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gegnere Castellani e Vicepresidente l'ingegnere Banfi. Tale Comitato del quale fanno parte oltre ai tecnici più noti e di provata capacità nel campo della televisione, anche rappresentanti ufficiali dei vari Ministeri interessati del Governo italiano, sta svolgendo un'importante attività tecnica consultiva, di assistenza e propaganda per l'affermarsi in Italia di una «coscienza» della televisione e la creazione di una regolamentazione tecnica necessaria per il futuro esplicarsi dell'attività televisiva al servizio del pubblico.

La configurazione orografica dell'Italia consente di «servire» tutta la Valle del Po, che è la regione più ricca e più attiva d'Italia, mediante un unico radiotrasmettitore situato su un rilievo montuoso di circa 1000 metri d'altezza ad una cinquantina di km al Nord di Milano. Parimenti sarà possibile servire tutta la costa del Golfo di Genova installando un trasmettitore sull'altura di Portofino a cavallo fra le due Riviere. Le città di Roma e Napoli potranno essere servite da impiant locali.

Tutti questi vari impianti disseminati lungo la penisola italiana potranno venire intercollegati mediante una rete di «ponti radio» ad altissima frequenza e cavi coassiali.

Posso assicurare che il Governo italiano e l'industria radioelettrica italiana sono fortemente interessati ad un sollecito e serio inizio di un'attività televisiva in Italia. Anche la RAI concessionaria dei servizi radiofonici e televisivi in Italia, succeduta all'EIAR nel 1945, ha allo studio un interessante programma di impianti trasmettenti di televisione ispirati ai più recenti sviluppi raggiunti da questa tecnica d'avanguardia.

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Electronics in Television

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Electronics in television, today, encompasses practically the whole field of television in its technical aspect. Electronics dominates all phases in the transmission and reception of television signals. The studio camera, the remote program pickup system, home type television receivers of all kinds and Professor Fischer's giant theatre projector all employ electronic methods. It is hence essential to restrict the theme of my talk to certain aspects of electronic television — namely, recent developments in electronic camera tubes and, in less detail, in viewing tubes. I may add, finally, some remarks on our work on color television. In order to establish a frame of reference for this discussion, it is advisable to digress briefly to consider the television standards which have been adopted in America and the reasons for their adoption. This is all the more appropriate in view of the important role which the question of standards assumes in the present conference. Our American experience in this field may contribute to the background for the discussions on this subject.

The selection of the number of lines in the picture and the number of picture frames transmitted per second assumes a central position in the choice of television standards. Together these two figures determine the frequency channel required for the transmission.

Since the standard practice in motion picture projection is to project the film at 24 frames per second with a two-blade light shutter giving a flicker frequency of 48 per second, it would seem that a frame frequency of 24 and a field frequency of 48, interlaced, would be satisfactory for television. The use of interlaced scanning is in effect the same as using the two-blade shutter in film projection. At the time standards were chosen, the difficulties due to stray magnetic fields and currents of the power supply frequency made it necessary to adopt 30 pictures per second in America and 25 in England. At first it was felt that the additional bandwith and other complications required for 30 pictures per second was a high price to pay for the elimination of power supply difficulties. However, if today we were free to make the choice between 24 and 30 pictures per second, the high brightness provided by modern television receivers would necessitate the choice of 30 pictures per second on the basis of freedom from flicker. Television receivers in general use in America provide a brightness of as much as 100 to 150 foot lamberts. For the same amount of image flicker at 25 pictures per second the brightness can be only 20 to 30 foot lamberts.

One may ask, why are pictures of 100 foot lamberts desired when the motion picture averages between 5 and 10 foot lamberts? The answer to this is that it is desirable to be able to view television images under normal lighting conditions as they exist in the home day or night.

Power supply difficulties are encountered if a frame frequency other than 25 per second is employed in a television system operating on 50 cycle power. In one American city this difficulty has been encountered where 30 frame per second receivers are operated on 50 cycle power. A similar problem will be encountered in a section of Canada where 25 cycle power is used. The choice of the frame frequency or number of pictures per second is therefore a compromise between freedom from flicker at the desired picture brightness, frequency bandwith and power supply difficulties.

The fineness of the detail which can be distinguished in a television picture depends on the number of lines transmitted and the frequency band used.

It has been found empirically that equal resolution in a horizontal and in a vertical direction is obtained if the frequency band is made equal to the product of a constant factor of 0.39 — the Kell factor — times the square of the number of television lines, the frame frequency, and the ratio of the width to the height of the picture, generally set at 4/3. Conversely, if the economics of television transmission and the number of competing stations which are to be accommodated in a given frequency range dictate the width of the frequency band, the appropriate number of television lines is found to

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be proportional to the square root of the band width. For a video band of 4.25 megacycles per second, which can be accommodated in a 6-megacycle transmission channel, the proper number of lines in the picture becomes approximately 525.

It may be noted that a line number of 525, which has been accepted as standard in America, is a suitable choice from other points of view as well. Empirically, it has been found that a distance equal to four times the picture height constitues an optimum viewing distance; for smaller distances the viewer does not take in the whole picture at once, while for larger distances surrounding objects intrude on his attention. A single line of a 525-line picture, placed at the optimum distance from the eye, intercepts a viewing angle of somewhat less than 2 minutes of arc, which is of the same order as the least angular separation resolved by the average eye. Hence, increasing the number of lines beyond 525 has relatively little effect on the entertainment value of a television picture. As a fact, it is found quite generally that, subjectively, a picture improves considerably in passing from 400 to 500 lines, much less, on increasing the number of lines from 500 to 600, and negligibly in passing beyond 600 lines.

While the gain in entertainment value to be achieved by increasing the line number beyond 525 is slight, the economic factors mitigating against such an increase are numerous.

It need scarcely be mentioned that, from a number of points of view, it is undesirable to make the number of lines so great that the picture supplies more detail than the eye can resolve. The increase in number of lines is reflected in increased cost and complexity of all components of the system. The change from 525 to 800 lines, for example, would require video and intermediate circuits in the receiver having a bandwidth of 9.7 megacycles as compared to 4.25 for 525 lines. The problem of deflection of the electron beam at the higher speed becomes more difficult and expensive at 800 lines. The number of stations in a given block of frequency band is reduced by more than half. Higher broadcast frequencies would be required for the wider video band of the 800 line picture. Recent measurements made in New York City on 67 Mc., 288, 520, and 900 Mc., indicate that the difficulties due to reflections from hills and buildings increase as the carrier frequency is increased. The shadows produced by hills and buildings also become more severe as the carrier frequency is increased. As a result of our television broadcast experience in the band from 50 to 216 Mc., and our field survey extending on up to 900 Mc., it may be said without question that the most satisfactory television service will be obtained at a carrier frequency as low as may be used and still remain free of long distance transmissions. This places the most desirable frequencies for television broadcast in the region between 50 and 70 Mc.

To sum up the subject of choice of number of scanning lines, recent comparison measurements of 35 mm motion picture film as normally taken, printed, and projected, with the present 525 line television system adopted in the United States indicates that when the limitations of the television system are only the number of scanning lines (525) and the video bandwidth (4.25 Mc.), the television system has detail corresponding to 85 per cent of the 35 mm motion picture. This would indicate that, indeed, little is to be gained by an increase in the number of lines in the television image.

