RCA REVIEW

A Quarterly Journal of Radio Progress

Published in July, October, January and April of Each Year by
RCA INSTITUTES TECHNICAL PRESS
A Department of RCA Institutes, Inc.
75 Varick Street, New York, N. Y.

VOLUME IV October, 1939 NUMBER 2

CONTENTS

SUBSCRIPTION:

United States, Canada and Postal Union: One Year $1.50, Two Years $2.50, Three Years $3.50
Other Foreign Countries: One Year $1.85, Two Years $3.20, Three Years $4.55
Single Copies: 50¢ each

Entered as second-class matter July 17, 1936, at the Post Office at New York, New York, under the Act of March 3, 1879.

Printed in U.S.A.

THE ORTHICON, A TELEVISION PICK-UP TUBE

By

Albert Rose and Harley Iams

Research and Engineering Department, RCA Manufacturing Company, Inc., Harrison, N. J.

Summary—*Extensive laboratory and field tests have shown that the Iconoscope is capable of transmitting clear, sharp television pictures even under conditions of unfavorable illumination. An analysis of the operation of the tube suggests that improved efficiency and freedom from spurious signals should result from operating the mosaic at the potential of the thermionic cathode, rather than near anode voltage. The beam electrons then approach the target with low velocity, and the number of electrons which land is dependent upon the illumination.*

Several new designs were developed to make sure that the beam of low-velocity electrons was brought to the cathode-potential target in a well-focused condition, that the scanning pattern was undistorted, and that the focus of the beam was not materially altered by the scanning process. A magnetic field perpendicular to the target was found to be useful in focusing and guiding the beam. In some of the tubes, the scanning beam was released by a flying light spot moving over a photocathode. In other tubes it was found more convenient to develop the beam in an electron gun with a thermionic cathode. Special horizontal and vertical deflection systems capable of operating in the presence of a magnetic field were evolved.

The electron gun type of pick-up tube, which has been called an Orthicon, has a maximum signal current output over 300 times the noise in a typical amplifier. The signal is proportional to light intensity. The resolution is sufficient for the transmission of a 441-line picture. Spurious signals are neglible. Within the accuracy of measurement, all the photoemission is converted into video signals. In its present developmental form, the Orthicon gives promise of becoming a useful television pick-up tube.

INTRODUCTION

WITH the beginning of scheduled television broadcasting in New York, it is natural that a great deal of attention should be given to the commercial aspects of the art. Engineers realize, however, that research and development work must continue if future improvements are to be assured. Further investigations have, therefore, been carried on to provide ways to transmit clearer images, with less illumination. This paper will discuss an improved form of pick-up tube resulting from some of these investigations.[1]

---

[1] See, also, Albert Rose and Harley Iams, "Television Pick-up Tubes Using Low-Velocity Electron-Beam Scanning," *Proc. I.R.E.*, Vol. 27, No. 9, pp. 547-555, September (1939).

At the present time, the RCA television system uses Iconoscopes to convert the optical image into a sequence of video signals for transmission to the receiver. Several previous publications have described these tubes and explained how they operate,[2,3,4] so that a brief review of their characteristics is sufficient to serve as a basis for a discussion of new pick-up tubes.

Extensive laboratory and field tests have shown that the Iconoscope is capable of transmitting clear, sharp television images, even under conditions of unfavorable illumination[5]. The spectral response is sufficiently like that of the human eye to give a natural appearance to the viewed scene. In the circuits associated with the tube, provision is made to "keystone" the deflection (so as to make the scanning beam move over the mosaic in a rectangular pattern) and to introduce shading signals into the amplifier (to compensate for the "dark spot" signal).

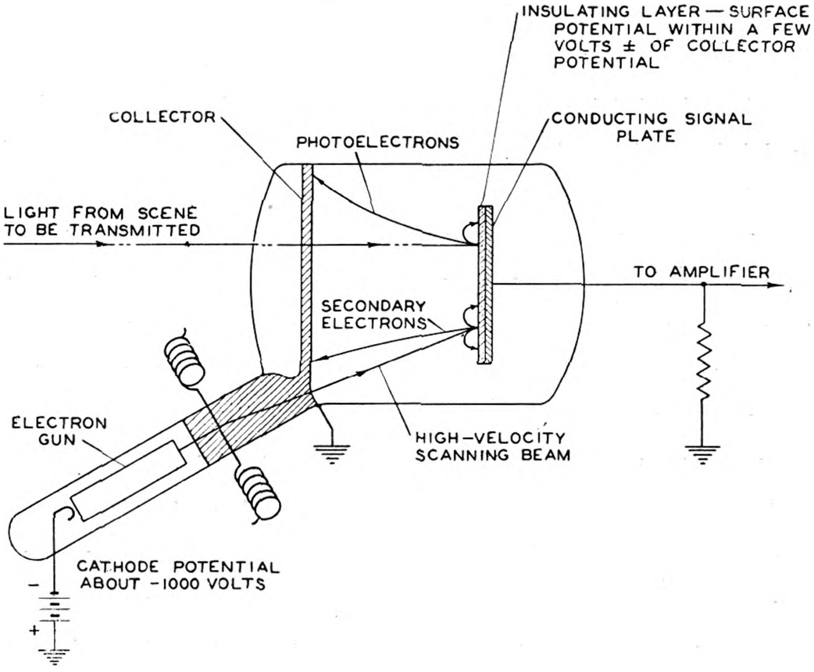


Fig. 1—Schematic diagram of an Iconoscope.

