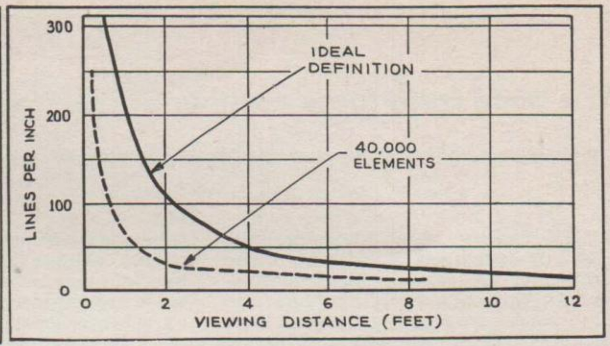


Fig. 19. A chart showing the relation between lines per inch and the distance of the eye from the screen for best results.

Despite the fact that the satisfaction in television reception is determined among other things by the number of lines into which the picture has been cut during transmission, no agreement could be settled until now about the number of lines to be used uniformly by all television stations in the United States. (The new RMA standard is 441 lines.) On the other hand, much work has been done during the last few years to find the right number of lines necessary for a satisfying television transmission, and we now know exactly how many lines are necessary to reproduce an acceptable television image. The results of the various experiments made in this country by E. W. Engstrom (RCA) and in Germany by R. Thun (German Post Office) are given in Table I.

TABLE I

No. of Lines	Classification by E. W. Engstrom	Classification by R. Thun
60	entirely inadequate	8.8 per cent
120	hardly passable	51.0 per cent
180	minimum acceptable	84.0 per cent*
240	satisfactory	97.0 per cent
360	excellent	99.5 per cent
480	equivalent of practical condition	100 per cent

(*Quality of home movies.)

Perhaps the most significant element in human vision is that the amount of detail which we can see in a picture is limited by the structure of the retina. Although the image focused on the retina by the lens of the eye may be perfectly continuous, the retina will give to the image seen a finite structure, depending principally on the number of "cones" which lie in the central spot. It appears possible for the human eye to see separately at one time about 100,000 elements; this is, probably, not more than one-tenth of the number of cones in the retina. This range, however, is greatly extended by the facility with which the eyes can move from one point on an object to another; and from these considerations it was suspected that an image of perhaps 200,000 to 400,000 elements would compare favorably with that which the human eye gives us.

It will be seen from a study of standard half-tone pictures that a television image of 200,000 elements will approach near enough to the limit of the eye to make greater detail seem unnecessary.

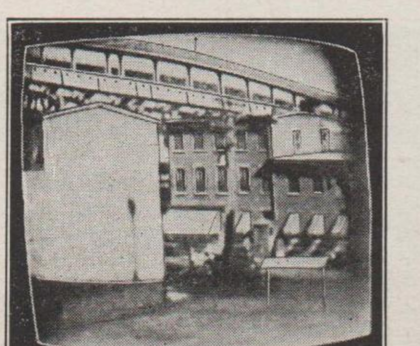
Let us outline, then, the requirements of a television system which is to handle 200,000 elements, assuming that 12 pictures are to be transmitted per second. We shall have two scanning frequencies; one of them a sawtooth wave having a period of 1/12th-second, and the other a similar wave of 4800 cycles per second. Our highest fundamental picture frequency will be 1200 kilocycles and, with single-sideband transmission, we shall require a wave band 1200 kilocycles wide.

When this work was first undertaken, it seemed quite apparent that three definite problems existed, namely: (1) a suitable scanning system to handle this high speed; (2) an amplifier capable of passing this very wide band of frequencies; (3) the perfection of a suitable wire or short-wave radio link which would take care of the wide waveband required. At the present time it is perhaps allowable to say that the first two problems have been completed.

Considerable work has been done on the development of a four-meter radio link. The progress to date indicates that quite satisfactory television service could be had for distances up to about 25 miles by proper location of the transmitter. Blurs from double images and fading may not, after all, cause particularly serious trouble. Absorption by conductive obstacles will make it necessary, however, to locate the transmitter so that it will be almost visible from any part of the area it is to serve.

Some success has been obtained by the use of wired radio as a medium. It has been found quite practical to modulate a 300-kilocycle band upon a 1000 kilocycle carrier, and to transmit this over an ordinary telephone line; the pictures so transmitted are practically equivalent to those seen on a monitoring set located close by the transmitter. The attenuation in voltage has been found to be about 45 decibels per mile for a No. 19 pair cable. It would probably be necessary to relay every few miles with this attenuation; but it is thought that a cable line represents the extreme case and that, when an open wire line is used, television by means of wired radio becomes entirely within the range of possibility.

In the experiments so far, no attempt has been made to correct the line for phase shift and frequency discrimination; this may not be necessary, but it is thought that considerable improvement in the trans-



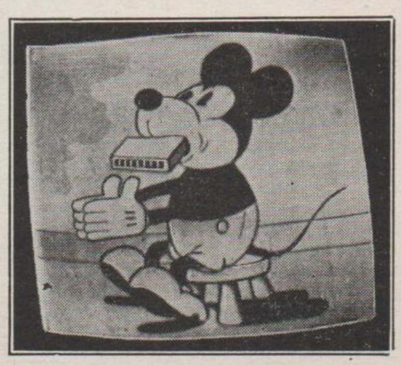


Fig. 20 at left shows an outdoor scene while Fig. 21 is a reproduction of a movie cartoon, both being examples of 180 line scanning. These reproductions are from cathode ray receivers.

mitted image might be attained by carefully making these corrections.

Synchronization is accomplished simply by putting the synchronizing frequencies on the same telephone wire; audio frequencies may, of course, be put on the same pair.

The present method of transmission by means of wire, however, is based upon the use of the so-called co-axial cable. This cable is an important development which enables the extremely high frequency television audio impulses to be sent over "wire" without the loss that would be inevitable if they were sent over the ordinary present day wire circuits. Even the circuits used by the broadcast chains to carry their programs come nowhere near the efficiency of the co-axial cable.

The main difficulties in high definition transmission appear to have been definitely solved by the use of the ultra high frequencies. These frequencies are considered to run from about 40 mc. to 200 mc. with several small bands excepted for amateur operation and other uses. As is now well known, these bands are semi-optical in nature, that is, the signals follow line of sight paths more or less. This means that the transmitters will be limited to an average radius of about 50 miles apiece. This is a distinct advantage, however, because there will be no trouble from interference with distant stations, such as is often apparent now on the regular broadcast band, when 2 stations in widely separated parts of the country interfere with each other. This means that many television stations may be operated on the same frequency, the only precaution being that they should be located several hundred miles apart. These high frequencies act in strange ways, and if the stations were located nearer together, there would probably be interference at times. It is likely that, as the necessary R.F. equipment for both transmission and reception is advanced and perfected, the television band will extend higher and higher, even into the range of so-called micro-waves, for more and more stations could then be accommodated.

In light of present day experiments it seems reasonable to believe that the ultimate in television pictures will require no more than about 500 lines, and from moving picture experience we have seen that between 20 and 30 pictures or frames per second is entirely adequate for very fine flickerless reproduction. This means that with present television technique, the maximum band width that will be required is about 3,000 kc., or 3 mc. When it is remembered that the present audio broadcast band is only about 1 mc. wide the impossibility of using the lower frequencies for television becomes apparent, since 1 of these maximum bandwidth stations would cover 3 of the present broadcast bands! Since there is such a great deal more territory in the "ultra highs" and it has the advantage of short distance transmission also, the disadvantages of less efficiency of R.F. apparatus are much overbalanced. The chart in Fig. 22 shows the extent to which the ultra high frequencies are to be requested by the various organizations.

While on the subject of picture definition it may be of interest to compare the present status of television with the pictures we are accustomed to view in the theatres.

(1) Mode of Picture Production. The methods of producing the pictures are **entirely different** in the two cases of theatre motion picture, and home television reception, odd as that may seem. The theatre picture is projected as a complete unit, one entire frame at a time. The delineation is produced and limited by aggregates of silver grains in the developed positive image.

The television picture is produced by a luminous dot (or "dot-element"), the brightness of which is accurately controlled as it passes in succession over a series of parallel and closely adjacent lines until it has covered the entire area of one frame.

In the theatre case, the entire picture is on the screen at a given instant of time, to be succeeded by full-screen darkness prior to the projection of the next frame, and so on.

In the television case, there is never anything more than a more or less bright dot upon the screen! The television picture depends even more upon persistence of vision than the theatre picture, being in fact nothing more than a flickering and flying dot. (It must be added that certain technical details of television picture production have not as yet been standardized. However, the above-cited features appear likely to be present permanently.)

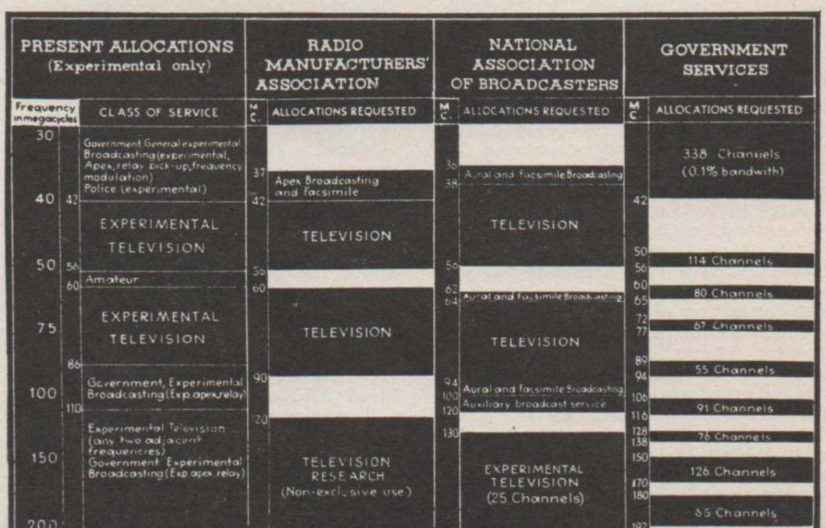
(2) Number of Picture Elements. The number of picture elements determines the detail or (roughly) the story-telling capabilities of the picture. In round numbers, the theatre picture has something of the order of 5,000,000 picture elements, whereas even a good home television picture will probably have something like 150,000 elements. This is a ratio of 30-to-1 in favor of the theatre picture.

However, it must be noted that **the entertainment value** of a picture in motion (whether produced by projection or by television) is not in direct proportion to the number of picture elements which it contains, so that we are not entitled to draw the conclusion that theatre pictures, though more detailed in structure, are necessarily far more entertaining (particularly on the small home screen) than television pictures. Probably a television picture in the home will be described by most as a "fair home movie."

(3) Grain and Line Structure. Theatre pictures of reasonable size from a suitable positive show negligible grain if viewed at moderate and practicable distances, and of course show no line structure (for monochrome pictures).

Television pictures show no **grain** structure, but may show a slight **line** structure if viewed too closely. However, high-detail television pictures, viewed at normally comfortable distances, will show practically no line structure—and certainly none that is objectionable.

(4) Color of the Picture. Theatre pictures are normally black in the shadows and white (blue-white or yellow-white) in the highlights.



(Reproduced from "Electronics" magazine)

Fig. 22. At left is present allocation of ultra high frequencies. Other columns show future requests.

When projected from toned or tinted positives, they show the corresponding hue.

Television pictures are also practically black in the shadows, but the highlights may be bright yellow, greenish yellow, or even a practically neutral white. (The latter color will probably become common practice in television as development of the art proceeds.)

(5) Possibility of Full-Color Pictures. It is readily possible today to produce theatre pictures which show substantially the colors of nature or at least an acceptable approximation thereto, although there are definite economic handicaps in production and reproduction of such pictures.

Television in full-colors seems to be an almost impracticable proposition in the present or likely early state of that art. (However, small-scale demonstrations of its abstract possibility have indeed been given.)

(6) Size of the Picture. Theatre pictures range in size from, say 6 x 8 ft. to perhaps 18 x 24 ft., or even more in special cases. Thus, their area is between 48 and 432 sq. ft.

Home television pictures range from about 6 x 8 ins. to perhaps 18 x 24 ins. or, in special cases, somewhat more (though generally at the cost of picture detail and brightness). Thus their area lies between about 0.3- and 3 sq. ft.

On this basis the area of the theatre picture is about 100-160 times that of the home television picture. A more normal comparison would be with the approximate 30 x 40 in. **home** motion picture, having an area of about 8 sq. ft., or say about 5 times that of the average television picture.

(7) Picture Brightness. Theatre pictures are generally adequately bright for viewing in a darkened auditorium (that is, an auditorium with illumination about 0.5-foot-candle).

The television pictures are also sufficiently bright to be viewed in a dimly lighted room—but dark window shades will be required for daylight hours, and for the evening as well if the street lighting outside the home is at all bright.

(8) Flicker of the Picture. The theatre picture consists of 24 frames per second, each of which is generally projected twice before the next frame reaches the screen. Flicker is absent, although traces of an effect depending upon picture sequence are still found in the case of rapidly moving objects, and in the stroboscopic backward-turning of the wheels of pictured vehicles.

Television pictures may be projected in two sets of 30 pictures each, the two sets being projected in 1 second. "Interlaced" scanning may be used, and under these conditions a substantially flickerless picture is obtained. Despite the projection of 60 half-detail pictures per second by this method (equivalent closely to 30 full-detail pictures per second), it is possible to use ordinary 24-frame-per-second motion picture film for the television subject without undue difficulty by the use of technical expedients which cannot be here described.

(9) Viewing Distance. Taking an optimum viewing distance of 4.5 or 5 times the picture diagonal, theatre pictures may be most conveniently viewed from 45 to 135 ft. from the screen.

Home television pictures will be viewed from about 4 to 11 ft. from the screen.

This is a ratio of viewing distances of about 11-to-1 in the two cases.

(10) Audience Size. Long experience has demonstrated that the comfortable size for theatre audiences ranges from 500 to 5,000 persons, with perhaps some doubt at one extreme or the other.

The corresponding home audience may be expected to include from 3 to 15 persons, a ratio in favor of the theatre of about 200-to-1.

It must not be inferred, however, that the economic ratio for the two fields is anything like as high as this—indeed it has not yet been determined just what will be the cost per person per hour of entertainment for home television-telephone broadcasting. .

(11) Synchronism of Picture With Sound. In the theatre, the picture and sound are correctly associated within 1/42-second, assuming proper editing and threading.

In the case of home television-telephone programs, the synchronism is even closer (though this is not noticeable as an advantage), and is entirely correct and automatic. Some rather romantic writers on the subject have dilated upon the "marvel" of the synchronism of picture and sound in such programs. As a matter of fact, considering the fundamentals of the processes employed, it would be even more marvelous if synchronism were **not** attained for television-telephone broadcasting reception!

It is not practicable at this time, before mass production of television equipment has been initiated, to give a reliable comparison of the cost of theatre and home equipment. In a general way it may be said that theatre equipment costs in the thousands of dollars and home equipment about the same number of hundreds of dollars, thus giving a cost ratio of perhaps 10-to-1. Here again some caution must be used in interpreting such figures since there are numerous other economic factors involved in a valid comparison.

Some numerical data concerned with picture detail are here given as of present interest. These consist first of a personal opinion, in motion picture terminology, of the value and characteristics of television pictures having various numbers of dot-elements composing them. The figures are understood to be merely generally descriptive, but it is believed they are instructive in judging the "motion-picture value" of various television systems; hence, they are reproduced in Table I.

TABLE I

Elements in Picture	"Motion Picture Value"
10,000	A fair close-up of one person (head and shoulders).
20,000	Two persons in a moderately good close-up (though without fine detail).
40,000	Fair medium shots.
80,000	Good medium shots and fair, long-range shots.
160,000	Excellent close-ups of several persons, good medium shots, and acceptable long-range shots (except for unusual "pageant" subjects and the like).

Taking the last-mentioned type of television picture, and assuming flickerless transmission, it is found that the required "side-bands" produced by the picture modulation of the ultra-short-wave carrier have a width in the order of 1.5 mc. (or about 150 times the frequency band required for high-fidelity or 10,000-cycle sound reproduction)!

Besides these 11 points there are other considerations that must be made. By this time the reader must see that there can be a close connection between motion pictures and television, **if such is desired.**

A person viewing a small picture in motion with synchronized sound might find some difficulty in knowing whether he was viewing a sound motion picture projected from film or a television-telephone broadcasting reception.. He might be even more puzzled if the subject matter were, say, a newsreel used to control the television-telephone transmitter, an entirely feasible procedure. Obviously the technique of producing a television-telephone broadcast program will closely resemble that of producing a sound motion picture. Methods of costuming, make-up, script construction, "camera" technique, sound pick-up, set construction, illumination, and the like may well be similar in the two fields, though probably not with the same degree of elaborateness in the case of television. There is one respect in which they will necessarily differ if an original performance (rather than a film record) is broadcast. This is a limitation of television-telephone broadcasting; namely, the possibility of only one "take," viz., the one that is broadcast. In motion picture production, any reasonable number of takes may be made; not so in broadcasting, where the radio wave irrevocably carries the selected performance to all homes.

As has been mentioned above, sound motion films may be excellent subject matter for programs from some stations, and may even afford one means of syndicating programs in somewhat the same way electrical transcriptions (phonograph disc records of programs) are now used. It is not believed, however, that television-telephone syndication will be fully satisfactory unless there are also actual interconnecting wire or radio networks between the outlet stations, since there will be many occasions (for example, a speech by the President, a political convention, an evening prize fight, and the like) when the public can hardly be completely satisfied by any radio performance which does not take place at the same time as the actual event. Indeed it must be admitted that this is one of the outstanding capabilities of radio broadcasting which it would be unwise to discard.

Many persons are convinced that television broadcasting will whet the appetite of the "lookers," and, so far from diminishing the theatre audience, will build it up by arousing interest among children and adults alike in the probably more elaborate and highly developed offerings of the theatre. It is also clear that the theatre can, to a considerable extent, utilize radio advertising by television-telephony; for example, by the sponsored transmission of trailers of one sort or another. Radio will then offer the theatre a remarkably effective method of submitting its "sample line" to the public.

We are inclined to be definitely optimistic when considering the effect of television upon the theatre. The argument that television broadcasting may keep people out of the theatre does not appear to have much weight. Consider, for example, the following controlling principles:

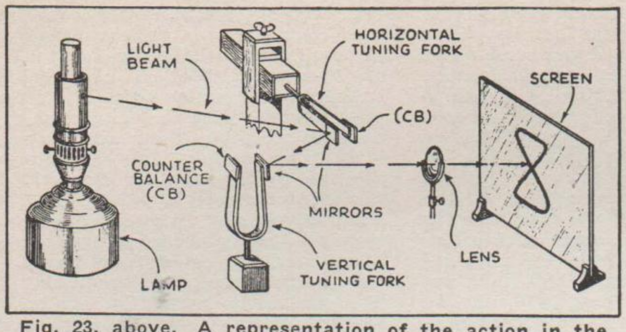
(1) Intrinsically, the home is certainly not so good a showplace as the theatre. First—it is more difficult to suppress natural and man-made noises in the home; second—here manners tend to be more "free and easy" than is desirable for showmanlike presentations; third—the problem of setting up the theatre in the home is far from simple when furniture must be moved to afford a good view of the screen and the home folks and guests located in the corresponding convenient viewing positions; and, fourth—home lighting is rarely as controllable or suitable for picture presentation as is the case in the theatre. Indeed, the customary surroundings of the home are not especially favorable for the creation of a world of illusion, which has always been the successful function of the theatre. It is not maintained that there will not be value and interest to the home presentation—quite the contrary. It is stressed, however, that the home has certain disadvantages of long standing for program presentation which cannot be disregarded.

