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An experimental light-weight colour television camera

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The article below describes the portable colour television camera which was illustrated in this journal a few months ago. The construction of such a small camera has been made possible by the development of an (experimental) "Plumbicon" [*] camera tube which is smaller than the "Plumbicon" tubes used in the studio camera. The pictures taken with this miniature camera compare well in quality with those taken with the studio camera at present in use.

The days when television cameras were only used in studio or outside broadcast work now seem very distant. Quite early on, it became apparent that television would be of service in industry, in education, and for many other purposes. A striking example in medical education is the televising of surgical operations so that they can be seen by large numbers of students [1]. A more recent application is the use of a television camera in conjunction with an endoscope, enabling doctors to look at a patient's internal organs on a television screen. The use of closed-circuit television is also becoming more and more widespread in other areas of education, in research work, and in industry. One interesting example is the use of a television camera in conjunction with a microscope, an arrangement which can be very useful in checking the manufacture of integrated circuits.

In some of the cases mentioned above, the information given by black-and-white television is sufficient. Often, however, colour can be vitally important; this is particularly so in medical applications [2]. However, this is just the sort of application where the considerable bulk of the ordinary colour camera makes things difficult. What is needed is a small and light-weight camera that will not get in the way during an operation. Such a camera would also be very suitable for use in conjunction with other instruments, and in television broadcasting a small portable camera for colour television could create a wealth of new possibilities.

With these applications in mind we have developed an experimental colour camera whose size and weight have been reduced to the minimum that present-day techniques will allow.

This camera, which weighs three kilogrammes and compares in size with a 16 mm cine camera, was demonstrated to professional users a few months ago [3]. *Fig. 1* shows the camera connected to a microscope for checking an integrated circuit. In this article we shall discuss a number of problems that were encountered in the development of the special pick-up tubes for this camera and in the construction of the camera itself.

The camera tube

A first requirement in the development of the new camera was that as far as possible it should have the same good characteristics as the larger camera with "Plumbicon" tubes which was described earlier in this journal [4]. However, the dimensions of a colour television camera containing three camera tubes are largely

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[*] Registered Trade Mark for television camera tubes.

[1] See Philips tech. Rev. **11**, 42, 1949/50.

[2] W. Holm and F. H. J. van der Poel, Colour television in medical teaching, Philips tech. Rev. **20**, 327-330, 1958/59.

[3] Philips tech. Rev. **29**, 188, 1968 (No. 6).

[4] See H. Breimer, W. Holm and S. L. Tan, A colour television camera with "Plumbicon" camera tubes, Philips tech. Rev. **28**, 336-351, 1967 (No. 11).

determined by the size of the tubes and their deflection coils. Before a miniature camera could be built it was therefore first of all necessary to make a "Plumbicon" camera tube which was much smaller than the tubes used previously, without sacrificing quality. The standard "Plumbicon" tube has a diameter of 30 mm and a length of 200 mm; in the miniature version these dimensions are 16 and 130 mm respectively. The image size of 8.4×6.3 mm (diagonal 10.5 mm) is scaled down by a factor of two from that of the standard tube. *Fig. 2* shows the two "Plumbicon" tubes with and without their deflection coils.

The design of the miniature "Plumbicon" tube is basically identical with that of the larger one described in reference [5]. The main problems presented by the reduction of dimensions were connected with the maintenance of a sufficiently high resolving power and with the accurate register of the images from the three tubes in the camera. We shall deal with these points at greater length in the following sections.

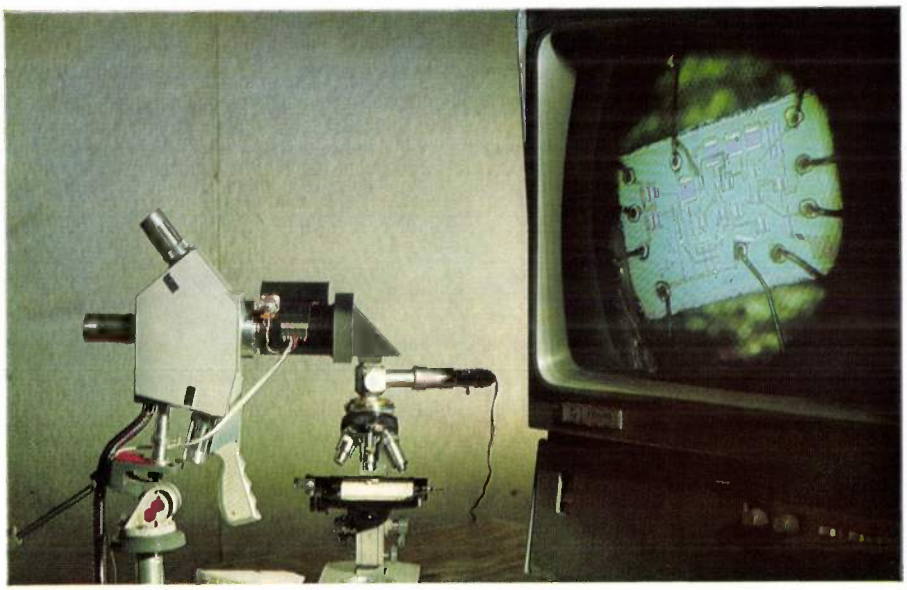


Fig. 1. The miniature camera connected directly to a microscope. The monitor is showing a picture of an integrated circuit which is placed under the microscope.

The electron beam is focused electrostatically. The advantages of electrostatic over magnetic focusing have already been explained in an earlier article describing a tube of standard dimensions [5]. Where space and weight are at a premium, it is obviously a great advantage to be able to dispense with bulky focusing coils. But this is not the only virtue of electrostatic focusing. Other advantages are that the picture is not rotated, magnified or reduced in size when the focus is adjusted, and moreover the deflection cannot affect the focusing, so that a sharp picture is easily obtained over the whole surface. Another important feature of electrostatic focusing is that it requires no power.

