Toshiba

"CHALNICON"

— A New Camera Tube for Color TV Use —

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Contents

1. INTRODUCTION

The "Chalnicon*" is a high performance camera tube using a new photoconductive target developed by Toshiba.** Please take a good look at the photoconductive layer at the front surface. There, you will find a "black" photoconductive layer. In this layer, the secret of the wonderful Chalnicon performance is hidden.

As is well known, the heart of a vidicon-type camera tube is the photoconductive layer where a light signal is converted into and stored as an electric charge. During this process, absorption of the light in the photoconductive layer occurs at the first stage. The color of the photoconductive layer of the Chalnicon is quite different from that of the Sb_2S_3 layer of the conventional vidicon or from that of the PbO layer of the Plumbicon.

The "black" color of the Chalnicon means that almost all of visible light waves are absorbed in the photoconductive layer of Chalnicon without being reflected. This is one of the reasons why the Chalnicon has a high sensitivity all over the visible light wavelengths.

The material of the black layer is CdSe or Cadmium Selenide. This material, together with CdS or Cadmium Sulfide, is well known as a highly sensitive photoconductor. Ever since the appearance of the Sb_2S_3 vidicon on the market, many attempts have been made in various nations to apply these highly sensitive materials to photoconductive targets of vidicon-type camera tubes, but in vain.

In Toshiba, studies on the nature of CdSe films started around 1962 at the R and D center. Since then, improvement after improvement have been successfully accomplished through many experiments and trials to make the CdSe film useful for the photoconductive layer of a camera tube.

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* Toshiba trade mark for TV camera tubes using CdSe photoconductive targets. Chalnicon is to be read as [kælnikɔn]

** Japanese abbreviation for <u>To</u>kyo <u>Shiba</u>ura Electric Company Ltd.

One of the most important improvements is an employment of a novel target structure — heterojunction type structure. In the conventional vidicon, one single photoconductive layer performs both the function of conversion from a light signal into an electric signal and the function of storing the electric signal simultaneously. In the Chalnicon, the light-electricity conversion is accomplished by one layer, or the CdSe layer, and storage of the electric signal is accomplished by another different layer. This separation of functions into two parts makes it possible to utilize the highly sensitive CdSe layer for the camera tube successively. Thus, the Chalnicon is based on a brand new idea.

The name "Chalnicon" comes from the fact that CdSe is one of the "Chalcogenides" which is the chemical name of sulfides, selenides or tellurides.

Owing to the nature of photoconductive CdSe layer, the Chalnicon has much higher sensitivity for three primary colors than the existing vidicon-type camera tubes. The Chalnicon becomes ideal for color TV use with several features listed below. Especially, the Chalnicon is unique in making it possible to reduce its size, as it has still enough sensitivity and also enough resolution even after drastically reducing the tube size.

We believe the "Chalnicon" will become a historical camera tube with full responsibility for the coming information and image ages, following the Image Orthicon creating the first TV age and the Plumbicon creating the color TV age.

2. CHALNICON FEATURES

Here are several "Chalnicon" features.

1. High sensitivity .... 20 times over the conventional vidicons and 4 times over the highest quality vidicon-type camera tube, such as the Plumbicon.

2. Broad spectral response over the entire visible range ······· High sensitivity for three primary colors helps to produce the natural color balance with excellent fidelity.

3. Extremely low dark current ······· The fundamental signal level or the black level is always low and stable. Change of color balance does not occur during long-time operation.

4. No image burn-in at all ······· No damage is observed on the video display, even if a brilliant spotlight is faced by the Chalnicon.

5. Characteristics stable for a long period ······· This realizes the high reliability and the easy maintenance of camera equipments.

6. Gamma value nearly equal to unity ······· Gamma value of light transfer characteristics is from 0.90 to 0.95. Thus, a video picture is obtainable with good contrast.

7. Negligible flare effect ······· Harmful irregurality of the color balance does not occur, especially in close-up shots.

3. CHALNICON STRUCTURE AND OPERATION

3.1 Structure and Tube Design

In Fig. 1, the Chalnicon is shown in a rough sketch explaining the role of each part. The Chalnicon has two types of tubes according to the diameters of faceplates as shown in Fig. 2. One is a 25 mm tube called E5001 and the other is an 18 mm tube called E5022. Both are magnetically focused and magnetically deflected tubes with a separate mesh electrode. The scanning sizes of E5001 and E5022 are $12.7 \times 9.5\,mm^2$ and $8.8 \times 6.6\,mm^2$, respectively.

The Chalnicon employes an indium sealing technique similar to that of the vidicon, so various modifications are possible in the future by changing the electron gun mounts according to specific applications.

3.2 Operation

An optical image is focused through the lens onto the photoconductive layer of the Chalnicon. Electron-hole pairs are created by the absorption of light at the photoconductive layer. This changes the electrical conductivity of the layer through photoconduction. The electrons enter the signal electrode leaving a positive hole, which moves toward the opposite side and is stored at the scanning surface of the layer, thus creating an electrical image or a surface potential image copying the optical image. Then the electron beam scans the surface, discharging or neutralizing the stored positive electric signal. The discharging current flows out as a signal output current from the signal electrode. This signal output current is utilized to reproduce the video display on the TV monitor.

4. CURRENT-VOLTAGE CHARACTERISTICS

Figure 3 shows an example of current-voltage characteristics of the Chalnicon. The upper curve is for the signal output current and the lower one is for the dark current. These characteristics are very important as they are closely connected with the operational condition for best use of the Chalnicon.

4.1 Signal Current-Voltage Characteristics

The signal current of the Chalnicon tends to saturate at higher voltages. In this point, the saturation of signal current, the Chalnicon is quite different from the conventional Sb_2S_3 vidicon and is similar to the Si vidicon or to the PbO vidicon.

One most important thing, when using the Chalnicon, is the adjustment of the target voltage to an optimum voltage. When you miss this adjustment, you will completely fail to utilize the wonderful powers of the Chalnicon.