(2) Conversely, the theatre has a number of definite and inherent advantages as a showplace. It arouses the interest of the audience by heavy theatre advertising in the press, by the play-up of the "fan magazines," and by other exploitation methods known to skillful managers, thus creating in the prospective audience the proper mood of pleasurable anticipation. The marquee and lobby of the theatre, ablaze with light and motion, and with attractive photographs of selected scenes from the picture displayed within, further attract the audience. Within the theatre, suave but real discipline is maintained by the ushers—a task calculated to daunt the bravest in the home. Furthermore, the price of admission, exacted at the box-office just before entry, is a powerful deterrent to lack of interest on the part of the audience. It takes a poor picture indeed to force the audience to cheat itself by inattention.

The program in the theatre generally is a well-planned arrangement of elements which fit together and which take as long as many reasonably be required to get the desired effect. In broadcasting, because of certain administrative problems, the successive elements of the evening program are coordinated only with the utmost difficulty, if at all, and necessarily run in 15- or 30-minute slices—a not always convenient or artistic time. At the present time, with the occasional obnoxious exception of excessively prolonged or unduly fulsome blurbs relative to approaching attractions, the theatre screen is practically free from advertising, whereas advertising and the sponsored program are at present the commercial bases of the maintenance of broadcasting. The elaborate perfection of some feature pictures will be duplicable only rarely within the necessary economic limits of broadcasting. To the preceding factors may be added the air-conditioning of many theatres and the attempts at comfortable theatre seating, lighting, and the like. All in all, theatres may be expected to be attractive places of the public regardless of other entertainment media.

(3) If we consider some deep-seated characteristics of human beings, it becomes further evident that the theatre has certain ways of holding its own alongside a successfully developed television-telephone broadcasting set-up. People are interested in change. If they are in the home a good deal—and most of them are—they naturally will seek some of their entertainment and diversion elswhere. The remarkable vogue of the automobile in which many people wander rather aimlessly from one place to another largely for the sake of motion is a case in point. People are also gregarious and somehow seem to have their emotional responses enhanced by crowd enthusiasm..

It seems most likely, therefore, that the theatre and television-telephone broadcasting will each be successful fields in their own domain, and that the theatre need not be unduly apprehensive over the advent of television..



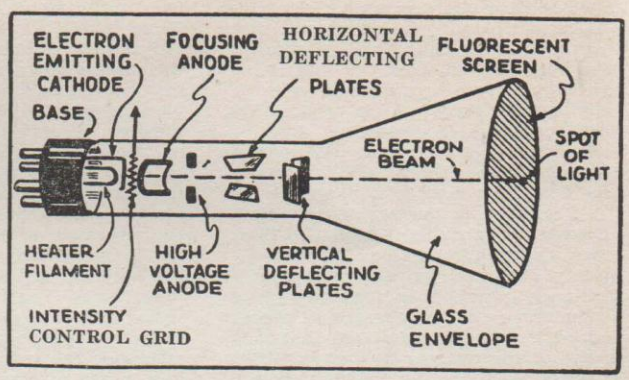


Fig. 23, above. A representation of the action in the cathode ray tube. Fig. 24, right, the elements of the modern type of tube.

CHAPTER 4

• TELEVISION in its present state of development, makes wide use of the so-called cathode ray tube at the receiving end of the system, although, as pointed out in Chapter 2, there are some very successful mechanical systems also in use. However, the cathode ray receiver is the one now most in the limelight in this country, due probably to the fact that it is used by several of the largest and most influential experimenters in the field, namely, RCA, Farnsworth, and Philco.

It is interesting to note the following comment when we are about to study the cathode-ray tube. It is from an interview in 1931 with Herr Nipkow, the inventor of the present day idea of scanning, and was made in answer to a question as to his ideas of the television apparatus of that time:

"Well, as a simple man I cannot say that so simply. You know, what the others have produced with the disc televisor—according to my basic patent—will not set the world on fire. After all, it is mostly only my old design, perfected according to the present status of technology.. In America, I have read somewhere lately, an American named Jenkins has invented a drum televisor. At any rate that is something new. There is at least a new idea in it, though Heaven only knows whether it will prove practical. If I am not mistaken, however, the Braun tube, the long glass tube with the deflected cathode ray, has the most prospect for practical realization."

The **cathode-ray tube** is an instrument which has as its moving part a stream of electrons. The stream may be considered as a flexible wire in which current is flowing. In the cathode-ray **oscilloscope**, the ray is deflected by electric or magnetic fields and its travel is observed on the "fluorescent" (glowing) screen at the end of the tube; in the oscillograph, this image on the screen is recorded (usually, on photographic film). Both instruments are of great value in all branches of engineering work. wherever alternating electrical currents are involved.

The cathode-ray tube has been known for many years and Professor F. Braun is credited with first applying the tube for measurement purposes—about 1897. In the same year of Braun's early experiment, Sir J. J. Thomson showed the rays were deflected by electrostatic and electromagnetic fields; further, the direction of deflection proved the particles in the rays were negatively charged. .

The latter part of the 19th century thus was a banner period in that it saw the birth of commercial radio, the determination of the value of the electron charge, and the birth of the cathode-ray tube and its cousin, the Fleming "valve" (tube)!

Now, the mass of an electron, being electrical and due only to the charge which it carries, is of very low order compared to the moving parts of a Dudell galvanometer with its mirror and strips, or a fibre of the Einthoven instrument. Consequently, the cathode-ray oscilloscope, utilizing this electron-beam as a "weightless pointer" having practically no inertia, has been hailed by technicians as an instrument especially suitable for use at the higher frequencies (where former oscilloscopes were useless); further, the development of new, inexpensive cathode-ray tubes has greatly accelerated interest in the application of this type of equipment. Service Men, and in fact technicians in every walk of engineering, are rapidly realizing the usefulness and increasing low cost of this tool.

The modern form of cathode-ray tube consists essentially of six main parts. These are: (1) A filament which serves to heat the cathode. (2) The cathode from which the electron stream is emitted. (3) A device for concentrating, controlling and focusing this electron stream into the form of a fine beam. (4) An arrangement for deflecting the beam (either electrostatically or electromagnetically). (5) The fluorescent screen or target which emits light when struck by the electron beam. (6) The glass envelope into which all the foregoing parts are sealed for the maintenance of a vacuum. (Fig 24) In this part of the discussion, we will consider only items 3 and 5 of this tabulation.

On their way from the cathode to the anode the electrons are acted upon by the **intensity** control grid, G. (See Fig. 26B.) The bias voltage applied to this control grid is made variable to provide a means of controlling the **intensity** of the electron stream.

As the electrons leave the cathode there is a tendency for the beam to spread out, fan-shaped, as it travels toward the screen. This spreading out is caused by the mutual repulsion of the individual electrons of

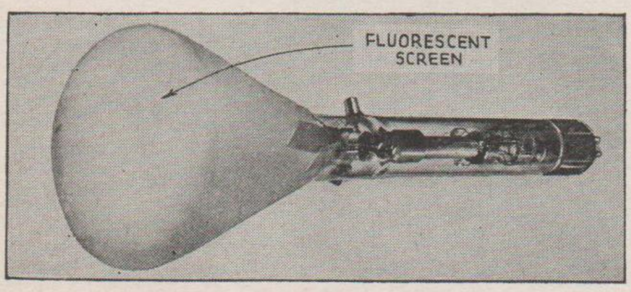


Fig. 25. A large cathode ray tube, the parts of which may be checked by comparison with Fig. 24. Note the size and angle of the deflecting plates in the neck of the tube.

which the beam is composed, since they are really all negative electrical charges and "like" charges repel each other. It is necessary to prevent this spreading out of the electron stream; in fact in order to get only a tiny spot of light on the fluorescent screen, S, it is necessary to actually focus the electron stream to a fine, sharp point at the screen, much the same as the light rays from an incandescent lamp, L, may be focused to a point, P, on a screen S, by means of the two lenses L1 and L2 as shown at (A) of Fig. 26. The amount of light may be controlled by the shutter T, which when closed completely shuts off the light. The size and definition of the image on the screen S are controlled by adjusting the position of the lenses to the correct distance. This is called "focusing".

The arrangement employed for controlling the intensity and focusing of the electron stream in the cathode-ray tube is shown in detail at Fig. 26B. The cathode, focusing electrode and anode considered together are often referred to as the **electron gun** because their function is to "shoot" the electrons along through the length of the tube.

When the electrons reach the anode they will have attained such high velocity due to its attraction that those which are in line with the tiny hole in its center will shoot right through it and continue on their way until they strike the inner surface of the far end of the tube.

The inner surface, S, of the flattened end of the tube is coated with a material that glows or "fluoresces" when electrons impinge upon it, thereby producing a bright spot of light. The material is usually bound on with pure waterglass. Several different materials, and combinations of them, are in current use for different colors of fluorescence. The most active material for producing visual light is zinc silicate (in the form of the powdered mineral **willemite**). This glows a bright yellow-green, to which the human eye is most responsive.

When the rapidly moving electrons strike the screen of fluorescent material, they are stopped suddenly and **their impact energy produces light which appears as a spot of fluorescent glow.**

Since the impact energy of the electrons varies as the square of their speed, or in other words, with the square of the voltage on the anode, the fluorescent-spot brilliancy increases rapidly as this voltage is increased. If the electron stream is focused carefully by adjusting the voltage on anode A1, the spot of light produced will be very small, but intense.

Because the size and intensity of the fluorescent spot of light produced on the screen are very important in the use of the cathode-ray tube, the intensity-control grid and the focusing anode are very important parts of the tube.

A spot that is too **large** will not give a sharp image; one that is too **small** may be difficult to see. A spot that is too **dim** may not photograph well or may not be seen with ease in a lighted room; a spot that is too **intense** will cause deterioration of the active material with which the screen is coated.

The latter is due to intense bombardment resulting at the point of impact of the electron stream on the coating of the screen. Just how intense is this bombardment and impact may be realized when it is known that the electron stream bombards the screen much as rapidly-fired machine-gun bullets would bombard a target, excepting that the machine-gun bullets would have a muzzle velocity of only about 2,000 miles per hour, whereas the electrons in an ordinary cathode-ray tube operated with 1,000 V. on the plate have a velocity of approximately 42 million miles per hour! Because of this intense bombardment of the screen, the beam should never be allowed to remain motionless, for if this occurs, the full impact energy of the electrons will be liberated and concentrated at the focused spot on the screen, causing the fluorescent material to disintegrate. A black spot will be observed in the screen after this occurs.

Cathode-ray tubes are rated according to the diameter of the screen: a "3-in." tube is one with a screen 3 ins. in diameter; a "5-in." tube has a 5-in. screen, etc.

The beam of electrons which is projected in a cathode-ray tube from the cathode to the screen, is nothing more than an ordinary unidirectional (one-direction) electric current, since it consists merely of a beam of rapidly-moving electrons. Therefore, since it is the equivalent of a current-carrying wire without inertia, it can be deflected or bent by the application of the magnetic field of a magnet, of a current-carrying coil, or by a static field such as is set up between metal plates to which a potential is applied.

The latter method is the one used in the cathode-ray tubes employed in radio service work. These **deflecting plates** constitute the important elements as far as the actual use of the tube is concerned.

In Fig' 27A, plates P1 and P2 in one set are arranged almost parallel to each other in one plane along the axis of the tube, and are equidistant from the electron beam. They actually diverge slightly in the direction of the screen, so that even though they are mounted close to the electron beam for strong deflection control, they will not be in the way of the beam whenever it is deflected near the extreme edge of the screen. Plates P3 and P4 (Fig. 27B), constituting the second pair are mounted at right-angles to the

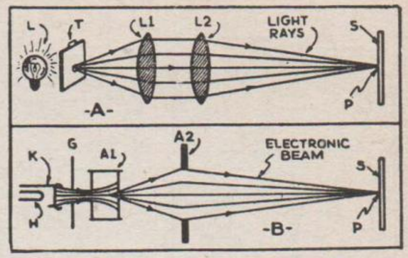


Fig. 26. Analogy between focusing cathode rays and light rays.

first pair, and are also equidistant from the electron beam.

The action of these deflecting plates upon the electron beam will now be studied. Suppose the cathode-ray tube is connected for operation and a spot of light is seen in the center of the fluorescent screen.

Now suppose that a voltage is applied to the two deflecting plates, P1 and P2, as shown in A of Fig. 27 (the other two plates are not shown here), so that Plate P1 is made **positive** and plate P2 is made **negative.** The positive plate will attract the negative electrons flying past it, and cause the beam to bend or deflect toward it as shown. The negative plate will repel the negative electron stream, aiding the action of the other plate in deflecting the beam to the position shown. Upon the application of this deflecting voltage, the spot of light moves from point A to point B on the screen. (Naturally, the amount of deflection depends upon the intensity of the beam, the anode voltage, and the voltage applied to the deflecting plates.)

If, now, the polarity of the defleeting plates is reversed, (P1 negative, P2 positive), the electron beam will be deflected in the opposite direction, and the spot of light will move back through point A to point C on the screen.

Now suppose that a potentiometer connected across a battery serves as a source of adjustable voltage to be applied to these two deflecting plates P1 and P2 as shown in Fig. 27A.

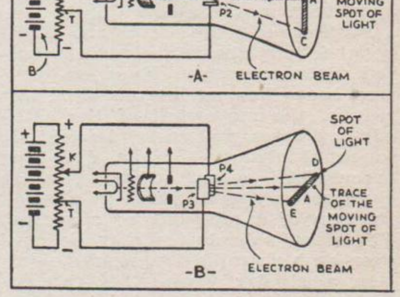


Fig. 27. Action of the 2 pairs of deflecting plates on the electron stream.

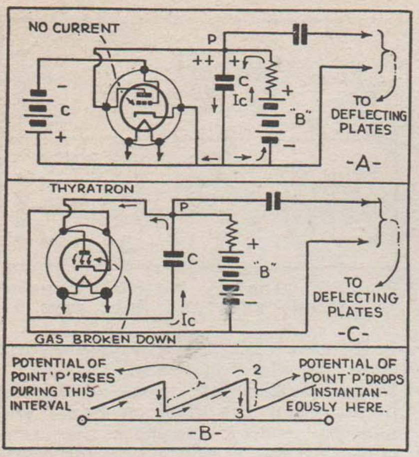


Fig. 28. The action of a thyratron tube and simplified circuit. Curve at B is of the sawtooth type.

When arm K is above center-tap T on the potentiometer, plate P1 is made **positive** with respect to plate P2 and the normal electron beam (which takes the path OA when no potential is applied to the plates) will be deflected toward plate P1 and strike the screen at point B. When the arm K is below the point T, the spot of light will appear at point C, because P2 is now **positive** with respect to P1 and the electron beam. These plates attract the electron beam just as the plate of any radio tube attracts electrons. However, in this case, the entire beam is bent by the attractive (or repulsive) force. If the contact K is now moved back and forth rapidly, the spot of light will move up and down the screen in a straight line B-A-C, and will trace this straight line on the screen.

Although each section of the line is generated at a slightly different time, the entire line will appear continuous for two reasons: first, because of the "persistence of vision" property of the eye (Persistence of vision is a property of the eye which enables it to retain the image of an object after the object has been removed. It is upon this principle that the motion picture projector works); and, second, because the spot on the screen actually remains bright for a short time after the spot itself moves away.

Furthermore, the movement of the beam follows the variation in potential instantaneously, since an electron beam has no inertia. For this reason, the movement of the cathode-ray beam will respond faithfully to rapid changes of the deflection potentials, even though these changes may take place in a small fraction of a millionth of a second. Therefore, this device may be used even on high radio frequencies.

In a similar manner, if the deflecting voltage is applied to plates P3 and P4, as shown in Fig. 27B, and varied in the same way, the line which the spot of light traces will appear in the horizontal direction shown. The amount of deflection of the beam is proportional to the voltage applied to the deflection plates, and the amount of voltage required to deflect the spot of light a distance of one inch over the screen is a measure of the sensitivity of the cathode-ray tube. (For instance, this value for a commonly used tube is approximately 75 V. per inch.)

Let us now consider the type of voltage that must be applied to the vertical deflecting plates for "sweeping" the beam horizontally, or "timing" it. This is commonly known as the **sweep** or **timing** voltage. From what has already been said, it will be realized that the voltage used should be a repeating or "recurrent" one. Furthermore, for most purposes it is preferable that it be one, which, when applied to the horizontal plates deflects the beam so that the spot of light is shifted **uniformly**, say, from left to right with an **abrupt** return from right to left, the return occurring in only a small fraction of the time taken to travel from left to right (so that the return may be considered as being practically instantaneous).

There are several ways of generating a saw-tooth sweep voltage of the wave form shown in Fig. 28B. Whatever develops it must be designed to generate a voltage which will increase uniformly to a certain value, then drop **abruptly** to zero, and repeat itself.

There are a number of electrical "sweep circuits" which may be employed for this purpose. A simple circuit of this kind, which employs a type 885 thyratron tube is shown in Fig. 28A.

The thyratron tube employed contains the cathode, grid and plate, as shown. Since it also contains gas, it is a tube capable of exerting a "trigger" action in the circuit. When normal grid-bias voltage is supplied to it, no current will flow through the tube unless the voltage applied to its plate is made high enough to ionize the gas in the tube (300 V. in this case). If this happens, the ionization of the gas causes the tube to break down immediately, the resistance of the path between the plate and cathode suddenly becomes very low, and the grid loses all control of the plate current.

Now let us see how this tube operates in the sweep-voltage circuit of Fig. 28A. The plate-cathode condenser, C, is charged by the plate supply voltage through the resistor.. The grid-bias voltage of the tube prevents plate current flow through the tube until the voltage across this condenser builds up to the breakdown value of the tube (300 V. in this case). The flow of the current into the condenser during this interval is shown in the simplified diagram at C of Fig. 28.

Another form of sweep circuit which may be used, is shown in Fig. 29. This is a motor-driven type. A motor whose speed may be controlled very accurately is ganged to the arm of a potentiometer, R, connected across a battery. As the arm of the potentiometer (which we will assume is rotating counter-clockwise) turns from A to B the voltage tapped off increases **uniformly** from zero to the full value of the battery. At point B the contact is broken, so the current drops quickly to zero and remains at zero until the arm reaches point A where contact is reestablished and the cycle is repeated over again.