Fig. 3 shows a schematic cross-section of the tube. The electron beam is delivered by a *triode gun Tr*, which consists of an impregnated cathode *K* (rated at 2 W), a control electrode or "grid" *G* and an anode A_1. The divergent beam is made to converge on the photoconducting target *T* by a focusing lens, formed by cylinders A_1, A_2 and A_3; cylinder A_1 contains a dia-

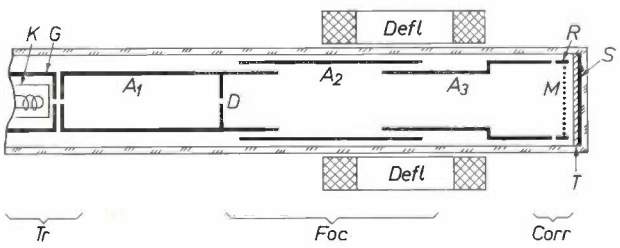


Fig. 3. Diagram of the construction of a "Plumbicon" tube with electrostatic focusing. *Tr* triode gun, consisting of the cathode *K*, the control electrode *G* and the anode A_1. The focusing lens *Foc* is formed by the electrodes A_1, A_2 and A_3. *D* diaphragm. The ring *R* and the mesh screen *M* together with A_3 form the correction lens *Corr*. *T* photoconducting layer. *S* signal plate. *Defl* deflection coils.

[5] J. H. T. van Roosmalen, Experimental electrostatically focused "Plumbicon" tubes, Philips tech. Rev. **28**, 60-66, 1967 (No. 2).

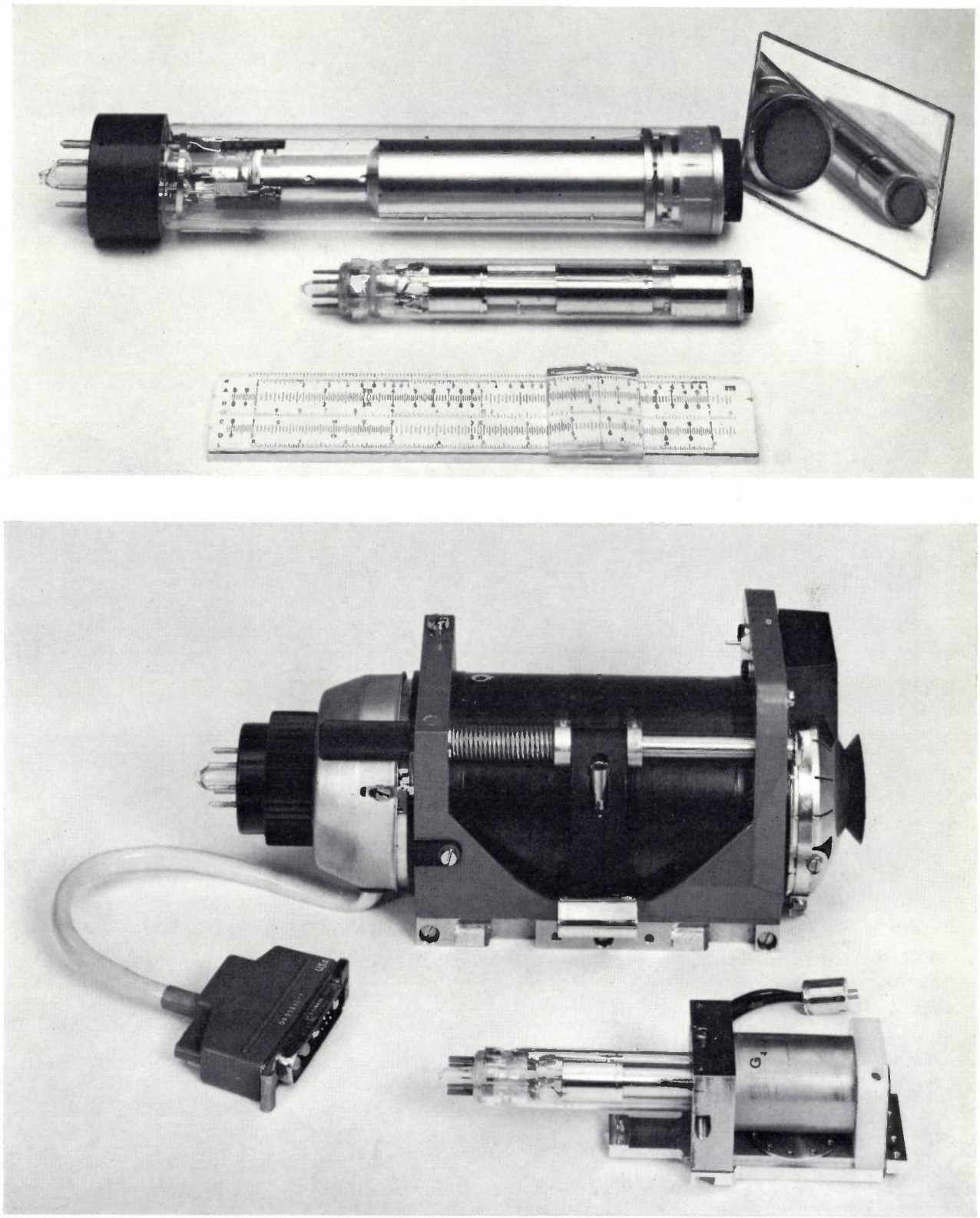


Fig. 2. *a*) Standard and miniature "Plumbicon" tubes. The dimensions of the tubes are 200 × 30 mm and 130 × 16 mm. *b*) The tubes mounted in their deflection coils.

phragm *D*. Following the focusing lens there is a *correction lens*. This consists of the right-hand part of A_3, a ring *R* and a mesh *M*. The potential of *R* and *M* is higher than that of A_3. This lens deflects the electron beam in such a way that the electrons arrive almost at right angles to the photoconducting layer. A description of the undesirable effects which occur when this condition is not met will be found in reference [5].

Focusing

The lens action of K, G and A_1 focuses the emitted electrons to the "crossover" and an image of the crossover area is formed on the photoconducting layer by the focusing lens. For good resolution this image must be small, and this requirement is of course accentuated when the image size of the tube is smaller.