The optimum voltage, which is determined from the signal current-voltage curve with the saturated signal current of 200 nA, is a voltage slightly higher than the knee-point of the curve. In Fig. 3, the optimum voltage is around 35 V. At the target voltages below the knee point or unsaturated region, a negative after image and a longer lag are opt to appear. So, it is not recommended to operate the Chalnicon at voltages lower than the knee-point. Be sure to set the target voltage to the optimum value. In the later section on "Setting-up Procedure", you will find the method to adjust the target voltage to the optimum value.

4.2 Dark Current-Voltage Characteristics

The dark current of the Chalnicon is as low as 1 nA, or below, at the optimum target voltage. This value is about 1/20 of conventional Sb_2S_3 vidicons and is almost equal to PbO vidicons, which are famous for their low dark currents. This property, the extremely low dark current, is a very favorable one for color TV camera tubes, as it helps to reproduce the black color of the object in "real" black on the TV monitor.

As is shown in Fig. 3, the dark current increases with the target voltage. When the dark current becomes extremely large, the picture quality goes wrong. So, again, it is recommended to operate the Chalnicon at the optimum voltage.

It is suitable to operate the Chalnicon in the temperature range of 25° C to 35° C. However, as shown in Fig. 4, no picture quality deterioration caused by the increase of the dark current proportional to the increase of environmental temperatures is observed up to a temperature of 60° C.

5. LIGHT SENSITIVITY

Ever since the appearance of the vidicon, it has been a long time dream for both makers and users to obtain a higher sensitivity camera tube. This dream comes true through the introduction of the Chalnicon developed by Toshiba. With this tube, dark scenes whose reproduction has previously been given up on because of their darkness, will come up into bright pictures on the TV monitor. The high sensitivity of the Chalnicon also helps to reduce the dazzling light level of TV studios to a soft light level.

5.1 Photosensitivity

Sensitivity of the Chalnicon is about 2670 μA/lumen. That is, signal currents of 160 nA are obtained for the E5001 25 mm tube at a faceplate illumination of 0.5 lux with 2854°K white light. The same signal currents are obtained for the E5022 18 mm tube at a faceplate illumination of 1 lux, as the effective scanning area becomes half of the 25 mm tube.

The sensitivity is about 20 times that of conventional Sb_2S_3 vidicon, but is less than that of Si vidicon. However, if the following spectral sensitivity is taken into consideration, it is understood that the sensitivity of the Chalnicon is effectively much higher than that of Si vidicon in the visible range.

5.2 Light Transfer Characteristics

Figure 5 shows the light transfer characteristics of the Chalnicon. The gamma value or the slope of the straight line is from 0.90 to 0.95. This value nearly equal to unity, helps to give a TV picture with a good contrast.

5.3 Spectral Sensitivity

A comparison of spectral sensitivities between the Chalnicon and various vidicon-type camera tubes is shown in Fig. 6. The peak sensitivity of the Chalnicon is located at 700 nm (700 mμ or 7000 Å) and is about 0.5 μA/μW; nearly equal to unity quantum yield. At 400 nm, the sensitivity is about a half of the peak value. As is clearly seen, the Chalnicon is superior to any vidicon over the entire visible range from blue to red. The Chalnicon is suitable for use as a color TV camera tube because of its wide and high spectral response, covering three primary colors.

6. RESOLUTION

High resolution is also one of the Chalnicon's features. Resolution usually goes wrong when the tube size is reduced, so that it has been considered, so far, that the resolution of a small size tube is not satisfactory in picture quality for broadcasting level.

The Chalnicons, not only the E5001 25 mm tube but also the small size E5022 18 mm tube, have excellent resolution, able to play an active part in the industrial field and in the broadcasting field.

Figure 7 shows amplitude response characteristics of the E5001. Under the standard operation (E_{G4} = 500 V, E_{G3} = 300 V and a field strength at the center of focusing coil of 41 Gausses), the center resolution is 750 TV lines, the corner resolution is 600 TV lines and the amplitude response is 45 % at 400 TV lines.

Figure 8 shows amplitude response characteristics of the E5022. Under the standard operation (E_{G4} = 400 V, E_{G3} = 240 V, and a field strength at the center of focusing coil of 50 Gausses), the center resolution is 700 TV lines, the corner resolution is 550 TV lines and the amplitude response is 25 % at 400 TV lines.

Resolutions of both tubes are improved under the high voltage operation, as indicated in Technical Data of the Chalnicon.

7. LAG

There are more or less lag problems for vidicon type camera tubes. Lag is a delayed camera tube response to the change of light levels and is usually divided into two types; one is the capacitive lag concerned with the electron beam scanning mechanism used to discharge the surface potential and the other is the photoconductive lag concerned with the delayed response of the photoconductive layer itself.

Usually, the lag is defined as the ratio of residual current at the third field (or 50 msec) after the cessation of illumination to the steady state illuminated signal currents of 200 nA.

7.1 Chalnicon Lag Characteristics

Chalnicon lags are typically 20 % for the E5001 25 mm tube and 10 % for the E5022 18 mm tube, as shown in Fig. 9. The origin of the lag in the Chalnicon is mainly due to the capacitive lag which is reduced by the reduction in scanning raster size. In this sense, the E5022 18 mm tube has a smaller lag compared to the E5001 25 mm tube.

The lag also depends on the signal current level. When the signal current is less than the standard 200 nA current, the video display seems laggy. It is recommended to operate the Chalnicon at the optimum signal current level nearly equal to 200 nA by adjusting the light level.

7.2 Improvement of Lag by Bias Light

Improvement of lag is possible by employing the bias-light when taking a low light level scene and, consequently, low signal current. Bias light has much effect on the lag in the rise rather than that in decay. Care should be taken to assure the uniform bias light to produce the uniform equivalent dark current (the real dark current plus the signal current by bias light) throughout the raster area.

7.3 Lag Dependence on Light Wavelength

The Chalnicon has hardly any lag dependence on light wavelength. That is, the lags are almost the same, only if the signal currents are taken at the same level, for instance 200 nA. This feature is favorable when the Chalnicon is used in a color TV camera, as follows.

If the adjustment of optical lens system of color TV camera is made to have the same level of signal currents in each of the red, green and blue color channels, no differences of lag characteristics occur in the color channels, so that the tail or head of a moving white or bright object does not have any special color like red, green or blue. Instead, the tail or head becomes a dim grey, which attracts little attention of the human eye. Thus, the Chalnicon lag apparently does no harm to color TV video display.