This general description of cathode-ray tubes holds true for both television tubes and the more generally known types used in laboratory apparatus for measurement work. For the latter work, a single sweep oscillator is used connected to one set of plates, while the voltage to be observed is connected to the other set. In television, however, a somewhat more complex setup is required. Here, both sets of plates are connected to separate sawtooth oscillators of different frequencies, one of which produces the horizontal scanning, while the other moves the electron beam vertically. The intensity of the beam is controlled by the grid, which, in the laboratory type is used merely to aid in controlling the intensity of the spot on the screen, and once set, is left so.

Most modern systems use the electromagnetic type of control, rather than the electrostatic, which has been described in detail. This simply means that the electron beam is deflected by electromagnetic fields created outside of the tube envelope. The magnetic deflection system has several advantages for television, one being that it is much cheaper to make the tube without the 4 plates inside, and then it is generally conceded that the magnets give better control for this type of work.

The cathode-ray tube satisfactory for television reception is a special development all of its own as people who have tried to adapt, for television, tubes which were intended for oscilloscope work have soon found. There are two common types of oscilloscope tubes in this country. One type has no focusing electrode but obtains a focus by changing the

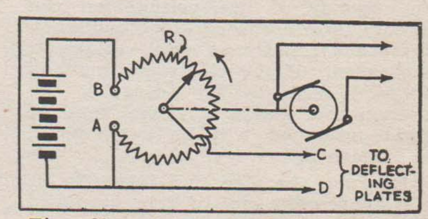


Fig. 29. A mechanical means to obtain the type of curve of Fig. 28B. This method is not very satisfactory.

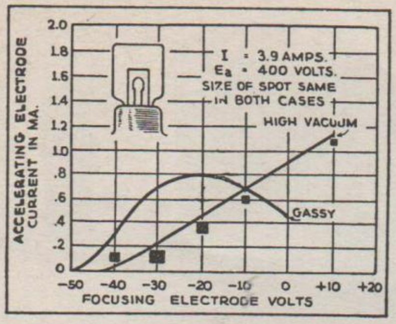


Fig. 30. Curve of accelerating voltage against focusing voltage shows how spot will vary in size.

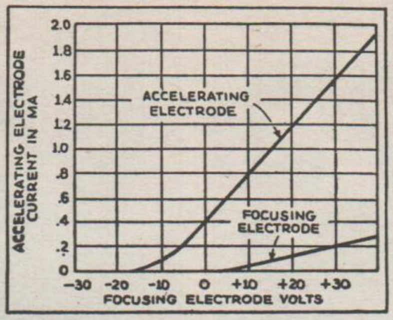


Fig. 31. Curve of a tube which meets the strict requirements needed for television operation.

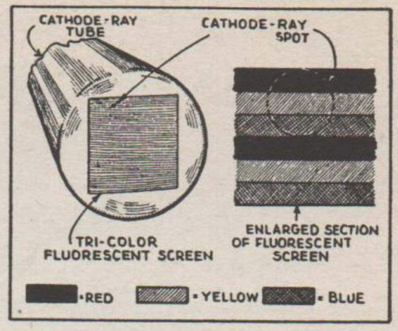


Fig. 33. How the active material is applied to the screen end of a tube to be used for colored television.

temperature of the filament. Obviously the temperature of the filament could not be changed rapidly enough to vary the intensity of the spot for television work. Furthermore the size of the spot changes with temperature which would blur the image if it could be seen at all.

The other oscilloscope tube has a separate focusing electrode and the minimum spot is obtained by adjusting the negative bias to the electrode. However, as the spot must remain the same size as the intensity of the stream is varied, this type is also unsatisfactory. The curve of accelerating electrode current vs. focusing electrode voltage clearly shows how the size of the spot will vary, as illustrated in Fig. 30.

In general there are two possibilities in cathode-ray tubes for television reception. The first is to design a small tube of extremely high intensity giving, say, an image about the size of a motion picture frame and then projecting it to the desired size as in a motion picture projector. This method is now in the stages of development.

The second possibility and the one more commonly being used is to make the screen of the tube the size desired for the image. This method is most satisfactory at the present time and is being used extensively in England and Germany. The maximum size at present is limited because the bulb must be made of "hard" glass as there is almost a ton of pressure on the flat screen! This glass necessitates the use of oxygen flames, and because of the volume a considerable period of time is consumed in exhausting them. However tubes having up to 5 in. screens can be made with soft glass without danger of breakage and at considerably less expense.

The required characteristics of a cathode-ray tube for television work are enumerated below.

(1) The tube should operate with A.C. on the filament and rectified A.C. on the other electrodes.

(2) The grid or modulating electrode should operate at a negative bias and draw no grid current in normal operation.

(3) The tube should be designed so that complete modulation can be obtained from the output of the detector, eliminating the use of A.F. amplification.

(4) In modulating the intensity of the spot the velocity of the beam should not change.

(5) During modulation the size of the spot should remain constant.

(6) It should be possible to adjust the spot for any number of lines per frame.

(7) The particle-size of the material on the screen should be small enough so that no grain shows in the picture.

(8) The decay curve of the fluorescent salt should be of the persistent type, the time of decay being slightly less than the time required for the spot to return to any given position.

In Fig. 31 is shown a characteristic curve of a tube which meets these requirements. The variation of the size of the spot with accelerating voltage is clearly shown in Fig. 32.

Unusual brilliancy can be obtained with a cathode-ray tube which contains a small amount of inert gas. The gas-filled cathode-ray tube now is practically universally used throughout Germany. That is the reason why German television pictures are brighter than the English. The high-vacuum type is more common here.

The material which is used for the fluorescent coating of the screen has also been highly developed. A combination of salts has been found by the Allen B. Du Mont Labs. that will not "burn" (discolor) when the stream is allowed to remain for some time on a given spot. In the past and with other types of cathode-ray tubes the operator must use care in keeping the stream moving at all times.

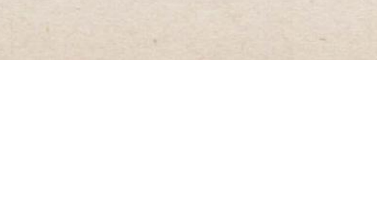


Fig. 32. Variation of spot size.

In summing up the advantages of a cathode-ray television receiver over other types, the most important is the ease with which it can be synchronized when the transmitter and receiver are on different power systems. The mechanical television receiver, because of its moving parts which have considerable inertia, requires no little amount of power to lock it in step, while the cathode-ray receiver, because of the fact that the only moving part is a beam of electron, requires no power to maintain synchronism. Another very important advantage is the ability of the cathode-ray receiver to be shifted from a system using, say, 60 lines per frame to one using 120 lines per frame, so as the art progresses the set does not become useless.

Other advantages of a "teletube" are noiseless operation, less weight in the set, less flicker in the picture and more natural color. It also lends itself more readily to the development of color television images.

Color television can be accomplished by one of several processes now available to the laboratory worker.

The salts which respond to the various colors can be applied in layers across the screen or the screen can be divided into sections and three primary colors applied in each section, as in Fig. 33. This is somewhat like the off-set color process of printing but it occurs so fast that the eye receives the effect of a blend of color. However, this development is a long way off because it is difficult to forecast whether the public will take to color television images. In the motion picture industry, the public demanded black and white pictures over color, although there are some excellent color movie processes.

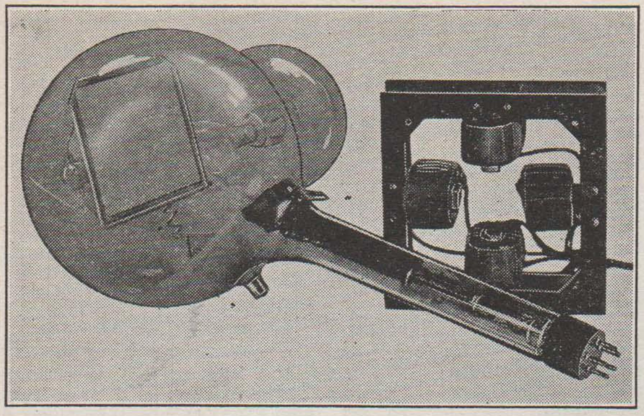


Fig. 34. The "Iconoscope" tube with its deflection coils. Note the oblong cathode at left.

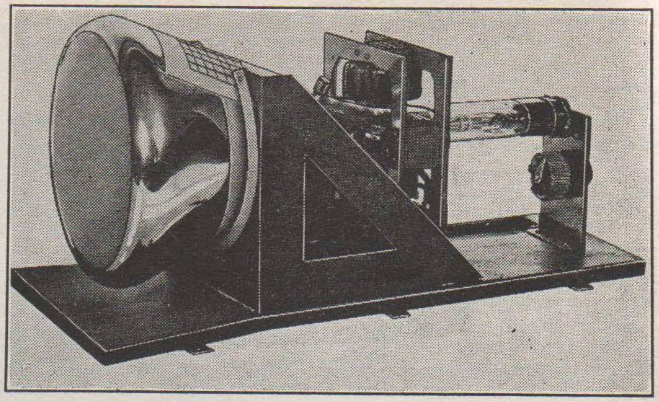


Fig. 35. The "Kinescope" receiving tube in its frame with the deflecting coils mounted in place.

CHAPTER 5

• SINCE television will form the basis of the next real "wave" of public interest in radio, the following description of the "last word" in television technique has been compiled.

The picture mosaic for a great number of years—since 1875, in fact, when Carey proposed the use of a multitude of selenium cells in imitation of the construction of the human eye—has been the ideal of scientists who have been trying to evolve a practical method of transmission and reception involving a system of television more nearly perfect in theory than that of the now out-moded "scanning disc."

Coupled with the idea of a "mosaic" system of television there has been the hope that moving parts could be eliminated—in other words that a "weightless-beam" could be used to supplant other methods of segregating the object view into its component elements, and, at a remote point, re-combining them. The weightless-beam principle of operation was demonstrated to be practicable in the **receiving** unit of a mosaic television system when the "Kinescope" (kine, motion; and scope, observe) was demonstrated to the radio fraternity several years ago. In this arrangement a cathode ray plays over a smooth glass surface covered with a fluorescent material, such as willemite, which has been made slightly conductive to permit the electron charge set up by the cathode ray beam to leak off.

The final link in the system, a **pick-up** device termed an "Iconoscope" (icon, image; and scope, observe), for use at the **transmitter**, has at last been developed by a pioneer in the field, Dr. Vladimir K. Zworykin of the research laboratories of RCA Victor Co.

The operation depends upon the use of a plate which is essentially a mosaic of minute, light-sensitive cells onto which the picture is projected by means of a lens system. These cells develop minute voltages in the condensers formed by the capacitance between these cells and adjacent conductive surfaces. The weightless-beam or cathode ray scanning these condenser units discharges them into the input circuit of a vacuum tube amplifying system. From this point the usual procedure of modulating the transmitter, radiation, and reception takes place. (A wavelength of 6 meters is particularly suitable for this system.)

In Fig. 34 is illustrated the new pick-up tube. It supplies the missing link in a theoretically perfect system of television. The schematic circuit illustrating the principle of operation is shown at A in Fig. 36; the manner in which it connects into a transmitter set-up is shown at B in the same figure.

The cathodes of the iconoscope tube are in the shape of a photosensitive mosaic on the surface of a "signal plate" and insulated from it; the anode is common and consists of the usual silvered portion on the inside of the glass bulb.

The capacity of each individual element with respect to the signal plate is determined by the thickness and dielectric constant of the insulating layer between the elements and the signal plate. The discharge of the positive charge of the individual elements is accomplished by a weightless electron beam originating from what is essentially an "electron gun," located opposite the mosaic and inclined at 30°-to-the-normal passing through the middle of the mosaic. Both mosaic and electron gun are enclosed in the same, highly-evacuated glass bulb. (The inclined position of the gun is merely a compromise in the construction in order to allow the projection of the picture on the surface of the mosaic.)

In practice, the number of individual photo elements in the mosaic is many times greater than the number of picture elements, which is determined entirely by the size of the scanning spot. Further, it has been found that all the elements of the mosaic should be of equal size and photo-sensitivity, and equal in capacity with respect to the signal plate. The fact that the exploring spot is much larger than the element modifies and simplifies this requirement so that the average distribution, surface sensitivity and capacity of elements over an area of the mosaic should be uniform.

The difficult problem of uniformity is solved by the help of natural phenomena. It is known that mica can be split into a thin sheet of practically ideal uniform thickness and it therefore serves as a perfect insulating material for the mosaic. The signal plate is formed by a metallic coating on one side of the mica sheet. The simplest method of producing the mosaic is by direct evaporation of the photoelectric metal onto the mica in a vacuum. When the evaporated film is very thin it is not continuous but consists of a conglomeration of minute spots or globules quite uniformly distributed and isolated each from the other. (Another possible method is that of ruling the mosaic from a continuous metallic film by a ruling machine.) The mosaic which is used at present is composed of a very large number of minute silver globules, each of which is photo-sensitized with caesium by a special process.

Since the charges are very minute the insulating property and dielectric losses should be as small as possible. Mica of good quality satisfies this requirement admirably. However, other insulators can also be used and thin films made of vitreous enamels have been proved to be entirely satisfactory. The insulation is made as thin as possible. Thus, the capacity to the signal plate of one square centimeter of mosaic is usually of the order of 250 to 300 mmf.

The sensitivity is of the same order as that of corresponding, high-vacuum caesium oxide photocells. The same relative efficiency is true also of the color response. (There is a cut-off at the blue part of the spectrum but it is due only to the absorption by the glass envelope.)

The electron gun producing the beam is quite an important factor in the performance of the iconoscope. Since the resolution or "definition" is determined by the size of the spot, the gun should be designed to supply **exactly** the size of spot corresponding to the number of picture elements for which the iconoscope is designed. For the examination of 70,000 picture elements on a mosaic plate about 4 in. high, the distance between two successive lines is about .016-in.; the diameter of the cathode-ray spot is approximately one-half of this size. This imposes quite a serious problem in the design of the gun.

The electron gun used for this purpose is seen by reference to A in Fig. 36 to be quite similar to the one used for the cathode-ray tube for television reception or the kinescope shown at A in Fig. 39, and which has already been described in several papers. This "gun" consists of an indirectly-heated cathode, shown at C in Fig. 36A, with the emitting area located at the tip of the cathode sleeve. The cathode is mounted in front of the aperture O of the controlling element G. The anode A consists of a long cylinder with three apertures aligned on the same axis with cathode and control element. This gun structure is mounted in the long, narrow glass neck attached to the spherical bulb housing the mosaic screen. The inner surface of the neck as well as part of the sphere is metallized and serves as the second anode, Pa, for the gun and also as a collector for photo electrons from the mosaic. The first anode usually operates at a fraction of the voltage applied to the second anode, which is approximately 1,000 volts.

The **focusing** of the electron beam is accomplished by the **electrostatic** field set up between the elements of the gun, and between the gun itself and the second anode. The theory of electrostatic focusing for this type of gun, briefly summarized, amounts to the fact that a correctly - shaped electrostatic field acts on moving electrons similarly to a lens on a beam of light. (The action of the field in the iconoscope gun is roughly equivalent to a composite lens consisting of four glasses — two positive and two negative.) The actual iconoscope illustrated has an overall length of 18 in.; the spherical diameter is 8 ins.

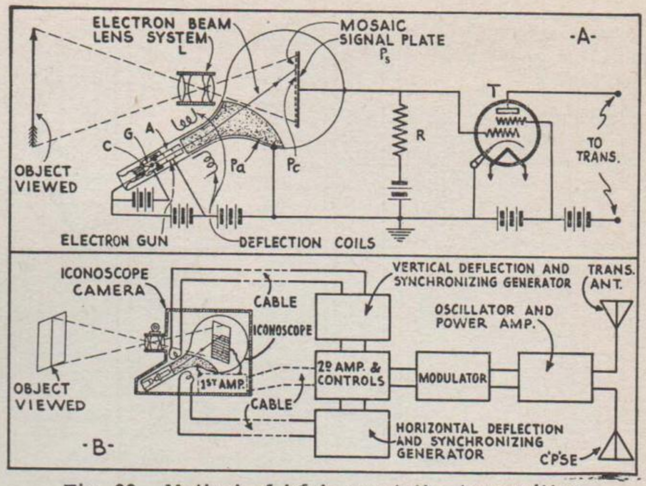


Fig. 36. Method of hook-up at the transmitter.

Fig. 37. The camera with amplifier.

The **deflection** of the electron beam for scanning the mosaic is accomplished by two **magnetic** fields at a right-angle to each other. The four deflection coils are arranged in a yoke which slips over the neck of the iconoscope. (The assembled deflecting unit is shown beside the iconoscope tube.) The scaninng is linear in both vertical and horizontal directions and is caused by saw-tooth shaped electrical impulses passing through the deflecting coils and generated by special tube generators. (The circuits for these generators as well as methods of synchronizing have appeared in the Proceedings of the I. R. E.)

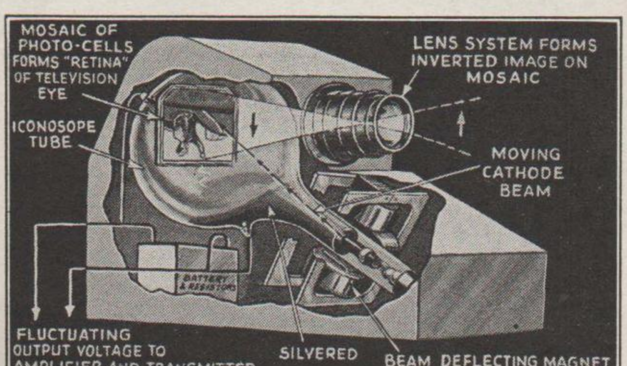


Fig. 38. Phantom view of the Zworykin Iconoscope.

Since the iconoscope is practically a self-contained pickup, it is possible to design a very compact "camera," illustrated in Fig. 37, containing the iconoscope and a pair of amplifier stages connected with the main amplifier and deflecting units by means of a long cable. Since the camera is portable, it can be taken to any point of interest for the transmission of a television picture.

The main feature of this scheme is that in the whole system there are no mechanically moving parts and the transmission of the image is accomplished entirely by electrical means.

The color response characteristics of the iconoscope make it convenient not only for the transmission of pictures in visual light, **but also pictures invisible to the eye** in which the illumination is either by ultra-violet or infra-red light.

The present sensitivity of the iconoscope is approximately equal to that of a photographic film operating at the speed of a motion picture camera, with the same optical system! The inherent resolution or "definition" of the device is higher than required for 70,000 picture element transmission. Some of the actually constructed tubes are good up to 500 lines with a good margin for future improvement!

With the advent of an instrument of these capabilities, new prospects are opened for high-grade television transmission. In addition, wide possibilities appear in the application of such tubes in many fields as a substitute for the human eye, or for the observation of phenomena at present completely hidden from the eye, as in the case of the ultra-violet microscope.