In the course of these tests, several significant discoveries were made. One of these was that the good operating sensitivity of the tube

---

[2] V. K. Zworykin, "The Iconoscope—A Modern Version of the Electric Eye," *Proc. I.R.E.*, Vol. 22, No. 1, pp. 16-32, January (1934).

[3] V. K. Zworykin, "Iconoscopes and Kinescopes in Television," RCA Review, Vol. 1, No. 1, pp. 60-84, July (1936).

[4] V. K. Zworykin, G. A. Morton and L. E. Flory, "Theory and Performance of the Iconoscope," *Proc. I.R.E.*, Vol. 25, No. 8, pp. 1071-1092, August (1937).

[5] Harley Iams, R. B. James, and W. H. Hickok, "The Brightness of Outdoor Scenes and Its Relation to Television Transmission," *Proc. I.R.E.*, Vol. 25, No. 8, pp. 1034-1047, August (1937).

is obtained in spite of an operating efficiency only 5 or 10 per cent of that which is theoretically attainable[4]. In other words, during typical operation only about one-third of the photoelectrons which the mosaic emits are drawn away, and only about one-quarter of the stored charge is effective in producing the video signal. This lowered efficiency is connected with the release of secondary electrons from the mosaic by the scanning beam.

The situation is illustrated in Figure 1, which shows the essential parts of an Iconoscope. Light in the optical image focused on the mosaic causes the emission of photoelectrons, leaving a pattern of charges corresponding in intensity to the light and shade of the scene to be transmitted. This pattern of charges is scanned by a beam of electrons, which strike the mosaic at high velocity. On the average, each beam electron releases several secondary electrons. Since the mosaic is an insulated surface, the electron current leaving it must (on the average) be equal to the electron current arriving. Thus, when the tube is in darkness, only as many secondary electrons can escape from the mosaic as there are beam electrons which arrive. The rest of the secondary electrons fall back on the surface near or far from the point of emission. Nonuniformities in the escape and rain of secondary electrons cause the "dark spot" signal.

Many of the numerous secondary electrons are emitted with appreciable velocity, so that the condition of one secondary electron leaving for each beam electron arriving means that the electric field near the mosaic is such as to hinder the escape of secondary electrons. This field also reduces the escape of the photoelectrons, which have lower average emission velocity. When the mosaic is lighted, those photoelectrons which escape contribute a positive charge to the lighted parts of the surface. These charges are partly dissipated by the rain of secondary electrons, but sufficient charge is stored during a frame period to produce a strong signal in an amplifier connected to the signal plate when the beam releases the stored charge.

LOW-VELOCITY ELECTRON BEAM SCANNING

If one could ignore the immediate practical problems and choose an ideal mode of operation for a television pick-up tube, he might want to provide a field strong enough to draw away all of the photoelectrons which are emitted, and he might prefer to do the scanning without involving secondary emission in the process. These conditions can be met by operating the mosaic, in known fashion, at the potential of the cathode in the electron gun.

Cathode-voltage operation is possible, for the potential of an insulated surface exposed to an electron beam is stable at this voltage[6]. High-vacuum cathode-ray tubes are usually operated so that the beam electrons strike the screen with high velocity, and liberate many secondary electrons. The screen potential then adjusts itself (usually near anode voltage) so that the number of secondary electrons which escape is equal to the number of beam electrons which arrive. However, the other stable condition occurs when the surface is at cathode potential. The beam electrons then approach the target, but are repelled and retire without striking. If the target becomes slightly positive (by photoemission, for example), the beam electrons land without producing appreciable secondary emission and restore the original voltage.

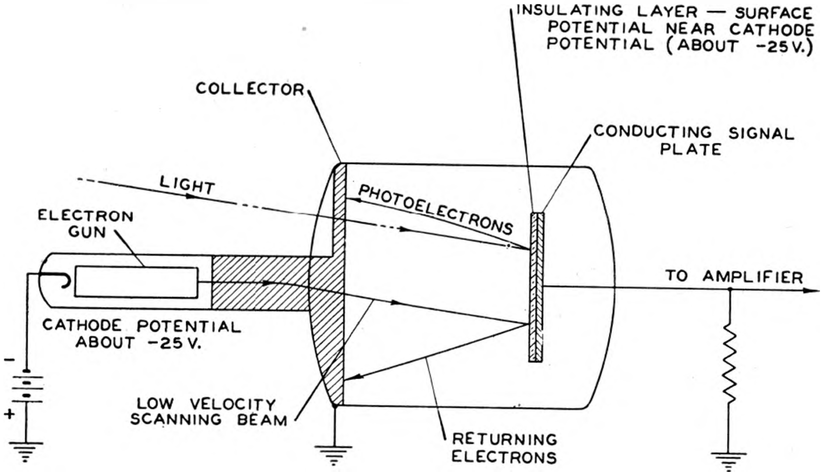


Fig. 2—Pick-up tube with cathode-potential target.

