

The Image Iconoscope— a Camera Tube for Television

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The oldest television camera tube, the iconoscope, is now used only for transmitting still pictures (e.g. the signal picture of a certain station) and film pictures. Further development of camera tubes in Europe has followed a course different from that in America. In the U.S.A. the image orthicon has become predominant, whilst in Europe the image iconoscope is widely used. Of the latter there are British and French versions and also one that has been developed in the Philips Laboratory at Eindhoven (Netherlands). This Philips image iconoscope is described here and compared with other camera tubes.

THE OBJECT of television is to transmit moving pictures via electrical means. This is achieved by "measuring" in succession the brightness of the very large number of picture elements into which the picture to be transmitted is imagined as being divided. This measuring consists in the conversion of the brightnesses into corresponding fluctuations of an electric current which in some way or other govern the signal transmitted.

However the time available for measuring the brightness of one picture element is very small, actually only 10^{-7} sec. A method can be imagined, whereby the imaged scene is illuminated continuously on a photosensitive plate, while for each picture element in succession in the space of time of 10^{-7}

sec a signal is transmitted which corresponds to an illumination that was present during the whole of the time ($\frac{1}{25}$ sec) available per picture. This idea is to be found materialized in all present-day television camera tubes. With this method there is a continuous accumulation of charge during a frame period, and thus these tubes have come to be known as "storage tubes."

The oldest form of storage tube is the iconoscope, designed by Zworykin (1933). In the main this article will be devoted to a modern camera tube named the image iconoscope. Some other types will be mentioned in passing.

Classification of Modern Camera Tubes

In the most important camera tubes of modern design there is a plate ("target" or "mosaic") on which is projected an electrical image consisting of a two-dimensional pattern of electric

Abstract by Pierre Mertz of a paper in *Philips Technical Review*, 13: 119-133, Nov. 1951.

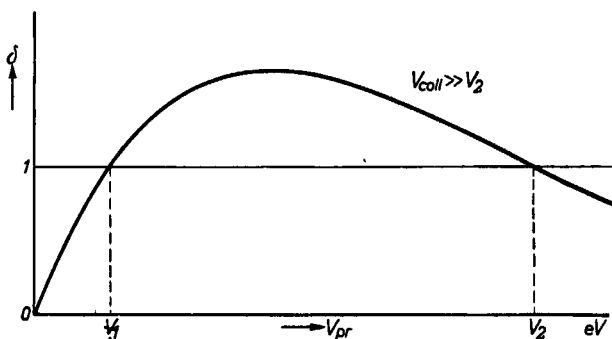


Fig. A. Secondary-emission coefficient δ of an insulator, as a function of the energy V_{pr} of the primary electrons. At two values of V_{pr} (V_1 and V_2) δ is equal to 1. This curve applies when the collector potential is high compared with V_2 .

potentials corresponding in amplitude and position to the luminance in the optical image of the scene to be transmitted. This electrical image is scanned point by point by a focused beam of electrons (the scanning beam), the potentials being thereby reduced to a certain "stabilizing potential" which in some way or other produces an electric signal.

The target is, of course, made of an insulating material, e.g. mica. When an electron beam is directed upon it the rule is that for every surface element, in the stable state, on an average just as many electrons have to be emitted as impinge upon it.

When the primary electrons impinge upon a surface element of the plate they release secondary electrons from the material. The secondary-emission coefficient δ , i.e. the average number of secondary electrons released by one primary electron, depends upon the material and the velocity (thus the energy) of the primary electrons at the plate. If V_{coll} is so high that the collector attracts all the secondary electrons towards it, then the variation of δ as a function of the energy V_{pr} (expressed in electron-volts) of the primary electrons is as represented in Fig. A. In the case of most materials there are two values for V_{pr} where $\delta = 1$; the

smaller of the two is denoted by V_1 , the larger by V_2 . For mica, for instance, these material constants are in the order of 10 volts and some thousands of volts, respectively.

Upon reducing V_{coll} , the potential of the surface will be stabilized at a value V_3 , where the current intensity of the secondary electrons actually reaching the collector (i_{coll}) is equal to the current intensity i_{pr} of the primary beam. As a rule V_3 is slightly higher than V_{coll} (Fig. B); in contrast with V_1 and V_2 , V_3 is therefore not a material constant.

Thus, when bombarded with slow electrons ($V_{pr} < V_1$) the surface potential becomes stabilized at zero, and when bombarded with electrons of high velocity it becomes stabilized at the value V_2 (provided $V_{coll} > V_2$) or at V_3 ($\approx V_{coll} < V_2$). For the target of a camera tube however no use is made of the value V_3 , for practical reasons; it is strongly influenced by the condition of the surface and thus is too variable from point to point.

It is according to these possibilities that camera tubes are classified as:

- (1) low velocity tubes, where the target is stabilized at cathode potential, and
- (2) high velocity tubes, where the target is stabilized at the potential $V_3 \approx V_{coll}$ (e.g. 1000 v).