The polarity of transmission was decided on the basis of making the noise in the picture as unobjectionable as possible and minimizing the complexity of the receiver circuits. This is attained with «negative transmission», in which the radio frequency signal becomes a maximum for the darkest portions of the picture. With this polarity, noise peaks show up primarily as black specks, which are much less objectionable than the predominantly white specks obtained with positive transmission. Furthermore, the synchronizing signals transmitted on a blacker-than-black pedestal during the horizontal and vertical return times of the beam are suitable for automatic frequency control of the electron beam scanning circuits and automatic gain control, and at the same time bias off the scanning beam in the viewing tube if the unmodified video signal is applied to the viewing tube control grid. It is not possible to combine these features with positive transmission.

Consider now the camera tubes which have been developed to transmit 525 line pictures at a rate of 30 per second. The camera tubes in use at the present time practically all make use of the storage principle, first introduced with the iconoscope, familiar to all workers in the television field. The standard iconoscope, shown in Fig. 1, still plays a large role in the transmission of studio programs. Its relatively simple construction, stable operation over an arbitrary range of scene brightnesses, and favorable contrast characteristics fit it for high-quality transmission wherever adequate illumination is no problem. Some thousand times as sensitive as an ideal non-storage pickup system, an iconoscope camera possesses approximately a fifth of the sensitivity of a modern motion picture camera.

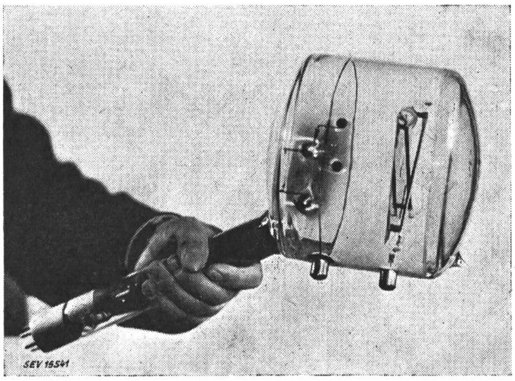

Fig. 1
The Type 1850-A Iconoscope

A much smaller iconoscope (No. 5527), suitable for industrial and amateur use, is shown in Fig. 2. It has a semitransparent mosaic 1.4 inch in diameter and an overall length of 9 inches. Electrostatic deflection and the absence of keystone correction minimizes circuit requirements. Apart from this, the principle of operation of the smaller tube is the same as that of the standard (No. 1850-A) iconoscope.

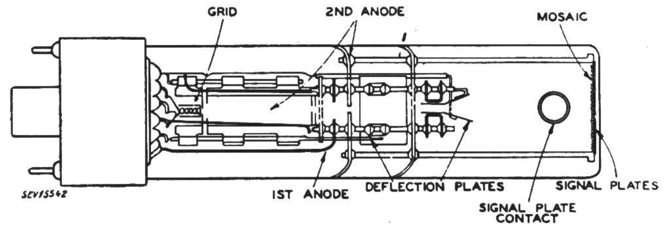

Fig. 2
The Type 5527 Iconoscope for Industrial and Amateur Use (Cross section)

Both iconoscopes employ photosensitive surfaces — mosaics — prepared by the oxidation and cesiation of a silver film which has been broken up into minute globules by heating. The spectral response of such mosaics deviates greatly from that of the conventional silver-cesium phototubes, the maximum sensitivity being attained near 4600 Angström units (Fig. 3).

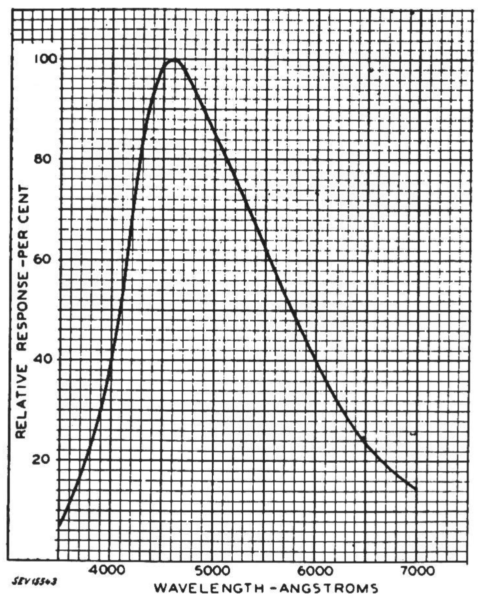

Fig. 3
Spectral Response of the Iconoscope Mosaic

A brief review of the operation of the iconoscope may render more recent developments in the camera tube field more meaningful. The central element in the iconoscope (Fig. 4) is the photosensitive mosaic deposited on a sheet of mica which is backed by a conducting film of platinum. The mosaic itself consists of a random distribution of photosensitive elements so minute that the mosaic may be regarded simply as a photosensitive insulating surface.

An image of the scene to be transmitted is projected on the mosaic, which is scanned, simultaneously, by a sharply focused 1000 volt electron beam. This beam ejects secondary electrons in excess of the number of incident beam electrons. The potential on any one single picture element of the mosaic rises, under the beam, to an equilibrium potential which is about 3 volts positive with respect to the collecting surfaces surrounding the mosaic.

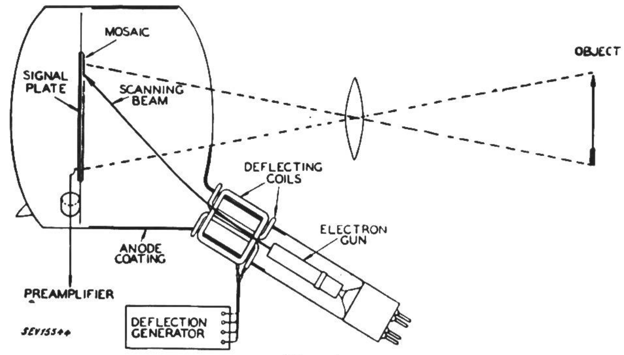

Fig. 4
Schematic Diagram of the Iconoscope

At this potential, the number of secondary electrons which actually leave the element is just equal to the number of beam electrons incident on it. Only a small fraction of these secondary electrons reaches the collector and causes the release of a like charge from the platinum backing, giving rise to the picture signal; the great majority rain back on the rest of the mosaic — particularly the portion which has just been scanned and is hence more positive than the rest. In the absence of illumination, the potential will hence drop, between scannings, first rapidly, then slowly to 0—1.5 volts below collector potential. With illumination, this drop is partly compensated by the emission of photoelectrons which, again, partly return to the emitting element, partly are redistributed over the remainder of the mosaic, and only in small part reach the collector (Fig. 5). In brief, the unfavorable

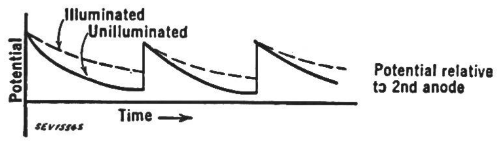

Fig. 5
Potential Variation
(Relative to the Collector) of an Unilluminated and an Illuminated Element of the Iconoscope Mosaic

field conditions in front of the mosaic cause only about 5 per cent of the photoemission between scannings to appear as picture signal at the instant of scanning; in addition, redistribution of the electrons over the mosaic commonly results in a falsification of the light values in the transmitted scene, known as «black spot» or «tilt and bend». This must be compensated by the monitoring engineer by the injection of suitable shading signals. Black spot may be reduced, but not eliminated, by proper distribution of the electrode surfaces, careful attention to the activation procedure, and operation of the iconoscope with a low-intensity scanning beam.

A final limitation to the sensitivity of the iconoscope is imposed by the low level of the signal output which, at low light levels, causes amplifier noise greatly to exceed the inherent shot noise of the picture signal.