7.4 Lag and Target Voltage

As mentioned before, there is a relation between I-V curve and lag, as shown in Fig. 10. The I-V curve starts to rise at lower target voltages and saturates at high voltages. Vice versa, the lag starts to decrease at lower voltages and saturates to a constant value at higher voltages where the I-V curve saturation takes place.

If the target voltage is raised up to exceedingly high voltages, the lag sometimes tends to decrease due to the increase of dark currents, as is the nature of lag. However, this is not recommended from the stand point of picture quality, as stated in the preceding section on dark current. By adjusting the target voltage to the optimum value, so that the best condition is obtained such as higher sensitivity in the saturated region, smaller lag and good picture quality.

8. IMAGE BURN-IN

8.1 After Image and Target Voltage

No matter what high sensitivity the tube can realize, it is useless if the after image remains easily and interrupts the succeeding picture pick-up. In the Chalnicon, there are no worries about this after image problem only if the target voltage is set to the optimum value. To tell the truth, the adjustment of the target voltage so far stated is determined from the after-image phenomena.

At a target voltage below the optimum one, a negative after-image is apt to appear when an incident pattern is removed and a uniform white background is taken. This negative after image disappears by increasing the target voltage to some voltage, which is the optimum value of target voltage for the Chalnicon.

8.2 After-Image for Excess Light

At the optimum target voltage, neither the negative after-image mentioned above nor a positive after-image in the dark are observed. Also, no damage is observed due to the incidence of bright light spots, such as a spot light in a TV studio or direct sun beam. For image burn-in, the Chalnicon is much more stable than any other vidicon-type camera tubes.

8.3 Raster Burn-In

A raster burn-in is slightly observed under continuous operation, but it fades off rapidly with uniform illumination over the photoconductive surface. Thus, electronic zooming is possible to change the raster size during operation without serious degradation of reproduced pictures.

9. SHADING

Shading, which is usually observed in the conventional Sb_2S_3 vidicon, is seldom seen in the Chalnicon. On account of the saturated signal current-voltage characteristics, signal output currents do not make so much difference or give serious shading throughout the scanning area, even if these is a landing error of scanning electron beam causing a difference of electric fields across the photoconductive target between center and corner. Uniform video pictures can be obtained by using the Chalnicon.

10. FLARE

In the case of the vidicon type camera tube using a PbO photoconductive layer, such as the Plumbicon, a considerable part of the incident light is reflected at the yellow surface of the photoconductive layer. This reflected light is then reflected back at the front surface of faceplates to the photoconductor. This unfavorable reflection of incident light, the flare, causes spurious video signal.

One of the Chalnicon's features is no flare. As stated at the beginning, the color of the photoconductor is black without giving any harmful reflection of light from the surface of the photoconductor. Figure 11 shows a comparison of reflectivity between the Chalnicon and two other typical camera tubes. As is shown, there is very little reflection of the Chalnicon in the visible range. It is not necessary to put a glass-tip or a glass-button in front of the faceplate.

11. SUITABILITY OF THE CHALNICON AS COLOR TV CAMERA TUBE

Features of the Chalnicon so far mentioned are desirable when applying the Chalnicon into the wide fields of industrial cameras and broadcasting cameras. Here are emphasized some useful points of the Chalnicon as a color TV camera tube.

There are very few deviations of characteristics, for instance photo-sensitivity and spectral response, in each Chalnicon. This means that, together with the wide spectral response covering the whole visible range, there are no tube specifications pertaining to some special color channel. Any Chalnicon is suited for use in any color channel or in the luminance channel.

Under a long period operation of color TV camera, the

Chalnicon works very stably. In the case of a conventional vidicon, considerable change of dark current levels is caused by the temperature increase of surrounding electronic systems, and, sometimes, after images persist, doing harm to picture quality. Instability of dark current and sticking after image are no problem in the case of the Chalnicon.

In addition, high resolution and negligible flare effect become advantages in producing excellent color pictures with fine quality.

The appearance of a color TV camera in small size and yet with high quality picture is expected by making full use of the features of the Chalnicon. Variations of color TV cameras are possible from the handy and mobile one for broadcasting use including CATV use to the high class one for industrial use. Especially, as the Chalnicon has a special ability to reproduce the delicate tone of color from violet to red, a color TV camera for medical use is most promising.

12. SETTING-UP PROCEDURE

In order to utilize the wonderful features of the Chalnicon fully, please follow the setting-up procedure given below.

1. Carefully wipe the faceplate of the tube with soft deerskin or flannelet to keep the surface of the faceplate clean. Tiny little dust particles, faint stains or even fingerprints on the faceplate are caught by the highly sensitive Chalnicon and displayed clearly on the TV monitor.

2. If the TV camera was designed for conventional Sb_2S_3 vidicon, take the circuit or equivalent of the automatic sensitivity control off and make the target voltage variable to set it to the optimum voltage. Instructions for target voltage adjustment are given later.

3. Insert the tube into the deflection unit and connect the socket with the base pin. Be careful not to touch the faceplate with the fingers.

4. Place the tube at such an angle that the horizontal scan is essentially parallel to the plane passing through the tube axis and short index pin.

5. Cap the lens and set the iris for minimum opening.

6. Apply a maximum negative bias to Grid-No. 1 voltage, resulting in the condition of beam cutoff. Set the target voltage at zero, if possible.

7. Set deflection controls for maximum overscan and apply the recommended electrode voltages to the tube, as indicated under typical operation procedures in the Technical Data.

8. Apply the optimum target voltage indicated as Esj in the Inspection Sheet attached to the tube. If no Inspection Sheet is attached to the tube, set the target voltage at 30 Volts temporarily. (Coarse target voltage adjustment).

9. Decrease the Grid-No. 1 bias to allow electron beam scanning start. With this procedure, a faint over-scanned image appears on the TV monitor.

10. Point the camera at a test pattern (for example, RETMA pattern). The test pattern illumination should be reduced to as low as one-tenth or one-twentieth of the level when used for Sb_2S_3 vidicon.