Just as in the development of the large "Plumbicon" tube with electrostatic focusing, the dimensions, the mutual alignment and the potentials of the electrodes were fixed after calculating electron paths for different configurations. *Fig. 4* shows a number of equipotential surfaces for the final version, together with some electron paths for the undeflected beam.

deflection increases and there is a greater danger of breakdown between R and A_3. For a small d_M it follows from the equation that the beam current I_b has to be small, but if it is too small the photoconducting layer will not discharge fast enough, i.e. the speed of response will suffer. Moreover, the maximum permissible current density j_0 and the temperature T_k are fixed for the type of cathode employed. Finally, if we make α_M large, we introduce difficulties because of spherical aberration in the focusing lens and because of defocusing action of the deflection coils.

The effect of the *spherical aberration* of the focusing lens is that the electrons are scattered over a circle of confusion. The diameter Δd_M of this circle at the mesh

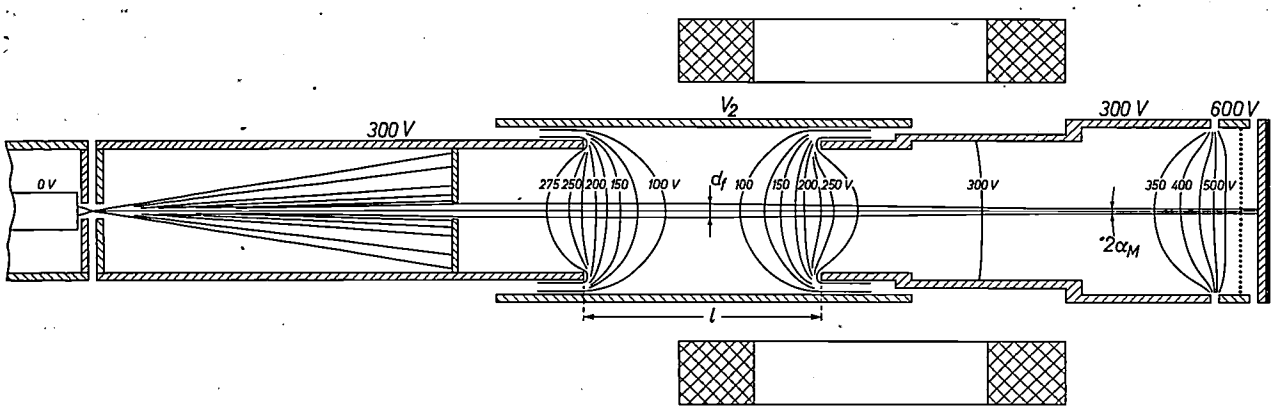


Fig. 4. Some equipotential surfaces and electron paths for an undeflected beam. The voltages at the electrodes A_1, A_3 and R (see fig. 3) are given with respect to the cathode. The voltage V_2 of A_2 is used for focusing the beam. d_f beam diameter at the centre of the focusing lens. $2\alpha_M$ aperture angle of the beam at the mesh. l spacing between A_1 and A_3.

The size of the image of the crossover area can be adversely affected by several factors connected with the electron-optical section. These are the thermal spread of the electrons, the spherical aberration of the focusing lens and the mutual repulsion of the electrons.

The effect of the *thermal spread* is that the beam has a diameter of

$$d_M = \frac{2}{\alpha_M}\sqrt{\frac{I_b k T_k}{\pi j_0 e V_M}}$$

at the mesh. Here α_M is half the aperture angle of the beam at the mesh, V_M is the potential of the mesh, I_b is the beam current beyond the diaphragm, j_0 is the current density at the centre of the cathode, T_k is the cathode temperature; k is Boltzmann's constant and e is the electronic charge. We wish to choose the quantities in this equation so as to make d_M as small as possible, but there is a limit for each quantity. If the voltage V_M is raised, the energy required for the deflection increases and there is a greater danger of breakdown between R and A_3. For a small d_M it follows from the equation that the beam current I_b has to be small, but if it is too small the photoconducting layer will not discharge fast enough, i.e. the speed of response will suffer. Moreover, the maximum permissible current density j_0 and the temperature T_k are fixed for the type of cathode employed. Finally, if we make α_M large, we introduce difficulties because of spherical aberration in the focusing lens and because of defocusing action of the deflection coils.

The effect of the *spherical aberration* of the focusing lens is that the electrons are scattered over a circle of confusion. The diameter Δd_M of this circle at the mesh is proportional to the cube of d_f, the diameter of the beam at the centre of the focusing lens:

$$\Delta d_M = B d_f^3.$$

Obviously, we want to keep the aberration coefficient B as small as possible. A configuration giving an acceptable spherical aberration was again found by calculating the electron paths. The results of a number of such calculations are summarized in *fig. 5*, where B is shown as a function of the distance l between A_1 and A_3. It can be seen that B decreases with increasing l. Since a larger l would require a longer tube, some limitation was necessary and we chose $l = 16$ mm.

It is easier to meet the various conflicting requirements when a diaphragm D is placed in the anode A_1 (see fig. 3 and fig. 4), since it is then possible to use a lower ratio between I_b and j_0. We shall return presently to the problem of deciding the position and size of this diaphragm.

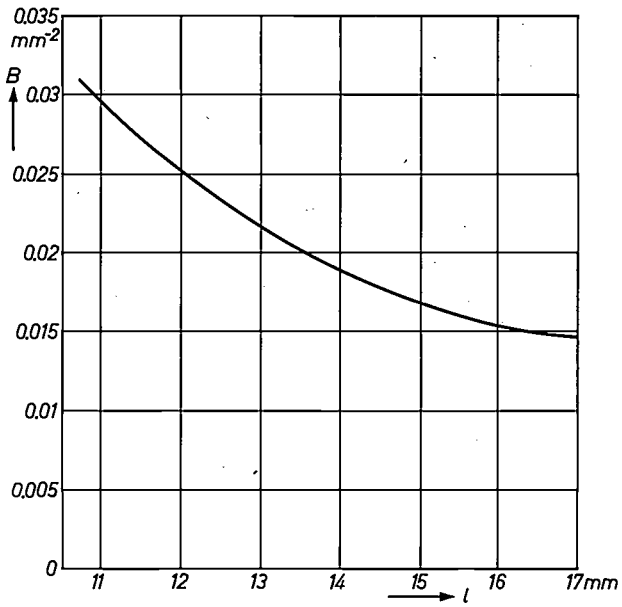


Fig. 5. Spherical-aberration coefficient B as a function of the spacing l between anodes A_1 and A_3.

