TELEVISION

THE CRYSTAL BALL OF RADIO

CHARLES WILLIAM LEHRBACH

FREYBOURG PRINTING CO., INC.

INTRODUCTION

This work is an attempt to present a non-technical explanation of that much mentioned but little understood new art—Television. In my estimation, most printed discussions of the subject available to the general public contain either too little or too much information. A person who might be interested but who lacks technical knowledge is not helped by the former condition just as one who is slightly trained is not helped by the latter.

My hope is that a general discussion of the history, development, and vital features of Television, presented with suitable analogies in everyday language, will supply a need to those who are mentally active and eager to keep in step with new and important developments.

It has been said that all analogies limp. This is undoubtedly true but surely if you did not understand the meaning of the word "walk", to see a person limp would be a great help toward that understanding. For that reason, I feel that with limping analogies and non-technical language, these pages will reveal an interesting and understandable "picture" of Television.

Charles William Lehrbach.

TELEVISION

The Crystal Ball of Radio

PART I.

History of Television

Man's imagination has been an unquestionably significant factor in the development of the world since its beginning. It would be difficult to conceive of what stage of evolution we would now be experiencing if it were not for this factor.

Throughout this development, imagination has been called upon to perform many different tasks. It will always be a medium through which the human mind can transcend the often harsh realism of everyday existence to enjoy a glimpse, if only a fleeting one, of what might be. Some men have crystallized these glimpses and given us fables, mythologies, and stories of fancied things, people and happenings. It is interesting to note that many of these fancies have, in later years, become realities. Surely the creator of Pegasus, or the Magic Carpet had no idea that some day people would fly as they do today nor did Jules Verne realize that his brain child, the submarine, would ever be more than a wild dream.

Imagination has also helped create real and useful things which are necessary for better living or the furthering of existing developments. Illustrative of men who dealt in such imagery are Thales, Archemides, Euclid, Da Vinci, Galileo, Volta, Ampere, Faraday, Newton and many more including our modern philosophers, mathematicians, physicists and scientists.

Exactly when the idea of Television was first conceived probably no one will ever know. Dreamers through the ages have thought of seeing great distances but it was not until 1873 when the photoconductive or light sensitive properties of selenium were discovered that a basic need for the possible electrical transmission of images was found. A few years after this discovery a suggestion was made as to how selenium might be used for picture transmission. The idea was to fabricate a mosaic of selenium cells which, in a way, imitated the construction of the retina of the eye. This suggestion was not actually put into practice until thirty years later at which time it was found to be possible but highly impractical with respect to wire transmission and absolutely impossible with respect to radio transmission.

In 1884, Nipkow, a German, invented what is known as a scanning disc. This disc is perforated spirally. Revolving, its function is to break light impressions, which are reflected from an object, into small picture elements. These elements are then converted into corresponding electrical impulses. Unfortunately, selenium was found to possess too much inertia, which means that it was too "lazy" in an electrical sense, to act as a light converter for this whirling "scanning" disc. It was not until the photo-electric cell, a new type of vacuum tube light converter, and means of amplifying weak electrical impulses were discovered that Television became more than an impractical idea.

John Logie Baird, a Scot, is credited with the first successful transmission of pictures. In April 1925, Baird, with crude apparatus, gave a public demonstration of silhouettes transmitted by wireless. January 1926 saw the first transmission of pictures in motion accomplished by the same man. These were indeed startling developments. From then on men in other countries seemed to be caught by the spirit of these unusual accomplishments and proceeded either to experiment on the basis of the Baird system or devise methods of their own.

In America C. F. Jenkins was a pioneer in this field, inventing what is known as a disc prism. This was an ingenious device performing the same function as the scanning disc but evidently not as well because it was abandoned later. In Germany von Mihaly was responsible for a device called the "Telhor". This accomplished scanning by small mirrors vibrating in a strong electromagnetic field. Weiller invented a mirror drum which was used with moderate success. Numerous other ingenious devices were developed, all embodying the principle of breaking an image into "picture elements". Most of these methods, however, lacked many vitally necessary practical points.

The development of Television through the ingenuity of these men depended upon the use of rather cumbersome mechanical equipment, the efficient limit of which did not satisfy the demands of "high definition" image transmission that would have a substantial commercial and entertainment value. It was with this urgent need in mind that two men, Dr. V. K. Zworykin and P. T. Farnsworth, working independently, succeeded in creating the present method of image transmission which is known as "Electronic Television".

PART II

"Tools"

In building anything it is essential, if the job is to be done well, to know the tools you are to use and how they are to be applied. In order to build an understanding of the accomplishment of Television there are certain "Tools" in the from of devices, physical and electrical principles and theories with which you must become familiar before that understanding can be realized. Mention of these "Tools" will be frequently made, therefore they will be numbered for the purpose of subsequent reference.

#1

"Electrons"

Matter is composed of molecules, molecules composed of atoms, and atoms are composed of electrons and protons. The theory is that the proton, which possesses a positive (+) electric charge, is in the nature of a heavy nucleus and is surrounded by negatively charged electrons. It must be remembered here that in electricity like charges repel each other and unlike charges attract, i.e., two positives repel and two negatives repel but a positive and negative attract. Therefore, the negative electrons which whirl around the center positive proton are attracted to it as we are attracted to the earth by the force of gravity. The number of electrons and their structure around the nucleus determines the kind of atom. For example, hydrogen, the lightest gas known, has the smallest atom containing only one proton and one electron. These negative particles (electrons) rove around the proton and do not leave its sphere of attraction unless energized by some external force. When this happens they can be utilized, depending upon the conditions imposed.

#2

"Photo-Conductivity"

This is also referred to as the Photo-electric effect. Some metals such as lithium, potassium, rubidium, caesium, sodium, barium, nickel, etc., have, in certain forms, the peculiar property of emitting electrons when they are exposed to light. This emission constitutes a flow of electric current (called photo-electric current). The value of this property with respect to television is that the current produced is proportional to the intensity of light affecting the metal. That is to say, a weak intensity of light will produce a weak photo-electric current and a strong intensity will result in a correspondingly strong current. Light, in this case, is the external force mentioned in #1 Tools.

#3

"Photo-Electric Cell."