11. Take the lens off to display the video of the pattern on the TV monitor. Adjust the beam-focus control, the lens stop and the optical focus to obtain the best picture.

12. Adjust the test pattern so that its corner has a position slightly inside the outer boundary of photoconductive area, as shown in Fig. 12. The area of test pattern image is recommended to be equal to the standard scanning size ($12.7 \times 9.5\,mm^2$ for E5001 and $8.8 \times 6.6\,mm^2$ for E5022). The procedures 11 and 12 are accomplished alternatively until the best picture is obtained.

13. Reduce the horizontal and vertical scanning so that the edges of the test pattern image just extend to the edges of the scanned area, as seen on the TV monitor as shown in Fig. 13.

14. Adjust the average signal currents to 200 nA by changing the test pattern illumination or the lens iris.

15. Remove the test pattern in a horizontal direction or take a uniform white background by moving the camera itself.
If a negative after image is observed under the white or bright backgrounds as shown in Fig. 14, raise the target voltage slowly up to a value where negative after image fades off into

smooth white or bright backgrounds, as shown in Fig. 15. This voltage without negative after-image is the optimum voltage of the Chalnicon. If no negative after-image is observed at the pre-set target voltage, it may be that the target voltage exceeds the optimum voltage. If so, decrease the target voltage until the negative after image appears, as shown in Fig. 14. Then, increase the target voltage to just enough voltage, the optimum voltage, to erase the negative after-image.

If the target voltage goes over the optimum value by some chance, the picture quality in the dark goes wrong due to the increase of the dark current, as shown in Fig. 16. To avoid this deterioration in picture quality, it is recommended not to raise the target voltage above the values of Esj listed in the Inspection Sheet. There are no problems about picture quality when the target voltage is set to the optimum value. (Fine adjustment of target voltage).

16. In case it is necessary to get average signal currents of more than 200 nA, the optimum value of target voltage becomes slightly higher than that for the average signal currents of 200 nA.

17. By adjusting the target voltage by following the procedures given above, there are no problems for ordinary operations to reproduce good quality picture. However, if it happens that a positive after image remains when taking brilliant lights, such as spot lights in a TV studio or direct sun beams, raise the target voltage up to the value where the positive after image dissappears.

18. After adjusting the target voltage correctly, adjust the alignment field, beam focus, horizontal centering and vertical centering so as to obtain the best quality picture.

REFERENCES

1) K. Shimizu, O. Yoshida, S. Aihara and Y. Kiuchi, "Characteristics of experimental CdSe vidicons," IEEE Trans. Electron Devices, vol. ED-18, Nov. 1971, pp 1058 ~ 1062.
2) K. Shimizu, O. Yoshida, S. Aihara and Y. Kiuchi, "Characteristics of the new camera tube with a CdSe photoconductive target," presented at the 5th Symposium on Photoelectronic Image Devices, London, 1971 (to be published)

Written by O. Yoshida

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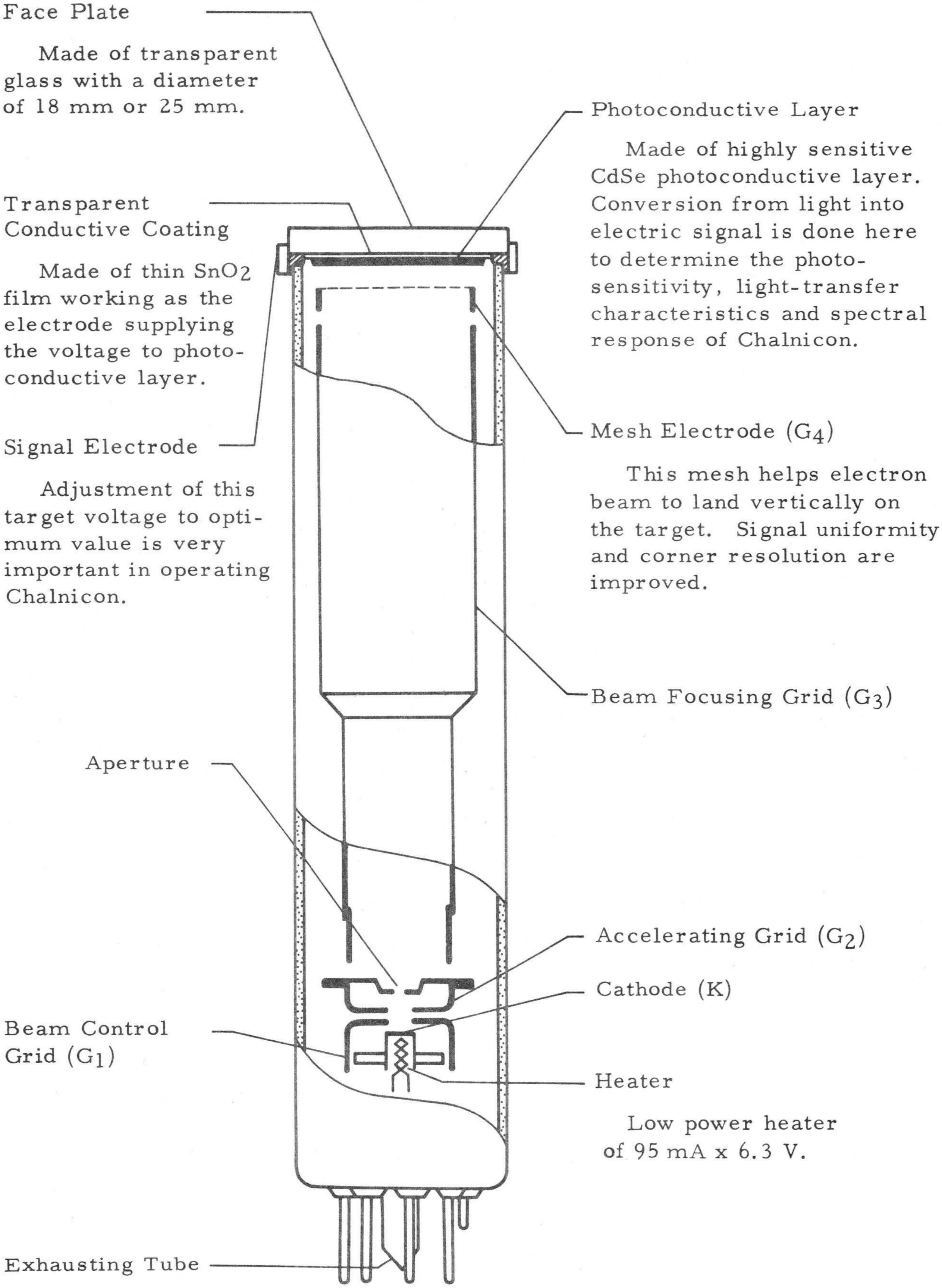