Figure 2 illustrates the operation of a television pick-up tube with its photosensitive target at cathode potential. In the absence of light the beam electrons approach the surface, are slowed to zero velocity, and then are drawn away. There is no signal in an amplifier connected to the signal plate. When light falls on the mosaic, all the photoelectrons are pulled away by the strong electrostatic field between the mosaic and the anode. The charges given the surface are not dissipated by a rain of electrons, but are stored until the scanning beam approaches. When the beam comes near a lighted area, and finds it a few volts positive, electrons land until their negative charge brings the surface to cathode potential again. The velocity with which the beam electrons reach the surface is so low that secondary emission is not involved to any appreciable extent. The signal is simply due to the impulses given the signal plate by the beam electrons, as they arrive at the lighted parts of the target.

---

[6] A. W. Hull, "The Dynatron," *Proc. I.R.E.*, Vol. 6, No. 1, p. 5, February (1918).

DESIGN PROBLEMS

So far, much of the discussion has related to ideals. Some of the problems which must be solved before a pick-up tube can be made to operate in a satisfactory manner with its target at cathode potential are illustrated in Figure 3. When the electron beam is deflected, in usual fashion, at an angle to the axis of the tube, the electrons do not approach the target perpendicularly. The negative voltage needed to keep an electron from landing on the mosaic is only as great as the component of velocity perpendicular to the mosaic, and the electric field is not able to stop motion parallel to the surface. When conditions are as illustrated, the beam charges one part of the target to cathode potential, and other parts slightly more positively. Also, the point of contact of the beam may be elongated into a line. This situation may be expected to cause a loss of resolution at the edges of the picture, and unstable operation when the electrons move with considerable velocity tangent to the surface of the target. These considerations suggest that it would be preferable for the beam always to approach the mosaic nearly perpendicularly, or for the beam to be constrained.

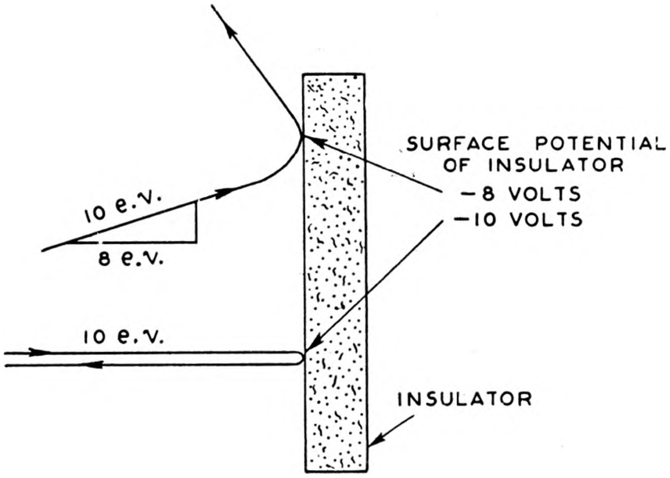


Fig. 3—Electron paths near target.

Another important problem is that of providing sufficient beam current (about one microampere) in a beam which retains its small diameter when the electrons are slowed to almost zero velocity and are subject to strong local fields at the mosaic surface.

In the solution of these problems, a magnetic field perpendicular to the mosaic and extending to the source of the electron beam has been found useful. When the field is made sufficiently strong, the beam is focused and refocused many times between the cathode and the target. In a uniform magnetic field, the final size of the scanning spot is substantially the same as that of the source of the beam. The magnetic field can also be used to keep the beam electrons from proceeding very far across the surface of the mosaic at grazing incidence. Electrons which tend to move in this fashion cut across the lines of flux, and move in circular paths. The diameter of these circles can be made as small as is desired by increasing the strength of the magnetic field.

Several types of pick-up tubes based upon these principles have been designed. In some, the scanning beam is developed at a photocathode illuminated by a moving spot of light, while in others the beam originates at a thermionic cathode. The name Orthiconoscope (or Orthicon, for short) has been used to denote these tubes in which the target is operated at cathode potential. (The Greek prefix "orth", meaning straight, is added to the well known term "Iconoscope" to describe the linear relation between light and signal output, which has been observed.)