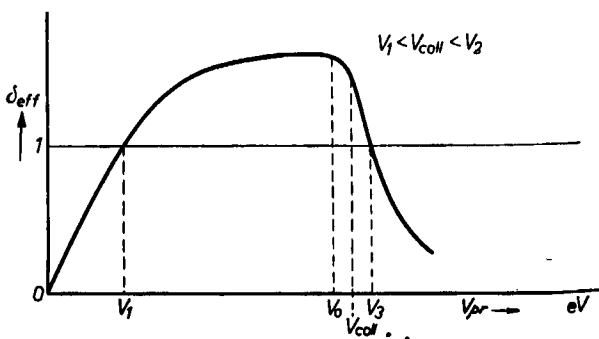


Fig. B. Effective secondary-emission coefficient δ_{eff} of an insulator, as a function of the energy V_{pr} of the primary electrons when the collector potential V_{coll} is smaller than V_2 (cf. Fig. A). $\delta_{\text{eff}} = 1$ at $V_{\text{pr}} = V_1$ and at $V_{\text{pr}} = V_2$, the latter value being a few volts higher than V_{coll} . To the left of V_0 (slightly lower than V_{coll}) the curve is identical to that in Fig. A.

Among the first belongs the image orthicon, which is the type of tube mainly used in the U.S.A., while belonging to the second group are the iconoscope and the image iconoscope, the latter often being given preference in European television circles. One of the reasons for this preference is related to the large number of lines adopted on the West-European continent (625, and in France 819): with a high electron velocity it is easier to satisfy the high requirements for the focusing of the scanning beam which are demanded for the definition required for such a large number of lines.

The Iconoscope

The iconoscope is the camera tube which in its time gave such an impetus to television.¹ It is schematically represented in Fig. C, while in Fig. D a photograph is given of the Philips iconoscope, type 5852.

A lens (objective) projects an image of the scene onto a target of thin mica coated on the front with a mosaic of minute, mutually insulated, photosensitive elements. On the reverse side is

a coating of metal, called the signal plate, forming the output electrode and externally connected to earth via a resistor. A ring-shaped coating of metal on the inside of the envelope serves as collector and is connected to earth direct.

The action of the iconoscope is sometimes explained in the following (inadequate) way. The incident light causes the photoelectric elements of the mosaic to emit photoelectrons, which are taken up by the collector. Thus a positive electrical image is formed on the mosaic. The photoelectric elements together with the target form as many minute capacitors. As the scanning beam moves across the mosaic the group of capacitors belonging to a certain picture element are discharged. Through the resistor via which the signal plate is earthed there then flows a small current corresponding in intensity to the charge of the picture element, thus corresponding to the local luminance of the optical picture. Thus in the scanning of the electrical image a series of current impulses are generated which together form the video current.

Actually the position is not so simple as this. Such a description does not take into account the part played by

¹ See, e.g., *Philips Tech. Rev.*, 1: 18-19, 1936.

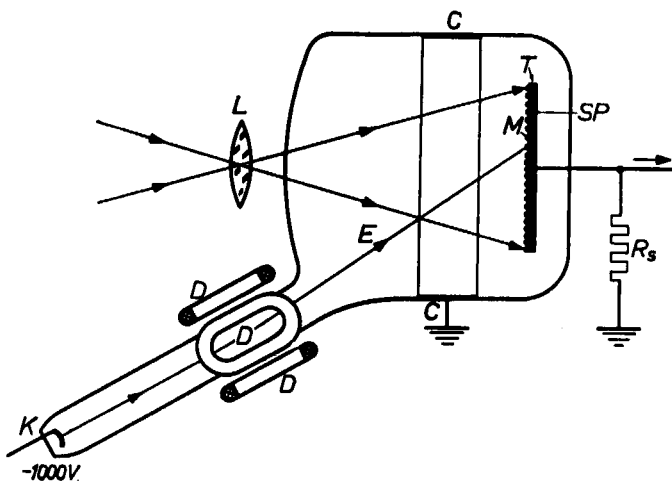


Fig. C. Iconoscope. *L*, a lens projecting the scene on the mosaic *M* of the target *T*. *SP*, signal plate; *R_s*, load resistor; *C*, collector; *K*, cathode; *D*, deflection coils; *E*, scanning beam. The (electrostatic) focusing is not shown.