The primary aims in a research program designed to remove the weaknesses of the iconoscope were, hence, threefold: 1. The increase in the picture signal, 2. the elimination of shading, and 3. the raising of the output level to a point where the amplifier noise does not influence the final picture. The first two aims may be attained by so altering the field conditions at the target or mosaic surface that the collection of the photoelectrons and secondary electrons emitted from this surface is practically complete; the last aim requires a preamplification of the electron current carrying the picture signal by a technique, such as secondary-emission multiplication, which introduces a minimum of extraneous noise.

The first successful system for both increasing the picture signal and raising the output level is incorporated in the image iconoscope or super-emitron, simultaneously developed in the United States and England. Here (Fig. 6) the image is pro-

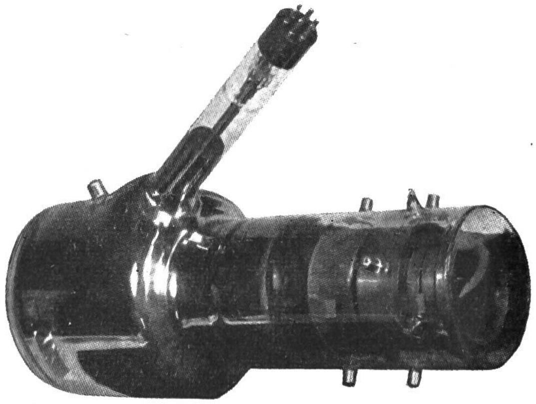

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Fig. 6
An Image Iconoscope

jected on a semitransparent photocathode whose electron emission is then focused by an electric or magnetic electron lens on a target; the latter is scanned in the same manner as in the iconoscope. The signal gain is here derived primarily from the greater photosensitivity of the continuous photocathode, as compared with that of the mosaic, and the secondary emission multiplication at the mosaic. While the improvement in sensitivity obtained in this manner was found to be material — of the order of 10 — and the attainment of even greater gains appeared feasible, the image iconoscope has for several years been superseded, in the United States, by other tubes which combine increase in sensitivity with the elimination of shading difficulties.

These tubes — namely the orthicon and the image orthicon — remove the consequences arising from the poor collection of secondary and photoelectrons by transferring the equilibrium point of the target surface from the potential of the collector to that of the cathode of the scanning beam gun. If an electron beam strikes an insulated surface with a velocity such that the number of secondary electrons ejected from the surface exceeds that of the incident primary beam, the surface will be charged positively until it takes on a potential a few volts higher than the neighboring collecting surfaces: on the other hand, if the beam strikes the surface with a kinetic energy sufficiently small that fewer electrons are ejected from it than arrive, the surface will be charged negatively until it reaches a potential slightly below beam cathode potential, at which no additional electrons can reach it. This will take place in general when the kinetic energy of the incident electrons is less than 10 electron volts.

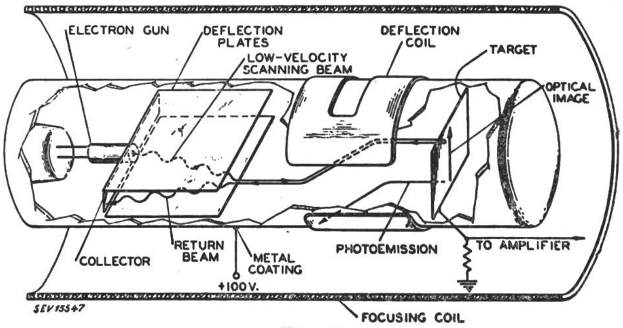


Fig. 7
Schematic Diagram of the Orthicon

In the orthicon (Fig. 7) the electron beam is focused by a longitudinal magnetic field and may be deflected both horizontally and vertically by a superposed magnetic field. Furthermore, through careful design of the deflecting plates and coils, the amplitude of oscillation of the electrons about the magnetic field lines may be minimized, so that sharp focus can be maintained for a considerable range of the target potential. The beam focusing attained in this manner has been demonstrated to be capable of yielding 1400 line resolution in a 2-inch diameter orthicon tube.

Consider, now, the mechanism of signal generation in the orthicon in greater detail. In complete darkness the insulated photosensitive target surface will take on a potential which is slightly below the potential of the gun cathode, so that no beam electrons can reach it — any electrons which do reach it simply drive the surface more negative, so that the condition is evidently stable. Imagine now that a portion of the target is illuminated. The photoelectrons which are emitted from it are collected completely, traveling essentially the same route as the scanning beam electrons which just fail to reach the target and are turned back. Thus, in the time between scans, a positive charge is built up on the target which is identical with the total photoemission in a frame time. At the instant of scanning, the potential of an illuminated element of the target is sufficiently positive that the beam can reach it. Since, as long as the beam strikes an element, the number of electrons arriving at it exceeds that leaving in the form of secondary and reflected electrons, the beam in effect deposits a number of electrons on the target which is just equal to that which has been ejected by the light in the preceding frame time. An equal charge is released from the signal plate and constitutes the signal current. Thus, from the point of view of efficiency of collection and freedom from spurious signals, the orthicon constitutes an ideal storage tube. On the other hand, as in the iconoscope, the signal level obtained from the camera tube is too low to render amplifier noise negligible in comparison with the shot noise of the picture signal. Furthermore, at very high light levels, the simple orthicon here discussed becomes unstable; with increasing potential of the target, the ratio of the sum of the reflected and secondary electrons to the primary beam electrons increases. Thus as the target potential is rendered more positive with increasing illumination, the beam is eventually incapable of returning the illuminated elements to the negative equilibrium point. The potential then builds up rapidly until the secondary emission ratio comes to exceed unity, so that the element goes positive instead of negative under the beam. The picture signal derived from the element is now reversed in polarity, so that, under very intense illumination, a portion of the image suddently becomes «blacker than black». This occurs, in particular, when flash bulbs are exploded in the field of view of the camera. After the source of intense illumination has been removed, equilibrium may again be restored by leakage.

It may be noted that the secondary and reflected electrons constituting the return beam closely follow the path of the incident beam through the deflecting fields. The return beam hence reaches the collector electrode in a region close to the anode aperture. This arrangement facilitates the introduction of an electron multiplier structure surrounding the gun to multiply the return beam current and thus provide a high level output signal, as we shall see presently in the image orthicon.

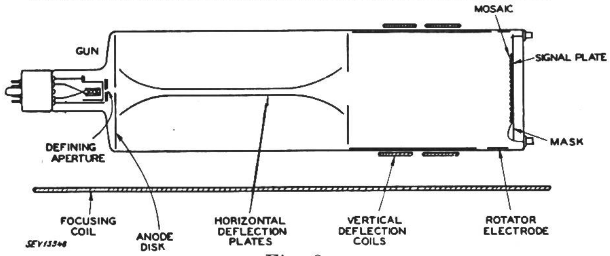


Fig. 8
The Orthicon
(Cross section)

The gain in sensitivity of a simple orthicon (Fig. 8) over that of the iconoscope has been found, in general, to be of the order of 5 — smaller than might be expected, since the transparent mosaic utilizes the incident light less efficiently than the opaque mosaic of the iconoscope. At higher light levels, furthermore, the picture quality obtained with the iconoscope tends to be more pleasing, since its lower contrast tends to equalize the noise in the low lights and in the high lights.

The principal drawbacks of the simple orthicon-inadequate signal level, relatively low photosensitivity, and instability at high light levels — are overcome in the image orthicon. This tube incorporates an electron imaging section of the type employed in the image iconoscope, a fine-mesh collector screen to limit the target potential and prevent instability, and a secondary-emission multiplier to raise the level of the picture signal so as to make amplifier noise insignificant.