This cell consists of a cathode (negative) and an anode (positive). The cathode is a plate surfaced with one of the photo-sensitive metals mentioned above. The anode is in the form of a gauze of wire and is placed in front of and a short distance from the cathode. In actual use a positive source of electric current is connected to the anode and a negative source is connected to the cathode. Both electrodes are sealed in an evacuated tube. When light strikes the metal, electrons are released and attracted (unlike attract) toward the positive anode from which electrode they are then "drawn off". The negative source just mentioned is connected to the cathode for the purpose of supplying electrons to replace the ones released by the action of light.

#4

"Amplification"

Despite the fact that the Photo-electric cell satisfies certain basic needs, the current resulting from its photo-sensitive qualities is extremely weak and consequently must be amplified or made stronger before it can be used. The amplification of weak currents is a problem which has been solved by the development of Radio. It is accomplished in Television in the exact manner as are converted sound impulses which result when a microphone is affected by sound waves.

Briefly, amplification is the affecting of a strong constant current by weak electrical impulses (photo-electric currents) in such a way as to result in a new series of impulses, similar in all respects to the original weak ones except that they possess greater strength or intensity. This process, accomplished by means of amplifying tubes and various electrical devices, is repeated many times until the final result may be a million times greater than the original cause.

#5

"Radio Carrier Wave"

An essential "Tool" in the accomplishment of Television or Radio is the means by which amplified electrical impulses, representing converted light or sound, can be practicably carried to receiving sets in various parts of the country. Actually this is done by means of a high frequency alternating current having a constant frequency and the speed of light. This "Tool" is called the Radio Carrier Wave. The various converted impulses are impressed on or modulate the carrier which in turn delivers them for the purpose of reception. The carrier may be likened to an endless belt stretching in all directions from the source of transmission. The "Packages" of electrical impulses are placed on the "Belt" and as they pass the different receiving points they are taken off as needed.

#6

"Fluorescence"

Fluorescence is the property of some material to absorb electrical energy and give off or emit light. The most important feature of this property is that the light emitted is proportional to the amount of electrical energy absorbed, i.e., strong energy—strong light, weak energy—weak light. Natural Willemite and numerous synthetic fluorescent materials possess this ability of energy to light conversion. Originally a material was used which gave a light green glow, a shade which is near the color range to which the eye responds most strongly. However, other fluorescent materials which give white light have become standardized because we are accustomed to black and white contrasts of photography.

#7

"Perststistence of Vision"

Persistence of Vision is that peculiar ability of the eye which permits it to retain an impression approximately one-tenth of a second after the cause of the impression has been removed. It is upon this phenomenon that the success of Moving Pictures and Television depends. In viewing a moving picture you are in reality seeing a succession of still pictures called "frames" which present to the eye, in regular and successive order. the various positions an object must take to complete a particular motion. For example, consider that a man raising his arm over his head is photographed 24 times each second his arm is in motion. Assuming that it takes two seconds to complete the act, the result will be 48 frames taken in regular and successive order. When these stills are projected on a screen at the same rate of speed as that of photographing, the impression of the first frame will not have left the eye, due to persistence of vision, until the second frame appears. The second remains until the third appears, continuing in this manner until the 48 frames have been viewed, thus presenting the illusion of motion. If the time elapsing between the projection of the "stills" is greater than one-tenth of a second, the impression of the first frame would have left the eye before the second appeared. This gives the effect of "flicker" or dark spaces between the frames, so prevalent during the infancy of movies.

#8

"Neon Tube"

The neon tube consists of two electrodes, positive and negative. The negative is a rectangular metal plate covered with nickel and placed inside the tube in a vertical position. Directly in back, at a short distance, is the positive electrode, a short metal rod also vertically placed. The tube is filled with a gas called neon. When a current is passed through the tube by means of the electrodes, the gas is caused to glow, the intensity of the glow being proportional to the strength of current passed through the tube. An unusual property of neon gas is that it can be made to glow and then be extinguished at the almost unbelievable rate of a million times a second.

PART III

Fundamentals of Transmission and Reception

The reason objects are visible to us is that light is reflected from them to our eyes. If there were no light there would be, as far as our sense of sight is concerned, no object. When there is light, our eyes receive varied intensities relatively placed which, when focused on the retina of the eye and carried to our brain, are resolved into an image of all we survey.

Unfortunately man cannot exactly imitate the human eye either mechanically or electrically. He can and has, however, overcome almost insurmountable difficulties and created a successful substitute — a combination of the photo-electric cell and scanning.

Due to the fact that light cannot be transmitted over wires or through the medium of a radio carrier wave, it is necessary, for picture transmission, to have some means by which light intensities can be converted into electrical impulses of proportional strength. The invention of photo-electric cell (#3 Tools) satisfies this need.

This cell alone, however, is not capable of viewing an object and converting it into one electrical impulse which would represent the varied intensities reflected from the object when taken as a whole. The one impulse received would be the average intensity of the whole surface and as such would have no meaning if again changed from electricity to light. The result would be a single intensity of uniform brilliance in no way showing the various degrees and relative positions of shadows and highlights reflected by the viewed object.

The following explanation will show more clearly what is meant.

If you were given a column of figures such as:

1
22
4
6
9

(numbers representing various intensities reflected from an object in their relative positions) and were told to send this column to a friend by giving him the sum only, you would immediately see that this is impossible. Your friend, receiving the sum of 42, could not tell of what individual figures and their relative positions, the total was the result. If, however, you were permitted to send one figure (one intensity) at a time, in proper order, the task would be perfectly possible.

How then can a picture or scene be treated in order to transmit it electrically? This question was answered by Nipkow, a German inventor, in 1884, when he suggested that an object be "scanned". That is, the intensities reflected from an object would be utilized bit by bit much as you utilize word after word to understand the full meaning of this page. If you were asked to scan this printed page what would you do? You would quickly read the first line from left to right. Then you would return your glance from right to left, at the same time dropping it slightly until it was on a level with the second line. This process would be repeated with the third, fourth, etc., until you had reached the bottom. Nipkow's idea was to use a specially prepared disc, its purpose being to break the sum of light reflected from an object's surface into individual components or small picture elements. These elements, which represent light intensities, are converted into proportional electrical energy and as such are transmitted and received in regular and successive order and properly placed at a speed, which due to persistence of vision (#7 Tools) permits the finally received image to appear as a reproduction of the original.