The correction lens

The potential of the mesh M and the ring R is twice as high as that of the cylinders A_1 and A_3 (600 and 300 V respectively). If the deflection coils are positioned in such a way that the distance between the deflection point (the apparent point of origin of the deflected beam) and the mesh is about twice the diameter of the mesh, then the correction lens brings the deflected beam very nearly parallel again with the axis of the tube [6]. The barrel distortion which this causes is compensated by suitable design of the deflection coils. *Fig.6* shows the central trajectory of the beam in a number of deflected positions.

Because of the smaller image on the photoconducting layer, the mesh used in the standard tube, with a pitch of 36 μm, had to be replaced by a mesh with a pitch of only 18 μm. The wire thickness is 5 to 6 μm after an etching process. This finer mesh allows about 45% of the electron beam to pass through it.

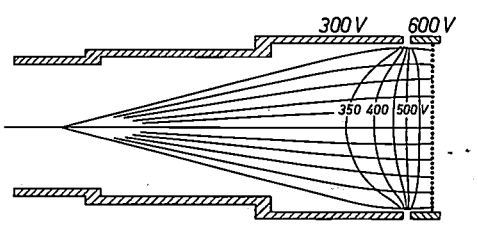


Fig. 6. Central trajectory of the beam in a number of deflected positions. The correction lens makes the electrons "land" at right angles to the photoconducting layer.

The aperture angle of the beam

An important point in the design was the establishment of the position and size of the diaphragm. Moving the diaphragm away from the crossover, while keeping its diameter constant, makes the aperture angle smaller and so makes the beam narrower. An advantage of a narrow beam is that it reduces the spherical aberration of the lens and the defocusing action of the deflection coils. On the other hand, at constant current it has the effect of increasing the mutual repulsion of the electrons. There should therefore be an optimum aperture angle of the beam which gives the best resolving power. This has been verified in experiments with a number of tubes in which a movable diaphragm could be located anywhere between 6 and 21 mm from the crossover. (The diameter of the aperture was 0.35 mm.) This made it possible to vary the beam diameter at the centre of the focusing lens between 2.4 and 0.7 mm. Some results of the measurements made with these tubes are collected in *fig. 7*. The figure shows the

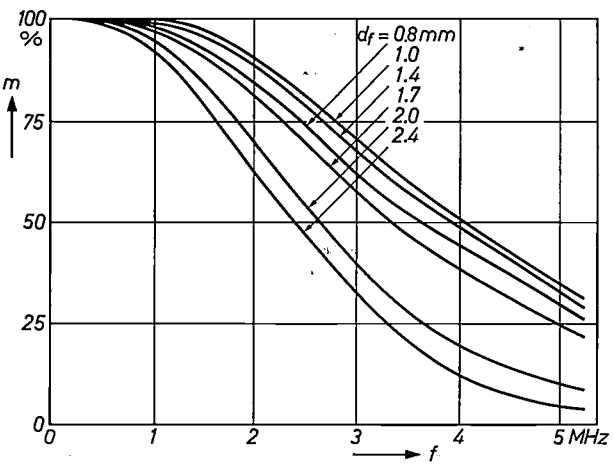


Fig. 7. Modulation depth m as a function of frequency f for some values of the diameter d_f of the beam at the centre of the focusing lens. An optimum value of m is achieved at $d_f = 1.0$ mm.

modulation depth m [7] as a function of frequency, with d_f the diameter of the beam at the centre of the lens as a parameter. We see that the value of d_f for which m is greatest is approximately 1.0 mm. At a frequency of 5 MHz the modulation depth is then 35%.

Fig. 7 shows the modulation depth at the centre of

[6] J. H. T. van Roosmalen, Dutch patent application No. 6513751.

[7] An account of the way in which this quantity expresses the resolving power is given in E. F. de Haan, A. van der Drift and P. P. M. Schampers, The "Plumbicon", a new television camera tube, Philips tech. Rev. **25**, 133-151, 1963/64, in particular fig. 17.

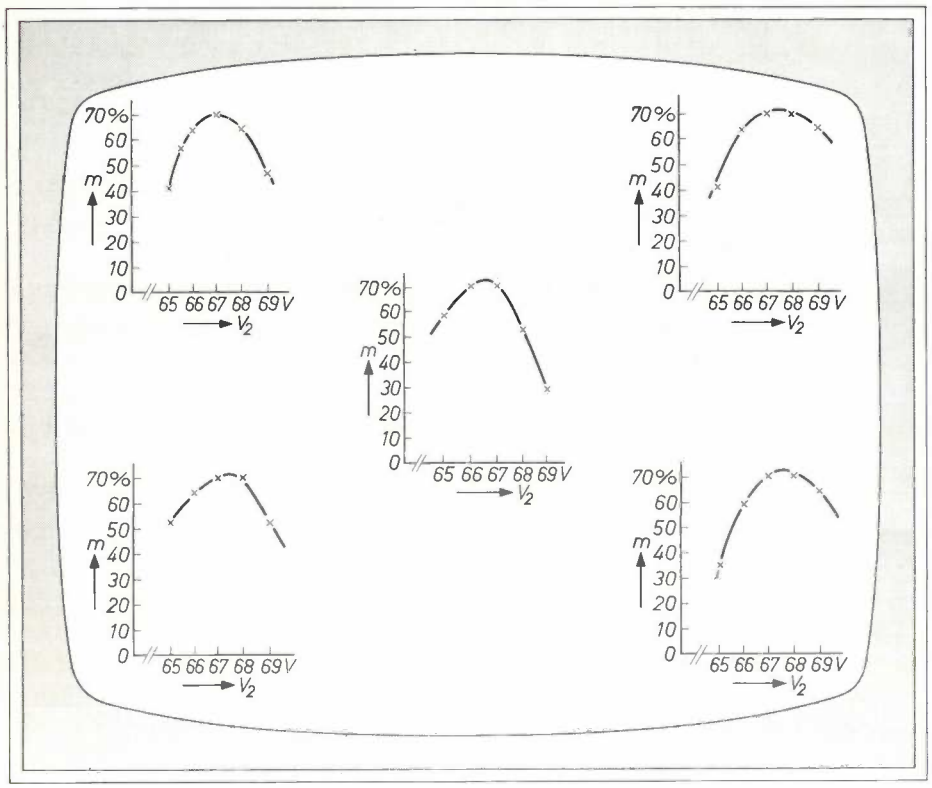


Fig. 8. Modulation depth m as a function of the voltage V_2 on electrode A_2, measured with white light, at the centre and at the four corners of the picture. The frequency used was 3 MHz and the beam current 0.2 μA. At $V_2 \approx 67$ V the resolving power is optimum over the whole area.

