PERFORMANCE OF THE VIDICON, A SMALL DEVELOPMENTAL TELEVISION CAMERA TUBE*

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Summary—*The performance of developmental Vidicons utilizing three different developmental types of photoconductive layers is described in this paper. Data is given on gamma, sensitivity, illumination considerations, spectral response, persistence, and life. Vidicon construction and operation as well as signal-to-noise limitations are discussed.*

INTRODUCTION

THE Vidicon is a developmental television camera tube employing a thin layer of photoconductive material as its light-sensitive element. The paper describes the performance of developmental Vidicons employing several different types of photoconductive layers. Although the operation of the Vidicon has been presented in detail in other papers,[1] the principles of operation and a description of its construction will be given so that the significance of the performance data will be evident.

PRINCIPLES OF OPERATION

Figure 1 illustrates the basic principles of Vidicon operation. In this tube the electron beam is of low velocity as in the scanning section of the image orthicon. As shown in the illustration, the photoconductive layer, or photolayer, which is scanned by the electron beam, is backed by a signal plate which is maintained positive with respect to the cathode by an externally applied voltage. The electron beam current is maintained sufficiently high so that each element of surface on the gun side of the photolayer remains near cathode potential. In the interval between scans, wherever the photolayer is conductive due to the presence of light, the migration of charge through the layer causes its surface potential to rise toward that of the signal plate. On the next scan a sufficient number of electrons is deposited to return

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* Decimal Classification: R583.6.

[1] P. K. Weimer, S. V. Forgue and R. R. Goodrich, "The Vidicon—Photoconductive Camera Tube," *Electronics*, Vol. 23, pp. 70-73, May, 1950; also, *RCA Review*, Vol. XII, pp. 306-313, September, 1951.

the surface to cathode potential. The result of this deposition is a current in the circuit which produces, across the load resistor, a voltage drop proportional to the charge built up between scans. The fluctuations in the voltage across the load resistor become the video signal applied to the first amplifier stage.

Electrical Requirements of the Photoconductive Material

The photosensitivity of the photoconductive material may be as high as attainable, but in order that the signal produced be approximately proportional to the conductivity, the illumination in the picture highlights should be limited to a value such that the surface potential

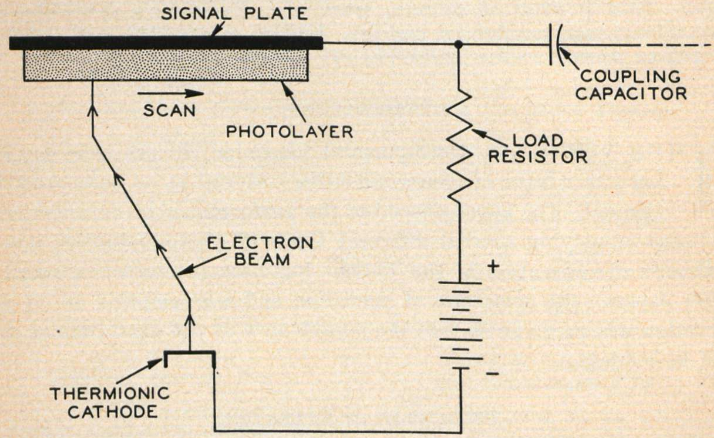

Fig. 1—Basic principles of Vidicon operation.

change is small compared to the signal-plate potential. With the 1/30 second television frame time and the dielectric constant of the order of 10 for photoconductors, the resistivity in the highlights should not be lower than about 10^{10} ohm centimeter. The dark resistivity should be large compared to this value.

Vidicon Construction and Operation

In the developmental Vidicon, the signal plate is a coating of transparent conductive material deposited on the inside of the glass faceplate so that the optical image may be projected through it to the photolayer. Figure 2 shows the arrangement of parts in the tube together with the positioning of the associated components. Grid No. 2 accelerates the beam of electrons emitted by the thermionic cathode. Grid No. 1, the control grid, operates at 0 to —100 volts with respect to the cathode. A small fraction of the electron-beam current passes through the small aperture (0.002 inch in diameter) at the faceplate end of Grid No. 2. The beam passing through the aperture is imaged on the photolayer by the magnetic field produced by the external focusing coil. Deflection is obtained by external coils placed within the focusing field. The long electrode, grid No. 3, controls the potential of most of the space through which the electrons move. Focus adjustment is obtained by varying either the current through the focusing coil or the grid-No. 3 voltage, which is slightly less than 300 volts. A 500-mesh screen at the faceplate end of grid No. 3 provides a uniform decelerating field for the electrons. For the particular focusing coil