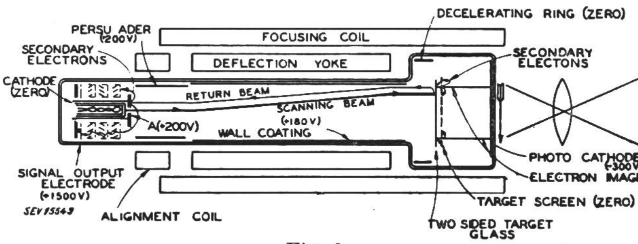


Fig. 9
The Image Orthicon
(Schematic Diagram)

The general arrangement of the image orthicon is shown in Fig. 9. Like the orthicon, the image orthicon is immersed almost completely in a uniform magnetic field produced by a solenoid. Both vertical and horizontal deflection are magnetic. This is essential for the operation of the tube, since it is necessary that the region near the defining aperture at which the return beam arrives be independent of the deflection amplitude. With the type of deflection employed in the image orthicon, both the scanning beam and the return beam travel along the magnetic field lines passing through the defining aperture as axis.

The light image of the scene to be transmitted is formed on a transparent photocathode of high sensitivity, whose emission is then imaged by the magnetic focusing field on the target. The target consists of a thin film of high-conducitivity glass stretched on a frame. Close to it is mounted a 500—1000 mesh-per-inch metal screen which is maintained at beam cathode potential and thus prevents the target surface from assuming a potential greatly in excess of that of the beam cathode. The accelerated and focused photoelectrons eject secondary electrons from the glass target, which are collected by the target screen. In this manner bombarded target areas are charged positively, in correspondence with the intensity of illumination on the photocathode. The opposite side of the target is scanned by the low-velocity beam which, in effect, deposits just enough electrons on the target to neutralize the positive charge stored by secondary emission since the preceding scan. The return beam, consisting of the difference of the incident beam and the electrons deposited on the target, falls on a disk surrounding the defining aperture. The secondary electrons which are thus ejected from the disk are drawn into a multiplier structure consisting of a series of pinwheel dynodes surrounding the gun. The variable part of the output current of this multiplier constitutes the picture signal current; the magnitude of this current is sufficient that the noise introduced by the succeeding thermionic amplifier is insignificant compared with that already present in the output current.

A number of features of the image orthicon merit closer examination. Beginning with the image section, this represents essentially a simple image tube with superposed electrostatic accelerating field and magnetic focusing field. The negative potential of the photocathode is adjusted so that the photoelectrons describe a single loop before they arrive at the target; for a magnetic flux density of 60 gauss, the accelerating potential becomes 300—400 volts. The mesh of the target screen, which has a trans-

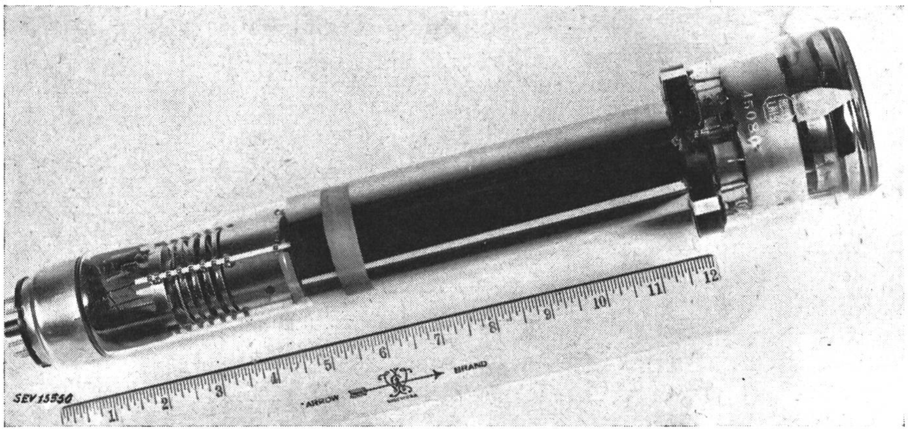


Fig. 10
The Image Orthicon
(External Appearance)

mission of the order of 50 per cent, is sufficiently fine that it does not limit the resolution of the system.

The external appearance of an image orthicon with a 1.6-inch diameter image area is shown in Fig. 10. Tubes of this type are now manufactured with two different types of spectral responses. One of them (the 2P23) employs a silver-rubidium photocathode with high red sensitivity, the other (the 5655), a compound silver-antimony-cesium photocathode with maximum in the blue and ultraviolet (Fig. 11). The first is intended primarily for outdoor work, the second for studio pickup. Image orthicons of much smaller dimensions have been constructed also for special purposes; an example is shown in Fig. 12.

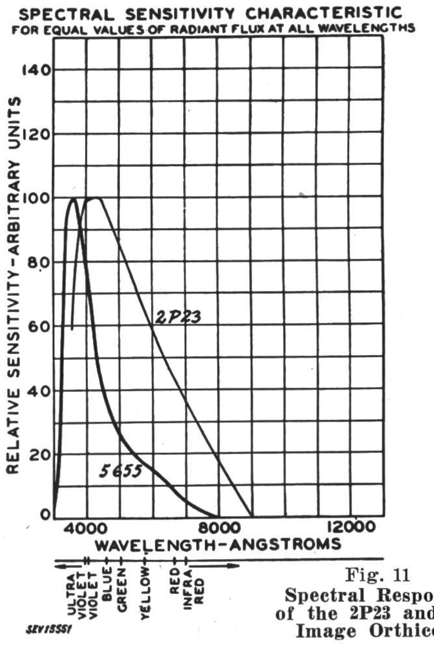


Fig. 11
Spectral Responses of the 2P23 and 5655 Image Orthicons

The glass target consists of a film 2—5 microns in thickness, and has sufficient conductivity that a potential difference on the two sides of the target is largely equalized in the course of a frame time. Yet, in view of the thinness of the target, the diffusion of charge taking place in this time from one picture element to the next is negligible — the diameter of a single picture element is of the order of 50 microns. Thus any positive charge which is accumulated on one side of the target through secondary

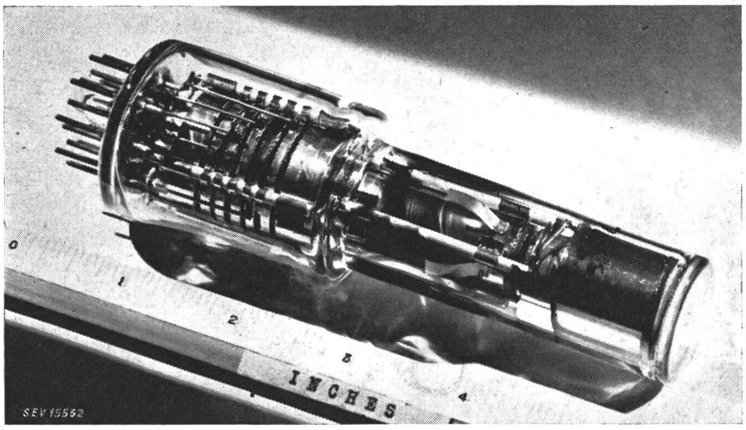


Fig. 12
Small Image Orthicon

emission elicited by photoelectrons, is quite promptly neutralized by the negative charge deposited by the scanning beam. In greater detail (Fig. 13), at low levels of illumination, the potential of the picture side of the target is raised, in the interval between scans, to a potential of the order of 1 volt or less, practically all of the secondary electrons being collected by the target screen. The potential of the beam side of the target rises to the same positive potential. At the instant of scanning,