We close this review of the iconoscope television tube with the com-

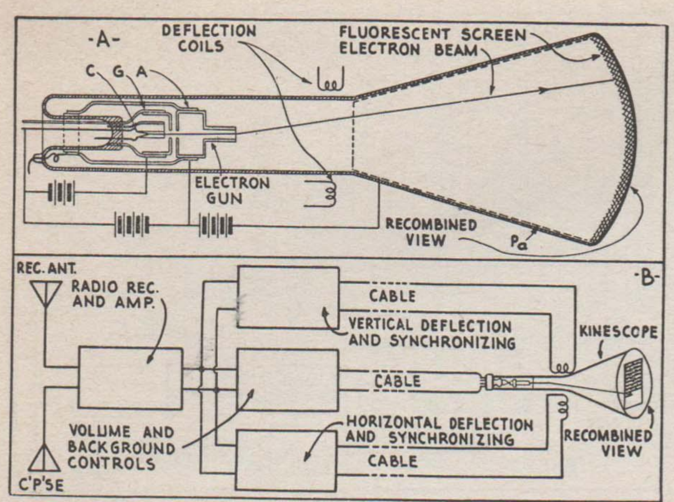


Fig. 39. The construction of the "Kinescope" and a simplified diagram of the complete receiver.

ment to those who are in favor of overnight developments, that it has taken ten years for Dr. Zworykin to bring this equipment to the present state of laboratory perfection; finally, a reasonable amount of time must elapse before all the manufacturing "bugs" have been taken out of the design, and an inexpensive instrument made commercially available to you and me.

The reception of images transmitted by the iconoscope is accomplished by means of the cathode ray receiving tube or "kinescope" (also described in past issues of the Proceedings of the I. R. E.) shown in Fig. 35. Complete block diagrams of the circuits associated with the transmitting and receiving ends of the whole system are shown in Figs. 36B and 39B, respectively. The tube illustrated measures about 18 x 8 in. in diameter.

The tube, shown in its mounting frame in Fig. 35, reproduces its moving images on the larger, or "target," end which is covered with a material known as Willemite (a zinc ore) or a similar fluorescent substance. This end of the tube is about seven inches in diameter, and it is possible to throw on this an image as large as 4 x 5 inches. However, a serious problem attending its operation is that of the voltage necessary. The tube should operate with at least 3,000 volts of anode (corresponding to plate) potential; and more if images larger than 3 inches square are required. The picture thus formed is green, instead of red, as with a neon glow-lamp; the new tube requires, however, less power output from the amplifier of the radio receiver to produce brilliant images.

The arrangement shown in Fig. 41 for a home television receiver, shows the tube built in a vertical position, into the console of a set of commercial design. A mirror set in the lid of the console, when turned up to an angle of slightly more than 45 degrees, makes the image visible to a large number of spectators, even in a moderately-lighted room. The automatic scanning system holds the image in frame; since the impulse of the ray upon its fluorescent target has a persistence comparable to that of the human eye, the image lingers slightly, and it is possible to reduce the number of "frames" needed per second. This, again, makes it possible to transmit more scanning lines on a single radio channel, and give larger images in more detail.

At the receiver the signal is detected and amplified in the usual manner, led to the band-pass filter (Fig. 39B) and then to a "controlling element" regulating emission from filament of the cathode tube, just as the grid controls the current passed by an ordinary vacuum tube. (See detail of the "electron gun" in Fig. 39A). Through the narrow opening in this control element, a stream of electrons darts into the first anode A, and then out, past the deflecting magnets. The first anode, with a potential of 300 to 400 volts, gives the electron stream a certain velocity; this, when the stream passes through the opening in the first anode, is further highly increased by a potential of 3,000 to 4,000 volts impressed on the metallic coating of the inner walls of the bulb.

With no deflecting influence from either side, the electron stream would continue straight down the center of the tube—as shown in an interesting photograph made from an oscillograph tube operating on similar principles (Fig. 42). However, around the neck of the new Zworykin tube there are two sets of deflecting magnets; the first swings the ray back and forth, to correspond with one motion of the scanning transmitter. The second set of coils moves the beam at right angles to the first deflection. The result is a complete scanning of the fluorescent screen on the target. At the same time, the modulation of the biasing voltage (on the controlling element or grid, next to the cathode) varies the intensity of the ray, and consequently the brilliancy of the moving spot of light. The result is that an image of light, and dark points is built up, in synchronism with the transmission; just as in the system of mechanical scanning in front of a glow-lamp. .

In order to accomplish this purpose, however, it was necessary to design a special tube; the device Dr. Zworykin has produced for television, he calls the "Kinescope." In laboratory cathode-ray tubes, a high degree of vacuum has been maintained only by connecting them to an air pump in constant operation; this is impossible for home apparatus. The previous low-voltage tubes have not given enough light for the duty imposed in this case. The kinescope has an oxide-coated, indirectly-heated cathode, and its various operations are under thorough control through the means described above.

For the radio transmission of television signals in a single "channel," there is superimposed upon the image-frequency (from the photoelectric cell) a series of high audio-frequency impulses, occurring only when the light beam passes the interval between pictures, and lasting but a few cycles. A band-pass filter removes the picture component, which is of the same frequency as that of

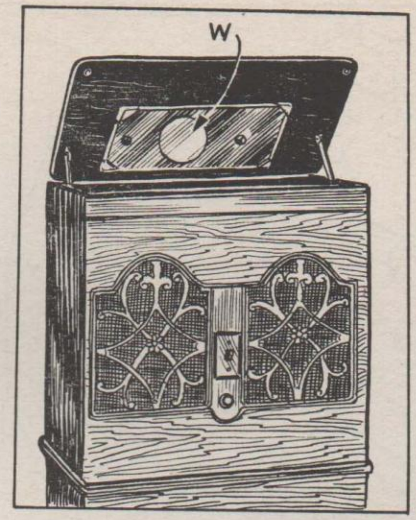
Fig. 40. Dr. Zworykin holding one of his tubes.

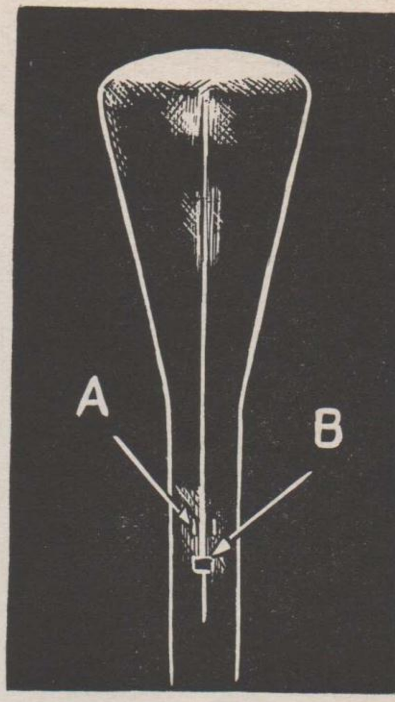
the horizontal scanning. Then a portion of the voltage which drives the vibrator, at the transmitter, is impressed upon the signal, and the complex current thus produced is passed into the modulator and registered on the carrier wave.

At the receiver, the band-pass filter separates the synchronizing frequency from the signal; the latter goes to the control element and the former to the deflecting coils of the kinescope. The modulation caused by the framing impulses does not affect the pictures because it occurs only in the intervals between frames.

An interesting variation of the RCA system has recently been perfected in Italy, and is here described briefly. It was developed by Mr. Arturo Castellani, who is called the "Zworykin of Italy".

The latest progress of the Castellani-SAFAR television system is a Telepantoscope, a television camera for direct pick-up, which is at present used for the transmission of a 240-line image, but has all qualities claimed for a 340-line transmission. The nucleus of this new camera is a very ingenious combination of a photoelectric cell with a cathode-ray tube. This combination is used in the direct pick-up devices designed by Zworykin and Farnsworth in this country. It is well known that the experiments using ordinary photoelectric cells for direct pick-up have not been very successful because of lack of sensitivity in the photoelectric cells. Mr. Castellani increased the sensitivity of such a photoelectric cell by means of a very interesting trick. He uses the electron beam as produced by a cathode - ray tube as a "pulling" device. That means, expressed in simple language, that the electron beam of a cathode - ray tube "touches" the surface of the photoelectric cell, and provides by this an "easy going" road for the electrons, as radiated by the photoelectric cell. The cathode-ray beam operates by this trick as if a small brush, made of very fine litz wires, were moved across the surface of the photo-sensitive layer of the cell.





Above, Fig. 41. The receiving tube is placed vertically, and is viewed by means of the mirror set in the cover of the case. This is typical construction in television receivers of RCA. Right, Fig. 42. A photo of the actual cathode ray, taken in Germany by Von Ardenne.

It is easy to understand that this "touching" electron beam decreases the resistance of the photo-cell against the radiating photo-electrons to nearly zero. The electrons radiated by the photo-electric cell are thus increased in speed. Increased speed of electrons might be compared with an increase of sensitivity, and this is the very point Mr. Castellani was driving for.

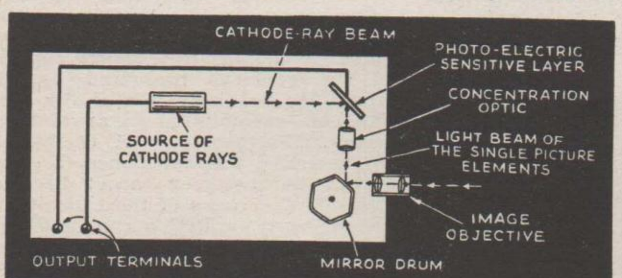
Compared to similar devices developed by Zworykin and Farnsworth the Telepantoscope operates with mechanical scanning devices. A tiny rotating mirror drum scans the image and reflects the single picture elements into the photo-cell part of the Telepantoscope.

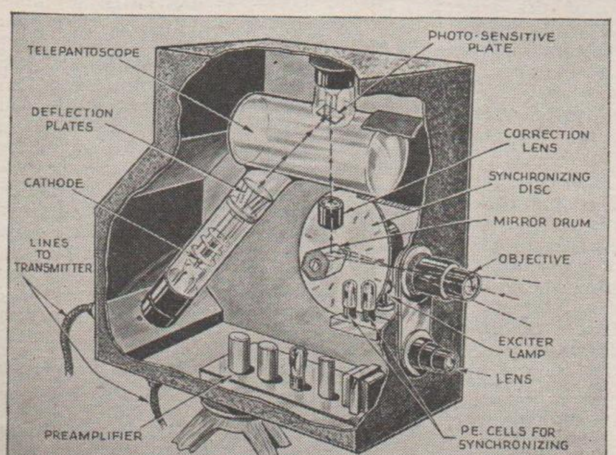
The Telepantoscope transforms these light impulses into comparatively powerful electric impulses in the range of 50 microvolts which are led directly to a small preamplifier. This preamplifier is of normal design but has a flat response curve from 25 cycles up to 1,000,000 cycles.

Since the dimensions of the Telepantoscope tube, of the scanning mirror drum and the preamplifier are not of very large magnitude all these parts are installed into a cabinet of about the same size as an ordinary movie camera.

The television receiver has a screen of 7 x 8 ins., and as reports from Italy indicate, the performance obtained with this receiver is of a high entertainment value.

Italy is not the only country with a system which has elements similar to the Zworykin system. Through a license agreement, commercial interests in both England and Germany are using apparatus almost identical to that employed here by RCA!





Above, Fig. 43, note that the cathode ray acts as a flexible wire in this system. Below, Fig. 44, the complete camera which uses mechanical scanning.

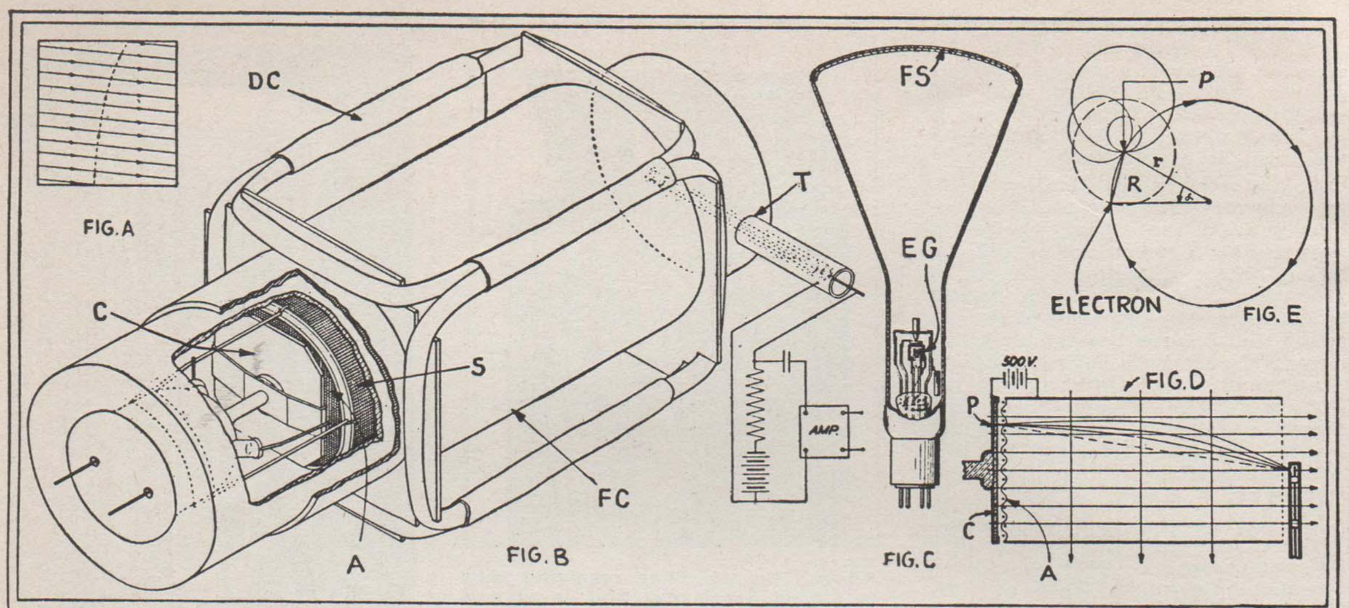


Fig. 45. Details of the Farnsworth system of television. The interior of the dissector tube is shown at Fig. B, while Fig. C shows the construction of the receiving tube. Fig. D details the path of the electrons from a point on the cathode, their rotary motion being shown endwise in Fig. E. The object is to bring them all to a point on the target.

CHAPTER 6

A detailed description of the Farnsworth system of television.

● THE Farnsworth system of television will be described in detail in this chapter. First we will cover the details of some of the earlier work on this method, then the latest apparatus will be described and pictured.

The highly novel transmitting pickup tube, called an "image dissector", is entirely different from any that is used in other systems, although the receiving equipment is somewhat similar to the more or less standard cathode ray design, with some exceptions which will be noted later.

The "image dissector" tube is shown diagrammatically in Fig. 45B and in cross-section in Fig. 45D. As will be seen, it comprises a cathode (C), coated with photo-sensitive material, which is parallel and closely situated to an anode screen (A). The anode screen is electrically connected to the electrostatic shield (S). At the end of the tube opposite the cathode is placed a target electrode (T) having all but a single small area shielded from the discharge.

This tube, considered broadly, is a photo-electric cell wherein provision is made for forming an "electron image" of an optical image focused on its cathode surface. By "electron image" it is meant that, if a fluorescent screen were placed in the plane of the electron image, the original optical image would be reproduced. The condition necessary for the formation of this electron image is that all the electrons emitted from any single point on the cathode surface shall meet again in a corresponding point in the plane of the electron image.

An image of the object to be transmitted is focused upon the cathode, and the photo-electrons emitted therefrom are accelerated by a potential of the order of 500 volts between the cathode and anode screen. Most of them are projected into the region between the screen and target and, by means to be described later, combine to give an electron image in the plane of the target. This electron image, made up as it is of a prism of moving electrons, can be shifted by a magnetic field at right angles to the tube. By this means, the image is moved over the scanning aperture in the target shield.

In practice, two sets of coils are placed about the dissector tube, as shown in Fig. 45B, at right angles to one another. A sawtooth wave alternating current, of about 3000 cycles per second, flows through one set of coils; producing, let us say, a horizontal deflection of the image. A current of similar waveform, but with a period of 1/16-second, flows through the other set of coils, and produces a vertical deflection of the image. The resultant path of the image, relative to the aperture, is similar to that given in Fig. 45A; there will be 200 horizontal lines drawn for each traversal of the image, and the time of one line will be 1/3000-second. We shall therefore require an amplifier handling a band width of approximately 300 kilocycles, to amplify the target current.

The problem presented by the amplifier has been one of the most difficult encountered in any of this work. Furthermore, at the higher frequencies, the impedance in series with the dissector target becomes very low, because of the capacitance shunting it; and this causes a corresponding decrease in the amount of voltage delivered to the input of the amplifier. However, the whole problem has been greatly simplified by a system of "admittance neutralization," which is particularly useful in the neutralization of capacity, and which permits input impedance (as well as interstage tube impedance) as high as several megohms to be obtained, up to a million cycles or more. At the present time an amplifier is being used which has a frequency-characteristic approximately flat to 600 kilocycles. The "admittance neutralization" principle, as well as the design in general of these wide-frequency-band amplifiers, will be explained at another time.

Consider the path of the electrons which leave the same point, on the surface of the cathode, at which a point of light in the optical image is focused. If all of them traveled parallel to each other, a perfect image would be formed at any point of the beam. But they are emitted at different velocities, corresponding to potentials from zero to about three volts. The irregularity of the cathode's surface, large in proportion to the electrons, and the ending of electro-static lines of force near the wires of the anode screen (A) cause the electrons to spread out in conical ray—with an angle at the apex of about five degrees, in our present dissector tubes. Nevertheless, something of an image may be formed at the window by the use of low-frequency **(reddish or infra-red, presumably, to which photoelectric surfaces are less sensitive**—Editor) light, careful construction of the anode screen, and high anode voltage. However, it has been found possible to focus these electron rays magnetically.

This is done by creating a uniform magnetic field of proper intensity, with lines of force parallel to the axis of the tube. This causes the electrons to follow spiral paths, all **tangent** to the line of magnetic force through the point P where they originate. Each electron, viewed from directly ahead, is describing a circle, large or small, as it travels forward. (See Fig. 45E.) However, regardless of the speed of the electron, and the diameter of the circle, it will reach the same point on the circle, from which it started, in the same time; that is, every electron will be in line with P at a given time. This makes it possible to bring the whole beam of electrons to a point on the target, as shown in cross-section in Fig. 45D.

If we change the direction of the field, the point where the electron beam is focused will be shifted; and, by imposing a transverse magnetic beam on the lengthwise field, we will deflect the electrons proportionately. In this manner the deflecting coils, carrying alternating currents, will cause the beam to move from side to side.