For a practical analogy of scanning, assume that you wish to send a photograph of yourself to a friend. The restriction of messenger service to be used is that it can carry only one segment of the picture of uniform intensity at any one time (a condition comparable to that imposed by a photo-electric cell). This condition immediately eliminates the possibility of sending the photograph as a whole, it being composed of various intensities relatively placed. Logically, the next thing to do is to divide the photograph into small squares or "picture elements" (see figure #1). These elements will then represent one intensity only or at least reach a limit where the change of intensity within a square is so slight it can be considered as being uniform throughout. The photograph is now prepared in a manner which will satisfy the messenger service. The first square, starting from the upper left-hand corner is sent, immediately the second square in the same horizontal line is sent. Then the third, fourth, etc. When the first line is exhausted. the second line, again starting from the left, is treated in the same way. This action is repeated line after line until all the squares have been sent. Each element as it is received by your friend is placed in the same relative position it originally occupied. When all the elements have been received and properly placed, the picture can be viewed exactly as you viewed it before it was delivered. If this whole transaction can be made to take place in less than one-tenth of a second, the impression of the first square would not have left your friend's eye before the last square was viewed, due to persistence of vision (#7 Tools). The resulting effect would be that of having a complete photograph instantaneously set before him.

Actually the first successful Television used the scanning disc to break a viewed scene into picture elements. (See figure 2). This disc was perforated. The holes were placed around its periphery, or outer edge, in the shape of a spiral and were of equal angular displacement. That is to say, if there were sixty holes, they would be six degrees apart—there being 360 degrees in a complete circle. By referring to figure 2 (eight hole disc shown for simplicity) it will be seen that each succeeding hole in the disc is nearer the center by exactly the cross section of one hole. This would mean that if the disc were revolved, the path of all the holes in one complete revolution would be, in effect, the same as if a circular strip were cut from the disc. The width of this strip would be the same as the distance from the radially outer edge of the first hole to the radially inner edge of the last hole in the spiral.

If a light were placed on one side of the disc so that it would cover the area formed by the circumferential and the radial distance between holes (see figure 2a), the following effects would be noticed. At a slow speed, the motion of the beam cast by a hole travelling through the lighted area would appear to the eye in its true form; e.g., a moving spot of light describing a slightly curved line. As this hole left the lighted area the next hole would enter and the beam of light permitted to pass through would describe the same line directly below the one which had just passed. If, however, the speed of revolution were increased, an entirely different effect would be experienced. Due to persistence of vision the impression of the first spot of light, as it described its line at this increased speed, would not appear as a moving point but as a lighted arc of a circle. When a speed is reached which will permit every hole on the disc to pass through the lighted area in a tenth of a second or less (approximately the time it takes for an instantaneous impression to decay from the retina of the eye) we have the desired condition for successfully scanning an object for transmission. i.e.. that of presenting to the eye an illusion of a whole made up of parts. (See figure 2b — enlargement of 2a when speed mentioned is reached).

Logically. if a duplicate of the scanning disc used were placed against it hole for hole, the effect resulting from one disc would not be changed by two placed together in this manner. Now let us assume that the duplicate, still traveling at the same speed with the holes occupying similar positions as the original, is moved along a common center shaft so that the discs are a foot apart. The resulting effect would still remain unchanged. If, however, you had the original disc and your friend in the next town had the duplicate, the speed and hole position remaining the same. the function of the first disc would be as originally stated whereas the duplicate disc would be of no use unless means can be devised which would overcome the effect of distance.

This was originally accomplished with the following "Tools": the Photo-electric cell, the amplifier. the radio carrier wave, and the neon tube.

In place of the surface which was scanned by the moving beams of the original scanning disc, you will put the photograph that has been divided into "picture elements". Your eye will be substituted by the photo-electric cell. This is connected with the amplifier which in turn is connected with the carrier wave. Your friend uses a radio receiver (which naturally includes an amplifier) and instead of the usual loud speaker he inserts a neon tube in its place (#8 Tools). The duplicate scanning disc is then placed in front of the neon tube.

Referring to the transmission analogy wherein the divided photograph was used. it will be remembered that the elements were sent in regular and successive order by the "messenger service". With the present set-up the same thing is accomplished. Starting on its path from left to right, the spot of light. passing through the first hole on the sending disc falls on the first "picture element" in the upper left hand corner of the divided photograph. (Figure #1). (It must be mentioned here for the sake of simplifying the explanation that although the path of the moving scanning spot of light is actually in the form of an arc of a circle, for all practical purposes it can be assumed the path is a straight horizontal line from left to right.) The uniform intensity of light reflected from this "element" is then viewed by the photo-electric cell and converted into a corresponding electrical impulse. This impulse is then amplified and placed on the carrier wave. As the wave passes your friend's house, the receiver picks up the impulse, amplifies it and feeds it into the neon tube (#8 Tools). The neon tube will then glow with an intensity corresponding to the intensity of the original "picture element". At this instant the first hole in the receiving scanner is occupying the same position as the first hole in the sending disc. Therefore your friend, viewing the intensity of light from the neon tube which is permitted to pass through the hole, will experience the same effect as he would if he were viewing the original "picture element". This completed, the spot of light at the transmitting end falls on the second "element" in the same horizontal line. The reflected intensity is now converted from light to electricity, transmitted, received, converted from electricity to light, all in time to pass through the receiving disc as a duplicate of the original "second" element. This process is repeated element for element, line for line, until the whole picture has been scanned. If this is done at a speed at which persistence of vision comes into play, the result will be the same as explained in the previous analogy — "The resulting effect will be that of having a complete photograph instantaneously set before him (your friend)". This process constitutes the transmission of one frame. For continuous transmission which would enable the televizing of still or moving plates. 24 frames per second are necessary. (#7 Tools).

PART IV

Limits of Mechanical System

The definition or clearness of images transmitted in this manner depends largely on the number of picture elements into which a viewed scene can be broken.

It was explained in the divided photograph analogy previously given that in order to satisfy the messenger service, one picture element should represent a single intensity of light or at least reach a practical limit where the change of intensity within one of these elemental areas is so slight it can be considered as being uniform throughout.