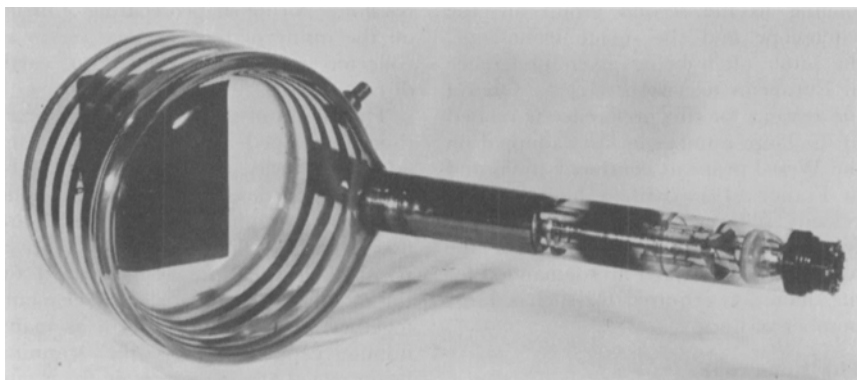


Fig. D. The Philips Iconoscope, Type 5852.

secondary emission.² Not all the secondary electrons reach the collector, firstly because the potential of a bombarded surface element is higher than V_{coll} . The secondary electrons which do not reach the collector fall back on other parts of the mosaic. This dis-

tribution of the secondary electrons is called the redistribution effect, and it is of essential importance for the action of the iconoscope.

After the surface element in question has been scanned, it will continue to receive secondary electrons originating from other surface elements, until it is scanned by the beam again. Thus its potential V begins to drop (Fig. E).

During a considerable part of the

² V. K. Zworykin, G. A. Morton and L. F. Flory, *Proc. I.R.E.*, 25: 1071-1092, 1937; and W. Heimann and K. Wemheuer, *Z. tech. Phys.*, 19: 451-454, 1938.

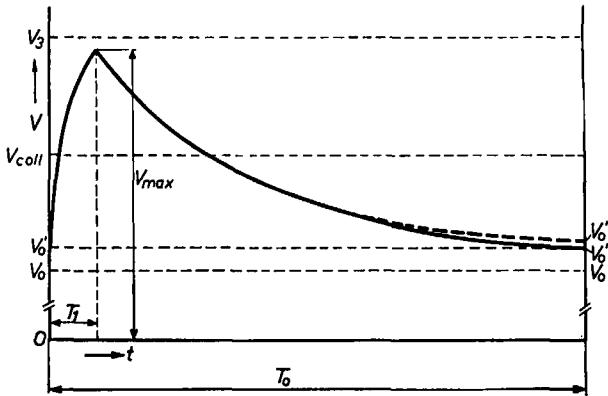


Fig. E. Curve of the potential V of a picture element on the mosaic of an iconoscope, as a function of the time t . Fully drawn line: mosaic not illuminated; broken line: mosaic illuminated. T_0 = scanning period for the whole image (0.04 sec), T_1 = scanning time for one picture element (10^{-7} sec; in the drawing highly exaggerated). For the meaning of V_{coll} and V_3 see Fig. B, and for V_0 , V_0' , and V_0'' see the text.

scanning period the potential V of the element is higher than V_{coll} , and the photoelectrons do not possess sufficient energy to overcome this potential difference. Photoemission begins, therefore, when — owing to the redistribution effect — the potential V has been sufficiently reduced.

The most important features of the iconoscope will now be briefly discussed.

As already explained, it is due to the redistribution effect that photoemission can take place, but this is only possible during a fraction of a scanning period. Thus we are still far removed from a continuous photoemission such as was imagined in the case of an ideal storage tube! This is one of the reasons for the iconoscope's rather low sensitivity.

A second cause of the lack of sensitivity lies in the mosaic form of the light-sensitive layer. The insulation between the elements does not contribute towards photoemission, so that a considerable part of the surface of the target is photoelectrically inactive.

The main cause of spurious signals (see the literature quoted in footnote ²) is that the redistribution does not take place in the same way all over the

mosaic, owing to the surroundings of the elements not being the same everywhere.

When the iconoscope is illuminated the spurious signal is superposed on the picture signal and only if the latter is of a reasonable strength is the spurious signal not very disturbing. It is for this reason that with the iconoscope very high intensities of illumination are needed.

The stronger the illumination on a certain part of the mosaic, the higher is the potential V_0'' at that spot just before it is scanned by the beam. This has two consequences: there is slightly less chance of further photoelectrons escaping, and there is a somewhat greater attraction of redistributed secondary electrons. Both these effects result in the amplitude of the signal increasing less than proportionately with the illumination. This nonlinearity is rather an advantage than a disadvantage in that it compensates fairly well an inverse nonlinearity between the beam current and the control voltage in the picture tube of the receiver. Thus there is no need to take steps to compensate the latter nonlinear effect.

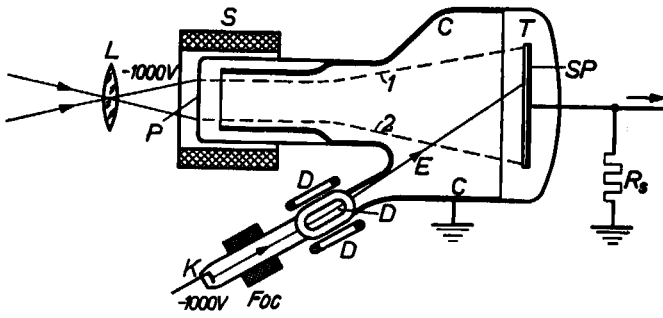


Fig. F. Image iconoscope. *P*, photocathode; *S*, coil of the magnetic electron lens; 1 and 2, paths of photoelectrons; *FOC*, focusing coil. Other letters have the same meaning as in Fig. C.