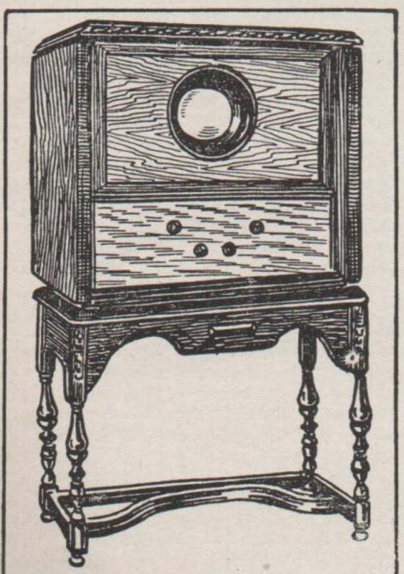


Fig. 46. A television receiver developed in 1931 by Farnsworth. Note that the cathode ray tube is horizontal as in the latest Farnsworth sets.

The present dissector tube with its carefully-made anode screen produces a stationary electron image which is not inferior to a very good optical image. When the image is deflected for scanning, however, the resulting moving image is slightly blurred at the edges, for the following reasons:

1. The distance from the cathode is slightly greater than at the center.
2. The velocity of the electrons toward the aperture is less for the edges than for the center.
3. The magnetic field, in the direction of the electron's path, increases with the angle from the center.

All these factors are reduced by increasing the deflection distance. In practice, 15 degrees deflection on each side of zero is the value used, when the scanning aperture is not smaller than 15/1000-inch.

The high-vacuum-dissector tube such as that depicted in Fig. 47A comprises a cylindrical glass envelope, having at one end a flat window (W) which is polished before sealing in. At the other end is a stem, upon which the elements of a tube are supported and through which the leads pass. The inner end of the stem carries a short glass pillar (P) terminating in a square button; the button supports a silvered mirror on which is deposited a photo-sensitive film. A band clamp is supported from the stem, having welded to it wires which carry the anode structure.

The anode structure itself (see Fig. 47C) is made by winding very fine tungsten wire around a tungsten-nickel frame as shown. This is supported from the collar, so that it is closely parallel to the cathode. Supported separately from the collar is a cylindrical screen, usually of fine nickel mesh, which conforms closely to the inner surface of the glass envelope. (In the latest types of tubes, this screen has been replaced by a platinum coating on the walls of the tube.)

Two general types of targets are in use; that shown in Fig. 47D is designed to make use of secondary emission; while that shown in Fig. 47E is intended only for primary emission.

After the elements of the tube have been sealed in, it is sealed to the pump in much the same manner as an ordinary photoelectric cell, provisions being made to distill into the tube a small amount of potassium. After the tube has been baked for three or four hours on the pump, and the vacuum is as good as can be obtained, a small amount of potassium is distilled into the tube and allowed to condense where it will. Then, by heating the lower portion of the tube, the potassium is deposited upon the cathode; the tube

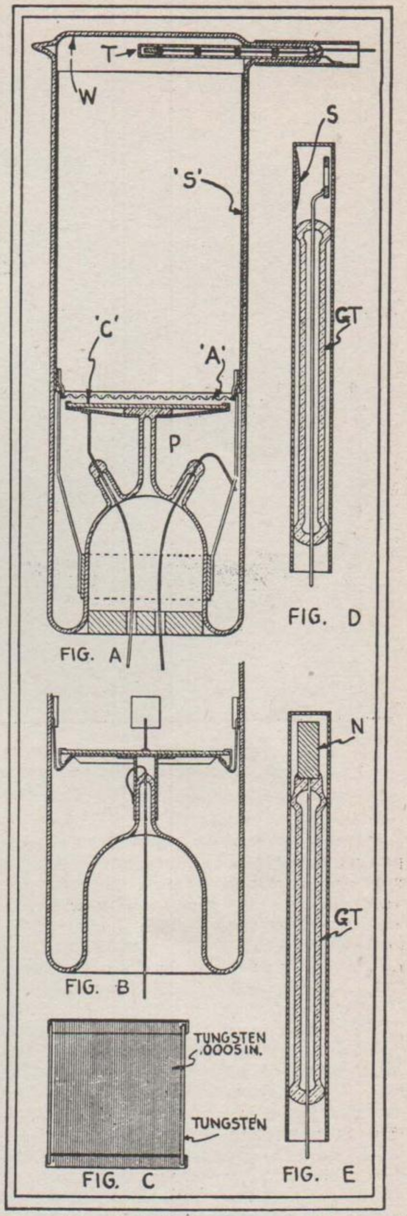


Fig. 47. Detailed cross sections of various parts of the image dissector tubes used by Farnsworth.

having been designed so that the cathode remains cool, unless the stem is heated.

It is necessary to be very careful in this process, to dry the potassium very slowly. Otherwise there is produced a glazed cathode surface which has been found to be inferior in uniformity to an unglazed surface. Care must also be taken to keep the target of the tube warming during the potassium distillation, to insure that no metal condenses inside the target shield.

After the tube has cooled thoroughly, hydrogen is admitted and the surface colored by the Elster-Geitel process. Care must be taken

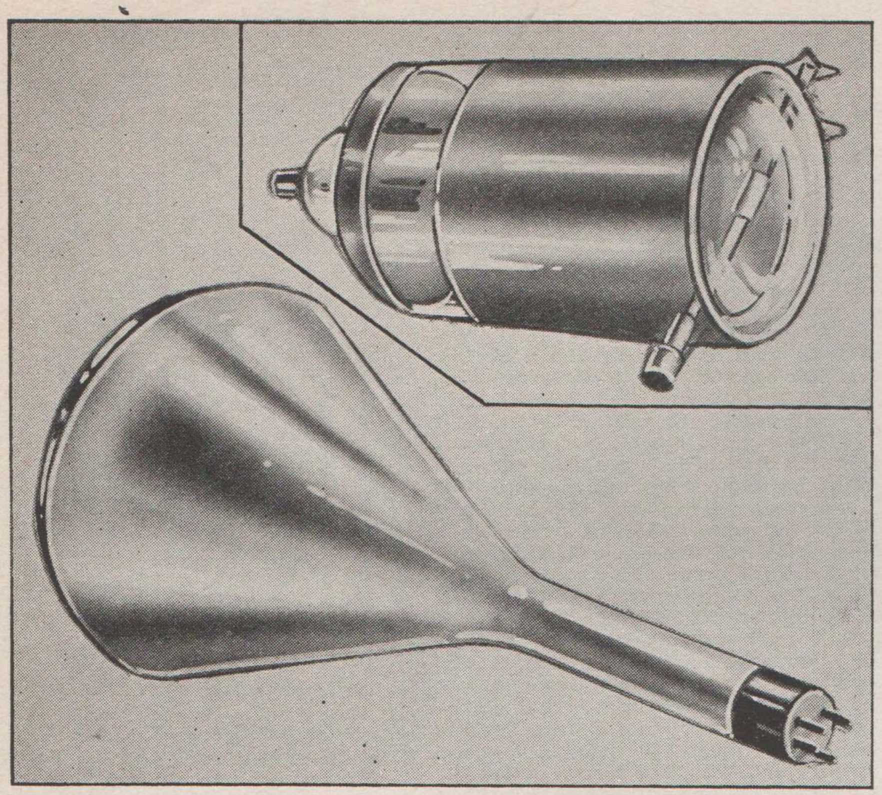


Fig. 48, above, the dissector tube, which is used for transmitting. Fig. 49, below, the "oscillite" receiving tube.

at this stage to insure the exact pressure of hydrogen which will permit the entire surface to form at one time; otherwise a non-uniform emitting surface will result. The cell is then carefully pumped to rid it of all traces of hydrogen; after which it is sealed off the pump.

The work of A. R. Olpin and L. R. Koller has indicated two general methods for greatly increasing the sensitivity of photoelectric cathodes; the Olpin process particularly has been applied with great success to the construction of dissector tubes. The general technique, as it has been evolved for the preparation of these "sodium-sulphur" dissector cathodes, is closely similar to that employed by Olpin. One rather interesting side light is that if, in the preparation of the sodium-sulphur cathode, it is spoiled for some reason or other, a moderately sensitive dissector is secured simply by admitting hydrogen and passing a glow discharge, as in the Elster-Geitel process. This usually gives a cell with a sensitivity of one microampere per lumen **(unit of illumination)** and the sensitivity seems to be more permanent than with the potassium-hydride cell.

The sensitivity of such a dissector, like that of the usual potassium-hydride photocell, is best at about one-half microamp./lumen (or one-twentieth that of a gas-filled photo-cell) though this can be nearly doubled by the use of secondary emission from the target. The potassium-hydride cell, is therefore, not sensitive enough to be used with light reflected by an image; these types of cells are used with transparencies and a 400-watt tungsten lamp.

The sodium-sulphur cathode dissectors have a sensitivity of 6.5 microamps./lumen; a suitable light intensity may be obtained by illuminating the face, or an object of equal reflecting power, at a distance of one foot with a 1500-watt tungsten lamp. This sensitivity, therefore, approaches the order of that required for direct scanning.

Zworykin reports sensitivities of 25 microamps./lumen; this sensitivity would permit direct scanning with lamps that are not too bright to be used with animate subjects. Dissectors of this sensitivity, however, have not been built as yet.

Dissector tubes may be built to operate without an anode screen. Fig. 47B shows the construction of such a tube. Its principal advantage is its simplicity; it has the disadvantage of giving a rather poor electron image, and has not thus far been built with a ratio, of aperture to cathode area, greater than one to five thousand.

The picture frequencies from the amplifier are re-built into an optical image at the receiver by means of an electron-beam tube, or "oscillite," as shown in Fig. 49. This is simply a modified Braun oscilloscope, which makes use of the electron-image principle of the dissector tube, to allow good light intensity to be obtained.

It is required to generate at the receiver, two alternating currents of sawtooth waveform, identical to those used at the transmitter. These currents, of course, have to be synchronized with those at the transmitter; to accomplish this, use is made of the fact that these currents induce a strong voltage pulse in neighboring circuits during the steep part of their slope. This voltage pulse is, accordingly, introduced into the picture frequencies' circuit, and serves at the receiver to hold the scanning generators in step. It serves the further purpose of turning off the oscillite "spot" during the return part of its path; that is, during the very steep part of the sawtooth wave-cycle.

This system of synchronization is very simple and very effective. It does not require any extra transmission medium for the synchronizing impulses, nor even any extra equipment such as filters, etc., to separate the synchronizing impulses from the picture frequencies. Much work has been done in the development of these sawtooth-wave generators, and on this system of synchronization, but space requirements will not allow their being reported here.

The principle of magnetic focusing becomes very useful in the construction of oscillite or receiving tubes. It enables us to focus back, to a point, all electrons from a single emitting point; and thereby to obtain very good light intensity in one of these tubes. In fact, the light intensity so obtainable is limited only by the properties of the fluorescent material. Spot intensities can be obtained which turn fluorescent material black and inactive after only a few seconds' exposure. The element used in this work will be described later on.

The receiving system used in connection with the dissector tube is closely similar to that proposed by Nicholsen and Rosing, and to that recently demonstrated by Zworykin. The oscillite tube differs from Zworykin's "kinescope" in the means used for focusing the spot and in the detail of the "electron-gun" element.

The magnetic focusing principle, as stated before, permits all electrons having a source in the same point to be focused back to a point on the fluorescent screen. The electron-gun element has been designed with the idea of securing the greatest possible number of electrons through a given-sized aperture, and limiting the angle of this beam to that which can be accurately focused. This element comprises a spiral filament coated only on the inside. A shield, perforated by a hole of the same diameter as the filament helix, is placed over this filament. The anode is tubular in form, and placed in front of the cathode; while

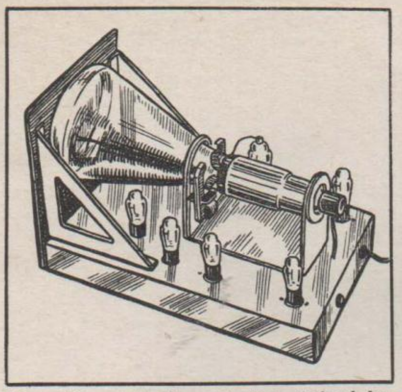


Fig. 50. Interior of the television scanning chassis. Note tube sizes.

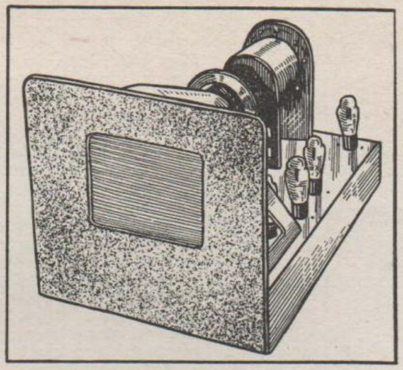


Fig. 51. The screen upon which the picture appears is 5 x 6 ins. long.

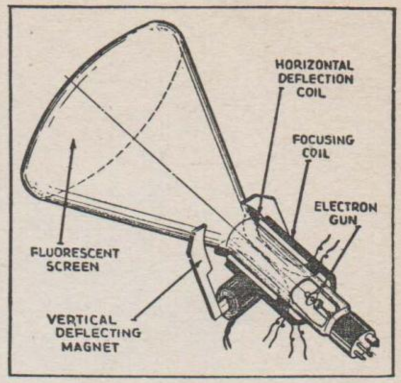


Fig. 52. Arrangement of parts around the "oscillight" tube base and neck.

a ring grid is placed about midway between the filament shield and the anode.

The merit of this type of element lies in the fact that the anode tube is located, approximately, at the focal point for the electrons leaving the emitter. The anode voltage, required to create this focal point at the entrance to the anode tube, may be of any value between 1500 and 2500, for the tubes we are using at present.

An interesting effect has been noted with regard to the operation of these tubes; they function only when secondary electrons are emitted from the fluorescent screen. Sometimes a black spot will appear on the end of the tube, due to that point's charging up negatively. It will be recognized that an unstable condition exists here, and that a point on the fluorescent screen will assume either a large negative or a large positive potential with respect to the anode. This effect is not bothersome at all; in fact, it is necessary to have very high current density, in order to observe it.

The deflection-coil system used with the oscillite tube is exactly similar to that used with the dissector tube; the power required in these coils for the largest possible pictures may be generated with a '10 tube, while that for the focusing coil is quite negligible. One type of scanning generator used at the receiver embodies a helium glow-tube feeding a '10 power tube.

The circuit required to get the requisite amount of power from a '10 tube into an entirely inductive load has been developed over a period of several years; the details will not be given here.

These generators are synchronized by coupling them with the main picture-frequency circuit since, as explained before, the requisite pulses are induced at the transmitter.

The latest development of this receiving system is shown in Figs. 50, 51 and 52.

This reproducer, incorporating all the essentials of a television receiver except the radio-frequency and detector circuits, is shown in the photographs. It contains magnetic circuits for focusing and scanning with the cathode-ray tube, oscillators to deflect the ray in scanning, and the high-voltage supply for the anode of the tube.

Magnetic fields are employed entirely for focusing and deflecting. These offer two outstanding advantages: simplicity and cheapness of construction of the cathode-ray tube, and a sharpness of focus throughout the picture field which is difficult to obtain by any other means.

A single amplifier stage for the picture signal is included on the chassis. This may be compared to the output stage of a sound receiver except for its wide-band amplification. Another tube amplifies and detects the line and picture-frequency synchronizing impulses which are transmitted with the signal. This permits separating the impulses from the signal on the basis of their amplitude and polarity. They are then applied to the respective oscillators to effect automatic synchronizing.

The scanning circuits are designed for a 240 line picture field, a value which has been shown to give very pleasing picture detail. This line structure with a picture repetition rate of twenty-five per second is widely used in current developments of high-fidelity television in Europe. For this combination, the line scanning frequency is 6,000 cycles. A vacuum tube oscillator supplies current of this frequency and of a saw-tooth wave-shape for transverse or line scanning. This produces a uniform scanning rate with consequent even illumination and equally sharp detail across the whole width of the picture field. The return of the scanning spot requires but one-tenth as long a time as the scanning of one line; approximately 1/60,000-second. During this short period, an impulse is received over the picture channel to synchronize the oscillator, automatically holding it in step with the transmitter. The oscillator employs one tube of an ordinary receiver type and a small transformer of special design.

Vertical or frame-frequency scanning is accomplished with saw-tooth currents which are generated by an oscillator similar to that used for line scanning. This scanning runs at 50 cycles per second so that the picture field is scanned twice during each picture. Between successive scannings the whole picture field is displaced vertically by an amount just sufficient to cause the lines of one scanning to fall between those of the preceding one. This process is known as interlacing; it has the effect of reducing flicker and line structure of the reproduction.

The anode of the cathode-ray tube is supplied with 4,000 V. by a small unit employing a rectifier tube no larger than a radio receiver tube. The high-voltage transformer is also quite small, and standard types of receiving set condensers are connected in series for filtering.

The cathode-ray tube is a Farnsworth "Oscillight" with a 9 in. screen, which produces an image 5 x 6 ins. The image is black and white and bright enough to be viewed in a partially lighted room.

Figure 52 shows the details of this tube. In place of the receiving aperture there is an "electron gun" which sends an intense beam of high velocity electrons down the axis of the tube. This beam is focused (by means of a magnetic field) on the fluorescent screen where it produces a bright spot of light. A special electrode, whose action is similar to that of the grid in a three-element vacuum tube, is connected to the input signal pulses and serves to control the intensity of the electron beam, and consequently the brightness of the fluorescent spot, keeping this brightness proportional to the light intensity of the spot on the image being scanned at that particular instant. A pair of magnetic deflection coils (whose action is analogous to the corresponding pair on the image dissector, which is used in the transmitter) is fed with a current of the same frequency and wave-form as that feeding the latter,

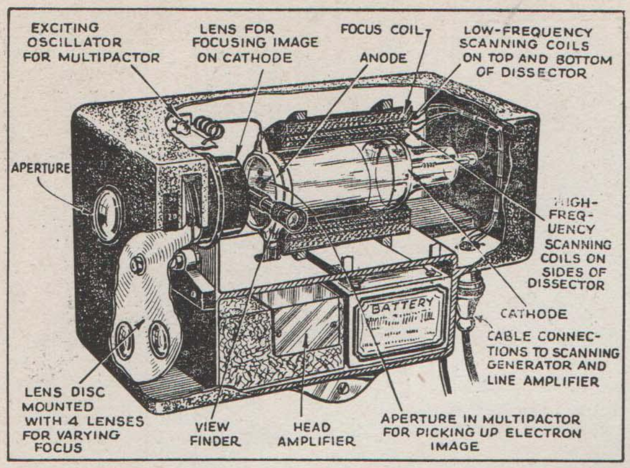
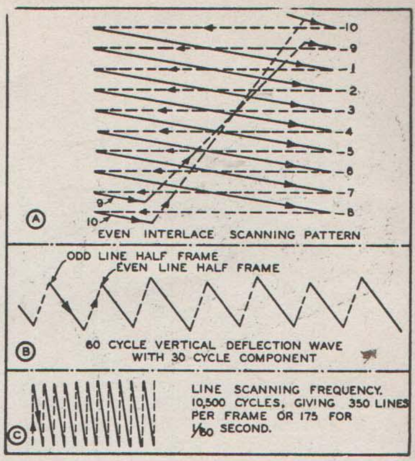


Fig. 53, left, cutaway view of the improved camera. Note the dissector tube which is the heart of the device. Fig. 55, right, the principle of interlaced scanning, which is described more fully on page 29. The scanning beam skips every other line, then retraces and fills in the lines which were missed on the first coverage.



and serves to displace the cathode-ray spot on the fluorescent screen, causing it to trace out a line of the image. The low or image frequency magnetic deflecting field of the oscillight differs from that in the dissector in that an iron-core electromagnet is used, but its action is essentially the same, since it displaces the cathode-ray beam at right angles to the lines at a uniform rate, such that successive lines are displaced by the width of the spot from the preceding line. Thus at any instant the position of the spot on the fluorescent screen of the oscillight corresponds exactly to the position of the scanning aperture on the electron image in the image dissector tube, and the brightness of the spot corresponds to the brightness of the corresponding point on the optical image.