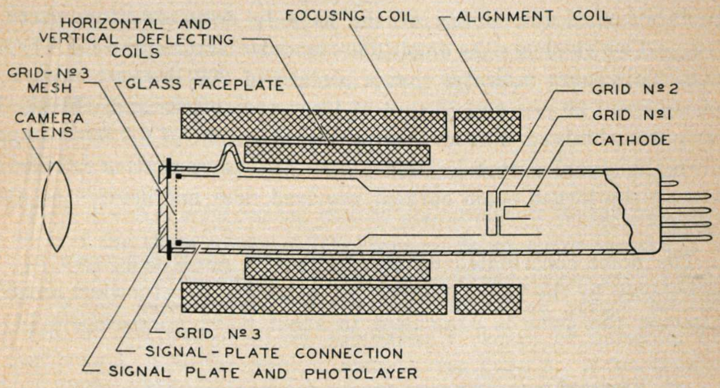

Fig. 2—Arrangement of parts in Vidicon and positioning of associated components.

and focusing-coil-current value used when the data described in this paper was taken, the electrons make one loop between the grid-No. 2 aperture and the photolayer. The potential of the signal plate is approximately 30 volts positive with respect to the cathode. The thickness of the photoconductive layer, approximately 0.0002 inch, is small compared to the diameter of the electron-beam spot and, hence, any lateral conductivity is negligible.

A photograph of the developmental Vidicon is shown in Figure 3. The tube is one inch in diameter, has an over-all length about 6¼ inches, and has a useful sensitive area about ⅝ inch in diameter. For a 3 to 4 aspect ratio the image is ⅜ inch high and ½ inch wide.

Performance Data

The Vidicon is capable of resolving at the center of the picture at least 350 television lines per vertical picture height; with a suitable

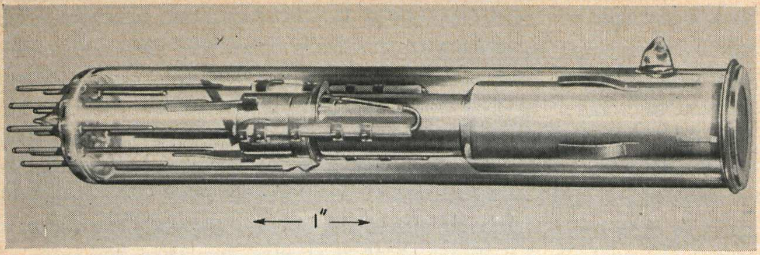

Fig. 3—Photograph of developmental Vidicon.

amplifier, 500 to 600 lines can usually be seen. A more complete specification of the ability of the tube to show detail is given in Figure 4 which shows the amplitude-response-factor curve for a typical tube. This curve indicates that a pattern of 300 lines provides a response about 20 per cent of that of large-area blacks and whites. The curve was obtained with an average signal output of 0.2 microampere. When the signal output is larger, some loss of resolution is observed because the larger beam current required does not provide as sharp a spot.

The noise contributed by the Vidicon is small compared to that contributed by the associated circuit. With the usual peaked amplifier response, the noise is equivalent to about 0.002 microampere in the

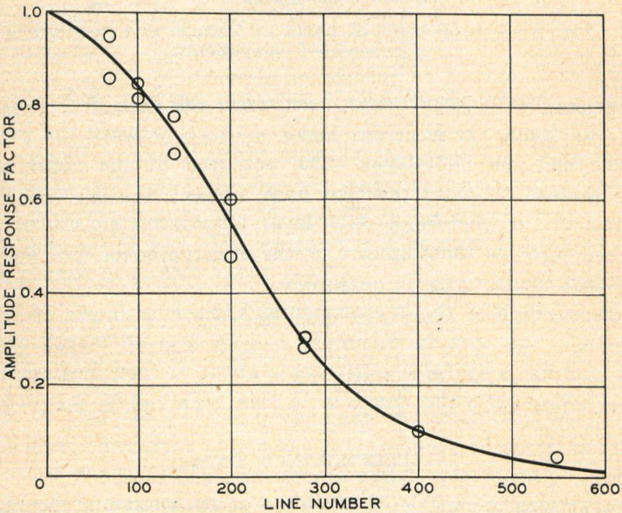

Fig. 4—Amplitude response factor of typical developmental Vidicon.

load resistor. A 0.2-microampere output signal, therefore, should have a signal-to-noise ratio of about 100 to 1.