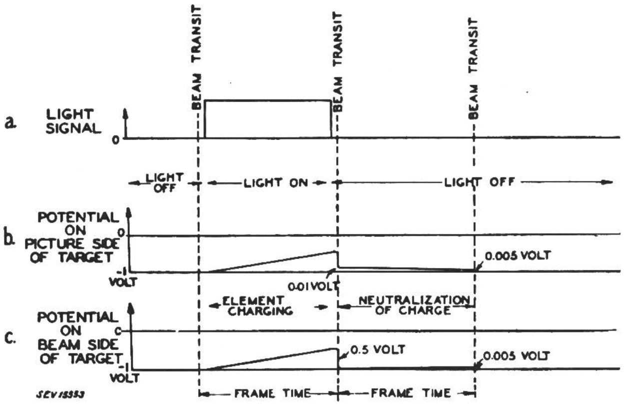
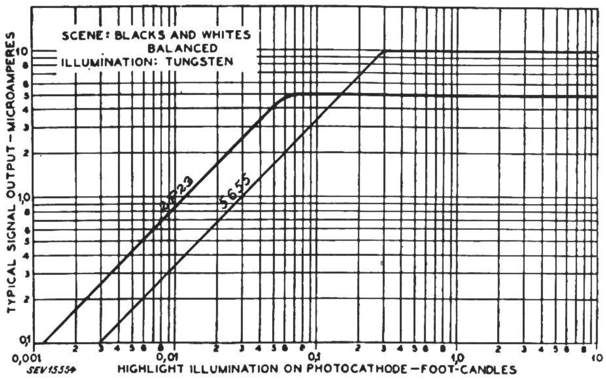


Fig. 13
Potential Variation
of a Target Element Corresponding to a Temporarily Illuminated Portion of the Photocathode of the Image Orthicon

it is brought back to equilibrium potential. The image side potential drops, at the same time, to a value slightly above equilibrium, in view of the fact that positive charge is deposited on one side of the target, negative charge on the other. The resulting difference in potential across the target is equal to the potential rise of the target in the preceding scanning period multiplied by the ratio of the mutual capacities of target and screen and of the two sides of the target. Taking into account both geometrical factors and the differences in the dielectric constant, this ratio is normally of the order of $^1/_{100}$. In the succeeding frame time, the difference in potential between the two sides of the target is largely neutralized by conduction. If, instead, the target were highly insulating, the total charge deposited on the picture side would accumulate until its potential would be so high that only enough secondary electrons could leave to balance the photoelectrons arriving at the target element in question. Thus, after a certain initial period, a stationary picture projected on the photocathode would cease to be transmitted.

If the signal strength obtained from a uniformly illuminated target is plotted against the illumination of the photocathode, curves such as those shown in Fig. 14 are obtained. The initial portion of the curves is perfectly linear; then, as the target potential approaches the potential of the target screen, it reaches a constant saturation value. It might seem, hence, that no contrast would appear in the image as soon as the illumination over the entire target would exceed that corresponding to the knee of the curve. This is far from being the case, however. At target potentials which are positive with respect to the screen, a large portion of the secondary electrons are not collected, but are either returned to the emitting element or neighboring portions of the target. Since more secondary electrons are generated on target areas corresponding to more brightly illuminated portions of the image, these supply more electrons to neighboring areas than they receive from them. As a consequence, bright areas appear brighter near the edge and are surrounded by a dark halo in the transmitted picture; for a halftone picture the resulting contrasts appear quite normal. The effect is similar in character to the contrast accentuation which arises from physiological causes when the eye observes adjacent dark and bright areas.

The operation of the image orthicon described so far applies for closespaced targets — that is, targets which are separated materially less than a picture element diameter from the target screen. Here the voltage rise of a picture element, for a given illumination, is directly proportional to the spacing of the screen and target and inversely to their mutual capacity; the signal current for the maximum target potential, or the range of linear increase of signal current with illumination, is inversely proportional to this spacing. This is no longer the case when the spacing becomes larger than a picture element diameter. The effective capacity of a picture element relative to the target screen, which determines the maximum signal current, is



Fig, 14
Variation of Signal Current
with Illumination of Photocathode for two Image Orthicons

now no longer given by the product of the parallel plate capacity of target and screen multiplied by the ratio of the element area to the total target area, but, essentially, by the capacity of the target element in free space. The latter is, of course, independent of the spacing and of the same order as the parallel-plate capacity determined for a separation equal to the element diameter.

In detail, up to an illumination which is sufficient to raise the target potential as a whole from the equilibrium potential under the beam to screen potential, the operation of the tubes with wide-spaced and close-spaced targets is identical for a uniformly illuminated target. If the illumination is increased beyond this point, the signal from a close-spaced target soon reaches a constant value. With the wide-spaced target, on the other hand, the signal continues to increase, though at a slower rate.

As the potential of the target is brought down to its negative equilibrium point under the beam, the potential of the remaining portions of the target — particularly those close by — is pulled down, to an extent decreasing with increasing separation, along with the potential of the element. As a consequence, these neighboring portions, ahead of the point scanned, will be able to store additional charge by secondary emission before they, too, are scanned and generate the picture signal. As the light intensity is increased, more additional charge is stored in this manner and eventually released as signal current. It may readily be seen, however, that this process, also, presently reaches saturation.

If we consider a strongly illuminated sqare on a dark background, projected on the photocathode for a small fraction of the frame time, we can infer the charge and potential distribution before and after scanning the rectangle from the requirement that no signal is obtained from the portion ahead of the rectangle and beyond it, and that the potential in the rectangular area assumes the positive equilibrium value after exposure. If the intensity of the square is low, on the other hand, the increase in potential as the result of exposure will be constant throughout its area and given by the total photoemission. A qualitative plot of the potential and charge distributions for these two cases, before and after scanning, is given in Fig. 15. The signal is given simply by taking the difference of the charge distribution before and after scanning. It is seen that the illumination influences the charge distribution over a considerably larger area than that which corresponds to the illuminated rectangle. It is assumed throughout that a certain equilibrium

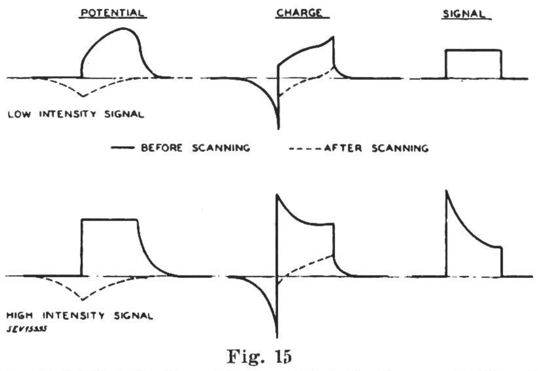


Fig. 15
Potential Distribution, Charge Distribution, and Signal
for an Intermittently Illuminated Rectangular Area on a Dark Background, After Repeated Scanning, for a Large Target-screen Separation; Redistribution Neglected

condition has been reached as the result of several successive scannings of the target after repeated identical exposures. In the case of the strongly illuminated square, contrast at the edges would be further accentuated by redistribution, which has here been left out of account. The characteristic effect of the large target-screen spacing is the strong accentuation of the brightness of the leading edge of an illuminated area. The signal results here from short-time storage, in the period just preceding scanning, so that, for instance, a thrown tennis ball does not appear as a white streak, but rather as a succession of individual images of the ball.