It has also been explained that a photo-electric cell viewing an object as a whole will interpret the various intensities reflected from its surface merely as one average electrical impulse. Therefore, if a photograph is divided into four parts we are only allowed four different intensities. If divided into sixteen parts we are allowed sixteen variations of intensity. Thus, the more elements, the more different intensities possible until the limit of uniform intensity in one element is reached. At this time, practically every change of light intensity on the surface of a viewed scene can be truthfully interpreted into electricity and subsequently converted into light. If a word picture of a building were given you merely by saying it had four windows, a door, a roof. it would not be as clear as a minute description of every item of construction.

With this in mind, let us discuss the clearness and picture detail possible by using this mechanical scanning disc system.

Figure I shows that the number of picture elements into which a scene is divided depends upon the number of perforations in the disc. recalling that each horizontal row of elements was scanned by a single perforation. Thus if a disc had thirty holes, assuming the holes and total viewed area to be square, there would be 900 picture elements in one frame, (referred to as a thirty-line picture.) Actually, thirty hole discs were used in the earlier stages of Television. 900 elements, however. did not satisfy the conditions necessary for tolerable image detail so experiments with 60, 120 and 180 holes (60, 120, 180 line pictures) followed. Unfortunately, the increase of holes in the disc. although approaching the solution of higher definition with respect to picture elements, did not solve major difficulties inherent in mechanical systems in general; namely, the comparatively small amount of time that light came into contact with the photo-electric cell as the perforations whirled through the lighted area; secondly, practical synchronization of transmitted and received images; and thirdly, a sufficient number of elements.

First let us consider the problem of light. This limitation introduced a seemingly insurmountable problem which stood in the way of the real goal of Television — that of transmitting outdoor pictures, as well as studio scenes, thereby making the scope of this new art as great as that of motion pictures.

In disc scanning, the amount of time the reflected light from one picture element affects the photo-electric cell is very small. Assuming the use of a 240 hole disc, there would be 240 x 240 or 57,600 picture elements. Multiply this total by 24 frames per second and the resulting time of exposure of one element is $\frac{1}{24 \times 57,600}$ or $\frac{1}{1,382,400}$ of a second. Consider the infinite brilliance of one element during this brief space of time necessary to cause an impulse in the photoelectric cell which would be strong enough to amplify, if the exposure necessary to affect a whole photographic plate in ordinary sunlight is in the nature of 1/50 of a second.

Secondly, there is the problem of synchronization. Mention has been made that the duplicate or receiving disc must be traveling at not only the same speed as the original or sending disc but the corresponding holes of each disc must occupy similar positions. If this does not occur, the result will be either no intelligible image or an effect comparable to that often seen at the movies when the projector is not properly framed — that of a split frame showing the lower half of the picture above the upper half. Synchronization is possible in mechanical systems but, at present, the apparatus necessary and the fact that such apparatus is not always dependable prevents a mechanical system from becoming a real commercial possibility.

Thirdly, the number of elements or lines possible with a scanning disc is not sufficient to produce an image possessing sufficient detail to be of practical value. Discs have been made with as many as 240 holes but beyond that number, the scanners become cumbersome and unwieldy. Other mechanical devices such as mirror drums and vibrating mirrors, both producing more lines, have been developed but again the problem synchronization has prevented their complete success.

PART V

Electronic Television

Problems presented by mechanical systems were not too great to be solved. Proof of this is the development of a new and completely electrical system of Television called "Electronic Television".

With the present development of electronic television, the science of transmitting and receiving pictures has reached a stage where it has emerged from infancy and has entered lusty adolescence with sturdy manhood not far off. The two men who have been responsible for the basic discoveries in this field are Philo T. Farnsworth of Farnsworth Television, Inc. and Dr. V. K. Zworykin of the Radio Corporation of America. George H. Eckhardt stated in the introduction of his book, "Electronic Television", "It would be impossible to conceive any new development that would not encroach upon the basic research done in one or the other of these laboratories."

In the electronic system all mechanical moving parts are completely abandoned. The scanning disc and other comparatively heavy devices whose inertia or mechanical laziness hindered the success of practical high definition systems have been replaced by the electron beam, sawtooth wave generators, deflection coils and many other purely electrical devices.

First let us consider the developments in Electronic Television for which Dr. Zworykin is responsible.

To replace the clumsy mechanical transmitters and to overcome their drawbacks already mentioned, Dr. Zworykin developed an ingenious image pick-up device which has been patented under the name of "Iconoscope" meaning "image observer".

The "Iconoscope" consists of 3 main component parts; the mosaic, the electron gun and the glass envelope. (See figure 3). The mosaic (M) is formed by a mica plate, one side of which is metalized, the other covered with millions of infinitely small globules of silver sensitized to light with caesium (See #2 Tools). Each globule is separate from the others and forms a minute photo-electric cell and at the same time a small condenser.

Let us consider now the action of a condenser. Figure 4 shows the form of a condenser such as a cross section of a globule on the mosaic would make.

Two metal plates, A and B, separated by an insulator form a condenser (comparable in the Iconoscope to the silver-caesium as B, the mica as the insulator, separating "A" and "B", and the metalized back as A). If electrons are caused to leave B, as shown by the arrow, B then possesses a deficiency of electrons. In other words, it is positively charged. This positive charge attracts, through the mica, negative electrons towards the inner surface of A thus causing A to have an excess of electrons or be negatively charged. The condenser by virtue of the unequal distribution of these negative particles becomes what is known as charged. Now if B, from some source, received electrons to make up for the deficiency, those in A will no longer be attracted toward B and will be released. This release will cause a flow of current equal in strength to the deficiency which existed in B. The condenser is now said to be discharged. We shall see later how this discharge is brought about in the Iconoscope.

The electron gun, so named because of its ability to fire a steady stream of electrons in the form of a narrow beam is not, in a strict sense, a new development. It has been used in Cathode ray tubes for various purposes other than Television. Its new use, however, is ingeniously different. Figure 5 shows diagrammatically how the electron gun is constructed.

A is the indirectly heated Cathode the end of which is coated with an oxide preparation. Referring to Tools #1, mention was made that electrons do not leave the attraction of the central proton unless energized by some outside force. In Tools #2 it was explained that light was one means of furnishing an external force to cause the release of electrons from some metals. There is also another force, namely heat, which causes an electronic emission from certain metallic oxides. This fact is made use of in the Iconoscope as is shown by the presence of the heater H contained in A.