Although the sensitivity of the Vidicon increases with increasing signal-plate voltage, a limit is set by the dark current which increases with a higher exponential power of signal-plate voltage than the signal. The useful limit is determined by the amount of nonuniformity in the dark-current signal background which can be tolerated under the conditions of use. The data given in this paper was taken within the limitation of a maximum tolerable dark current of 0.04 microampere.

PHOTOCONDUCTIVE LAYER

Three developmental types of photolayers are discussed in this paper. These types are referred to as 1, 2, and 3. The material of which type 1 is made is amorphous selenium,[2] type 2 is of antimony trisulfide,[3] and type 3 is a modification of type 2.

GAMMA, SENSITIVITY, AND ILLUMINATION CONSIDERATIONS

Figure 5 is a typical log-log plot of signal output versus light flux for each of the three photosensitive layers. In all cases the slopes of the lines are less than unity; the output, therefore, is not proportional to the applied illumination. In the usual operating range, between 0.02 and 0.2 microampere, the approximate slopes, or gammas, are 0.9 for type 1, 0.75 for type 2, and 0.7 for type 3. A low-gamma camera tube provides compression of the electrical signal range which is desirable for amplification and transmission and which also helps to compensate for the high gamma of the kinescope. Because the response of the Vidicon is nonlinear, it is necessary to specify the light or signal level and to require uniform illumination over the scanned area when sensitivity is being determined. Sensitivity is specified here at a low signal level, 0.02 microampere, because the low-lights are most critical for amplification of the signal. With this definition, the sensitivities of developmental Vidicons having photoconductive layers 1, 2, and 3 are, respectively, 100, 300, and 50 microamperes per lumen. As an example of illumination requirements, one millilumen on the useful photosensitive area 3/8 inch by 1/2 inch, which yields a signal output in the useful range between 0.02 and 0.2 microampere for any of the three types, represents a tube illumination of

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[2] P. K. Weimer and A. D. Cope, "Photoconductivity in Amorphous Selenium," *RCA Review*, Vol. XII, pp. 314-334, September, 1951.

[3] S. V. Forgue, R. R. Goodrich and A. D. Cope, "Properties of Some Photoconductors, Principally Antimony Trisulfide," *RCA Review*, Vol. XII, pp. 335-349, September, 1951.

about ¾ of a foot-candle. With an f:2 lens and a scene reflectance of 50 per cent, the scene illumination would be about 30 foot-candles of incandescent light.

Spectral Response, Persistence, and Life

There are several possible ways of defining the spectral sensitivity of a nonlinear device. For the data given in this paper the spectral sensitivity is taken as the reciprocal of the amount of energy at each wave length required to obtain the same signal. This signal is chosen to be 0.02 microampere. As shown in Figure 6, the response of photolayer 1 is limited to the blue end of the spectrum, photolayer 2 peaks

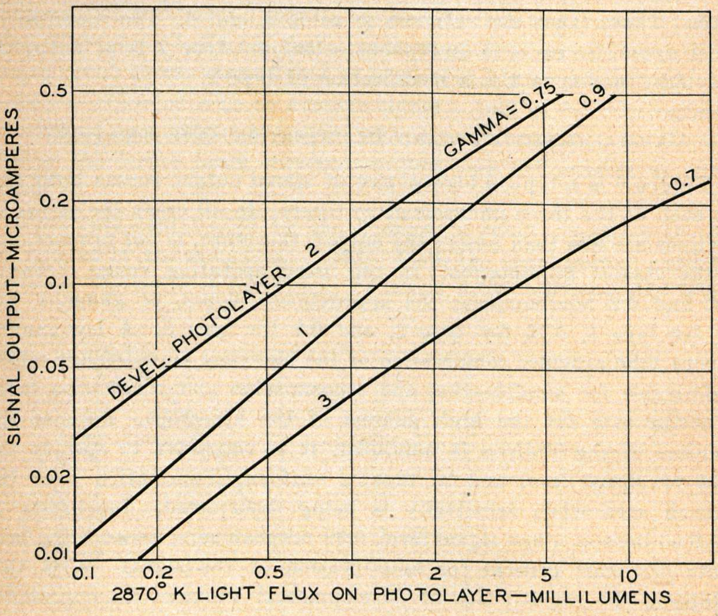

Fig. 5—Transfer characteristics.