the screen. How good is the resolving power at other parts of the screen? This can be seen in *fig. 8* which gives plots of the modulation depth against V_2 (the voltage at A_2) for the centre and the corners of the screen; the modulation depth is measured with white light and at a frequency of 3 MHz. It can be seen that at the same voltage of about 67 V the optimum value $m = 70\%$ is almost reached at all places. This indicates that the pictures from the miniature tubes are equally sharp over the whole area.

The photoconducting layer

Reducing the image size and changing the thickness of the photoconducting layer affects the sensitivity, the resolving power and the lag of a camera tube.

The *sensitivity* and the *resolving power* depend on the wavelength of the light. This is due to the absorption of the light in the layer. In a "Plumbicon" tube blue light at a wavelength of 400 nm is fully absorbed in the first few microns of the layer, whereas only about 10% of red light at a wavelength of 620 nm is absorbed in the full 20 μm thickness of the layer. This makes the tube less sensitive to red light. Since the layer is polycrystalline there is scattering, and this is most pronounced for red light because of the lower absorption, thus giving a lower resolving power. Any reduction in image size must therefore be accompanied by a reduction in the thickness of the layer. Since this means that less red light is absorbed, however, the red sensitivity is reduced at the same time.

Recent developments have enabled us to improve both the resolving power and the red sensitivity by increasing the absorption of the layer for red light. Layers with increased red absorption have already been used in experimental "Plumbicon" tubes of standard size [8]: they have been made by incorporating a very small quantity of lead sulphide in the lead monoxide layer. Lead sulphide, which is also used in infra-red photocells, absorbs radiation at wavelengths extending to 3 μm. A small concentration of it in the lead monoxide layer increases the absorption of red light to such an extent that both sensitivity and resolving power are substantially improved. This made it possible to reduce the image area of the miniature tube by a factor of 4 and the thickness of the layer by a factor of 2. The sensitivity of a miniature "Plumbicon" tube at 620 nm is 0.11 μA/μW as compared with 0.04 μA/μW for a standard tube [9]. The resolving power of the miniature tube also compares very well with that of the standard tube: the modulation depth at a frequency of 5 MHz is 35% for the miniature tube as we noted earlier and 42% for the standard tube.

The *lag* of a "Plumbicon" tube is greatest at low light levels, mainly because of the beam-current lag. This lag occurs because the capacitance of the layer is charged via the beam, which has a certain effective resistance. Other factors involved here, apart from the capacitance of the photoconducting layer, are the signal current, the dark current and the cathode temperature. If a change in the incident luminous flux at the

[8] E. F. de Haan, F. M. Klaassen and P. P. M. Schampers, An experimental "Plumbicon" camera tube with increased sensitivity to red light, Philips tech. Rev. **26**, 49-51, 1965.

[9] The standard tube referred to is type XQ 1020, which has a lead-monoxide layer as described in reference [7]. This tube has been accepted universally for studio use.

[10] See reference [7], page 147.

time $t = 0$ suddenly causes the current through the layer to change from i_1 to i_2, the current i_a supplied to the photoconductor by the beam may be described as a function of time as follows [10]:

$$i_a(t) = \frac{i_2}{1 + \left(\frac{i_2}{i_1} - 1\right) \exp\left(-\frac{ti_2}{CV_0}\right)}.$$

In this expression C is the capacitance of the layer and V_0 is a constant which is proportional to the cathode temperature. At a sudden transition from dark to light i_1 is the dark current and $i_s = i_a - i_1$ is the signal current; at a transition from light to dark, i_2 is the dark current and $i_s = i_a - i_2$ is the signal current.

filament reaches the lead monoxide layer through the glass envelope of the tube, so that there is some illumination at the layer even when there is no image projected on it. This effect is more pronounced in the miniature tube than it is in the standard tube.

Fig. 9 shows the relative variations of the signal current as a function of time for an abrupt transition from dark to light. Curve *a* relates to the standard tube ($i_1 = 0.5$ nA) and curve *b* to the miniature tube ($i_1 = 1.5$ nA). These curves were not calculated with the same signal current for the two tubes. In fact, as we shall see when we come to discuss the camera, it has been found possible to reduce the noise level to such an extent that the miniature tube can be operated at a