Fig. G. The Philips Image Iconoscope, Type 5854.

The Image Iconoscope

The greatest disadvantage of the iconoscope is its lack of sensitivity, and it is for that reason that attempts have been made to develop camera tubes with greater sensitivity, while still retaining the good picture quality obtained with the iconoscope when the scene is sufficiently illuminated.

A year or two prior to 1940 a more sensitive version of the iconoscope, called the image iconoscope, was developed in the U.K. and in the U.S.A.³ Some improvements on this have since been made in the Philips Laboratory at Eindhoven, as will appear in the course of this article.

In the case of the image iconoscope (Fig. F) a lens (objective) projects an optical image of the scene to be televised onto a continuous, transparent photocathode. The local density of emission of the photoelectrons corresponds to the local luminance of the optical image. This photoemission image is focused by an electron lens onto a target consisting in this case of a thin layer of insulating material applied to the signal plate. The metallized inner wall of the envelope serves as collector. An electron gun mounted in an arm of the envelope supplies the beam of electrons scanning the target.

The differences, compared with the conventional iconoscope, which are mainly responsible for the gain in sensitivity, are the following:

- (1) The surface of the photocathode is continuous, so that none of its effective area is lost in insulation between the separate photoelectric elements.

- (2) The stream of photoelectrons reaching the target is reinforced by secondary emission, each photoelectron releasing on an average more than two secondary electrons.

- (3) The secondary electrons released

from the target by the photoelectrons have a much greater energy than the photoelectrons in the ordinary iconoscope, so that secondary emission from a surface element begins immediately after that element has been stabilized by the scanning beam. This means a considerable gain in storage action.

Let us now consider more closely the principal parts of the image iconoscope and also the important question of electron-optical projection. The Philips type of image iconoscope is illustrated in Fig. G.

Contrary to ordinary photoelectric cells, an image iconoscope must have a photocathode which is semitransparent, because the light enters from the outside while the photoelectrons have to emerge on the inside.

The requirements greatly restrict the choice of photoelectric material to be used. The photocathode in the Philips image iconoscope consists of a very thin coating of cesium, antimony and oxygen applied to a flat part of the glass envelope. The sensitivity for the light from an incandescent lamp with color temperature 2600 K is about 45 μ a per lumen. The spectral sensitivity curve, compared with the relative luminosity curve for the normal eye, is slightly displaced towards the blue (Fig. H).

The optical image of the scene is converted into a corresponding photoemission image on the photocathode. The next step is to produce on the target an electrical image which is a faithful replica of the photoemission image. This requires that the small beams of photoelectrons emitted from points of the photocathode are focused on corresponding points on the target. For this electron-optical image formation an electron lens is needed.

An electric field has to be employed. This is obtained by means of a metal cylinder (e.g. the metal coating A on the inner wall of a glass tube, Fig. I) facing the photocathode P and applying a potential difference of, say, 1000 v

³ See, e.g., H. Iams, G. A. Morton and V. K. Zworykin, "The image iconoscope," *Proc. I.R.E.*, 27: 541-547, 1939.

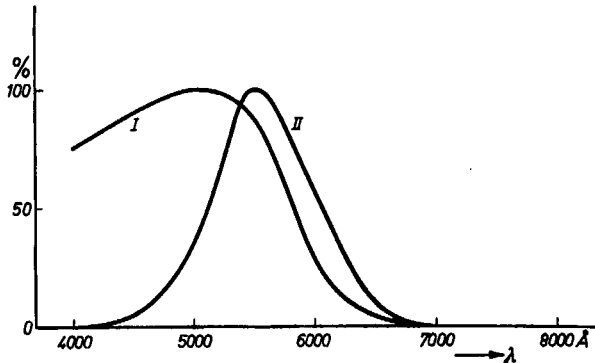


Fig. H. Relative spectral sensitivity of the Type 5854 image iconoscope (curve *I*), compared with the relative luminosity (curve *II*), as functions of the wavelength λ of the light.