As has already been mentioned, the picture signal in the image orthicon is carried by the return beam, whose current differs from that of the scanning beam by the number of electrons supplied to the target to return it to its negative equilibrium potential. This return beam falls on the disk surrounding the beam aperture, this disk acting as the first dynode of an electron multiplier. All electrodes facing this disk are at the same or lower potentials than the disk, so that the electron paths of secondary electrons ejected from the disk are bent around toward the annular stage of the multiplier, surrounding the gun structure. Before these electrons fall on the inclined vanes of the second dynode, they pass through a wide-meshed, 95 per cent transparent, screen, which shields the vane from the preceding dynode and thus permits secondary electrons to escape and reach the third dynode. Passing, in this manner, through a five-stage secondary-emission multiplier with a total applied voltage of 1500 volts, the return beam current is amplified by a factor to 300 to 1000 before it reaches the coupling resistor of the succeeding thermionic amplifier. This is quite sufficient to cause the shot noise from the beam to outweigh the noise introduced by the thermionic amplifier. The shot noise itself may be kept low by making the scanning beam current just high enough to discharge the most brightly illuminated elements in the field.

The great sensitivity of the image orthicon is readily demonstrated by pointing a motion picture camera at a subject and the image formed of the subject on a television receiver screen as indicated in Fig. 16; an image orthicon camera, provided with similar optics as the motion picture camera, and

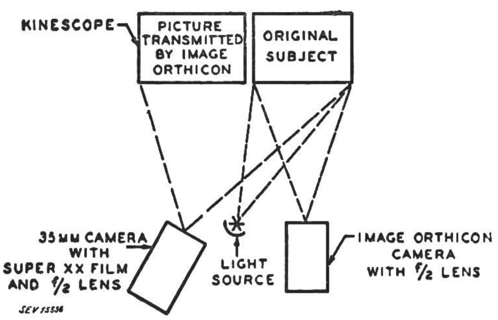


Fig. 16
Arrangement for Comparing Sensitivity of Image Orthicon and Motion Picture Film

connected to the receiver by cable, is trained on the same subject. With the illumination provided by a 40-watt incandescent lamp, the film records both a direct image of the subject and that reproduced on the receiver screen (Fig. 17). However, when the illumination is attenuated by a factor of 10, the direct image disappears. The image on the receiver screen continues to be perfectly recognizable even when the illumination has been dropped by a factor of 100, corresponding to a surface brightness of 0.02 foot lamberts — the brightness of white surfaces in full moonlight. Thus the image orthicon represents, in fact, a reasonably close approach to an ideal storage camera tube.

In the viewing tube field, perhaps the most striking improvement has been attained through the deposition of a thin reflecting metallic film, pervious

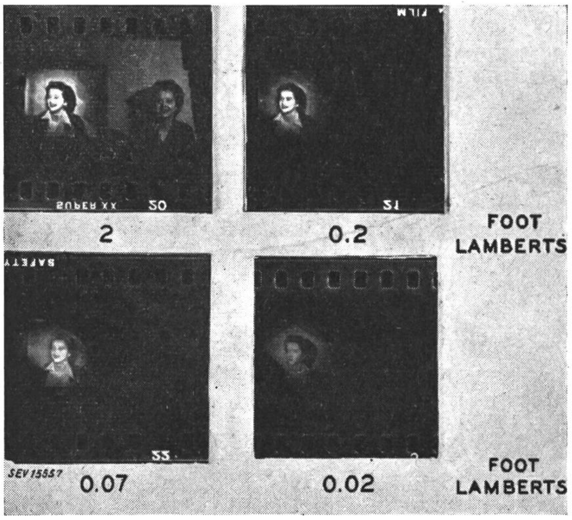


Fig. 17
Comparison of Sensitivity of Image Orthicon and Motion Picture Film

to the beam electrons, on the luminescent screen. The optical effect of such a film is indicated in Fig. 18. In the ordinary kinescope screen, over half of the light generated in the phosphor is lost, being emitted backwards; worse than this, a portion of this light returns, largely after reflection from the inner tube walls, to other parts of the screen and, thus, reduces the contrast of the image. With a fully reflecting metallic film on the back of the screen this is prevented. The light emitted in a backward direction simply reinforces that emitted in a forward direction.

The electrical effect of the metallic films is frequently of even greater value. Since, at very high bombarding voltages, the secondary emission coefficient of most luminescent materials is smaller than unity, the beam tends to charge the phosphor surface negatively with respect to the anode. Thus the electrons arrive at the screen with a kinetic energy materially less than that corresponding to the accelerating voltages and the amount of light generated by them is reduced accordingly. In addition, the local charging may give rise to some distortion in the television picture. With the continuous metallic film at anode potential deposited on the screen, the electrons arrive at the screen with their full kinetic energy and local charging effects are eliminated. Only in this manner can the full benefits of operation at very high voltages — 100 kilovolts or more — be realized. This is of particular importance in theatre television.

A final advantage of the metal film is that it prevents damage of the screen by negative ions reaching it from the gun assembly Unless these are removed from the scanning beam by an «ion trap», these ions gradually reduce the sensitivity at the center of the screen, producing an ion spot. The metal film effectively stops the ions and thus renders an ion trap unnecessary.

In practice, the aluminum film, which is from 500 to 5000 Å in thickness, depending on the

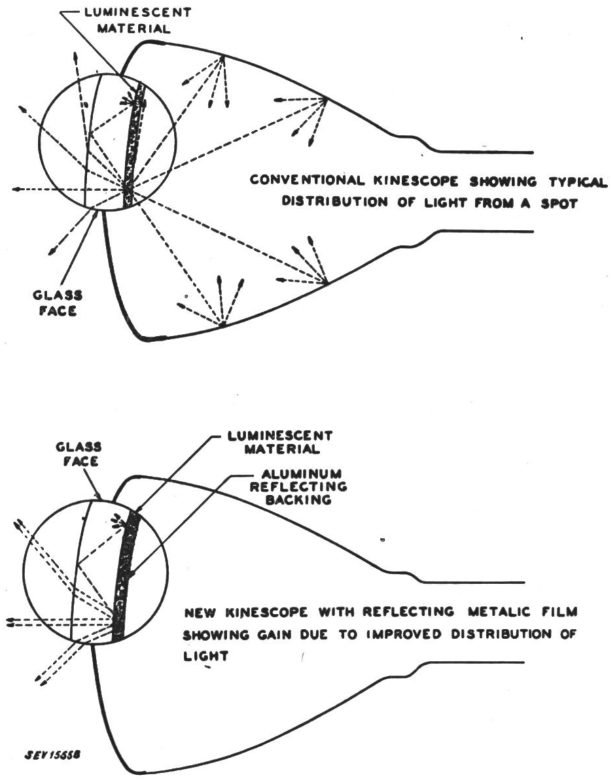


Fig. 18
Effect of Deposition of Reflecting Film on Kinescope Screen on Light Emission

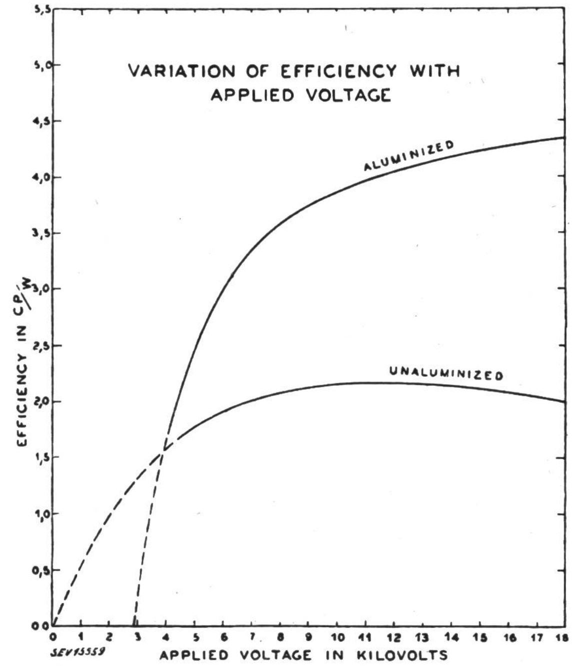


Fig. 19
Conversion Efficiency
of 12-inch Kinescopes with an without Metal Film as Function of Operating Voltage

operating voltage of the kinescope, is deposited on a thin cellulose blanket. This blanket disintegrates during the backing process, leaving a smooth, continuous aluminum film resting on the phosphor. Direct evaporation of the metal on the phosphor is unsatisfactory, since much greater quantities of metal are required to form a conducting layer. In addition, the metal envelops the phosphor grains, reducing the optical efficiency of the screen.