B is a sleeve called the grid sleeve with an opening directly in front of the coated end of the Cathode.

C is the anode (positive — remember that electrons being negative are attracted by a positive charge).

D is the second anode (positive).

C and D are both insulated from B.

When the cathode is heated by H, it emits electrons. A negative charge from an external circuit is given to B which forces (by repelling) these emitted electrons toward the central axis of the device and at the same time through the opening O. Once through, they are attracted by and through the aperture of C. D then comes into play, accelerating them toward a central axis and focusing them into a narrow concentrated beam of fast moving negatively charged particles.

With this in mind, let us view the action of the Iconoscope as a whole. Again referring to Figure 3, we see that an object or scene is focused on the mosaic exactly as it would be focused on the film of a camera; through a system of optical lenses. As the scene falls on the mosaic, each minute photo-electric cell on its surface emits electrons in proportion to the light or shadow of that part of the focused image falling upon it (#2 Tools). It must be remembered that when this emission is caused, each cell also acts as a condenser which now becomes charged with a strength depending upon the amount of emission. In other words, we have converted our projected image composed of light and shadows into an electrical image composed of small electrical charges of relative strength and placement. As an example. consider a photograph made of blotting paper whose absorbent qualities increased in proportion to the amount of light reflected from various points on its surface. If a large inked surface were then blotted with the photograph. the lighter area would absorb more and the darker areas less. You would then have on the surface an ink reproduction of the picture just as you have an electrically charged reproduction of an image on the mosaic.

With the mosaic in this state. the problem to solve is how to make up for the deficiency of electrons existing in the minute condensers in order to discharge them and thus set up the electric currents they potentially possess. If the whole mosaic were to receive electrons at one time. the results would not, as has been explained previously, satisfy the television "messenger service". The next step then is to supply a small area of the mosaic (representing our old friend the picture element) with electrons to make up for this deficiency. This can be done by scanning the surface of the mosaic with the beam from the electron gun. The beam is made to scan the surface of M horizontally from left to right, (notice path of beam on mosaic in figure) rapidly kick back, and start over again from left to right directly below the preceding line.

Now consider the scanning beam coming in contact for an instant with one of the small charged condensers, the strength of charge depending on the amount of light affecting it. Electrons pass from the beam into the condenser, the existing deficiency is corrected, and the condenser is discharged thus setting up an electric current (picture signal). Each picture element, the size of which depends on the cross-sectional area of the electron beam, is treated in the same way in rapid and successive order. The train of electrical impulses released from the mosaic by the moving electron beam represents the various intensities of light reflected from the scanned object. As in the mechanical systems, they are amplified in their regular and successive order and placed on the carrier wave.

A quick review of the explanation of the mechanical disc will show how the underlying idea of sending one element at a time is the same in both systems.

Perhaps the question has arisen in your mind as to how the electron beam is made to scan the mosaic.

The beam is very sensitive to magnetic attraction. Around the neck of the Iconoscope tube there is placed a yoke of 4 deflecting coils (see figure 6). These coils are connected to circuits which produce what is known as saw tooth currents. Coils "H" move the beam horizontally until the end of a line is reached. At this instant, the current is cut off, permitting the beam to return for the scanning of the next line. In order to produce a 240 line picture at 24 frames per second, the horizontal coils must attract the beam from side to side 240 times 24 or 5.760 times per second. The vertical coils attract it 24 times per second up and down. For a practical example, merely take a pencil, place it on a piece of paper and move it rapidly from side to side. This effect is the action of the horizontal coils on the beam. As you are moving the pencil back and forth, slowly draw your arm down the paper. This is the action of the vertical coils. Actually, the beam scans the mosaic very much the same as the light spot from a scanning disc explores a viewed object. The circuits controlling these coils are adjusted so that the beam explores the mosaic in the above manner as many times per second as the number of frames desired.

Summarizing, the advantages of the Iconoscope over a mechanical scanner are as follows:

1. The mosaic is at all times exposed to the projected scene, allowing the elements (condensers) which are not being scanned to increase their charge of electricity until the scanning beam again comes in contact with them. This makes possible current strength which cannot be obtained with a mechanical system.

2. The electron beam, having no weight, may easily and instantaneously be speeded or retarded by a synchronizing impulse, thus assuring a rate of scanning that can always be synchronized with the received impulse.

3. The number of lines into which an image can be broken may be increased far in excess of any mechanical scanning, which fact results in a true highly defined transmitted picture.

Electronic Reception

No less ingenious than the Iconoscope is Dr. Zworykin's development of a cathode ray receiving device which is patented under the name "Kinescope". This device is constructed as shown in figure 8. Its component parts are an electron gun (same construction as that in Iconoscope) and a fluorescent screen (#6 Tools). The fluorescent material is formed as a thin coating on the inner surface of the large end of the tube and is in a position to be acted upon by the electron beam. Remember that this device must receive intelligence as taken from the carrier wave and translate it, point by point, showing relative placement and intensity in a manner resulting in a faithful reproduction of the image dissected by the Iconoscope. Therefore, controls are necessary to regulate the intensity and placement of this received electrical intelligence.

Intensity Control

As the electron beam strikes the fluorescent screen at any point, the amount of light given off at that point depends directly upon the strength of the beam. (#6 Tools). It is evident that some control must be imposed on the electron beam to change its strength and, as a consequence, the intensity of light resulting from this strength. The control is simple. The grid cylinder B (figure 5) which covers the cathode of the electron gun and whose purpose is to divert electrons toward the central axis of the tube, is merely given a stronger negative charge than it normally receives. The repelling action becomes so strong that the electrons, which would ordinarily form the beam, are not permitted to pass through the aperture. The result is no beam — no light. When an impulse representing an intensity of light is sent by the Iconoscope and picked up by the receiver it is fed to this negatively charged control grid B as a positive impulse. This impulse causes the grid to become less negative in proportion to its strength. The resultant lessening of repelling force permits the beam forming electrons to pass through the control aperture "0" there to be acted upon by the other elements in the tube and finally striking the fluorescent screen. It should be readily seen that if a strong impulse is received and fed to the tube, a strong electron beam results and as a consequence, a correspondingly strong point of light on the screen. Conversely, a weak impulse — weak beam — weak point of light. Being able to reproduce faithfully any intensity of light the Iconoscope may interpret and trasmit, it is now necessary to distribute the received intensities so that their placement corresponds exactly with those being transmitted.