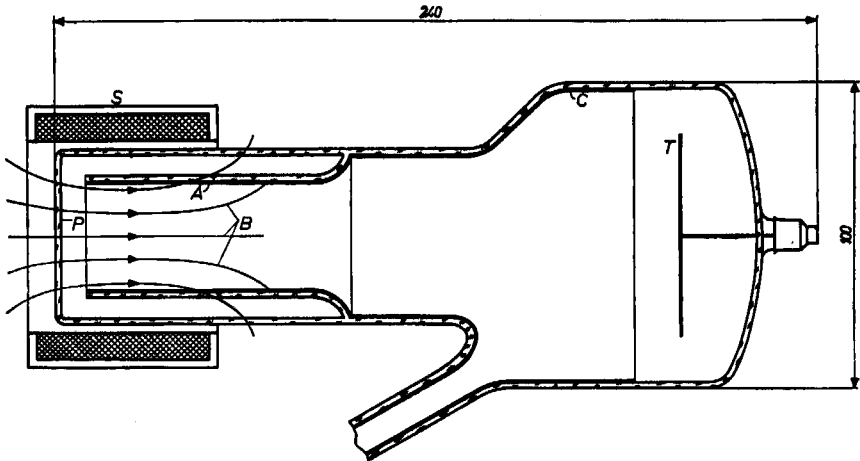


Fig. I. Formation of the electron-optical image of the photocathode *P* on the target *T* with the aid of an electric field (between *P* and the cylinder *A*) and a magnetic field. The latter (lines of flux density *B*) is produced by a focusing coil *S*. Dimensions are in millimeters.

between these electrodes. Since the cylinder forms, electrically, one whole with the earthed collector, the photocathode is given a potential of -1000 v with respect to earth.

This electric field alone, however, does not suffice; a magnetic field has to be added which focuses each electron pencil. Such a field can be produced by means of a coil placed concentrically

around the tube. The coil has to be of such dimensions and in such a position as to minimize aberrations, whilst the magnetic field must not disturb the movement of the scanning beam.

The movement of the electrons depends not only upon the two fields mentioned but also upon the velocities of the electrons leaving the photocathode. Some of them have zero initial

velocity, and the paths they follow are called the principal rays. Generally, however, the electrons leave the cathode with a certain velocity, with the result that they follow a more complex path.

Briefly, the course of a principal ray is as follows: at first the path is approximately parallel to the axis of the tube (the z axis), then it diverges farther and farther from that axis, turning about the z axis first clockwise and later counterclockwise in the form of a widening helix.

Although most of the electrons which leave the photocathode have velocities greater than zero and thus do not follow any principal paths, still it is the principal rays which determine the geometry of the electron-optical image. Each forms the axis of a small electron pencil.

The axial component of initial velocity gives rise to a certain "chromatic" aberration: a point of the photocathode from which electrons emerge with axial velocity does not result in a point being formed on the target but a small circle (scattering circle), the diameter of which is so small — thus the image so sharp — that the image iconoscope can quite well be worked with more than 600 scanning lines. In the image orthicon, on the other hand, the electric field at the cathode is ten times smaller,⁴ so that with this type of tube the formation of the electron-optical image is a limiting factor for the number of lines.

Owing to the predominance of the diverging forces acting upon the electrons following the principal path the image on the target is magnified, and owing to the tangential forces the electron image is rotated with respect to the optical image on the photocathode, the angle of rotation being about 30 to 40°.

With our image iconoscope the magnification is normally 3.75, which means to say that the scanned part of the

H. B. De Vore, *Proc. I.R.E.*, 36: 335-345, 1948.

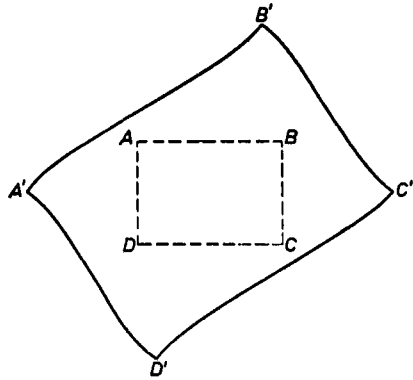


Fig. J. $ABCD$ is an image on the photocathode, $A'B'C'D'$, the corresponding electrical image on the target. The latter is magnified and turned with respect to $ABCD$ and also shows some S distortion, which always occurs when magnetic lenses are used (straight lines are projected with a slightly S-shaped curve). If the magnification is too small the S distortion becomes so pronounced that it can no longer be sufficiently corrected.

target, which always covers an area of 45 mm \times 60 mm, corresponds to an area of 12 mm \times 16 mm on the photocathode (the diameter of the active part of the photocathode is 20 mm). By exchanging the coil for another of different dimensions it is also possible, however, to work with a larger or a smaller magnification, thus projecting a smaller or a larger part of the photocathode on the target. The choice as regards the size of the effective photocathode is governed by requirements of an optical, light-technical and camera-technical nature. The limits for the magnification are 2.75 and 7.5 (diameter of the projected part of the cathode, respectively, 27 mm and 10 mm).

With a magnification greater than 7 to 8, owing to the "chromatic" aberration of the photoelectrons emerging with axial velocity (see above) there is too great a loss in resolving power.