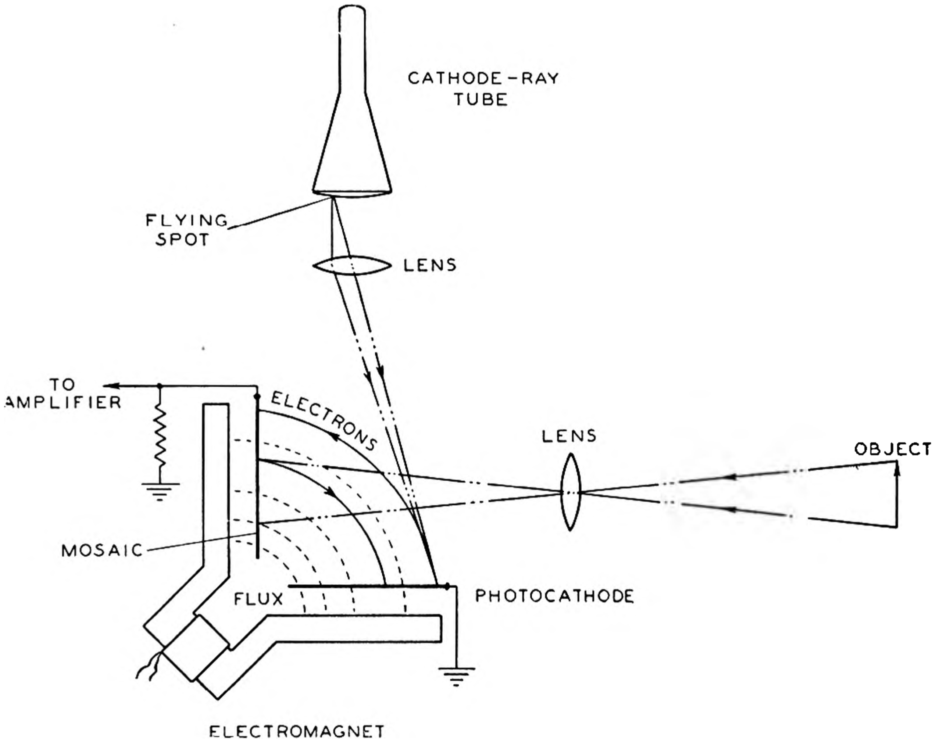


Fig. 4—Pick-up tube using photoelectrons for beam.

TUBES WITH PHOTOELECTRIC SCANNING BEAM

One of the tubes which has been built and tested is illustrated schematically in Figure 4. A charge image of the scene to be transmitted is developed by focusing the optical image upon a conventional mosaic. The electron beam which scans the mosaic is produced by photoemission from a conducting photocathode, which is illuminated by a flying light spot focused from the face of a cathode-ray tube with a short-time-lag screen. At any instant, the light from a single spot on the cathode-ray-tube screen is focused on the photocathode. The emitted photoelectrons are guided by the curved lines of flux between the pole faces of an electromagnet, and the beam is also focused by this field. When beam electrons approach a lighted part of the mosaic, they are absorbed and produce signals in the amplifier. From the dark parts of the mosaic the beam electrons are reflected back to the photocathode. Photoemission from the mosaic is collected by the photocathode.

The picture transmitted by this tube is quite sharp, and is free from spurious shading. Streaking, which one might expect because of time lag in the luminescent material, is not apparent. Most of the discharging of charged areas takes place in the first fraction of a microsecond, and after that the beam electrons fail to reach the target and their presence is not observed.

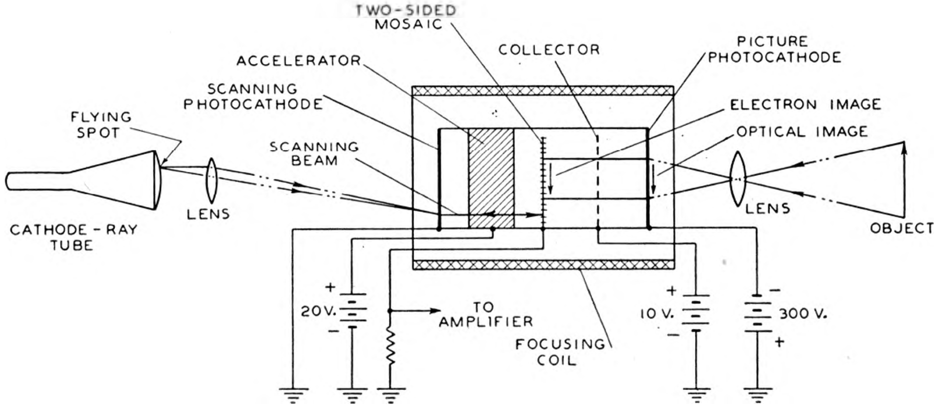


Fig. 5—Pick-up tube using secondary emission amplification.