Placement Control

The placement control is an exact duplicate of the yoke of four deflecting coils around the neck of the Iconoscope (see figure 6). These coils are energized by vacuum tube generators which are an integral part of the receiver and produce the saw tooth currents. They cause the beam to move back and forth, up and down on the screen in step with the beam of the Iconoscope. Figure 7 shows the saw tooth current graphically. The rise in attraction increases until the beam has scanned a line. The attraction is then cut off as shown by Y until it reaches the starting point for the next line. To further insure perfect synchronization, a synchronizing impulse is sent out on the carrier wave by the transmitter every time the Iconoscope beam reaches the end of a line. At the receiving end, this impulse is fed to the horizontal coils. If for any reason, the Kinescope beam is lagging or leading the Iconoscope beam, this signal pulls it into step in readiness for the next line. A similar impulse at the end of every frame (mosaic scanned once) is also sent by the transmitter thereby insuring not only perfect synchronization of lines but perfect synchronization of frames. The saw tooth current generated for frame control is the same as shown in figure 7 except that it occurs only after all the lines have been scanned once.

The Farnsworth System

Equally as ingenious as Dr. Zworykin's Iconoscope is the television pick-up camera devised by Philo T. Farnsworth. This device was also developed for the purpose of overcoming the drawbacks of a mechanical system; i.e. lack of sufficient light, definition and dependable synchronization. Figure 9 shows a diagrammatic representation of the pick-up tube, the heart of the camera. It is in the form of an evacuated glass cylinder.

A, the circular end of the glass cylinder, is the cathode (negative). It is coated with a smooth surface of silver which is processed with caesium in order to make it electronically sensitive to light.

B, is the anode, (positive) with a small perforation (C) in its center.

D, is an electron collector placed directly in back of the perforation (C).

The object to be televized is projected on A through a system of optical lenses. Light, affecting the photo-sensitive surface of silver caesium, causes electrons to flow toward and be attracted by B (B being positive). The important feature of this action, as in all pick-up devices, is that the number of electrons emitted from any one point of the surface depends upon the amount of light projected at that point, i.e., if one point of A is affected by twice the amount of light as that of another, it will emit twice the number of electrons or, twice the strength of electron current. Although the electrons do not actually flow toward B in a straight line from their source, a direct current (constant) focusing coil surrounding the tube changes their path so that the net result is the same as if they did. The result is an electron reproduction (invisible, of course) of the photographic image, projected on the anode.

The next step is again the fundamental step necessary for any system of television transmission; that of sending small elements of a whole in regular and successive order, i.e., scanning. In the Farnsworth system this is accomplished in a reverse manner as compared with others. Instead of the image being scanned by a moving beam of light or electrons, the electron image itself is moved from side to side and up and down. Referring to figure 9, it will be seen that all electrons released from A would strike B, except those in a direct line with the aperture C. These electrons would pass through C and strike the collector D, to be carried away as an electrical impulse proportional in strength to the amount of light which caused that particular stream of electrons to be released. The result then is the same as in all other systems; an electrical translation of a picture element. In this case, the size of the element is equal to the size of the aperture C. In actual operation the electron image is moved so that the upper right hand corner is permitted to fall on B at C. The first element is collected by D, amplified, and placed on the carrier wave. Immediately after this, the image is moved to the left for the second element, proceeding in this manner until every element on the first line has passed through C and been collected by D. The image is then quickly moved to the right and at the same time moved upward in order that the elements in the second line may pass in front of the aperture. By repeating this process for every line, each element of surface of the electron translation of the photographic image is permitted to pass through C, be collected by D and then utilized. The electron image is moved in the paths mentioned by means similar to those employed for moving the electron beam in the Iconoscope; that is, deflection coils (see figure 9) connected to their associated circuits are placed around the pick-up tube thus attracting and repelling the electron image in such a way as to accomplish vertical and horizontal movement. Actually, after the elemental impulses leave D they are fed to another ingenious Farnsworth device called a Multipactor. This device is built into the glass cylinder but for the purpose of simplicity is not shown in the figure. Its purpose is to greatly increase the strength of the impulses before they are amplified in the usual manner.

Farnsworth Receiving Device

The receiving device used in the Farnsworth system is called the Oscillight. It is basically identical to the Kinescope except for the focusing of the electron scanning beam. The Kinescope beam is focused electrostatically, which means that the electrons, after leaving the cathode and passing through limiting apertures, are forced into a thin stream by electrical pressure. In the Oscillight, the same result is obtained through the use of magnetic force. A coil carrying a constant or direct current, is placed around the neck of the tube exerting a steady magnetic force which forces the emitted electrons toward the central axis, focusing them into the desired beam.

Intensity and placement controls of the beam and the synchronizing impulses are the same as those used in the Zworykin system.

PART VI

Present and Future of Television

No doubt the question has arisen in your mind as to why television is not as great a commercial reality as radio. Explanations in this work have given the impression that the technical problems of pick-up and receiving devices have been efficiently and satisfactorily solved and thus no great barriers remain to impede progress. That is relatively true. but in a system as complex as television. there are other links in the chain of complete functioning which do not lend themselves to immediate satisfactory results.

Perhaps the greatest barrier is the limited distance of transmission possible on the carrier wave frequency used for television. In the analogy of a carrier wave (#5 Tools) it was explained that small packages of electrical energy were delivered on this wave to potential receivers. To enlarge upon this analogy, the greatest number of packages which the carrier is able to convey in any one second, depends upon its frequency or cycles per second. It can carry as many or less than the frequency but never more. There is the rub! High definition television demands a carrier whose frequency is greater than those used in the short wave band. necessitating a venture into territory which had never until recently been seriously investigated. Radio started on a long wave or low frequency. For example, our present day broadcast band from 200 to 545 meters which converted to frequency is 1.500 kilocycles per second to 550 kilocycles per second.