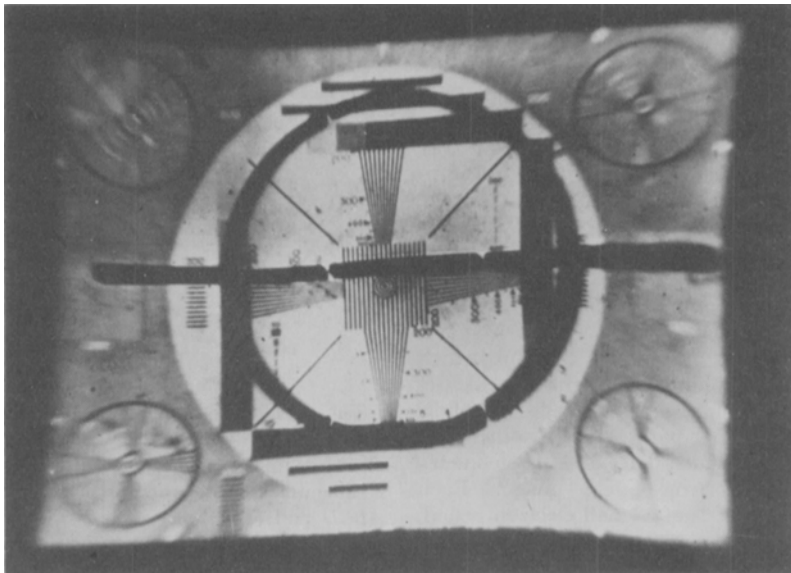


Fig. K(1). Picture showing a marked field curvature, pin-cushion distortion and S distortion. In Fig. K(2), there is only a slight S distortion, which can easily be corrected electrically.

These photographs have been taken with the aid of an experimental tube in which a fluorescent screen was used instead of a target. On the photocathode a test pattern was projected, as used in television, for detecting aberrations and checking the definition and gradation. The heavy black circle and the thick horizontal line in the middle correspond to markings on the photocathode for determining the magnification.

The lower limit of 2.75 is due to various other aberrations, which with a smaller magnification can no longer be sufficiently compensated. As such may be distinguished: field curvature, pin-cushion distortion and so-called S distortion. The first two are known from light-optics.⁵ By S distortion is meant the effect of the image of a straight line being projected as a line curved somewhat in the shape of the letter S (Fig. J). If the magnification is not too small the S distortion can be sufficiently corrected by electrical means (which we cannot enter into here), but if it is less than 2.75

this is no longer possible. In Fig. K(1) a picture is given showing all three aberrations to a marked extent. The picture in Fig. K(2), however, has only a scarcely perceptible S distortion, which is not troublesome.

The electron gun supplies the scanning beam. Just as is the case with most picture tubes, in the image iconoscope the beam is focused and deflected with the aid of magnetic fields.

In regard to the sharpness of the scanning, there are two things to be considered. The non-deflected beam is focused on the center of the target, where its diameter must be so small that the lines do not overlap when being scanned. If it is desired to work for instance with 1000 lines then, if the height of the scanned part of the target

⁵ A review of various optical aberrations is to be found, for instance, in: W. de Groot, *Philips Tech. Rev.*, 9: 301-308, 1947, in particular pp. 304 and 306.

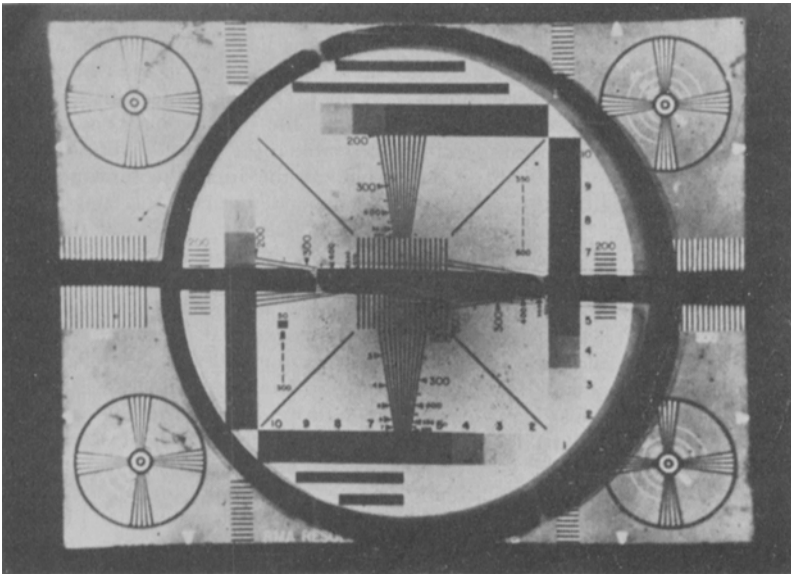


Figure K(2).

is 45 mm, the effective diameter of the focus must not be more than 45μ . This requirement is all the better fulfilled the higher the acceleration voltage is chosen, but this should preferably not exceed 1000 v.

Further, account has to be taken of the fact that in the image iconoscope the electron gun has to be mounted with its axis at an angle to the target. Consequently when the beam is deflected upward or downward the focus is no longer situated on the target. Therefore, to obtain sufficiently sharp scanning also away from the center, the beam must have a good depth of focus, which means that it has to be extremely narrow. Hence the angle of divergence $2\alpha_i$ (see Fig. L) has to be kept very small.