Fig. 1 Chalnicon Structure

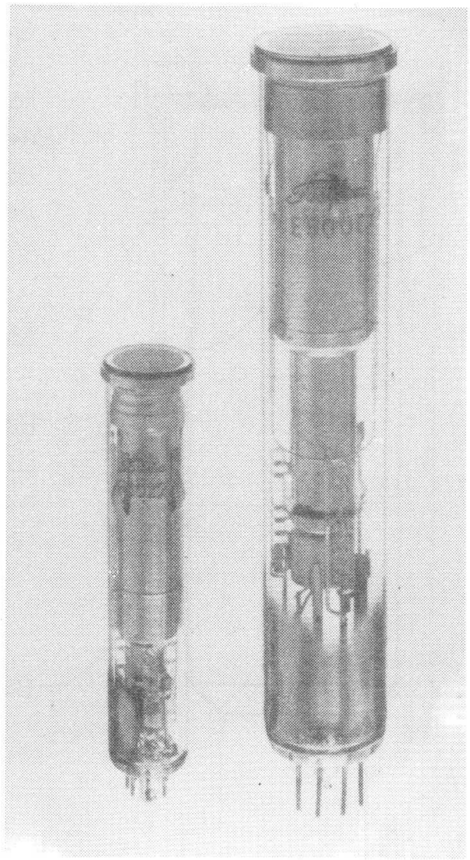

Fig. 2 Chalnicon (E5001 25 mm tube on the right and E5022 18 mm tube on the left).