Since the saw-tooth generators of image dissector and the oscillight are separate electrical units, it is necessary to provide some means of exactly synchronizing them. This is accomplished by means of synchronizing impulses which are sent along with the signal impulses. The line frequency generator feeding the image dissector is coupled to the output circuit of the image dissector in such a manner that it delivers a large impulse into this circuit during the back trace of the scanning line. At the receiving end this impulse comes through with the signal impulses and is amplified along with them. By means of a tuned selective filter circuit this synchronizing impulse is separated from the television impulses and after additional amplification is fed into the line frequency saw-tooth generator which feeds the oscillight deflecting coils. If this added impulse amounts to several per cent of the impulse produced by the generator it is sufficient to "lock" the line frequency generator of the receiver firmly in step with the corresponding generator at the transmitter. Since the "back trace" of the scanning line is not instantaneous it is desirable to extinguish the cathode ray during this back trace so that it does not appear on the fluorescent screen. This is done by means of coupling the line frequency generator to the modulator electrode of the oscillight in such a way that a large negative potential is applied to this electrode during the back trace, thus extinguishing the cathode-ray beam during this interval.

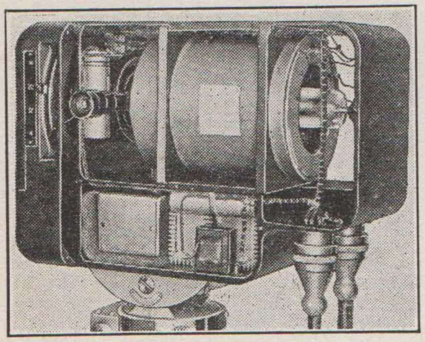


Fig. 54. Interior view of the latest television camera.

A new camera no bulkier than the standard motion-picture sound camera has been designed around the dissector-multiplier tube for picking up images for transmission by radio. This camera, shown in Figs. 53 and 54, is capable of **televiewing** any action that the motion picture camera can photograph. Thus, it is possible to bring scenes of any nature to the home by means of television. The camera complete weighs only 75 pounds, the overall dimensions of the camera box being only 10 x 12 x 15 ins. long!

The exciting oscillator and the head amplifier both use the new "acorn" (type 955) tubes so as to take up very little space. The leads to the camera from the main control panels must be well shielded; received-image "microphonics" are due to vibration of these leads.

Improvements in the televiewing camera were concerned primarily with increasing the over-all sensitivity of the camera unit. Improvement began with getting better photoelectric emission from the dissector cathode, greater gain in the multiplier, and a more efficient head amplifier. The over-all sensitivity of the camera is such, that now, an illumination of 40 foot candles at the lens is sufficient for satisfactory television pictures. The final important improvement came in newly designed focusing and scanning coils, which help to produce a television image free from distortion and ripples.

Much of the improvement in picture detail is due to the new method of interlaced scanning employed. If beyond a certain point the number of lines per frame be increased, the band of picture signal is increased without appreciably increasing the picture detail. Therefore, a method of effectively increasing the picture detail and reducing the flicker has been developed by doubling the frame frequency and letting the lines of alternate frames fall midway between each other. This method of scanning is called "2:1 even interlace" and is accomplished by impressing on the 60-cycle vertical deflecting frequency a 30-cycle oscillation of a magnitude just sufficient to change the amplitude of the 60-cycle oscillation by the space of ½

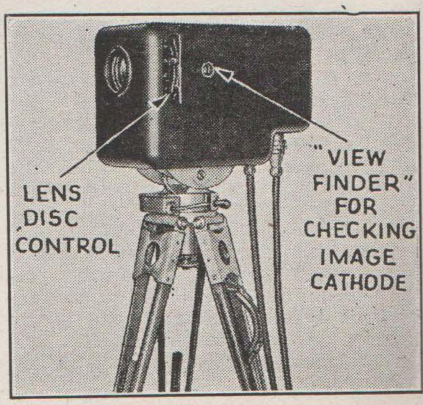


Fig. 56. The camera mounted on its tripod, ready for action.

line in the vertical plane of the picture frame. (See Fig. 55) This causes the "odd" and "even" lines to fall in alternate positions every 1/60-sec. Thus, if 350 lines are in every complete frame (1/30-sec.), there will be 175 "odd" lines on the frame the first 1/60-sec., and 175 "even" lines on the frame the second 1/60-sec.

The difficulty of maintaining such a scanning pattern is dependent on the accuracy of the 30-cycle oscillation impressed on the vertical deflection frequency. If the amplitude of this wave changes, the spacing between interlaced lines will vary, thus destroying the scanning pattern. At the present time, experiments are being conducted employing either 350, 441 or 450 line frames. **It is quite possible that a system employing 450 lines per frame will be the ultimate result.**

Interlaced scanning is a subject about which we today hear a great deal. Those who have not pioneered television would be inclined to think that this is something new, but interlacing has been investigated over a period of many years, and in fact, the quantitative constants have been rather well established.

Some of the advantages of interlaced (or offset) scanning are as follows:

1. A much lower scanning speed.
2. A smaller eye strain.
3. A faster permissible motion of the image.
4. The elimination of the picture "flash" when the eye winks.
5. A higher fidelity of the probable image when using a condenser-coupled electrical amplifying system.

It has been unpleasant to listen to some engineers speak of the number of scans per second as though television engineers had frequency to "burn"; and fidelity so fine as to necessitate practically putting the image out of focus in order to avoid unpleasant sharpness! Such is definitely not the case, and we must conserve every spot of the television picture and cause it to recur as infrequently as possible as long as we retain a thoroughly acceptable effect. In other words, using ordinary American business intelligence with our engineering, we must make our picture definition cost us as little as possible.

Now the reason for picture line frequency interposition in television can be illustrated very simply:— The probable image is a person's face—that is, although we must resolve every conceivable type of image, the human face is the most probable. Therefore, the scanning system producing the **probable frequency** will probably develop this most probable frequency by scanning a face. The face, if traced with an ordinary simple sequence (or non-interlaced) scanning system shows a practically similar waveform sequence in the electrical system, for each line-tracing across the forehead. The low-frequency (or shadow) variation is approximately the same in each case, and therefore, the average voltage developed in an alternating current amplifying system will develop in a general direction which will alter the effective bias on the control-grid in the amplifying system. Therefore, any system using condensers, or a so-called "condenser-resistance coupled" amplifier, will yield spurious shadows in the vicinity of any repeated waveform sequence which is either lighter or darker than that produced at zero signal level. For example, if each successive signal increases the charge in the coupling condenser, which does not have time to completely leak off between signals, then a continuous discharging current will cause a general change in brilliancy in that zone of the picture where these effects occur. Thus, the picture assumes a striped appearance having different zones of light and dark shadings.

A noticeable improvement in picture fidelity is immediately effected when a television engineer omits every other line on one scan of the image and inserts it with the next scan, alternately interlacing or off-setting, for then the number of repetitions of "forehead signal" or "hair signal," or "mouth signal" are reduced by 50 per cent and "interlaced" with other signals. Optically, this "shutter" or "lattice work" appears to move within itself, and the scanning system really has to trace very rapidly to effect a pleasant optical sensation. Now, if we off-set **3 times** so that we leave out **every 2 adjacent lines,** then a much more acceptable optical effect is achieved while tracing the picture at a fairly low scanning speed, and at the same time a lesser number of repetitions of the same type of signal occur in sequence; thus, only a few lines have "forehead signal" before they are followed with the signal produced from the eyes, or the teeth, etc.

Visible improvement in fidelity continues as we increase the number of offsets, but the optical advantages

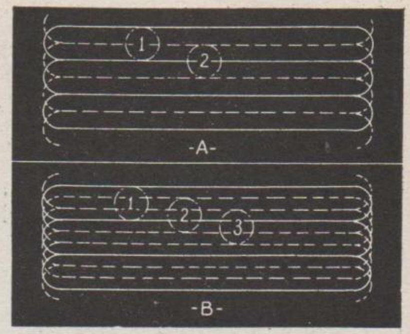


Fig. 57. Two different methods of offset or interlaced scanning.

of off-setting decrease if we follow too-rhythmic interlacing, for then we appear to see an apparent motion between the coarse-grained pictures that are interwoven. **It has been observed that the best optical and electrical effect is obtained when we scan sections of the picture as widely separated as possible** with each successive tracing of a line of the picture.

Great advantage is obtained if on every other complete cycle of scanning events, we cause the lines to be "half-offset" so that they trace in the manner shown in Fig. 57. The center of definition has now shifted to the point where absent lines formerly existed, and this "invisible offsetting" greatly reduces the apparent grain in the picture so that it can be made to appear extremely smooth. We call this "invisible offsetting" **definition multiplication,** for in effect, it takes a fixed lattice work, and puts it into a state of motion. This effect may be improved with two "invisible offsets" in the manner shown in Fig. 57B. Therefore, by operation of these two methods of scanning in cooperation, we achieve both the advantages of **definition multiplication** and line frequency interposition; or in other words the best optical effects **and** the best electrical effects. Hence, by the application of such a system we can say, "we have made television scanning progress."

That is, we can scan and produce the optimum definition with the minimum speed, with the minimum electrical frequency, and the cheapest possible electrical amplifying systems; and with devices which might otherwise have too much inertia for improperly-engineered, higher-speed systems attempting to produce the same definition at the same frequency.

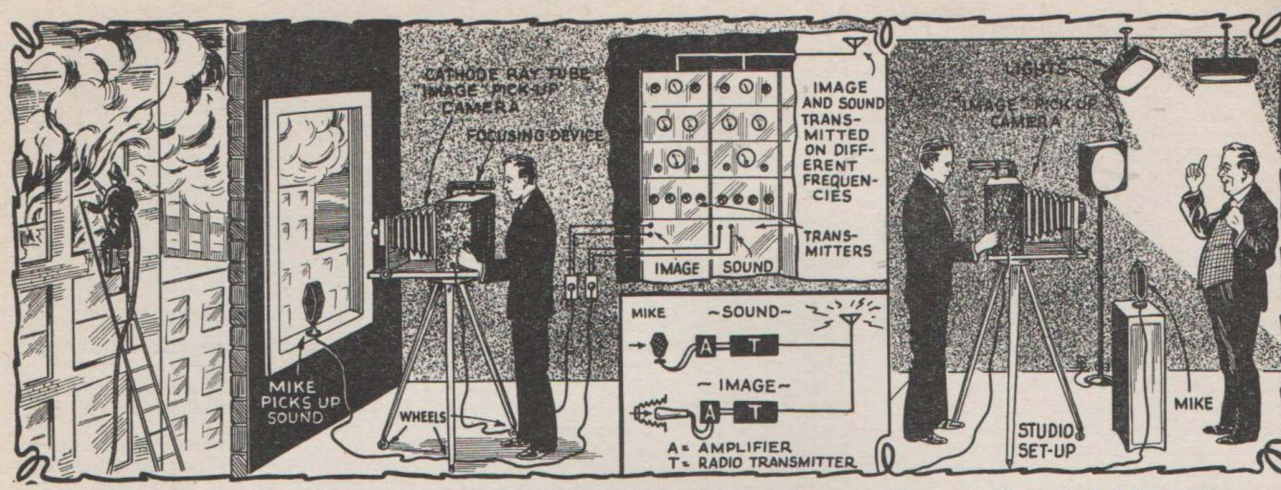


Fig. 57A. Technique employed in television transmission, both in and outdoors, in the latest RCA system.

CHAPTER 7

● SEVERAL months ago, a demonstration of television by the cathode ray principle was given at Camden by RCA. This was for the purpose of showing radio editors just what could be accomplished in the field at the present time. The results were excellent, and experiments are now going on to work out a practical system of coverage so that the public may enjoy the advantages of television.

The cathode ray method of scanning is employed in the RCA equipment. Two ultra-short wave transmitters are employed, one for sight on 46 mc. and one for sound accompaniment on 48 mc., as seen above. The television transmitter sidebands extend 1½ mc. on each side of the carrier or a total of 3 mc. The pictures contain 343 lines. Scanning is done at 30 pictures per second.

The receiving equipment consists of two separate receivers of the superheterodyne type, operating from a 110 volt, 60 cycle A.C. power-supply. Both receivers are in one cabinet. The receivers will tune from 40-80 mc. Details of the receiving equipment are shown in Fig. 58. See also Chapter 5 for technical considerations of this system. .

The cathode ray tube is mounted vertically in the cabinet, with the end where the image appears pointing upward, so that one would have to look down on the top of the cabinet to see the image directly. However, the television image, which has a size of 5 x 7 inches, is reflected on a metal mirror, which is so arranged that persons sitting in front of the set can clearly see the images.

The receivers employ a total of 33 tubes, all of which are of the standard receiving type, with the exception of the cathode-ray tube and its associated high-voltage rectifier. There are 3 metal tubes in the set; all the rest are glass.

A total of 14 controls is to be found on the set, 7 on the front panel and 7 under the movable top of the cabinet. This top is raised and lowered exactly as is the top of a radio-phonograph cabinet. Instead of a phonograph turn-table within, however there is the cathode-ray tube and the 7 controls mentioned above. The reflecting mirror is mounted on the inside of this movable top which is left in the raised position when "viewing" a broadcast.

The 7 front panel controls are for tuning, sound volume, high-frequency and low-frequency tone control; picture contrast, detail, and brightness. The 7 upper-deck controls are for adjusting the synchronism of the

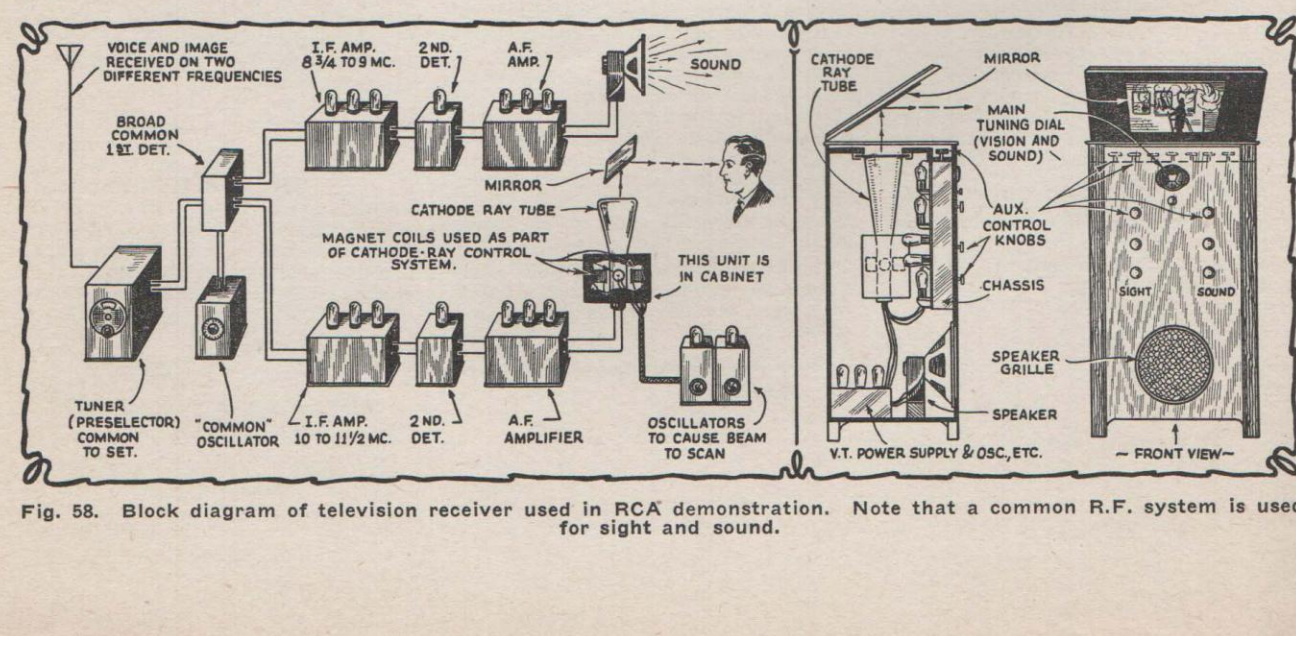


Fig. 58. Block diagram of television receiver used in RCA demonstration. Note that a common R.F. system is used for sight and sound.

Fig. 59. Unretouched photo of Jean Muir, movie star, as seen on the Philco system.

picture, the focus, the horizontal and vertical size and the horizontal and vertical "framing."

The input from the aerial and the first detector-oscillator stage is **common** for both the **sight** and **sound** channels. In other words, both sight and sound are tuned in by the **same control.** Since there is only one signal-frequency oscillator, and as this can be oscillating at only one frequency (disregarding harmonics) at a time, the 46 mc. **sight** carrier and the 48 mc. sound **carrier** must produce two entirely different beat frequencies when they are mixed with this oscillator frequency. This is just what happens and the result is that there are 2 different beat frequencies or "I.F.'s" in the output of the first detector. These are fed to entirely separate I.F. amplifiers and thence through separate second-detectors and audio systems, with the picture ending up at the cathode-ray tube and the sound at the loud speaker. The block diagram illustrates this arrangement clearly. The I.F. employed in the picture channel is from 10-11.5 mc. while that for the sound channel is around 8.75-9 mc.

A surprising thing about the demonstration was the negligible effect automobile ignition interference had on the pictures. Frequently the interference became strong enough to render the sound channel momentarily unintelligible, but instead of blotting out the image the interference caused only slight blurring of the images for a fraction of a second. This was not serious enough to be distracting to the eye.