in the red or yellow, and photolayer 3 peaks in the blue or green but has an appreciable response throughout the visible region. The spectral response curve for 3 is close to that of the image orthicon type 5820.

In general, the persistence of photoconductive materials becomes shorter when they are exposed to higher values of illumination. Figure 7 shows measurements of electrical signal decay made with each of the three photosensitive layers after the illumination had been

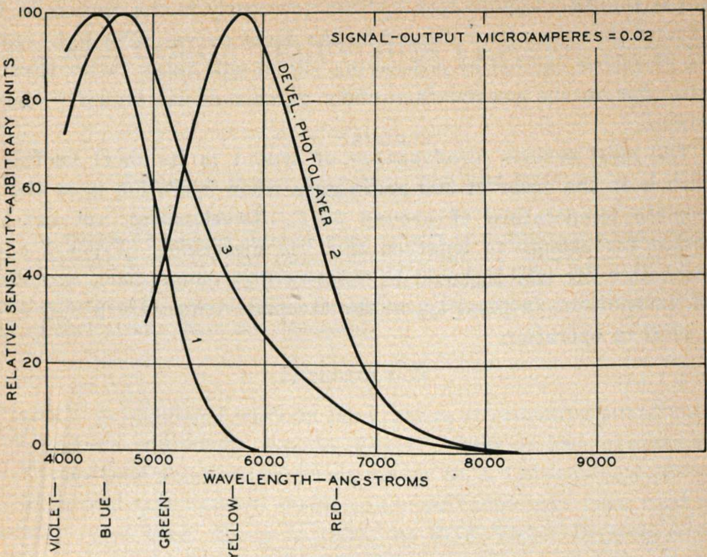

Fig. 6—Spectral sensitivity characteristics.

suddenly cut off. Photosensitive layers 1 and 3 have persistence short enough for use in motion-picture work where the subject does not normally move rapidly across the field of view. As shown by the curve, type 2 has the slowest decay. The corresponding signal build-up when

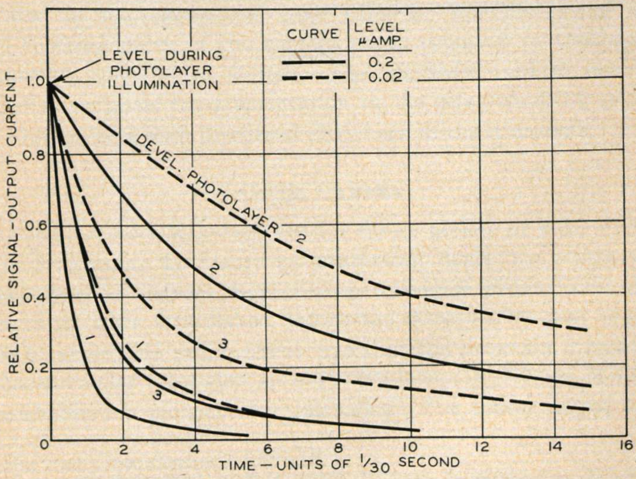

Fig. 7—Decay characteristics.

light is suddenly applied to a Vidicon previously in the dark is as fast or faster than the rate indicated by the decay curves. The light output of a kinescope excited by a decaying signal will decay faster than the signal due to the greater-than-unity gamma of its transfer characteristic.

The most serious disadvantage of type 1 is its short useful life which is in the order of 300 hours even when operation is at the low faceplate temperature of around 35°C. Development has not progressed far enough to lengthen this life materially. Types 2 and 3 have better life which should be more nearly commercially acceptable, and, in addition, in these types, the faceplate temperature may safely be 60°C in operation.

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