Fig. 19 shows measurements of conversion efficiency for two 12-inch kinescopes, identical except insofar as one of them was provided with an aluminum film on the screen. At very low voltages, the unaluminized screen is, of course, the more efficient since, at these voltages, a large fraction of the electron energy is absorbed by the metal film. However, above 4 kilovolts the advantage of the aluminized screen becomes increasingly pronounced. Even at 18 kilovolts the light output, for equal beam power, is more than doubled by the presence of the metal film.

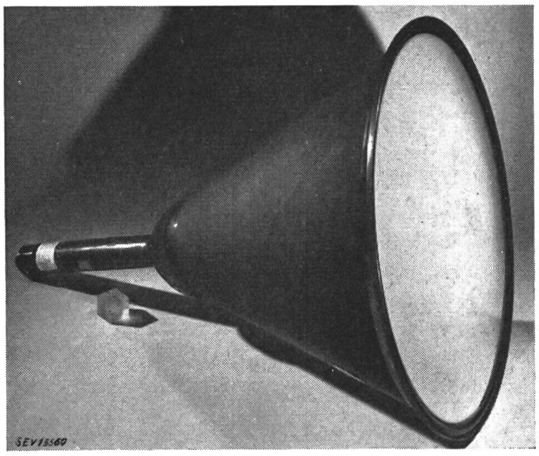


Fig. 20
16-inch Kinescope with Metal Wall

Another valuable development relates to the method of manufacturing large direct-viewing kinescopes. The employment of a metal envelope, to which the glass tube face and gun structure are joined by glass-to-metal seals, has permitted the use of a flatter tube face and has led to a material reduction in both production costs and tube weight. The weight of one of the new 16-inch tubes (Fig. 20) is found to be actually less than that of the all-glass 10-inch tube. This is made possible by the fact that the glass, particularly at the edge of the tube face, is not subject to comparable strains in the metal tube as in the all-glass tube.

In conclusion I may describe briefly some developments in color television which hold promise for future practice. There are two fundamental types of color television systems; the sequential type and the simultaneous type. As the name implies, in the sequential system the red, blue and green images are transmitted in time sequence, whereas in the simultaneous system these three images are continuously and simultaneously transmitted and projected in registration on the receiving screen.

There are several technical advantages to the simultaneous system. The most important of these lies in its making possible the development of a color system which is compatible with present black-and-white operating standards. This was a consideration of much importance in connection with developments of color television in America since black-and-white television has now achieved the status of a major industry here. Because of this it was important to develop a system which would not make obsolete the large quantity of existing equipment both at the transmitter and the receiver. The use of the simultaneous system of color television would make it possible for the present black-and-white receivers, with the addition of a frequency converter between the antenna and the receiver, to receive in monochrome the transmissions from a simultaneous color transmitter. Likewise simultaneous color receivers would be capable of receiving in

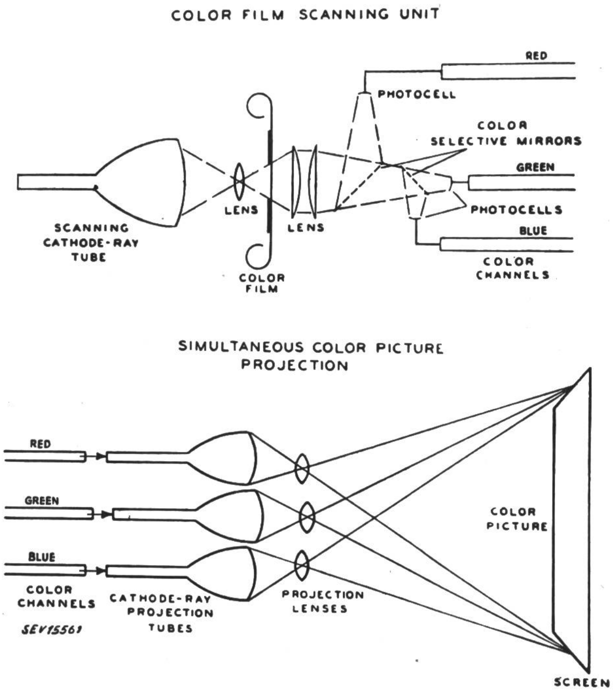


Fig. 21
Principle of Simultaneous Color Television System

monochrome the transmissions of the present black-and-white transmitters. These advantages of the simultaneous system of color television led to our selecting it as the one on which our research and development would be concentrated.

Fig. 21 illustrates the principle of the simultaneous color television system. The essential feature of the system is that a red, a green, and a blue image of the scene is transmitted over separate channels to form a red, green, and blue image in the receiver, which three images are then optically superposed to form a single natural-color image. Since the intensity distribution in the green image is made to correspond to the actual brightness distribution in the scene, the «green» picture signal may also be utilized to form a black-and-white image in a monochrome receiver.

Two geometrical requirements must be fulfilled to make a simultaneous color television system successful: 1. The three partial images transmitted by the system must be geometrically identical and 2. the optical registration of the three images on the receiver screen must be exact. The first example is most readily satisfied with a flying-spot system, such as that illustrated in Fig. 22. The scanning pattern produced by a uniform intensity beam on a short-persistence fluorescent screen is imaged on the object, here a motion picture film or slide. The transmitted light is split up into its red, green, and blue components by a pair of dichroic mirrors and is directed onto the photocathodes of three multiplier phototubes which serve to generate the three picture signals. At the receiver the three signals are applied to three kinescopes with red, green, and blue phosphors — eventually color-corrected

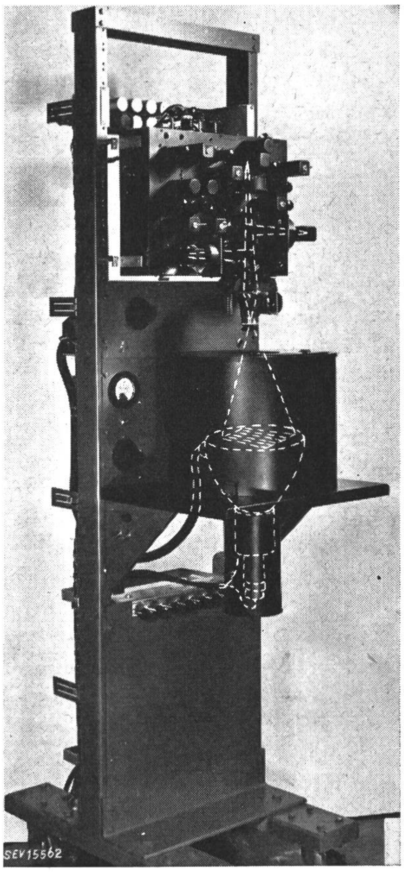


Fig. 22
Flying-Spot Pickup System for Slides

by the addition of filters. These images are projected by large-aperture, wide-angle lenses slightly displaced from the axis of the tubes onto a common viewing screen. Fig. 22 shows the actual realization of a slide scanner, showing a phantom view of the flying-spot tube and the light paths. A console receiver, with three projection kinescopes and accompanying *f*/2 lenses, is shown in Fig. 23.