The other day a number of editors from New York and Philadelphia were invited to the first public demonstration of television by the Philco television engineers. Unknown to most of the television world, Philco has been carrying on experimental television work for over eight years, but rather than make a premature announcement they have deemed it the better plan to wait until an appropriate development stage had been reached, before exhibiting even this experimental television apparatus to the public. A glance at the accompanying photos, Figs. 61 and 62, shows the appearance of the television receiver in its experimental form as demonstrated recently in Philadelphia. At that time the image as well as sound accompaniment was transmitted by radio over a distance of about seven miles. Later a second demonstration was given in the studio and laboratory, where the image currents were transmitted over a concentric transmission line about 75 feet in length.

In the **radio transmission** of the image the pictures were broadcast on 51 mc. and the sound on 54.25 mc. It is interesting to point out at this juncture that the separation between the sound and image transmission frequencies, amounts to 3.25 mc. which corresponds to the new RMA standard. The spacing between the picture and sound carriers as used by RCA in their Empire State Bldg. transmission in New York City, is 2.25 mc.

In the Philco television receiver here shown, two complete superheterodynes are employed. On one

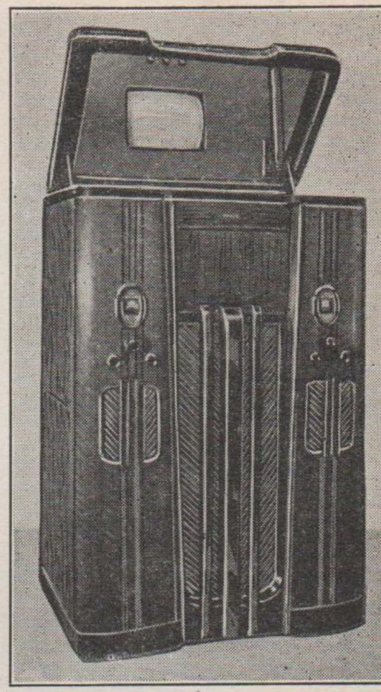


Fig. 61. Front of the Philco demonstrátion receiver. Image shows in mirror.

superhet the image signals are "tuned in," while the accompanying sound on its own particular carrier frequency is tuned in on the second superhet. In experimental tests a **single tuning control** for both sound and image receivers has been employed, but the two receivers have been left independent in most of the tests as this is only an experimental model and it gives greater flexibility in tuning. In the future a fixed ratio between the **image** and **sound** carrier frequencies will be preserved, and in that way the manufacturer of the television receiver of tomorrow will be enabled to "lock" the oscillator controls for both the sound and image receivers to a **single con-**

Fig. 60, left. The Philco television camera in use. An eyepiece on the top facing the rear enables precise sighting by the operator. An amplifier is included in the case.

Fig. 62, right. Rear of experimental Philco receiver. The large case shields the cathode ray tube. Visual and audio receivers may be ganged for single control operation.

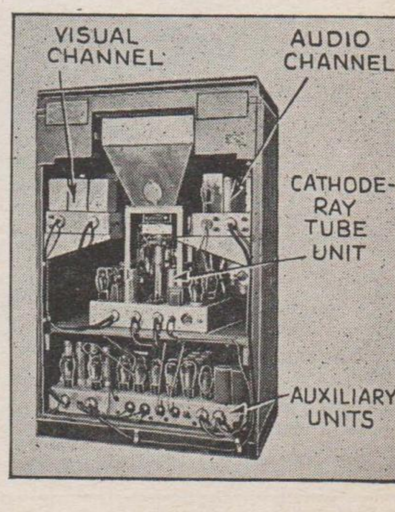
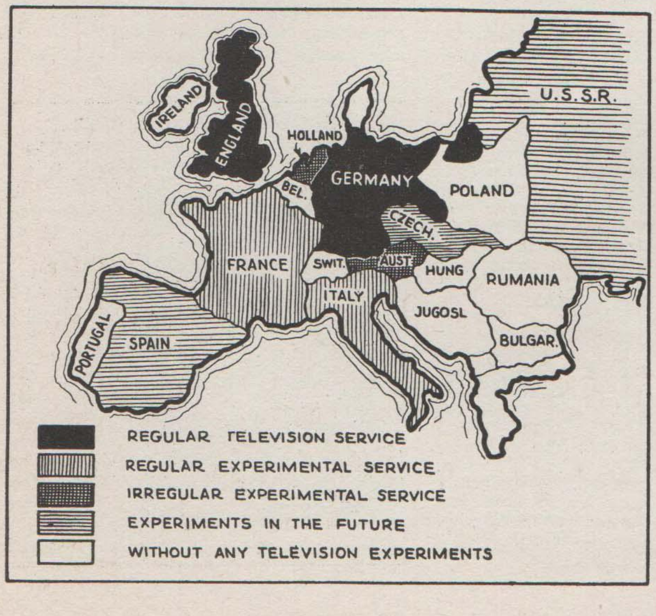


Fig. 63. A singer being televised in the Philco studios.

Fig. 64, above. The Philco visual monitor and control room. Fig. 65, below, a chart which shows the status of television in Europe.



trol tuning shaft and dial.

The size of the television image as seen by the observers in the Philadelphia demonstration was 7⅝ by 10 inches. A negative image is transmitted at the studio and 345 lines were used in scanning. Sixty pictures per second were transmitted with interlaced scanning, the proportions of the picture or aspect ratio being 4 to 3. The percentage of television signal devoted to synchronizing is 20 per cent, and the synchronizing signal is of the narrow vertical type. The channel width employed is 6 megacycles. The perfection of the image may be seen by reference to Fig. 59, and it should be noted that the printing screen considerably reduces the detail of the original picture, which is quite a bit sharper.

It is emphasized by both RCA and Philco that despite these successful demonstrations, television will not be ready for the public for possibly as long as a year or more.

The actual operation of a television transmitter is much the same as in the more common sound equipment, except that it is more complex. The outgoing signal must be monitored and passed through a control position. Such a control room is shown in Fig. 64. Other views are given herewith of various types of television equipment, including portable units and others.

The recent Olympic games at Berlin were widely covered by television, Fig. 67 showing a television camera used at one point. This machine uses a cathode ray tube similar to that employed by Zworykin in the RCA system.

Fig. 65 shows a chart of the European nations which are actively working with television. This map was published in the summer of 1935.

Fig. 66. Fernseh A. G. television car.

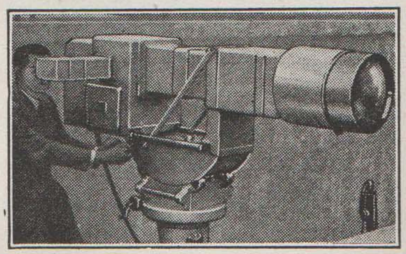


Fig. 67. Olympic television camera.

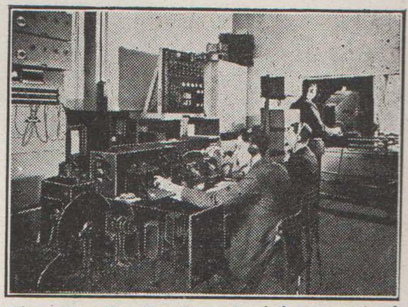


Fig. 68. B. B. C. television control.

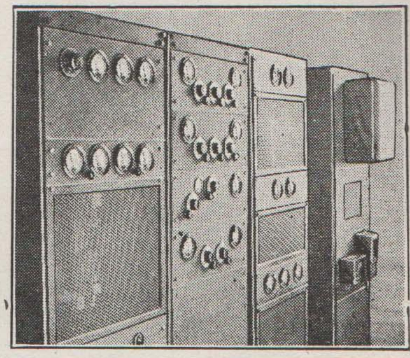


Fig. 69. Ultra H.F. transmitter.

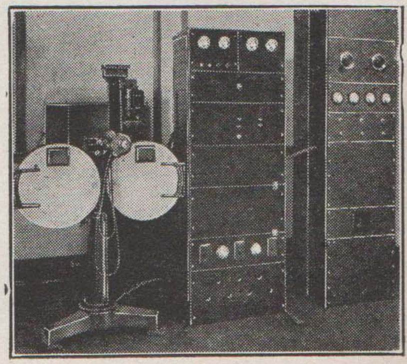
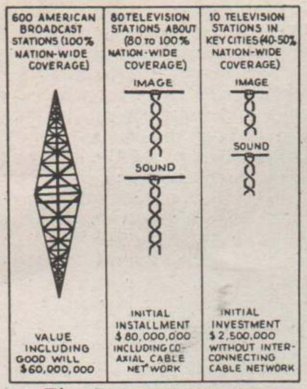


Fig. 70. Canadian visual equipment.



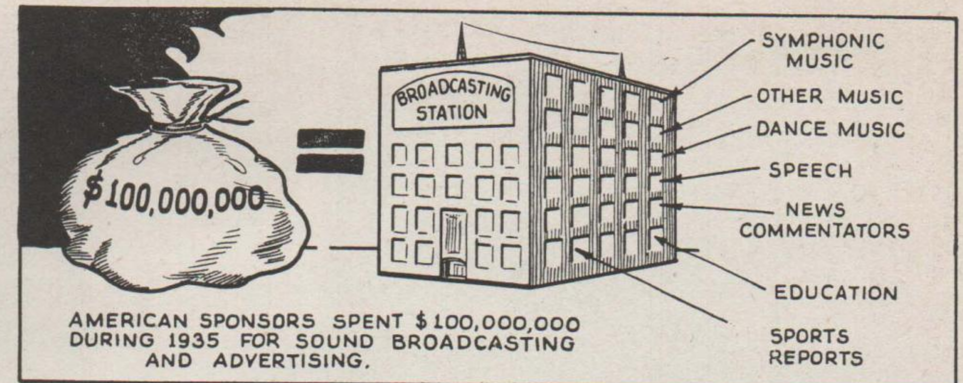


Fig. 71, left, television compared with broadcasting. Fig. 72, right, present air time cost to advertisers.

CHAPTER 8

The economic side and the future of television.

• SENSATIONAL reports published in newspapers that television is ripe for practical utilization, and that in a short time to come it will be introduced into the home, have aroused hope among optimistic radio listeners that this technical dream finally has become a reality. The pessimists however, in reading between the lines fail to envision such fast progress.

If we wish to find the reason why these pessimists—**and there are many of them among leading radio engineers** — have this negative opinion about an early achievement of television, we should remember that television can not really be considered as just a supplementary art to sound broadcast, but rather as an ardent competitor, **subject to entirely different technical and financial conditions;** and since money is the nourishing mother of all technical progress let's not only consider the technical problems of television, but also the financial complications which are involved in this interesting means of communication.

All of us know, that, at least at present, ultra-short waves are the only means by which television images of better quality can be radiated. However, since the effective range of ultra-short waves is very small, it is necessary to employ a large number of transmitters if most of the country is to be covered with television service.

According to estimates made by RCA Mfg. Co., 80 ultra-short wave stations will be necessary to give television a distribution equal to that of broadcasting. This firm (which should know best the cost of a suitable television station) has quoted its price **for one station** as approximately $500,000, which brings the total sum required to install a television network consisting of 80 such transmitters up to $40,000,000—or $500,000 per station. As RCA further stated, an additional $40,000,000, must be spent for an interconnecting network consisting of the newly developed coaxial cables, since normal telephone lines cannot be used for this purpose. The initial investment cost, in case television is to be introduced on a nation-wide scale, is, therefore, about $80,000,000 (see Fig. 71).

Despite the fact that $80,000,000 does not seem much money on paper —especially when it is remembered that such large-scale investments are fairly normal transactions among "big-money people" — one should keep in mind that in the realm of radio entertainment it is a tremendous amount of money **since all 600 American broadcast stations together have an estimated value of only about $60,000,000,** and this sum includes even the good-will!

A well-known Philadelphia group, not financially interested in present radio networks and probably not much interested in the manufacture of sound broadcast receivers, recently permitted some reports to "leak out," the gist of which are as follows: This group intends to erect in the beginning a television network of 10 stations, so located as to cover the **principal centers** of population. Among the cities selected are Boston, Los Angeles, New York, Philadelphia, Portland and San Francisco, etc. This network it is claimed would cover 40 to 50 per cent of the population of the country. Each station has been estimated to involve an outlay of about $250,000, which brings the total cost for the estire group of 10 stations to about $2,500,000.

This large variance in estimated price for a single station (or ¼-million vs. ½-million dollars) is a valuable key in understanding what goes on behind the curtain of television politics. There are, then, two outstanding groups that plan to put "big money" into television.

One group, bearing in mind (a) its respectable income from licenses to receiver factories; and (b) its large investments in broadcasting networks, does not dare to make hasty experiments which would endanger these sources of income. They consider also the important fact that in case regular television broadcasting should start in one single city only, the sale of sound broadcast receivers all over the country would be instantly paralyzed. The second group however is interested in television broadcasting **only,** and desires early financial returns from their investments in preliminary experiments, regardless of how much other branches of the industry must suffer.

However, both projects are at present no more than "projects" and 10 times as many reports full of alarming news "leaking out" from Philadelphia will not accelerate the first group into taking any premature steps since they know very well that television receivers because of retail prices being too high at present have no large-scale market. Another important point in their calculation is the fact that without a large-scale distribution of television receivers the project of television broadcasting is doomed to failure.

If we look at the following facts we will easily see that there must be a delay until television receivers are more reasonable in price. On January 1, 1936, there were, in the U. S. 22,869,000 families operating one, or more than one, radio receiver in each home. In addition, 3,000,000 auto-radio receivers are at present in use, which brings the number of

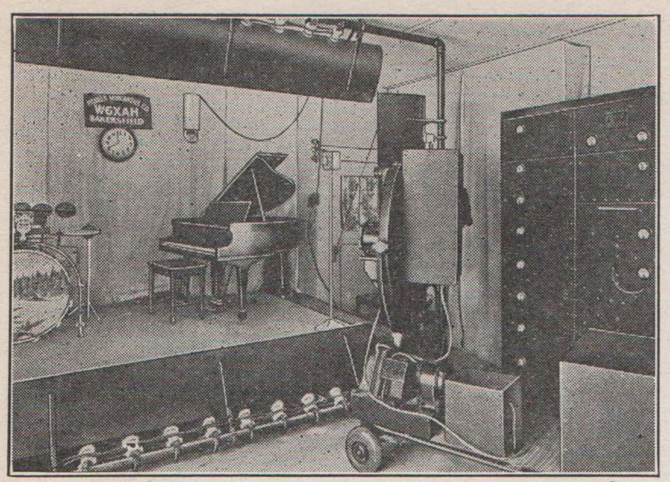


Fig. 73. Television studio of W6XAH in California.

"radio-outlets" to about 25,000,000.

To feed these 25,000,000 "outlets" with proper entertainment, American advertising sponsors have spent during 1935 approximately $100,000,000, or in other words $4.00 per "outlet" (see Fig. 72).

Since the average price of a modern television receiver is at present $400 (starting with $300 and varying up to $800), it is difficult to imagine that more than 100,000 television receivers will be in use in the first 3 years. This is a very important factor worthwhile keeping in mind, as we shall see.

We know by RCA estimates that in case a nationwide network of 80 television stations is to be operated it will cost $58,000,000 a year for transmitter operation and depreciation. Expressed in the shrewd language of the balance sheet this expenditure asks for a gross revenue of about $100,000,000 or **a gift of $1,000 to each owner of a television receiver by the sponsors!**

To believe that radio sponsors will spend this tremendous amount of money is ridiculous. But let's be generous, and double the estimated number of television receivers in use during the first 3 years (at a price per receiver of $400). This would bring the total up to 200,000 television sets. In addition to this "boosting" we shall cut the quite liberal estimated sum of transmitter operation cost, etc., and also the required gross revenue in half; which would bring us down to a sum of about $50,000,000.

However, once again, the balance sheet would indicate the impossibility of such a beginning, because television sponsors will have to make a donation of about $250 for each television receiver in operation, which leads us again into the dark. Much more favorable financial conditions are possible under the "Philadelphia Plan," which proposes the initial installation of only 10 stations, to be erected in important key-cities. This plan it is claimed, provides a coverage of about 40 to 50 per cent of our population. Transmitter operation, depreciation, etc., for such a small network would take approximately $2,000,000, but still the production cost of the program would ask for an expenditure by the sponsors of about $30,000,000, if the television program is to be an attraction capable of drawing attention away from sound broadcasting.

These considerations about the future of television have shown us clearly that the most important condition for its introduction into the home is not the money to be spent for the installation of a television network, but the prices asked for a receiver. To make television popular the sets will have to sell at a much lower price! But, with popularity and volume, we believe that they will cost no more than a better-grade radio receiver costs today and they will become just as popular.

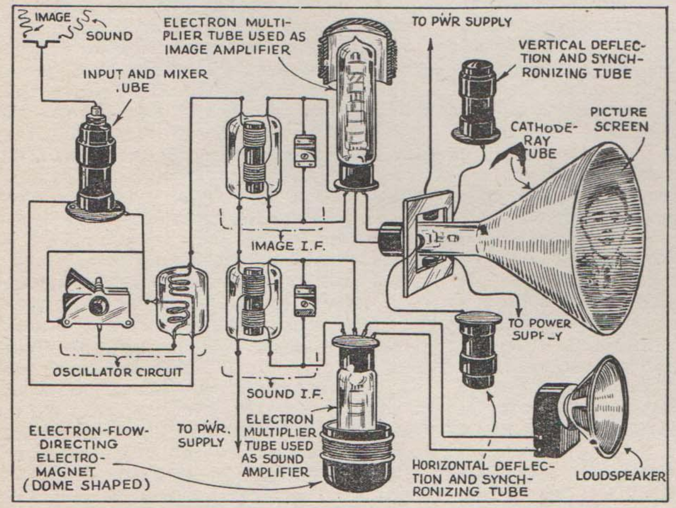


Fig. 74. What the receiver of the future may be.

Although the cabinets of present television receivers bear close resemblance to sound broadcast sets they are actually highly-complicated devices consisting of 4 or 5 distinct parts, each of which must not only function correctly within its own sphere of activity, but must synchronize with every part of the receiver.

The complex design of the present television set is clearly indicated by the number of the control knobs required. **The recently-demonstrated experimental RCA receiver worked only after 14 knobs were manipulated.** Of course, after the image had once been tuned in correctly, at least two-thirds of the control knobs did not require further attention; but nevertheless it is hard to imagine that a layman can handle such a labyrinth of control devices.

This single detail about the design of present American television receivers indicates that we have today about the same situation with television receivers as was the case with sound broadcast receivers in the early days of radio. Receivers were forbiddingly expensive, and had a large number of control knobs. Today there is only one control knob left for the actual tuning, and the 2 or 3 additional knobs which still remain are operated only once in a while, as for example when a change in wave-range is required. It took a long time to "induce" the many control knobs of sound broadcasting receivers to disappear but each time a knob disappeared a part of the initial high price disappeared too, and today we have the cheapest but the best receivers in the history of radio.

The same evolution is to be expected as far as television-receiver design is concerned. We are at present only at the beginning of the design of receivers for high-definition image reception, and yet there are already some interesting signs that in a short time to come television receivers will be simplified to a considerable extent. Instead of the 32 tubes applied in the newest RCA television receiver, only 4 or 5 will be necessary in the television receiver of 1945. The main trick of these simplified television receivers will probably be the newly-developed electron-multiplier tubes (see Fig. 74). These tubes are at present quite expensive, and consequently do not promote price reduction in television receivers.