Tubes which incorporate secondary emission amplification of the image, in a fashion somewhat comparable with the method used in the Image Iconoscope[7], have also been built and tested. Such an arrangement is shown in Figure 5. In this case, the optical image is focused upon a translucent photocathode and the resulting photoemission is focused upon a two-sided mosaic by means of an axial magnetic field. Secondary electrons released from the mosaic by the high-velocity picture electrons are drawn away to a collecting electrode, giving image amplification. The electron beam which scans the other side of the mosaic is obtained from a flying light spot moving over another translucent photocathode, and is focused by the same axial magnetic field which focuses the electron image. As in the previous tube, the scanning beam restores the mosaic to the potential of the

---

[7] Harley Iams, G. A. Morton, and V. K. Zworykin, "The Image Iconoscope," *Proc. I.R.E.*, Vol. 27, No. 9, pp. 541-547, Sept. (1939).

scanning cathode. When the tube is operated, the gain in sensitivity due to secondary emission amplification is readily observed.

While a number of tubes which use photoelectric scanning beams have been tested, these two examples are sufficient to indicate the methods that have been used. These methods make possible the scanning of a large mosaic with a well-focused beam of low-velocity electrons, resulting in the transmission of video signals free from spurious signals. Further, an increase in sensitivity through secondary emission amplification may be obtained. However, because the auxiliary apparatus to generate the flying light spot represented a complication, an investigation was made of tubes in which the beam is derived from a thermionic cathode, and is deflected in the presence of a magnetic field.

TUBE WITH A THERMIONIC SCANNING BEAM

The most important problem in the design of a pick-up tube, operating with its target at cathode potential, and using an electron gun to generate the scanning beam, is that of deflecting the beam without defocusing it. In the case of the tubes described above, each point on the target had a corresponding point on the photocathode such that the same magnetic line intersected both of them. Photoelectrons generated at one end of the line at the photocathode were focused at the target with substantially one-to-one magnification. A slight enlargement of the scanning spot occurred due to the emission velocities of the photoelectrons transverse to the magnetic field. If, in some way, larger transverse velocities were introduced into the motion of the beam electrons, they would describe helices of larger amplitude around the magnetic lines and result in a larger spot at the target. In the case of a tube using an electron gun, only the central point on the target is normally connected with the cathode by a magnetic line. If electrons from the gun are to reach other points on the target, either they must cross the magnetic lines of the axial field or they must be guided to other points by warping the axial magnetic field. Both of these devices are used in the form of Orthicon to be described. To insure, however,

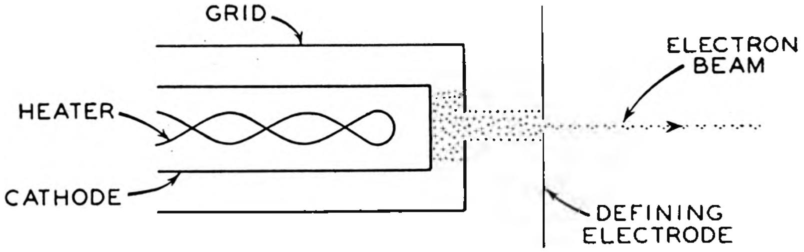


Fig. 6—Electron gun.

that the deflected spot is not larger than the undeflected spot it is necessary that no significant amount of velocity transverse to the magnetic field, imparted to the beam electrons by the deflection system, be retained by the electrons as they approach the target.

The simple electron gun shown in Figure 6 generates a stream of electrons moving parallel to the axis with a velocity of about a hundred volts. The cross section of the beam is limited to the size of a picture element by the defining aperture in the last electrode. In this state, the beam enters the deflection system and in this state it should emerge except for a displacement from the axis.

The high-speed horizontal deflection is accomplished by a pair of electrostatic deflection plates in combination with the axial magnetic field. A somewhat schematic representation of the path of the beam through the plates is shown in Figure 7. The beam is seen to be deflected in a plane parallel with the plates and to diverge from the axis only while it is between the plates. After leaving the plates, the beam continues parallel to the axis. The amplitude of deflection is proportional to the electric field and the transit time of the electrons through the plates, and inversely proportional to the strength of the axial magnetic field. Since the maximum amplitude of deflection is limited to the width of plates, these must be as wide as the target to be scanned. The wiggles in the beam in Figure 7, when viewed from the end of the plates, that is along the axis, appear as a series of cycloids. This is the two dimensional path described by electrons moving in crossed electric and magnetic fields. If the electric field from the deflection plates could be sharply cut off at the entrance and exit edges, the transit time of the beam could be adjusted so that only an