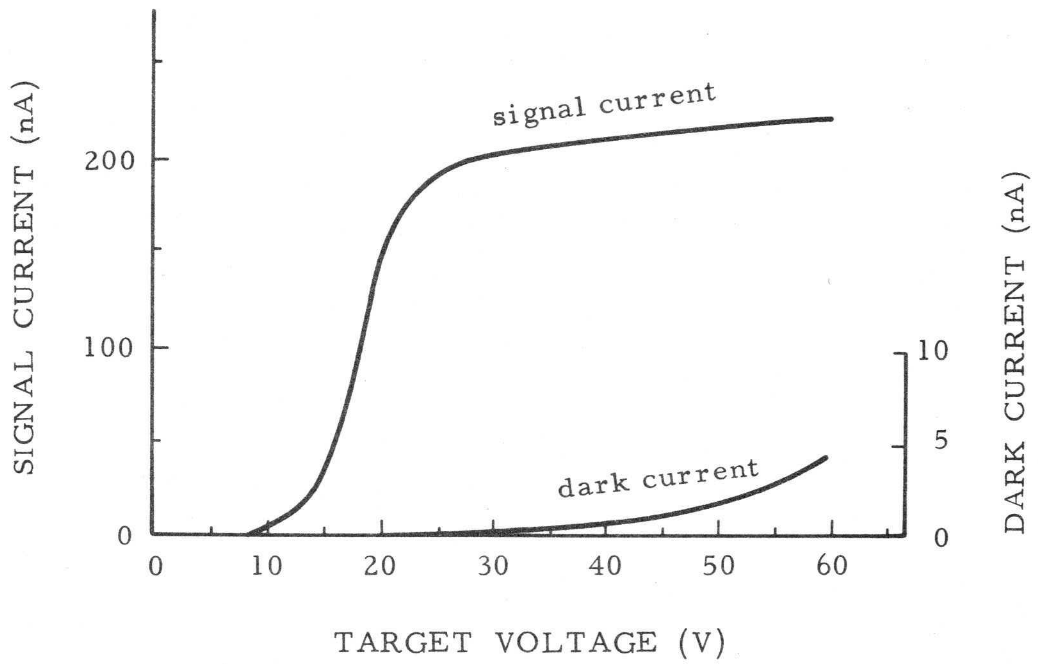

Fig. 3 Chalnicon Current-Voltage Characteristics

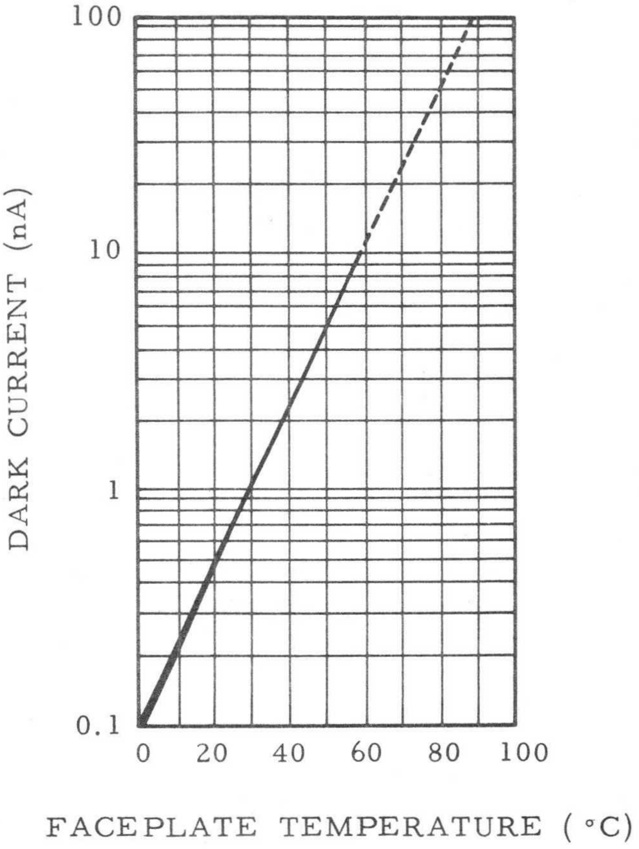

Fig. 4 Typical Dark Current - Temperature Characteristics

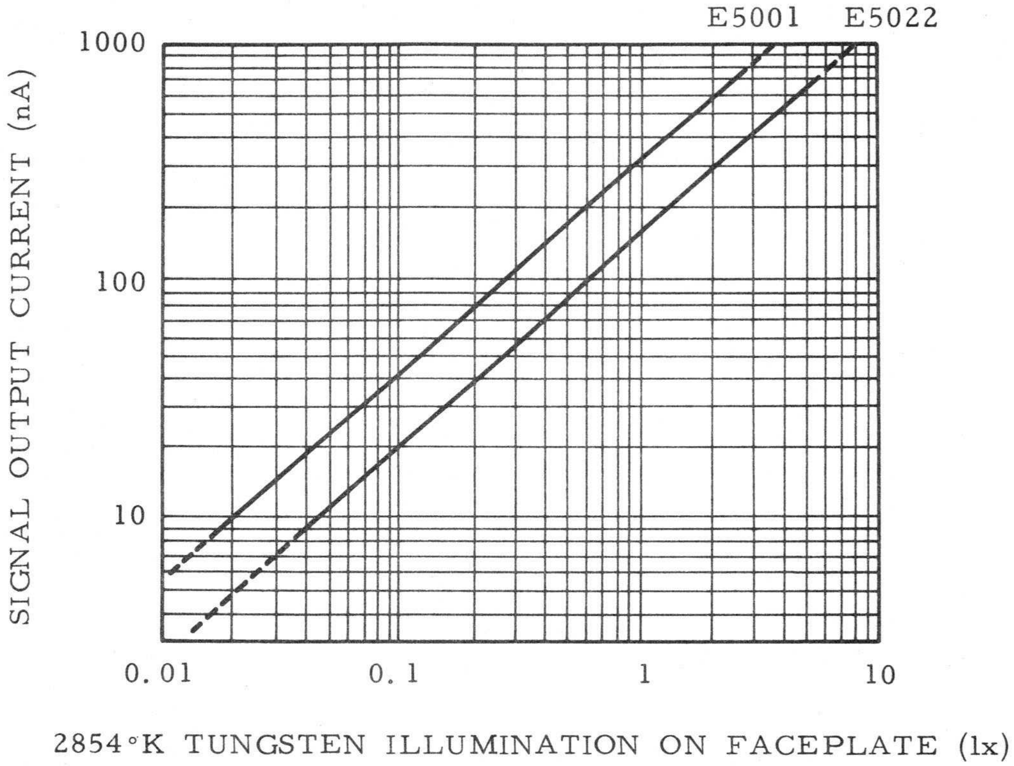

Fig. 5 Chalnicon Light Transfer Characteristics

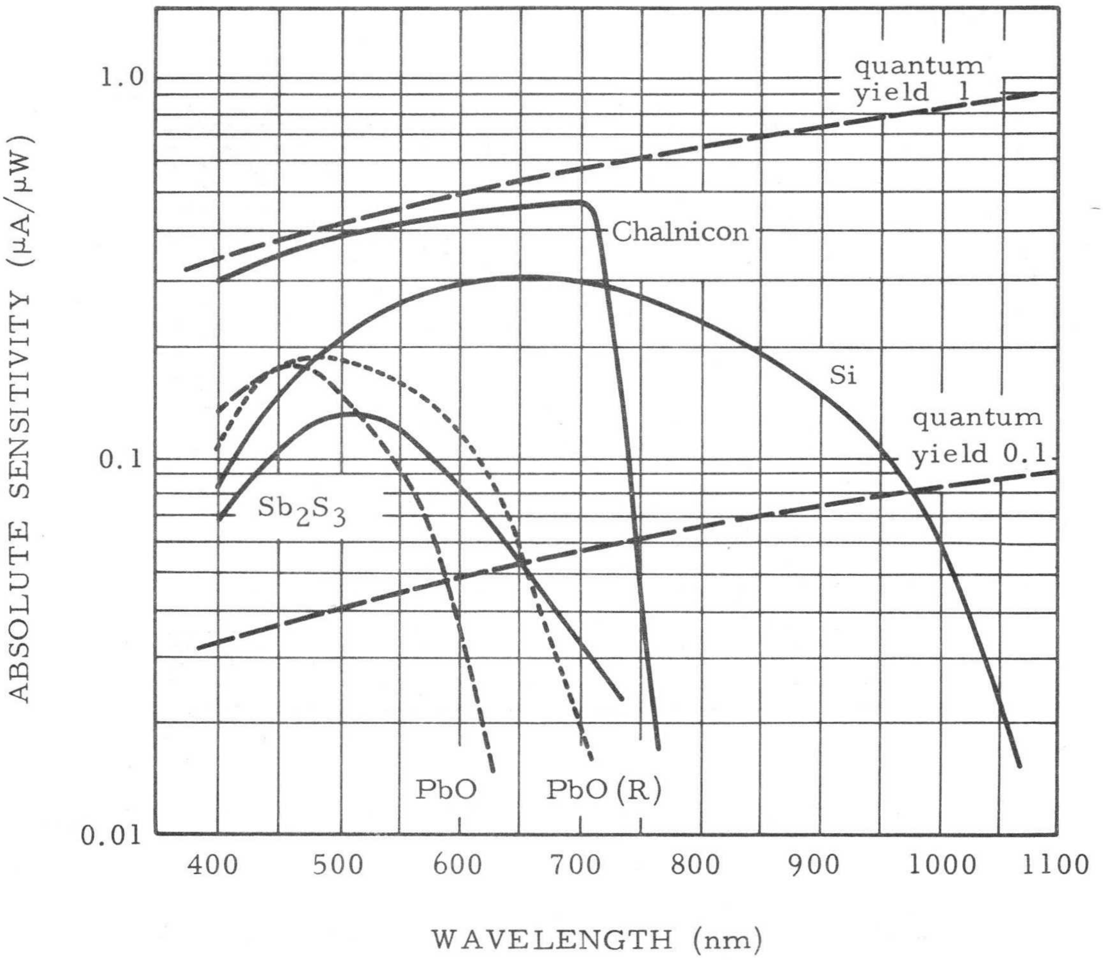

Fig. 6 Comparison of Spectral Sensitivities for Several Camera Tubes. (PbO (R) : PbO treated to extend the red sensitivity)