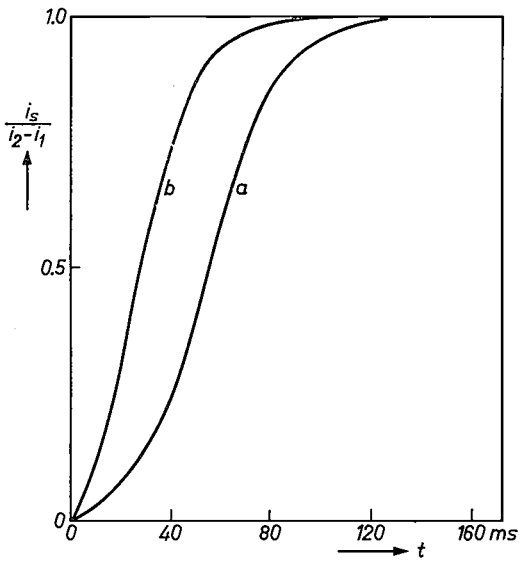


Fig. 9

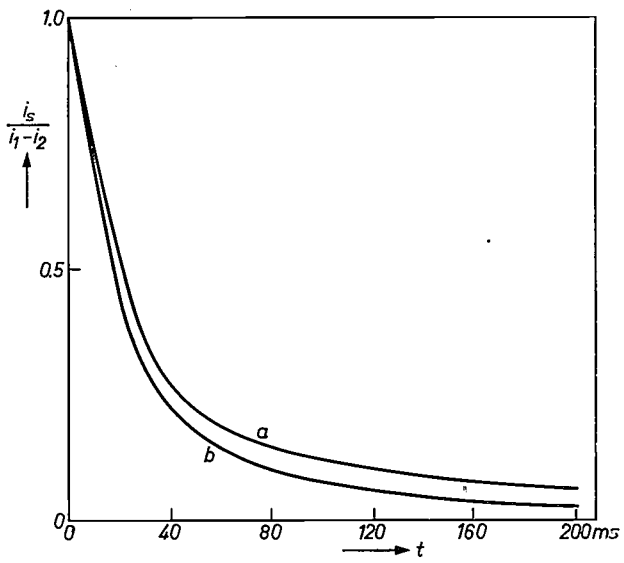


Fig. 10

Fig. 9. Relative variation of the signal current i_s with time t at a sudden transition from dark to light. The current through the photoconducting layer changes from i_1 (dark current) to i_2. The curve *a* refers to the standard "Plumbicon" tube (dark current 0.5 nA, capacitance of the photoconducting layer 1 nF), the final value of the signal current being taken as 20 nA. Curve *b* refers to the miniature tube (dark current 1.5 nA, capacitance 0.5 nF) and has been drawn for a final signal current of 10 nA.

Fig. 10. Relative variation of the signal current i_s with time t at a sudden transition from light to dark, *a* for the standard "Plumbicon" tube, *b* for the miniature tube.

It follows from the above expression that if i_1, i_2 and C are decreased by the same factor, the relative variation of i_a as a function of time does not change and neither therefore does the beam-current lag. Now in view of the above-mentioned scaling-down of the surface area and thickness of the photoconducting layer, one might expect that both the capacitance and the dark current of the miniature "Plumbicon" tube would be twice as small as in the standard tube. It turned out, however, that although the capacitance of the miniature tube was a factor of 2 smaller, the dark current was a factor of 3 higher (1.5 nA compared with 0.5 nA). The reason for this is that light from the signal current which is about half that of the standard tube. We have therefore assumed a signal current of 20 nA for the standard tube and 10 nA for the miniature tube. From fig. 9 it can be seen that the miniature tube has a smaller lag than the standard tube. This is partly due to the smaller capacitance and partly to the higher dark current.

Fig. 10 shows the results of corresponding calculations for an abrupt transition from light to dark. The smaller lag of the miniature "Plumbicon" tube is even more apparent here than in fig. 9. (The horizontal distance between the curves is particularly large in the lower part of the figure.)

The camera

During the first phase in the development of the small camera described here, we wanted to make use of the existing control unit of the studio camera [4]. To keep down the dimensions of the camera unit, however, it was decided that only the circuits which of necessity had to be near to the camera tubes would be included in it. The rest of the circuits were accommodated in a separate unit, the "intermediate unit" (see *fig. 11*), which is connected to the camera unit by a short cable. The intermediate unit is connected to the control unit by the same cable as is used with the normal studio camera.

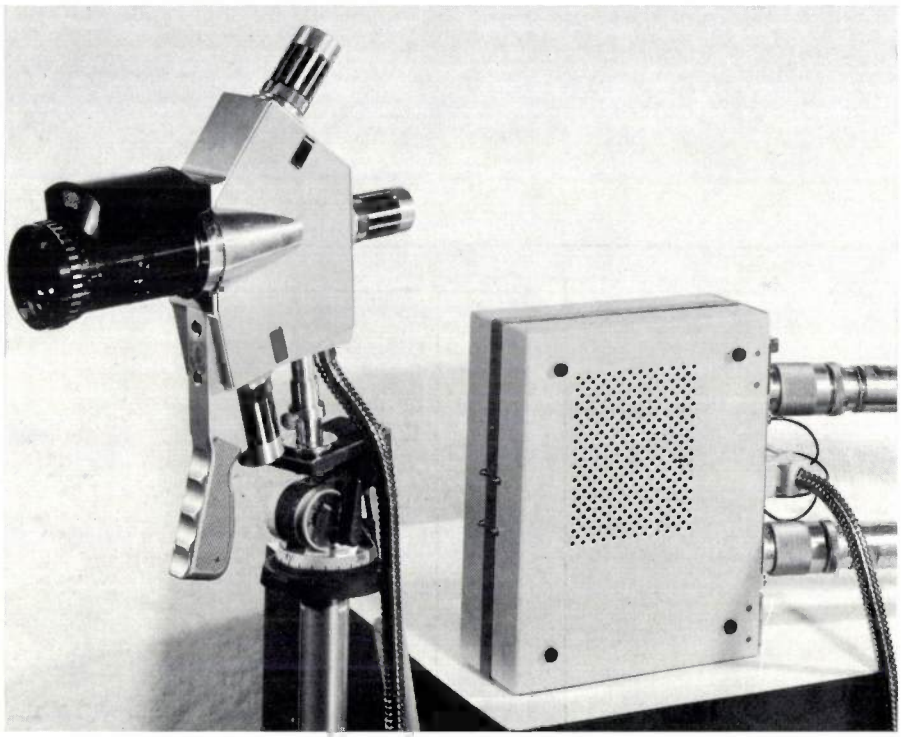


Fig. 11. The miniature camera with the "intermediate unit", which measures 28 × 24 × 10 cm.

Fig. 12 shows one side of the opened camera. The prismatic colour-separation system and the three camera tubes with their deflection coils can be seen in the picture; the three preamplifiers, the blanking amplifier and other circuits required for the operation of the "Plumbicon" tubes are on the other side of the camera.

The optical system

The optical section of the camera is basically the same as that of the studio camera. As in the larger camera the three camera tubes are not mounted with axes parallel. This arrangement requires good screening to keep out external magnetic fields, and this is much more easily achieved with the smaller dimensions of the camera.