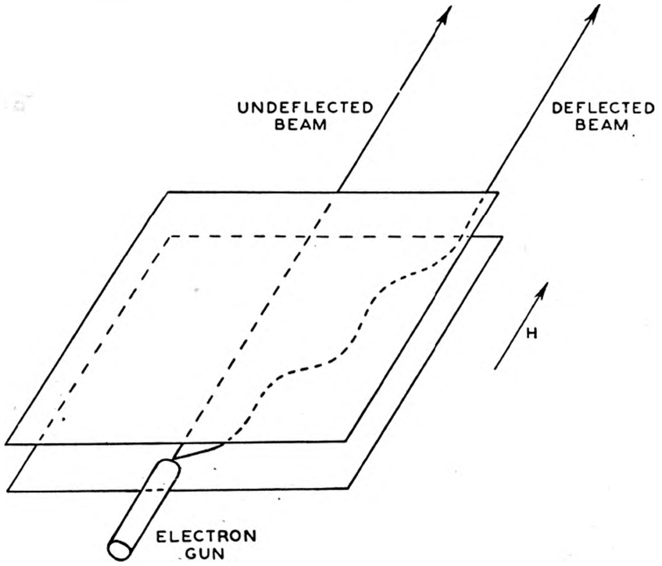


Fig. 7—Path of electron beam in electric and magnetic fields.

integral number of cycloids would be performed by the beam in passing through the plates. In this way, none of the transverse velocity represented by the cycloidal motion would be retained by the beam after it left the plates. While this is a possible arrangement, it has been found that a less critical way of insuring that the emergent beam retains substantially none of the transverse velocity acquired in the plates is to suppress the amplitude of cycloidal motion within the plates. The amplitude of cycloidal motion may be considerably reduced by admitting the beam to the plates through a gradually increasing electric field and similarly letting it leave through a gradually decreasing field. For this reason, the deflection plates are flared out at the entrance and exit ends.

Two significant distinctions are to be noted, in the above account, between electrostatic deflection in the presence of a magnetic field, as in an Orthicon, and electrostatic deflection in a magnetic field free space, as in the usual cathode-ray tube. First, the plane of deflection, which is perpendicular to the plates in the usual electrostatic deflection, has been rotated through ninety degrees into a plane parallel with the plates, in an Orthicon. Second, while the usual plates impart a transverse velocity to the beam which causes the beam to continue to diverge from the axis after leaving the plates, the plates in an Orthicon cause the beam to diverge from the axis only while the beam is between the plates. The axial magnetic field constrains the beam to motion parallel with the axis after it leaves the plates.

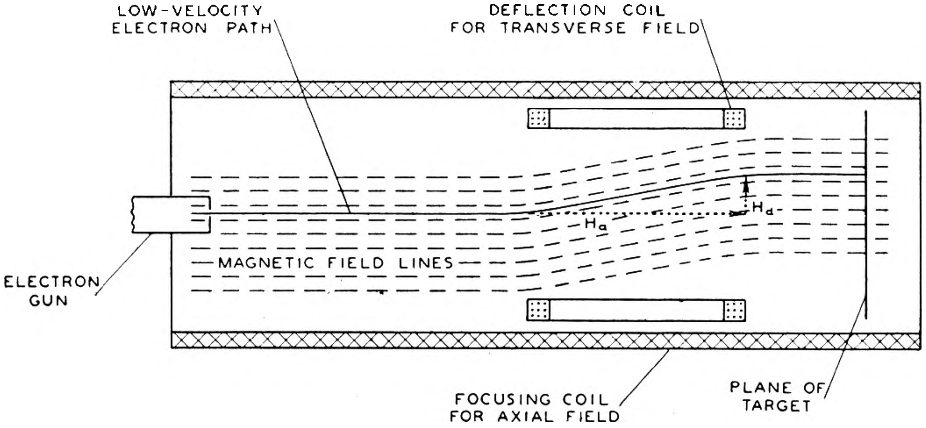


Fig. 8—Path of electron beam in warped magnetic field.

The low-speed vertical deflection is accomplished by a pair of magnetic coils. Here, again, while magnetic coils are used in the usual cathode-ray tube without an axial magnetic field, their action in an Orthicon is essentially different by virtue of this field. Briefly, the axial magnetic field rotates the plane of deflection through ninety degrees and causes the electrons in the beam to move parallel to the axis after leaving the deflection coils. The average path of the beam through a pair of deflection coils immersed in an axial magnetic field is shown in Figure 8. The amplitude of deflection is proportional to the magnitude and axial length of the deflection field and inversely proportional to the magnitude of the axial magnetic field. From Figure 8, it is evident that the separation of the coils must be as large as the height of the target to be scanned. While Figure 8 shows the average path of the beam to follow the magnetic lines closely, the actual path contains a helical motion imparted to the electrons due to their passing through a curved magnetic field. For small deflections, the amplitude of this helical motion is of the order of, or less than, the helical motion of the electrons due to their emission velocities. The magnetic coils may therefore be considered as a means of displacing the beam from the axis, without contributing any significant transverse velocity to the beam electrons.