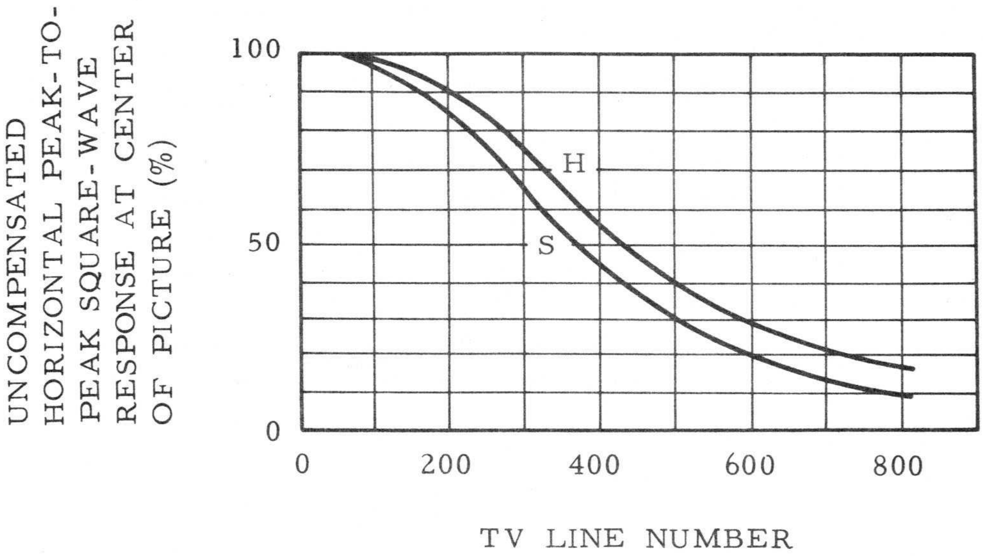

Fig. 7 Horizontal Square - Wave Response of E5001 Chalnicon. S : standard operation, E_{G3} = 300 V, E_{G4} = 500 V, H : high voltage operation, E_{G3} = 450 V, E_{G4} = 750 V. (Target Voltage Adjusted, Highlight Signal Current : 200 nA, Test Pattern : Transparent slant-line burst)

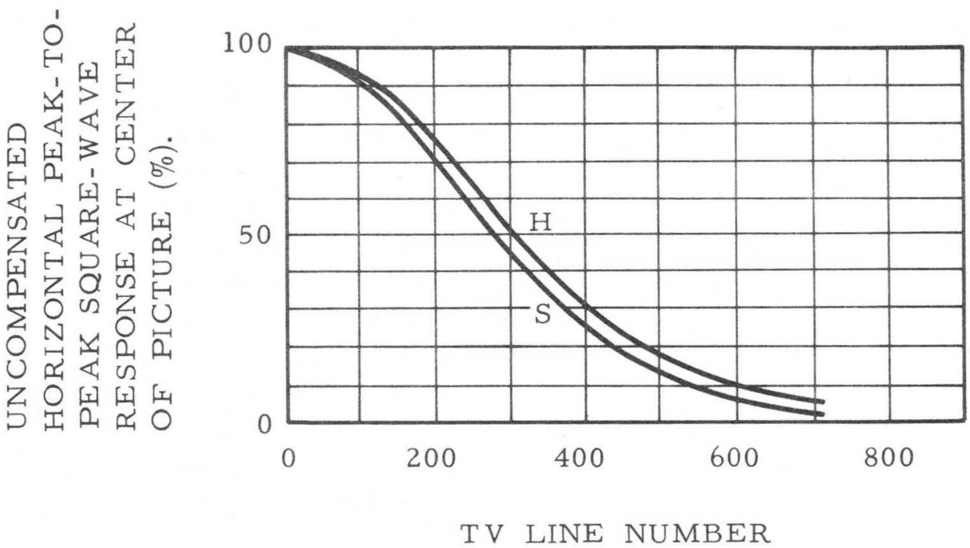

Fig. 8 Horizontal Square - Wave Response of E5022 Chalnicon. S : Standard operation, E_{G3} = 240V, E_{G4} = 400 V, H : High voltage operation, E_{G3} = 300V, E_{G4} = 500V. (Target Voltage : Adjusted, Highlight Signal Current : 200 nA, Test Pattern : Transparent slant-line burst)

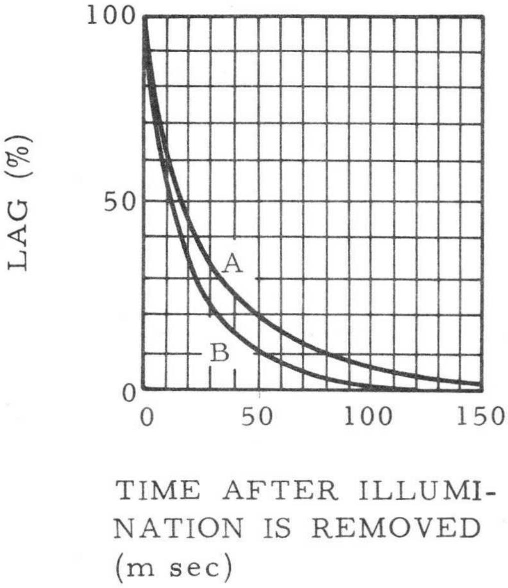

Fig. 9 Chalnicon Lag Characteristics.
A : E5001, B : E5022(Signal Current : 200 nA)