The flying-spot system is also found to be applicable to the projection of live scenes in the studio. For this purpose the flying-spot is made to scan the scene and a portion of the reflected light is coll-

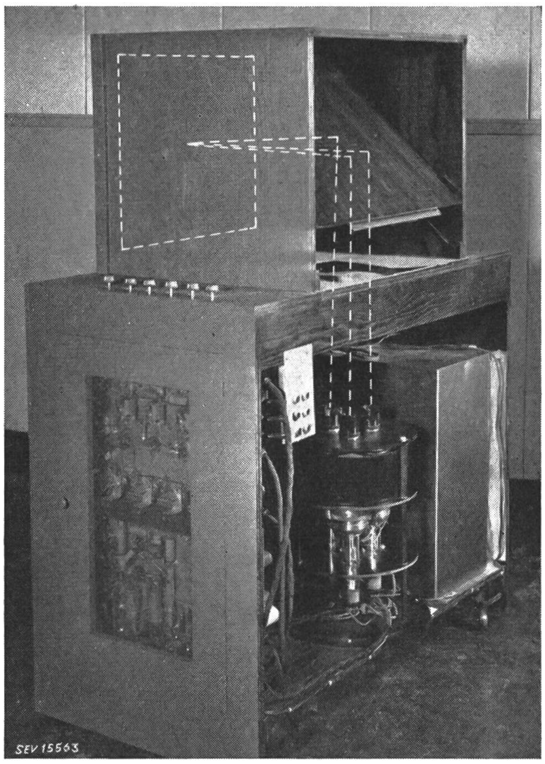


Fig. 23
Console Color Television Receiver

ected by a bank of multiplier phototubes provided with different filters, tubes with identical color response being connected in parallel. The employment of developmental large-cathode multiplier phototubes, with dynode structures similar to those

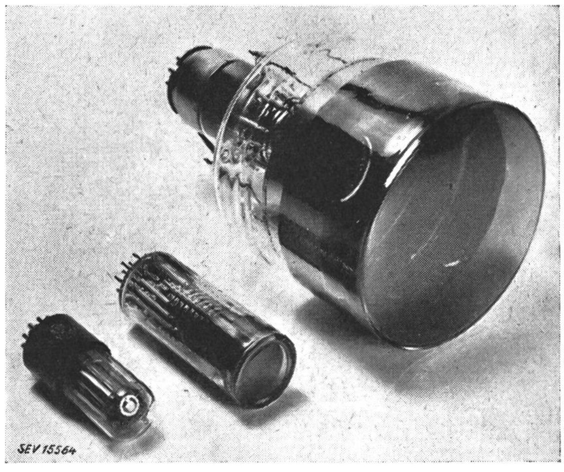


Fig. 24
Multiplier Phototubes Developed for Flying Spot Pickup

in the image orthicon, greatly enhances the sensitivity of this type of color pickup (Fig. 24).

Since ambient light only contributes noise to the picture transmitted by the flying-spot system, it must be excluded as far as possible. The flying-spot system is, hence, not suitable for outdoor pickup. A highly sensitive color camera may be obtained, however, by employing three image orthicons with separate wide aperture lenses, preceded by a beam splitting system consisting of a pair of dichroic mirrors (Fig. 25).

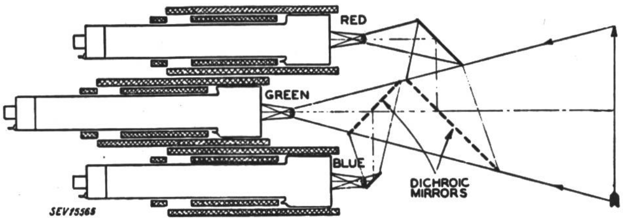


Fig. 25
Image Orthicon Color Camera
Schematic

It may finally be pointed out that the simultaneous television system has been found to give satisfactory large-scale pictures, suitable for motion picture theatres. The television projector employed for this purpose incorporates three individual projector tubes with Schmidt type projection optics (Fig. 26). Since the throw distance is large, the relatively large separation of the tubes does not interfere with accurate registration.

Since the frequency channel requirements for color television are much greater than for monochrome television, it must be anticipated that color transmissions will take place on much higher carrier frequencies than our present television transmissions. Accordingly, extensive field tests will have to be carried out before color television can be placed on a commercial basis. These tests may be time-consuming and expensive. In the end they will furnish the basis for a valuable supplementation of a satisfying and enriching television service.

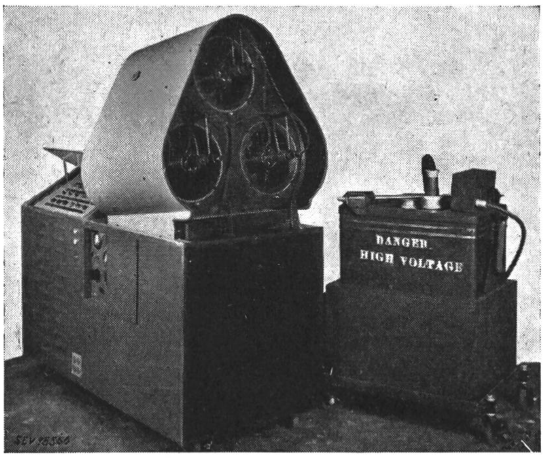


Fig. 26
Color Television Theatre Projector

I may conclude my remarks with some notes on the integration of television in modern home life, insofar as this is relevant to technical considerations. The apprehension has been voiced at times that television may exercise a paralyzing influence on family activities, particularly with the prevailing restricted living space. It has been argued that television, unlike radio entertainment, claims the complete attention of the observer and that, furthermore, the darkening required for satisfactory viewing would force other occupants of the living space into inactivity. This fear has proved unfounded. As with radio, after an initial adjustment period of a few months, there is a tendency to leave the television receiver turned on continuously, with undimmed room lighting. Attention is concentrated on the screen only when something of special interest is beeing presented. The bright images furnished by modern television receivers make darkening quite unnecessary. Thus, while television brings the world into the home to an extent never thought possible, before, it need in no way interfere with its normal activities.

Finally a few words to bring you up-to-date (Sept. 1948) on our progress in the United States. At this time there are 33 television transmitting stations on the air, and many more than this number under construction. Daily programs are reaching territory inhabited by over 40 million people and this coverage is expanding rapidly. More than 400 000 receivers are now in use, representing an investment by the public already of well over a hundred million dollars. Demand continues to exceed production which is going on at a rate of about fifty to sixty thousand receivers per month. Prices range from $ 100 upwards, with an average around $ 300 to $ 400. Programs are available at choice from several stations: in New York for example, there are six transmitters, and in some parts of the country one may have the additional choice from as many more stations. Radio relay links and coaxial cable networks are spreading rapidly, and are providing means for interconnecting stations and facilitating the transmission and exchange of program material. The image orthicon tube has been available since 1945 and hundreds have been and are being used for both studio and outside field cameras. One of the very latest commercial developments is the provision of equipment for life-size television pictures from a compact and simple projector which can throw brilliant pictures up to 7 ft by 9 ft in size from a distance of 17 ft. This projector, which has Schmidt type optics, is now in quantity production and was specially designed for presentation of television programs to large audiences for use in schools, clubs, hotels, hospitals, churches, and industry.

Television is no longer around the corner. It is beyond the doorstep: it has pushed its way through the door into the home and into our everyday life. In fact, the strengthening of home life, the propagation of cultural values, the education for citizenship, and the promotion of international understanding constitute the chief promise of television today.

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