The *camera lens* (a zoom lens) was specially developed for the small image format; the focal distance can be varied from 13 to 65 mm. The relative aperture is f/1.6. Because of the smaller image size, the depth of focus at the widest aperture is just as large as in the studio camera, whose lens is set to a relative aperture of f/3.2. The prismatic colour-separation system is adapted to the small dimensions and to the large lens aperture; the angles which the reflecting surfaces make with the optical axis have been made a little larger to avoid the edges of the picture being cut off (vignetting effect).

Image register

In the images which the colour-separation system projects on to the three "Plumbicon" tubes, the points corresponding to one point in the scene must be scanned simultaneously. The accuracy with which this is done depends on many factors. The requirements which this sets for the accuracy and stability of the mechanical construction are much tighter with the smaller image size than for the standard tubes in the studio camera. The camera housing was therefore milled from a single piece of metal. The deflection coils were carefully matched with one another and, as in the large cameras, they can be accurately aligned with respect to the optical axis by means of adjusting screws. To ensure that no errors are introduced by the camera-

tube tolerances, this alignment is carried out with accurately machined acrylic-resin tubes mounted in place of the "Plumbicon" tubes during the alignment procedure. The "Plumbicon" tubes are then placed in the camera and adjusted with screws until their electron-optical axes coincide with the axes of the optical system. If this were not done, differences in the geometry of the three tubes would lead to difficulties in the simultaneous scanning of the three images. Moreover, the three images might be displaced with respect to one another, resulting in less effective use of the surface of the sensitive layer.

Several other precautions have been taken to improve the registration of the three images, such as the provision of variable inductors and resistors to correct any differences in the impedance of the three deflection coils, which are connected in parallel.

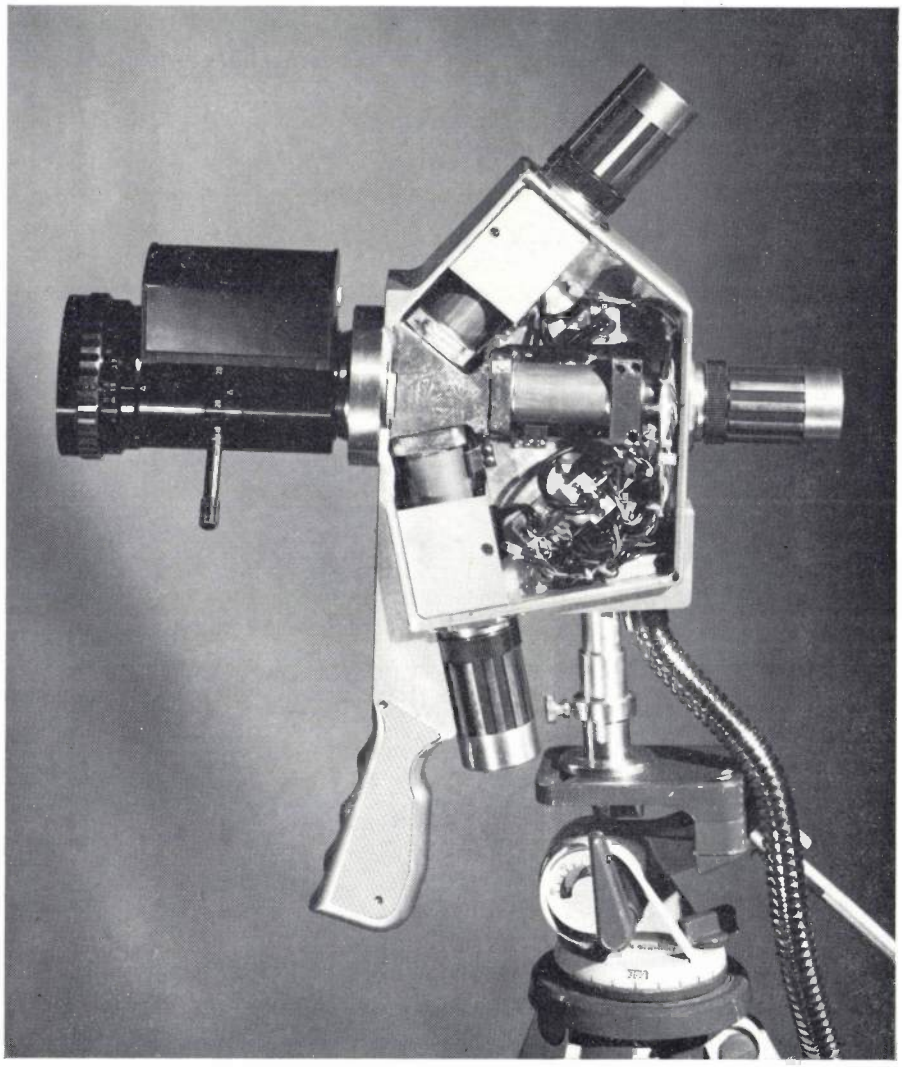


Fig. 12. The camera with a side-plate removed, showing the prismatic colour-separation system and the three "Plumbicon" tubes with their deflection coils. Some of the electronic circuits are on the other side.

Sensitivity

The sensitivity of the "Plumbicon" camera is limited on one hand by the amount of lag that can be allowed with moving pictures and on the other hand by the noise. In the studio camera the use of a field-effect transistor in the input stage of the signal amplifier gives such a low noise level that in practice the sensitivity of the camera is determined by the lag. The lag of the miniature "Plumbicon" tubes, however, is so much smaller that the noise is practically the only limiting factor here.

A large signal-to-noise ratio requires a high input impedance in the signal amplifier. This impedance is formed by the parallel connection of the signal resistance and the capacitances of the signal plate, the amplifier and the wiring. Because of the small dimensions of the signal plate and an extremely short connection

between signal plate and amplifier, the total capacitance has been kept smaller than 10 pF. This low capacitance, coupled with the use of a selected field-effect transistor with a particularly low noise contribution for the input stage of the amplifier, has enabled a signal-to-noise ratio 4 to 6 dB greater than that of the studio camera to be obtained at the same signal current.

Partly because of their reduced lag the tubes in the small camera can therefore be operated with a signal current two or three times lower than the standard "Plumbicon" tubes in the larger camera. A scene illumination of 400 to 500 lux is sufficient to obtain good quality pictures at the maximum lens aperture of f/1.6.