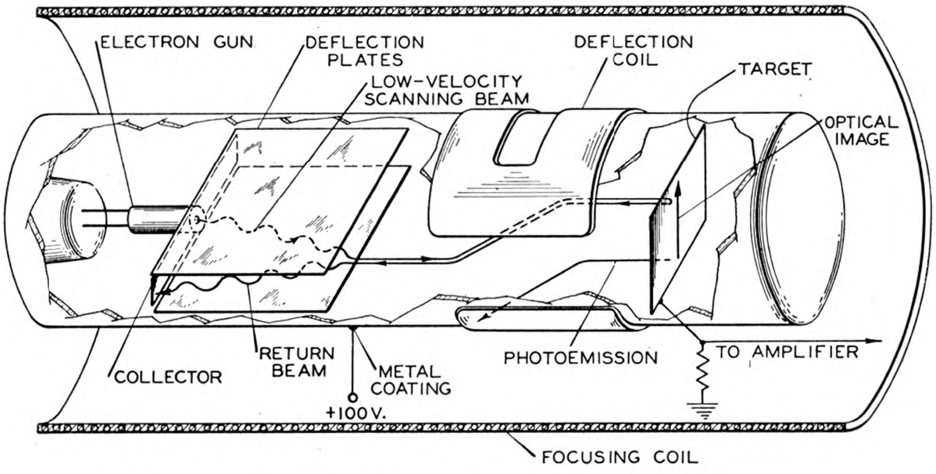


Fig. 9—Schematic diagram of an Orthicon.

The beam, as it leaves the deflection system and approaches the target, is in substantially the same condition as when it left the gun, except that it may be displaced from the axis. Since the target surface is at cathode potential, the beam passes through an electric retarding field sufficient to slow it to near zero velocity at the target. The target is a thin mica sheet, the side facing the beam being covered with a mosaic of photosensitive elements and the side away from the beam being coated with a translucent conducting film of metal known as the signal plate. The optical picture is focused on the photosensitive side through the translucent signal plate. The photoelectrons are drawn away from the zero-potential surface to various positive electrodes near the target (see Figure 9). As described earlier, if the element approached by the beam has been unlighted, the beam electrons will not land on the target, but will be brought to rest near it and be accelerated back away from the target. If the element has been lighted, enough of the beam electrons will land to replace the photoelectrons that have been drawn away during the previous frame time. In this way, the beam maintains the target at cathode potential and generates the video signal. The electrons which do not land at the target retrace substantially their original path as they return toward the electrostatic plates. In passing back through the plates, the beam diverges from its going path in the direction of the original deflection, as shown in Figure 9. The beam eventually strikes an elongated collector electrode, also shown in Figure 9.

OPERATING CHARACTERISTICS

The description of the operation of an Orthicon would lead one to expect a set of simple operating characteristics. This expectation has been borne out by numerous observations on the tubes. Briefly, substantially no signal is transmitted with no light on the target. With an optical picture focused on the target, a signal proportional to the light intensity at each point is transmitted. The maximum signal is limited by the amount of beam current. In some tubes a modulated beam current of one microampere has been observed. This corresponds to a signal current about three hundred times the noise level of a typical television amplifier.

Not only is the transmitted signal proportional to the light on the target, but also the conversion of possible photoemission into signal takes place at substantially 100 per cent efficiency. This requires that the photoemission from the target be saturated throughout the frame time, that the charge be fully stored for that time, and that all of the stored charge be useful in producing a video signal when the scanning beam passes over it. Tests made on Orthicons have shown that the photoemission from the target is saturated when the collector electrodes surrounding the target are more than twenty volts positive with respect to the target. Since these electrodes are usually about plus one hundred volts, a saturated photocurrent is assured under static conditions. During a frame time, the photoemission from the target is swept over the collecting electrodes by the field from the vertical deflecting coils. To test whether the photocurrent was saturated equally throughout the frame time and equally stored, a spot of light was projected on the target once a frame time for about one-tenth of the frame time. The signals, both of the photocurrent and of the discharge process, were observed on an oscilloscope. The storage time was varied from zero to a full frame time by varying the time at which the spot was projected on the target. No variation in either of these signals was observed throughout the full range of storage time, indicating that the photocurrent was equally saturated and the charge equally stored throughout the frame time. A final overall test, which compared the transmitted signal with a known amount of light on a target of known photosensitivity, showed that (within ability to measure) all of the stored charge (or by the above tests, all of the photoemission at the target) was utilized in producing video signal. As a result of this high operating efficiency, Orthicons with a target photosensitivity of one microampere per lumen exhibited approximately the same operating sensitivity as Iconoscopes with a target photosensitivity of ten microamperes per lumen.

THE TRANS-PACIFIC AIR EXPRESS
which will connect the United States
and the Orient starting this fall
is the result of two years'
intensive preparation

(Courtesy R. D. Knell)

Fig. 10—Television picture transmitted by an Orthicon.

Observations on the resolution of the transmitted picture showed more than four-hundred-line resolution over the entire picture and as high as six-hundred-line resolution in the center. For the particular size of target used, two and one-half inches wide, this means that the scanning beam near zero velocity can resolve elements on the target less than one two-hundredth of an inch apart.