Later. it was found that a shorter wave or higher frequency carried a greater distance than the long wave. It must be noted here, that radio was concerned not with quantity carrying characteristics of waves but with distance. Then came television! Early developments in this field. namely the 30. 60 and 120 line pictures could be accommodated by a long or short wave. However. as improvements in clearness of picture detail were made, the number of impulses per second increased until they exceeded the limit of a short wave (high frequency) carrier. Logically, the next step was to ultra-high frequency (1 to 10 meters). The impulse quantity carrying characteristics of this range were sufficient but it was found that the distance covered by an ultra-high frequency carrier was alarmingly less than the short wave, the outside limit being about 50 miles under good conditions. Such a range is certainly a far cry from the thousands of miles covered by short wave. Ultra-high frequency waves are usually referred to as "Quasi Optical" or "Line-of-Sight" Waves. Unlike longer waves which, in effect, follow the curvature of the earth, they keep going straight after reaching the visual horizon. The resulting limitation can easily be seen. A receiving aerial located past the horizon. (with respect to the transmitter). would not be in a position to pick up the carrier wave and its picture impulses. This difficulty can be overcome to a certain extent by the use of strategically placed booster stations or a network of co-axial cables (a nitrogen filled cable capable of carrying very high frequencies). The hope for the future is that a network of boosters and cables can be built which will serve the major and important sections of the United States. Naturally, the expense of such a project is, at present, prohibitive, for as yet those companies experimenting with television are receiving no return on money spent. Consequently, they must be sure of a permanent acceptance of the new development before such investments are made.

Installing a receiving aerial will no longer be a matter of dropping a wire out the window or tying it to a tree. The ultra-short wave is highly directional and must be picked up by a special aerial properly placed and directed, as far as possible, in the "line-of-sight" of the transmitting aerial.

Another obstacle is the danger of rapid obsolescence of transmitting and receiving equipment. The former might be tolerated by the broadcasting companies if the monetary return of improved service warranted it but the public would emphatically not stand for the necessity of the frequent purchasing of new receivers.

Radio is not confronted with this problem. An early type crystal set can still receive the present day broadcasts. Naturally, great advancement has been made in sensitivity of reception and sound reproduction but the basic structure has remained the same. In television, however, this is not true. An early type receiver capable of interpreting a 30, 60 or 120 line picture can in no way interpret a transmitted picture composed of any other number of lines. Imagine the limitations of a receiver which could pick up only station XYZ on 343 lines and not station PDQ because they transmitted on 240 lines or perhaps the types of scanning or frame frequency differed. Fortunately, the companies conducting experimental work will, in all probability, adhere to the recent agreement for the standardization for television transmission — namely, a 441 line picture with the full frame frequency of 30 per second using interlaced scanning. Intensive research has assured them that these requirements are sufficient to satisfy all needs for pleasing image reception.

Another question often raised is: How large is the received picture? Believe it or not, the writer's first experience was with a 60 line picture, the dimensions of which, on the receiving scanner, were about 1″ x 1″. The novelty was thrilling but the eye strain was annoying. It is needless to say that conditions have been vastly improved since then. The picture size of present home television receivers are in the order of 5″ x 7″ or 7″ x 11″, good viewing distance being 6 or 8 feet. There is no doubt that even these dimensions will be increased greatly. At this writing, there are many technical problems inhibiting the immediate possibility of greater dimensions. It is logical to assume, however, that when manufacturers produce home receivers for general public use, the picture size will be fairly well standardized if only for the reason that the set showing the largest picture will be the most desirable.

A further view behind the scenes of this new art reveals other problems which must be met. The technique of a complete television program will be vastly different from that of radio. A new staff of technically trained men is needed. Sight must be synchronized with sound. An entirely new program and studio technique must be developed. It will no longer be possible for actors to group around a microphone and read from the script safe from the eyes of an unseen audience. These actors must be letter perfect because there can be no retakes as there are in motion picture productions. The whole country will become a huge theatre, the audience ready and waiting to see a finished program.

Moving picture films can and will be used as material for television. The resort to this "canned" type of program will probably be greater than recordings on the radio. Only the larger television productions will enjoy full live productions. To increase the scope of a presentation, the combination of film and live talent may be used, the former supplying outdoor scenes or scenes unobtainable in the studio.

As to the exact type of program which will become most widely used, that remains to be decided by the broadcasting companies and the public. Intense research will be necessary in order to determine from past experience in radio and other fields of the entertainment world just what material gives the most sustained visual and audible pleasure.

Recently the head of one of America's leading broadcasting and radio manufacturing companies stated that it was his hope and belief that television would be supported by the public through the purchase of advertised articles rather than by means of a government taxation of receiving sets. It is a known fact that the high standard of excellence of American radio programs is primarily due to the former system. With this in mind, advertisers are keenly interested in the new art, hoping by means of sight as well as sound to create a greater demand for their articles, the public in turn benefitting by a continued high quality of home entertainment.

Inevitably someone asks: "How will television affect existing types of entertainment?" The answer is comparatively simple. In the first place, radio will not be replaced but rather supplemented by television. Just as sound added to sight in the motion picture industry increased the quality of productions, so will sight added to sound help radio. The scope of home entertainment will be broadened, its value becoming more tangible and educational, the fact being that sight impressions are more easily understood and impressing than sound.

The motion picture industry should have no fears. Television will supply an added outlet for film productions and a closer alliance between these two great industries will become necessary. As to the effect on motion picture theatres, the supposition is that better pictures will result in an effort to keep the public interested. The probability of telvision being used to transmit films from the central point to numerous theatres for projection purposes is very slight. Far too many technical problems stand in the way of such a possibility.

The legitimate theatre, opera, football games, boxing matches — all these publicly attended presentations will enjoy not only as much attention but may even experience a greater general interest through the public's education. It is logical to assume that television, necessarily resorting to diversified types of entertainment cannot compete with an organization specializing in one kind.

There is always the same cry when a new industry is created: "Men will be thrown out of work and present business will be affected." The net result when television emerges into full growth will be the need for: more technical men, more actors, more producers and generally better conditions throughout the production branch of the entertainment world.

The final question to be answered is "When will we have television for everyone?" One guess is as good as another. Perhaps in 1940 or 1945. There is probably more money and time being spent in this industry for experimental purposes than in any other of its type. There is one fact that can be counted on — Television is here to stay and is rapidly growing strong enough and healthy enough to hold its head high among the established arts of all times.