If a camera is to be used in conjunction with other optical instruments, the problem of the optical coupling of the instruments assumes vital importance. In such applications there may often be a considerable loss in luminous intensity and hence in sensitivity. This is the case, for example, when a large camera is to be used with an endoscope, necessitating the use of a flexible optical coupling. The fact that the miniature camera can be connected *directly* to the endoscope thus allows a significant gain in sensitivity.

Image definition

Because of the good resolving power of the miniature "Plumbicon" tubes, the definition is surprisingly sharp over the whole picture surface. The performance of the studio camera and the miniature camera can be compared by means of the experiment illustrated in *figs. 13* and *14*. As in the studio camera, the definition of contours in the picture can be further improved by means of contour signals derived from the green colour signal[11].

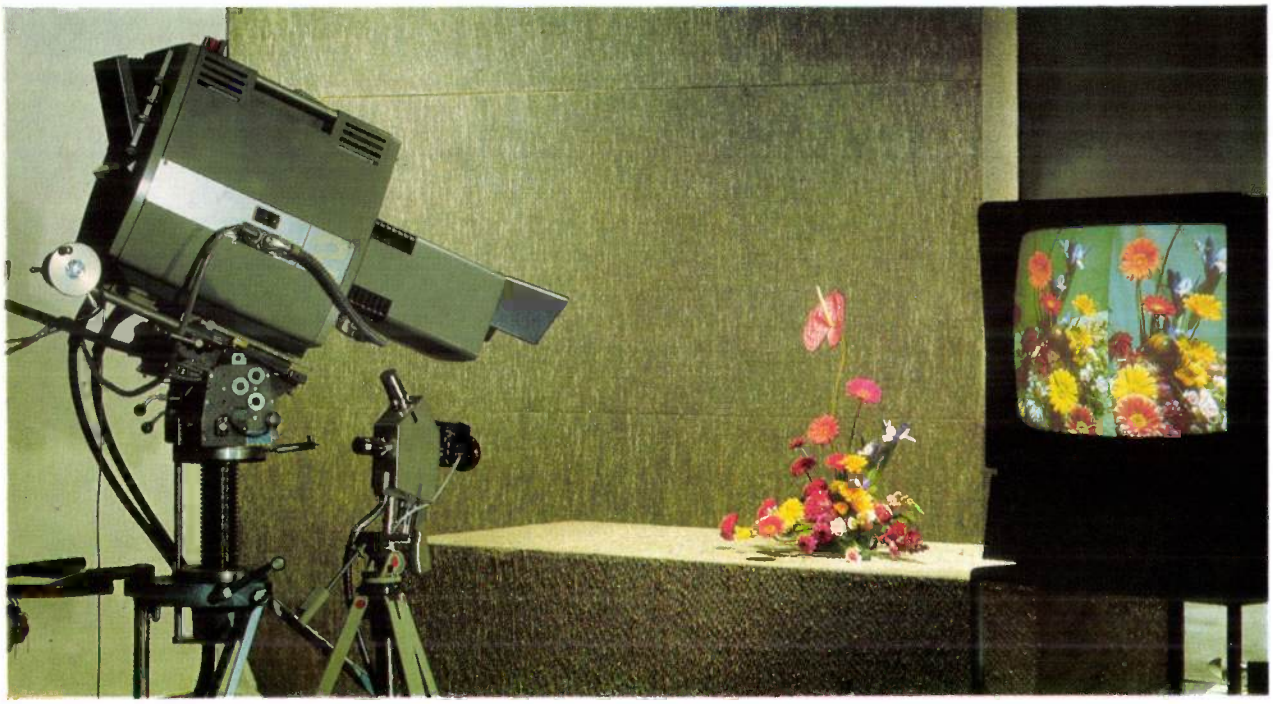


Fig. 13. The studio camera described in reference [4], and the miniature camera, both equipped with "Plumbicon" tubes. The "intermediate unit" (fig. 11) associated with the miniature camera is not shown. Both cameras are taking pictures of the same object to give a comparison of the picture quality: an electronic switching circuit permits the two pictures to appear side by side on the monitor screen at the right.

It is not possible to reproduce the colours of the scene and the monitor picture correctly on the same type of colour film. A better reproduction of the monitor screen is shown in fig. 14.

Even with the lower signal current, the smaller lag of the miniature "Plumbicon" tube gives better definition for moving subjects than is obtained with the studio camera.

When the miniature camera is used directly coupled to other optical instruments such as a microscope, a further improvement in definition can usually be obtained, since optical instruments generally have a circular image field. The deflection currents can then be increased so as to make use of the whole of the circular

[11] See reference [4], page 345 *et seq.*

photoconducting layer. Since less contour correction is necessary with this enlargement of the image size, this also gives a further improvement in signal-to-noise ration. (Of course, this enlargement of the image size also affects the sensitivity and the lag.)

with the camera tubes and with the camera itself do remain. For example, the advantages of the camera could be more fully utilized in outside broadcast work if the electronic circuits now housed in the intermediate unit could be mounted in the camera unit. This could



Fig. 14. The monitor screen in the experiment shown in fig. 13. The left-hand half shows the picture from the studio camera, which for this experiment was fitted with "Plumbicon" tubes of increased red sensitivity. The right-hand half of the screen shows the picture from the miniature camera.

The results obtained with the experimental camera already indicate that it would be very useful wherever it is difficult to install, mount, or connect up a large camera. However, one or two problems connected then produce a complete colour signal, and the camera could be connected by a thin cable to the mobile broadcast unit. An experimental camera of this type is at present under development.

Summary. Description of a small experimental colour television camera, fitted with specially developed miniature "Plumbicon" camera tubes with electrostatic focusing. The dimensions of the image on the photoconducting layer are only 8.4×6.3 mm. In spite of the small dimensions, the camera gives an image quality that compares very favourably with that given by a studio camera. Apart from applications in studios and for outside broadcasts, this camera also offers great advantages if images have to be viewed that have been produced by another optical instrument, for example a microscope. In such cases this small camera can be directly coupled to the relevant instruments. This reduces the loss of sensitivity and picture definition caused by the coupling elements needed when a large television camera is used for such purposes.