Two representative pictures transmitted by an Orthicon are shown in Figures 10 and 11. No shading-compensation signals were introduced into the television system from which these pictures were taken.

CONCLUSIONS

As a result of the tests which have been described, it may be concluded that the operation of a television pick-up tube with its target at cathode potential makes possible (1) the efficient conversion of photoemission into video signals, (2) a large signal output, and (3)

(Courtesy R. D. Knell)

Fig. 11—Television picture transmitted by an Orthicon.

the elimination of spurious signals. While developmental Orthicons incorporating these features have been built and operated, additional work to determine optimum designs is in progress.

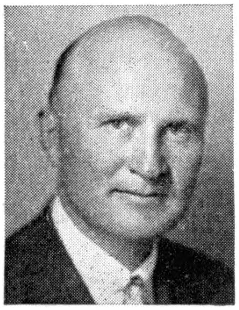
Thomas H. Hutchinson graduated to television from the theatre and radio. A native of California, he began his theatrical career in 1913. As an actor and director he engaged in the production of plays in the larger cities of the United States. His writing experience includes radio scripts and a comedy which achieved a Broadway run. He joined the National Broadcasting Company in 1928 as announcer and later served as Program Manager of the NBC Pacific Division, leaving that post to become Pacific Coast representative of a commercial account. In 1934, Mr. Hutchinson rejoined NBC in New York as a radio producer, and in 1937 was made Television Program Manager.

Harley Iams was born in Lorentz, West Virginia. He received the A.B. degree from Stanford University in 1927, and in 1927-1928 took the student course at Westinghouse Electric and Manufacturing Company. From 1928 to 1930 he was in the facsimile and television research department of that company. Since 1931 he has been engaged in television research for the RCA Manufacturing Company at Harrison, N. J. Mr. Iams is a member of the Institute of Radio Engineers.

Richard E. Mathes is a native of Minneapolis, Minnesota. He received his B.S. degree in electrical engineering from the University of Minnesota in 1924. That same year he joined the Radio Corporation of America engineering department, which in 1928 became the engineering department of R.C.A. Communications, Inc., where, as assistant head of the Central Office Engineering Laboratory in New York City, he is engaged in facsimile, multiplex and printer developments. Mr. Mathes is a member of Tau Beta Pi, of Eta Kappa Nu, of the I.R.E., and of the A.I.E.E.

Keron Caldwell Morrical was graduated from the College of Engineering of the University of Illinois, receiving the B.S. degree, in 1929. From 1929 to 1930 he was an engineer for the Public Service Company of Northern Illinois, and from 1930 to 1932 was a research engineer in Acoustics in the Building Materials Laboratory of the United States Gypsum Company. He was a special graduate research assistant in physics in the engineering experimental station of the University of Illinois from 1932 to 1934, and was instructor in the physics department of the University of Illinois from 1934 to 1936. During the period from 1932 to 1936 he carried on graduate work, receiving the M.S. degree in 1933 and the Ph.D. degree in 1936. Since 1936 he has been a member of the Sound Engineering Department of the RCA Manufacturing Company at Camden, N. J. Dr. Morrical is affiliated with the Acoustical Society of America, the American Physical Society, the Society of Sigma Xi, Sigma Tau, and Eta Kappa Nu.

Garrard Mountjoy, following his graduation with a B.S. degree from Washington University in 1929, joined the Sparks-Withington Company as a development engineer. For that company he spent some time in Europe designing radio sets for local conditions. He later became Chief Engineer of the Sparks-Withington Radio Development Department which position he held until 1935. Prior to entering college he spent a year with the Westinghouse Company. Since 1935, Mr. Mountjoy has been on the staff of the RCA License Laboratory.



Harold O. Peterson received his degree of B.S. in Electrical Engineering from the University of Nebraska in 1921. Following his graduation he served a year as testman for the General Electric Company. From 1922 to 1929 he was engaged in the development of radio communications equipment for the Radio Corporation of America, and since 1929 has been in charge of the receiver development laboratory of R.C.A. Communications, Inc. Mr. Peterson is a member of Sigma Xi, of Sigma Tau, and of I.R.E.

Albert Rose was born in New York City. He received the A.B. degree from Cornell University in 1931 and the Ph.D. degree in physics in 1935. From 1931 to 1934 he was a teaching assistant at Cornell University, and since 1935 he has been a research engineer in the Research and Engineering Department of the RCA Manufacturing Company at Harrison, N. J. Dr. Rose is a member of Sigma Xi.

James N. Whitaker is a native of Santa Rosa, California, and was graduated from the High School of that city. He served in the United States Navy from 1923 to 1927. Upon his discharge he joined the engineering department of the Radio Corporation of America, changing in 1928 to the engineering department of R.C.A. Communications, Inc., where he since has been engaged.