FINIS.

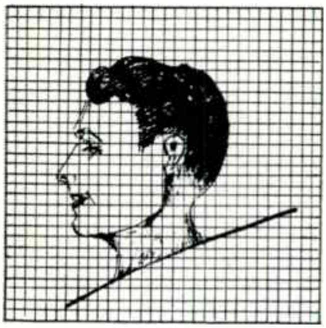

FIG. 1

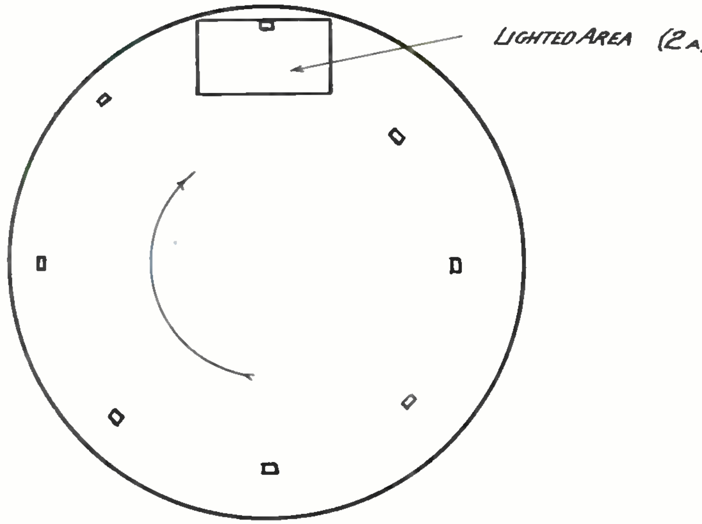

FIG. 2

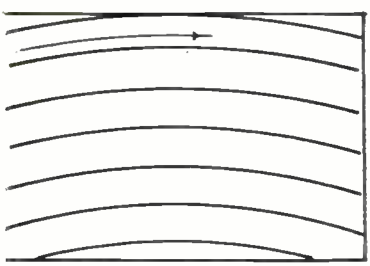

FIG. 2B

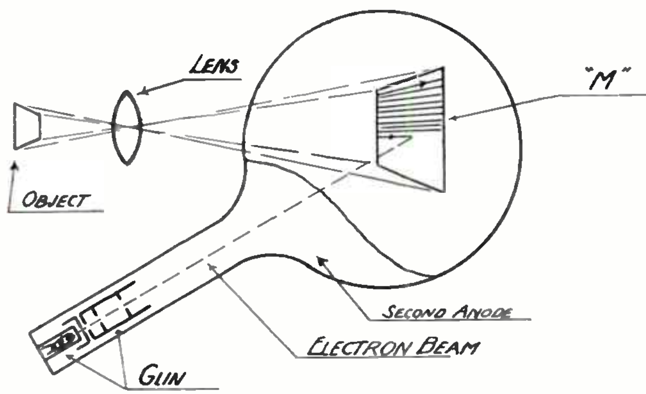

FIG. 3

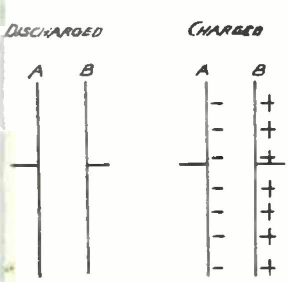

FIG. 4

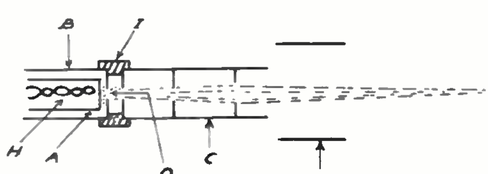

FIG. 5

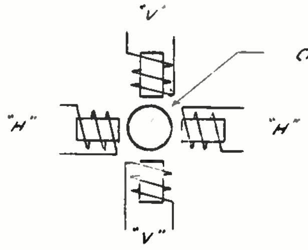

FIG. 6

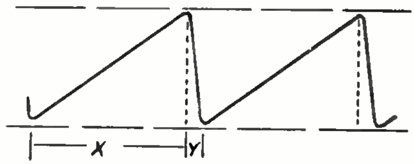

FIG. 7

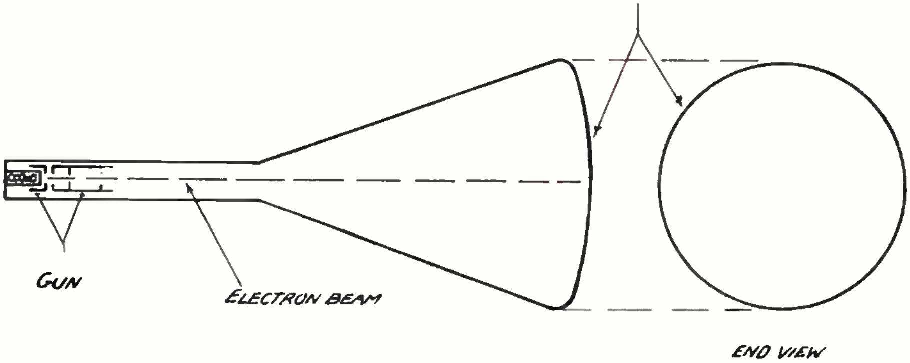

FIG. 8

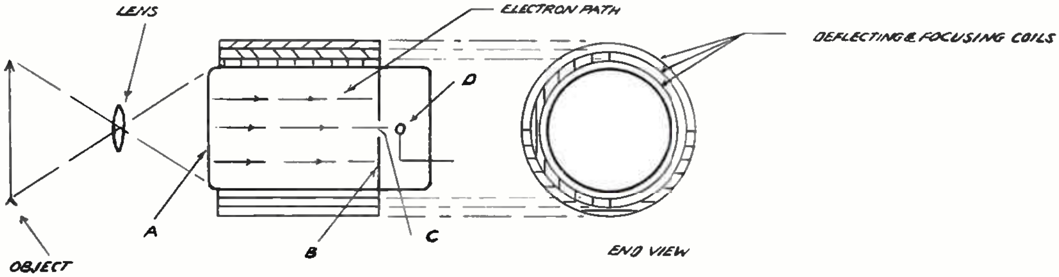

FIG. 9