It is, in general, difficult to obtain a fine focus with a very narrow beam on account of the mutual repulsion of the electrons, but fortunately the intensity of the beam current required is very low, in the order of $0.1 \mu a$.

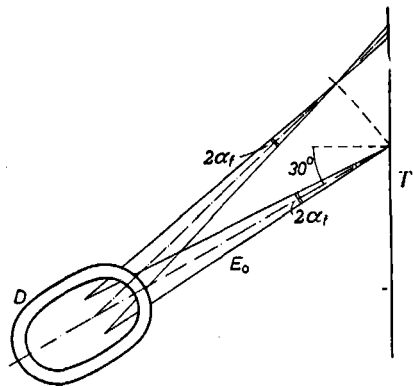


Fig. L. Assuming that the nondeflected beam E_0 has been focused onto the center of the target T , when the beam is deflected the focus will no longer be in the plane of T . This gives rise to blurring, the extent of which increases with the angle of divergence $2\alpha_i$.

In addition to this space-charge repulsion there is another factor limiting the spot size obtained with a very narrow beam: there is a very fundamental relationship between the angle of divergence $2a_t$ and the current density in the beam. In the case where the space charge is negligible this relationship is:

$$\sin^2 a_t = \frac{V_0}{V} \cdot \frac{j_t}{j_0}, \dots (1)$$

where $V_0 = \frac{1}{2}mv_0^2/e$ (with $m =$ mass, $v_0 =$ initial velocity and $e =$ charge of an electron), $V =$ the potential difference traversed by the electrons, $j_t =$ density of the beam current in the focus, and j_0 that at the cathode of the gun.

What has to be found is an optimum value for a_t at which, on the one hand, the focus is not too large and, on the other hand, the sharpness at the edges of the image does not differ too much from that in the middle. With our image iconoscope the position is such that this optimum value of a_t lies at about 3×10^{-3} radians.

This small angle of divergence, combined with a low beam current intensity (about $0.2 \mu a$), has been obtained by placing two diaphragms in the beam. The first, with a narrow aperture, confines the beam within the desired small angle. The second one, with a wider aperture, allows the beam to pass through without hindrance but intercepts the low-velocity secondary electrons formed round the edge of the first diaphragm.

With the focus of 45μ already mentioned and a beam current of $0.2 \mu a$, the average current density in the focus is $j_t = 12$ ma/sq cm. Substituting this in Eq. (1), and for V the value 1000 v, and for V_0 the value corresponding to the average initial velocity ($\approx 0.1 v$), we find for the average current density at the cathode of the gun $j_0 \approx 120$ ma/sq cm. The peak value of the current density is in fact several times greater. Although an ordinary oxide-

coated cathode may indeed be continuously loaded with such a current density, it is better to use what is known as an L cathode,⁶ since this has a much longer life. It would be quite undesirable if the useful life of a costly tube such as the image iconoscope were to be dependent upon the life of a component like the cathode of the gun.

The glass arm of the envelope containing the electron gun has been kept as narrow as possible (internal diameter 11 mm, external 14 mm), so that also the focusing coil and the deflection coils may be small. A camera with an image iconoscope is shown in Fig. M.

In practical use the resolving power of the Philips image iconoscope is found to be 900 to 1000 lines in the middle of the image and about 700 lines at the edges. (These limits are set by the electron gun; the resolving power of the electron-optical projection is very much greater.)

An improvement has been reached by coating the mica target with a thin layer of MgO, which leads to a considerable gain in secondary emission and hence sensitivity. Furthermore, owing to the coating of MgO, stains on the mica which cannot be removed and otherwise show up clearly in the picture are thereby made invisible.

The capacitance of a surface element of the target with respect to the signal plate is an important factor, and an increase of this capacitance must lead to greater sensitivity.

New tubes were therefore made with a mica sheet of only about 25μ thickness (also with a layer of MgO, thin compared with the mica) instead of the original sheet thickness of 50μ .

The reproduced picture of a scene televised under the normal studio lighting, or of an outdoor scene in daylight

⁶ H. J. Lemmens, M. J. Jansen and R. Loosjes, "A new thermionic cathode for heavy loads," *Philips Tech. Rev.*, 11: 341-350, 1950.