However, what mass production is able to do as far as tubes are concerned has been impressively indicated in the past. The first radio tubes were sold for about $10 each. Tubes of today having an efficiency 5,000 times greater than the initial ones are listed at about $1.00 or less. There is no reason to believe that the new electron-multiplier tubes (which also have the advantage of eliminating a great number of the television receiver circuit elements now required) should not be sold at a relatively reasonable price. This, if accomplished, would bring the television receiver within the reach of the man on the street.

Our discussion so far has indicated that there are no short-cuts to the inauguration of television which would bring it within the next year or so into every man's home. Two impediments have first to be overcome:

(1) The "1 tuning knob" television receiver has to be designed which must sell for a reasonable price.

(2) Quite a bit of interest has to be created for this new branch of radio communication by demonstrations in the vicinity of the listener's home.

Both tasks cannot be solved without the help of the amateur and experimenter.

Amateurs have actually boosted broadcasting reception technique in the past, and in fact some of the best men at present in the American radio industry formerly were amateurs. After broadcasting transmission and reception changed from a hobby into a money-making enterprise, amateurs were actually thrown out of the broadcast range, and restricted to the shortwave field, which at that time was without importance.

Again radio amateurs have done pioneer work, and have actually been responsible for exploring the short-wave bands. Their success in bridging continents with a few watts has not only promoted a completely new realm of long-distance communication but has also fertilized the field in which American radio industry has harvested the boom of the all-wave receiver.

The few engineers kept busy in the nation's leading television laboratories to solve design problems cannot do as much of the work as is necessary; nor can they attempt to equal the accomplishments of properly directed mass activity. **To make television receivers cheaper and earier to operate, then, the aid of thousands of radio amateurs (and experimenters) will have to be enlisted.**

In addition to their technical contributions towards fool-proof television receivers, amateurs will create interest among radio listeners by their demonstrations. This free publicity will again fertilize the field of which the American radio industry will harvest the fruits of its third boom, the fruits of the television era to come.

It may be of interest to those unacquainted with television to hear the views of some of the acknowledged experts in the field.

On the question of the price of receivers, Mr. Wm. H. Peck speaks as follows:

"As to the question of cost, I cannot, of course, tell what price cathode-ray receivers will retail for, though rumors set their prices between $350 and $750. But I can state definitely that our television receiver, in a console cabinet with screen, and capable of tuning-in all-wave radio broadcasts as well as television images will be sold for about $225 or less.

"But first cost is not the entire cost of any radio set. Tubes need replacing from time to time, and in my set there are 6 to 12 fewer ordinary tubes, to say nothing of the extremely costly cathode-ray tube—which I do not use. Cathode-ray tubes will vary in price according to the size of the image which they will produce. Those capable of showing pictures approximately 6 ins. square may sell, it is said, for as little as $5.00 and may last for 4,000 or 5,000 hours, while those producing larger pictures — say a foot square — will probably cost from $25.00 to $75.00, though their life may be considerably shorter."

Another advocate of the mechanical system of television, Mr. William Preiss says:

"It is not quite in balance to compare the cost of a small cathode-ray picture with the cost of the large picture produced by the mechanical system. However, cost is a vital factor and must be considered at least on the basis of the physical receivers that both systems propose to offer the public.

"Starting with the scanner, the cathode-ray tube, like an incandescent lamp, is consumed while it operates. The vibratory-mechanical scanner, somewhat like a telephone receiver, has an almost unlimited long life. It has no bearings or sliding parts. The factory cost of the former including shrinkage is about $20.00 and the latter about $4.00.

"The amplifier for the cathode-ray tube must supply 3 high-voltage circuits with accurate waveform power, with one of the circuits drawing all the lighting energy at frequencies between the bottom of the range and say 2 megacycles. The amplifier for the mechanical system likewise has 3 circuits, but only one of these must be of high fidelity over a broad band and that one is of medium output and voltage. The other two circuits are very low voltage and can be of any waveform. I would roughly estimate the cathode-ray system amplifier at about 3 times the cost of the amplifier for the vibratory-mechanical system. The latter should cost about $45.

"In addition to this equipment the mechanical system requires a source of light, a Kerr cell and a screen. These items should cost about $10.

"To sum up, the retail selling price of a cathode-ray receiver for a small picture, that is to say 6 x 8 ins. would be about $550. The retail selling price for a mechanical system receiver producing a 3 x 3 ft. picture would be about $200."

These statements are authoritative, since they come from the producers of this type of television equipment. There does not seem to be any really dependable figures on the cost of a cathode ray receiver, although many guesses from $250 all the way to $1,000 have been made.

Regarding the general television situation Dr. Lee DeForest, electrical and radio pioneer said in 1935:

"It is not to be questioned that an enormous amount of very careful research and development in television for the laboratory has been carried on in the United States during the past 3 years. Much of this work will prove useful hereafter in actual television in the home.

"Unfortunately the above statement cannot, in my opinion, be applied to all of the work which has been carried on in this country, England and Germany at terrific expense. In my opinion the inherent limitations of the cathode-beam tube will prevent its general acceptance by the public. The combination of an acceptably large picture, brilliant illumination and long life of the tube are irreconcilable; at least until someone has discovered a fluorescent layer of an entirely different order from anything known in the cathode-beam art today.

"However, a mechanical scanner has been developed which is small, noiseless, cheaply made, without rotating parts and possessing infinite endurance, which I believe is capable of solving the problem of an acceptably fine, brilliantly illuminated, reasonably large screen picture in the home.

"I look to see this system actually introduced within the next 12 or 18 months. Its introduction will parallel in a degree that of the introduction of radio broadcasting, gradually from a few centers, finding and paying its way as it goes, without the lavish financial program, calling for the fantastic figures in scores of millions of dollars, concerning which we have read so much in the newspapers in the past year."

Another pioneer in the field and now a noted consulting engineer in radio, Dr. Alfred N. Goldsmith, believes that the cost of television will cause its development to be slow but orderly. He says:

"Television is still partly in the research and development stage.. Nevertheless sufficient progress has been made to indicate many of the main lines of its practical application.

"Clear pictures of moderate dimensions and adequate detail can be transmitted and received although the equipment at both ends of the circuit is elaborate and more costly than that required for present-day broadcasting.

"Television development will proceed at a moderate pace in an orderly way during the next decade. Starting with individual stations in the largest cities, there will be an increased number of such stations until many millions of lookers receive adequate service. The interconnection of these stations into networks will follow in due course. In brief, television development will be steady but its cost is such as to limit the speed at which it is practicable to establish a nation-wide service."

The following excerpts from an editorial by Mr. Hugo Gernsback in "Radio-Craft" for August, 1936, effectively sum up the situation:

"Television is still entirely in the laboratory stage, and a host of problems still must be solved before television as a whole is an accomplished fact. It is true that tremendous activity is going on in television research in the United States, as well as abroad, but it would be rash to predict even today that television is just around the corner.

"As far as television **transmitting** is concerned, it can be stated that transmission technique has been fairly well perfected and, if other problems had been solved, television would be an accomplished fact today. In the transmission end of television, cost means relatively little. A transmitter costs anywhere from fifty thousand up to a half-million dollars. This would be a comparatively simple matter because quite a number of stations are ready to transmit almost immediately **if the television receiver problem had been solved.**

". . . the television broadcaster, for the first few years will concern himself with broadcasting simple plays or other actions in the studio; scenes from outdoors such as sports events, political broadcasts; action events such as fires, but most of all the radio audience will wish to see the speakers and singers in the future, because it wishes to meet them face to face. Perhaps this will not always be a happy idea, because some personalities, while they are excellent talkers or singers, may not have physical personalities which match their art. But we may be sure that even here, good make-up and other television tricks will readily fool the television audience.

"Television will do marvels when it comes to bringing to your home little-known scenic beauty which can be picked up at home and abroad. Furthermore, can you imagine anything more interesting than taking a personally-conducted tour, via television, through our great industrial establishments? Who would not like to see how automobiles are made, how steel is fabricated, how oil is refined, how shoes are made, and thousands of others? Here is a tremendous field for advertisers, where a real advertising job can be done minus the usual blatant sales talk, simply by letting the customers see for themselves what is going on behind the scenes without trying to sell them anything on the spot.

"The only way to popularize television will be to merchandise the product in such a way that the public can buy receivers at a popular price. This means a price range from $25, upwards. To be sure, the better sets will range all the way up to several thousand dollars, but this will be for millionaires. Ninety-five per cent of the television receivers, however, must be in the popular-price range if television is to assume the importance that oral radio has today. Television engineers and constructors, as well as manufacturers should always bear this in mind, because **the broadcast industry is not likely to invest millions of dollars, and then remain satisfied to broadcast to only a handful of television receivers.**"

TELEVISION STATIONS IN THE UNITED STATES

(Experimental Visual Broadcasting Stations)

—Corrected by the Federal Communications Commission, May 1, 1936—

Call Letters	*Power (Watts)*	*Company*	*Location*
		2000-2100 Kc.	
W2XDR	500 & 1000	Radio Pictures, Inc.	Long Island City, N. Y.
W8XAN	100	Sparks-Withington Co.	Jackson, Mich.
W9XK	50 & 100	University of Iowa	Iowa City, Iowa
W9XAK	125	Kansas St. Col. Agr. & Apl. Sc.	Manhattan, Kansas
		2750-2850 Kc.	
W3XAK	5000	Natl. Broadcasting Co. Inc.	Portable
W9XAP	2500	Natl. Broadcasting Co. Inc.	Chicago, Ill.
W2XBS	5000	Natl. Broadcasting Co. Inc.	Bellmore, N. Y.
W9XAL	500 & 150	First Natl. Television, Inc.	Kansas City, Mo.
W9XG	1500	Purdue University	W. Lafayette, Ind.
W2XAB	500	Atlantic Broadcasting Corp.	New York, N. Y.
		42,000-56,000, 60,000-86,000 Kc.	
W2XAX	50	Atlantic Broadcasting Corp.	New York, N. Y.
W6XAO	150	Don Lee Broadcasting System	Los Angeles, Calif.
W9XAL	150 & 500	First Natl. Television, Inc.	Kansas City, Mo.
W1XG	500	General Television Corp.	Boston, Mass.
W9XD	500	The Journal Company	Milwaukee, Wis.
W2XBT	750	Natl. Broadcasting Co. Inc.	Portable
W2XF	5000*	Natl. Broadcasting Co. Inc.	New York, N. Y.
W3XE	1500	Philco Radio & Telev. Corp.	Philadelphia, Pa.
W3XAD	500	RCA Manufacturing Co. Inc.	Portable
W3XEP	30000	RCA Manufacturing Co. Inc.	Camden, N. J.
W1OXX	50	RCA Manufacturing Co. Inc.	Portable-Mobile
W2XDR	1000 & 500	Radio Pictures, Inc.	Long Island City, N. Y.
W8XAN	100	Sparks-Withington Co.	Jackson, Mich.
W9XK	100	University of Iowa	Iowa City, Iowa
W9XAT	500	Dr. George W. Young	Portable

*Construction Permit for 12 kw. power.

Pending Application:

National Television Corp., C.P. for 2000-2100 kc., 500 W.

DISCONTINUED TELEVISION STATIONS

(Experimental Visual Licenses and Permits Discontinued or Expired)

Call Letters	*Company*	*Call Letters*	*Company*
W9XAA	*†Chicago Fed. of Labor	W1XAY	Lexington Air Stations
W2XCD	DeForest Radio Co.	W1XY	Pilot Laboratories, Inc.
W10XG	*DeForest Radio Co.	W2XBW	Radio Corp. of America.
W6XS	Don Lee Broadcasting Co.	W2XCO	*Radio Corp. of America
W2XCP	*Freed-Eisemann Radio Corp.	W1XG	Shortwave & Telev. Corp.
		W1XAV	Shortwave & Telev. Corp.
W2XCW	General Electric Co.	W2XBU	Smith, Harold E.
W9XR	Great Lakes B'casting Co.	W2XBO	*United Research Corp.
W3XC	*Jenkins Laboratories, Inc.	W1XAE	Westinghouse Elec. & Mfg. Co.
W3XK	Jenkins Laboratories, Inc.		
W10XU	Jenkins Laboratories, Inc.	W8XAV	Westinghouse Elec. & Mfg. Co.
W2XAP	Jenkins Television Corp.		
W2XCR	Jenkins Television Corp.	W2XBA	WAAM, Incorporated
W2XDS	*Jenkins Television Corp.	W8XL	*WGAR, Brodcasting Co.
W7XAO	Jerman, Wilbur	W8XF	*WJR, Goodwill Sta. Inc.

*C.P. only.

†Now licensed as Exp. Relay B C station.

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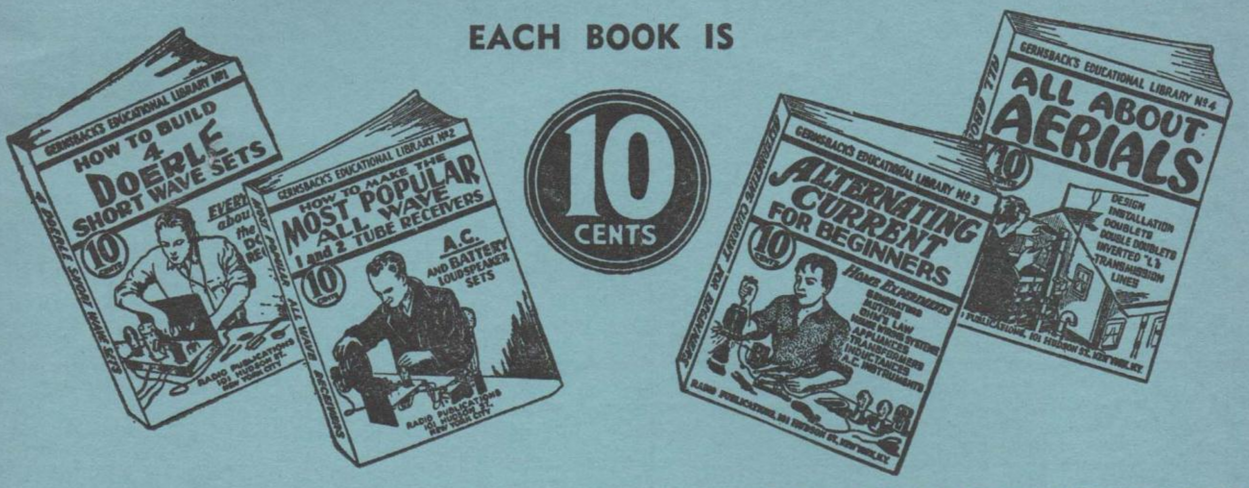

RADIO FANS! . . . Help yourselves to a radio education for the price of 40c, (10c per book). These books will give you a good foundation towards the study of radio. You'll be amazed at the wealth of information contained in them;—and you'll wonder how we can sell them at the low price of 10c each. Each book contains 32 pages written in simple, understandable language and profusely illustrated with circuit diagrams and illustrations. They are especially written for beginners but are useful review and reference books for the old timers as well.

All About Aerials

In simple, understandable language this book explains the theory underlying the various types of aerials; the inverted "L," the Doublet, the Double Doublet, etc. It explains how noise-free reception can be obtained, how low-impedance transmission lines work; why transposed lead-ins are used. It gives in detail the construction of aerials suitable for long-wave broadcast receivers, for short-wave receivers, and for all-wave receivers. The book is written in simple style. Various types of aerials for the amateur transmitting station are explained, so you can understand them.

How To Build Four Doerle Short Wave Sets

Literally thousands of radio fans have built the famous DOERLE Short Wave Radio Receivers. So insistent has been the demand for these receivers, as well as construction details, that this book has been published. Due to a special arrangement with SHORT WAVE AND TELEVISION, we present a complete 32-page book, printed on an extra heavy grade of paper with numerous illustrations. **Nothing has been left out.** Not only are all the DOERLE sets in this book, but an excellent power pack if you wish to electrify any of the DOERLE sets, is also described.
Contains **EVERYTHING** that has ever been printed on these famous receivers. These are the famous sets that appeared in the following issues of SHORT WAVE AND TELEVISION: "A 2-Tube Receiver that Reaches the 12,500 Mile Mark," by Walter C. Doerle (Dec., 1931-Jan., 1932). "A 3-Tube 'Signal Gripper,'" by Walter C. Doerle (November 1932). "Doerle '2-Tuber' Adapted to A. C. Operation" (July 1933). "The Doerle 3-Tube 'Signal-Gripper' Electrified," (August 1933) and "The Doerle Goes 'Band-Spread'" (May, 1934).

Alternating Current For Beginners

This book contains everything to give the beginner a foothold in electricity and Radio. Electric circuits are explained. Ohm's Law, one of the fundamental laws of radio, is explained; the generation of alternating current; sine waves; the units—volts, amperes, and watts are explained. Condensers, transformers, A.C. instruments, motors and generators—all these are thoroughly discussed. Housewiring systems, electrical appliances and electric lamps.
Here are some of the practical experiments which you can perform at home. Simple tests for differentiating between alternating and direct current; how to light a lamp by induction; making a simple electric horn; demagnetizing a watch; testing motor armatures; charging storage batteries from A.C. outlet; testing condensers with A.C.; making A.C. electro magnets; frying eggs on a cake of ice; making simple A.C. motors and many others.

How To Make The Most Popular All-Wave 1- and 2-Tube Receivers

There has been a continuous demand right along for a low-priced book for the radio experimenter, radio fan, radio Service Man, etc., who wishes to build 1- and 2-tube all-wave sets powerful enough to operate a loudspeaker. This book contains a number of excellent sets, some of which have appeared in past issues of RADIO-CRAFT. These sets are not toys but have been carefully engineered. They are not experiments. To mention only a few of the sets the following will give you an idea.
★The Megadyne 1-Tube Pentode Loudspeaker Set, by Hugo Gernsback. ★Electrifying The Megadyne. ★Mow to Make a 1-Tube Loud-speaker Set, by W. P. Chesney. ★How To Make a Simple 1-Tube All-Wave Electric Set, by F. W. Harris. ★How To Build A Four-In-Two All-Wave Electric Set, by J. T. Bernsley, and others.

Each book contains 32 pages, profusely illustrated with clear, self-explanatory diagrams. Each contains over 15,000 words of clear legible type. They are an education in themselves and lay the ground-work for a complete study of radio and electricity. If you do not think that these books are worth the money asked for them, return them within 24 hours and your money will be instantly refunded.

Send for our FREE circular listing 48 new 10c Publications

This big circular, containing a list of forty-eight new construction publications, describes briefly each of the projects. The list covers the building of radio receivers, short-wave equipment, electrical devices and a wide variety of mechanical devices.

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[ ] Alternating Current for Beginners, No. 3 ....10c
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