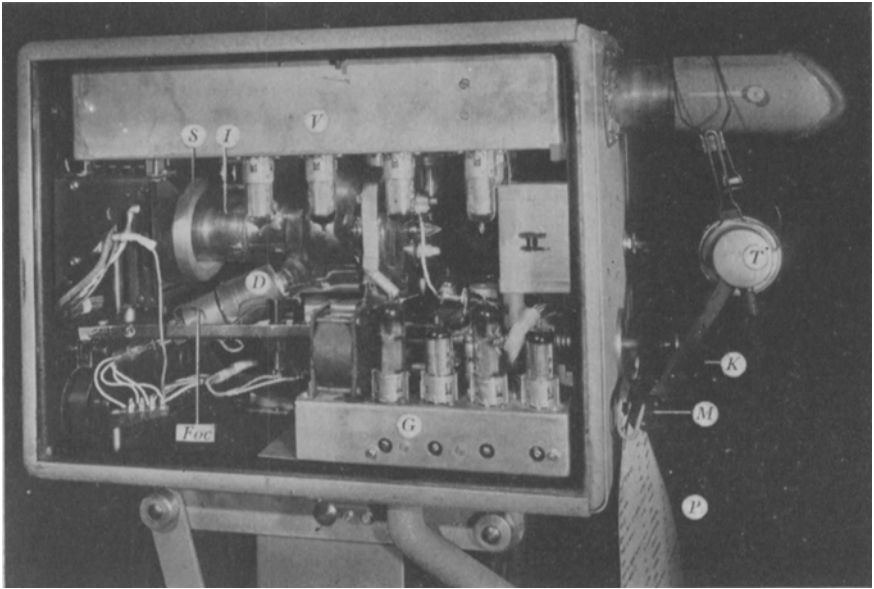


Fig. M. One of the cameras used for the experimental television broadcasts at Eindhoven. One side panel and a screen have been removed. *I*, image iconoscope Type 5854; *S*, image coil; *FOC*, focusing coil; *D*, deflection coils; *G*, time-base generator; *V*, chassis with monitor picture tube and accessories; *M*, microphone and *T*, telephone for communication between the operator and the control room; *K*, knob for exchanging the objective; *P*, playbook.

(even in bad weather), with the image iconoscope last described, is almost free of "noise" and shows excellent gradation.

In the image iconoscope spurious signals arise from the same cause as in the case of the conventional iconoscope: the various surface elements of the target are not all in the same position with respect to the scanning beam. In the image iconoscope, however, the situation is more favorable: with the tube described (mica 25μ thick, beam current $0.2 \mu\text{a}$) and with an illumination producing a photocurrent of more than $0.1 \mu\text{a}$, the spurious signals are so weak that there is hardly any need of compensating measures. In practice a photocurrent of $0.1 \mu\text{a}$ can be obtained with an illumination of the scene of about 1000 lux, when using a non-

diaphragmed, normal objective with aperture $f/2$.

Comparison of Different Types of Camera Tubes

Let us now compare, briefly, the two main types of camera tubes, the high-velocity and the low-velocity types.

In the first place there is the question of sensitivity. This resolves itself into two factors (disregarding the efficiency of the optical system), viz. the sensitivity of the photocathode (photocurrent I_{ph} in relation to the light flux falling on the cathode) and the sensitivity of the scanning mechanism (ratio of signal current I_s to photocurrent I_{ph}).

As regards the sensitivity of the photocathode of the two high-velocity tubes — the conventional iconoscope and the

image iconoscope — the latter has very much the advantage, owing to the continuity of the photocathode. Among the low-velocity tubes there are likewise types with a mosaic cathode and others with a continuous cathode, the latter including the image orthicon, which as regards photocathode sensitivity is equal to the image iconoscope.

The scanning sensitivity of low-velocity tubes is simply $1 \mu\text{a}$ signal current per μa photocurrent. In high-velocity tubes the phenomenon of redistribution complicates matters, but the scanning sensitivity of the ordinary iconoscope can be put at $\frac{1}{25}$ $\mu\text{a}/\mu\text{a}$ and that of the image iconoscope, at about $1 \mu\text{a}/\mu\text{a}$.

Although, therefore, the image iconoscope has about the same scanning sensitivity as the simple low-velocity tube, the $I_s = f(I_{ph})$ curve is not linear, whereas in the case of low-velocity tubes it is linear; the nonlinear curve is favorable, as explained when dealing with the iconoscope.

There is a means, however, of appreciably increasing the scanning sensitivity of low-velocity tubes. The electrons from the scanning beam which are not taken up by the target and return to the gun can be collected in a multiplier,

placed around the gun, which works with secondary emission and thus multiplies them. This is what takes place in the image orthicon, commonly employed in the U.S.A. In this way the scanning sensitivity may be raised to a value of 25 to 100 $\mu\text{a}/\mu\text{a}$, which is of course valuable when scenes have to be televised in poor light. However, the current of the returning beam can be modulated only up to about 20% and consequently contains a relatively large amount of noise.

It has already been explained that in regard to spurious signals the image iconoscope has a decided advantage over the ordinary iconoscope. The image orthicon is free of spurious signals of this nature, but on the other hand it is subject to another interference connected with the fact that the secondary-emitting surfaces of the multiplier do not have exactly the same secondary-emission coefficient over the whole area ("dynode spots").

Electron-optically, high-velocity tubes have undeniably the advantage over those of the other group, in that with electrons of a high velocity it is easier to obtain a scanning beam with a high resolving power, and there is much less trouble from interfering electric and magnetic fields.