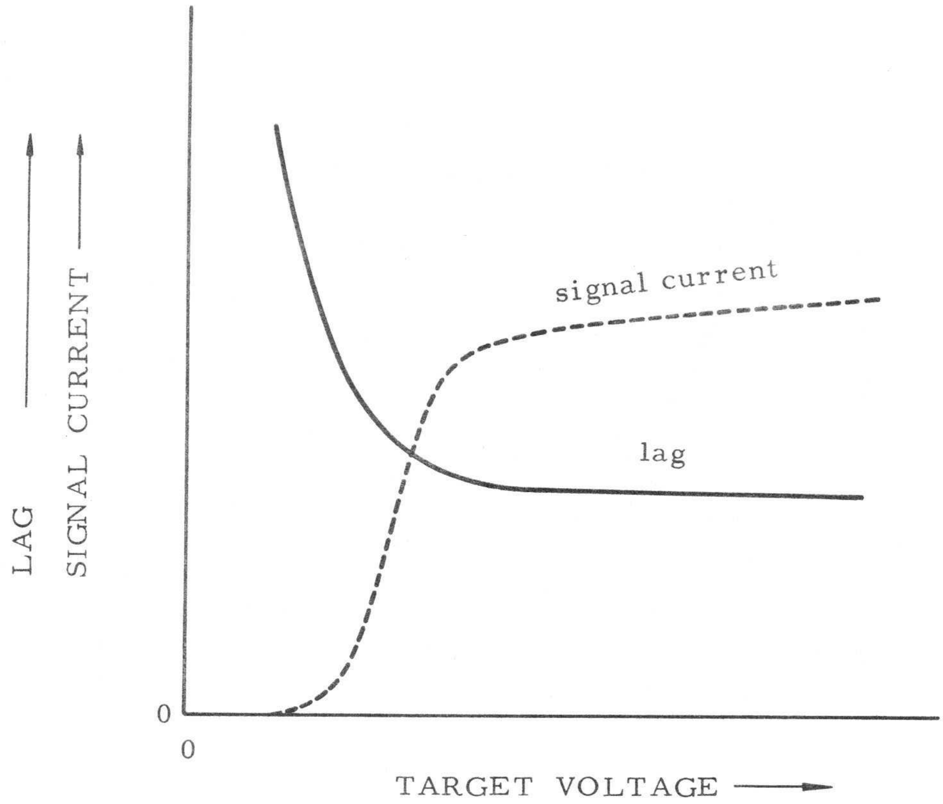

Fig. 10 Chalnicon I- V Curve and Lag.

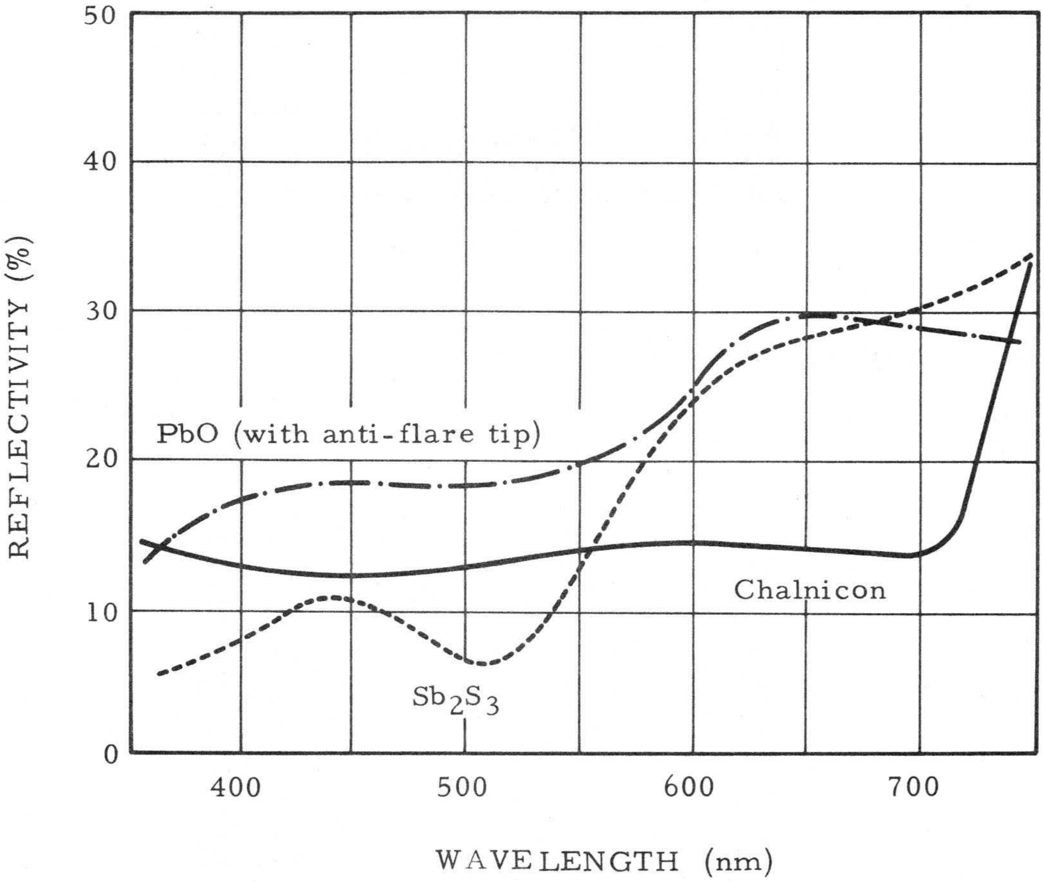

Fig. 11 Comparison of Reflectivitiy between Chalnicon and other camera tubes.

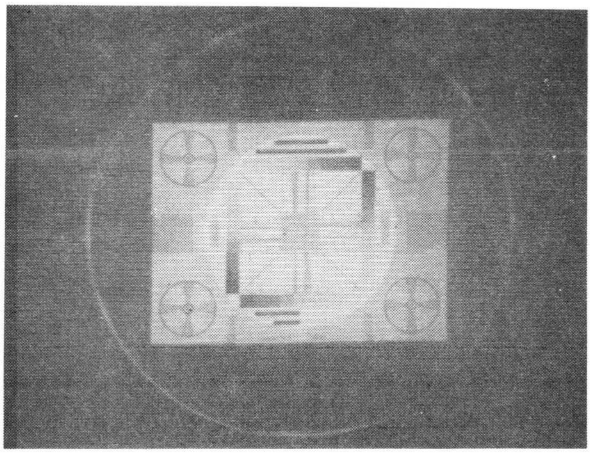

Fig. 12 Positioning the Raster Size by Test Pattern (RETMA Pattern).

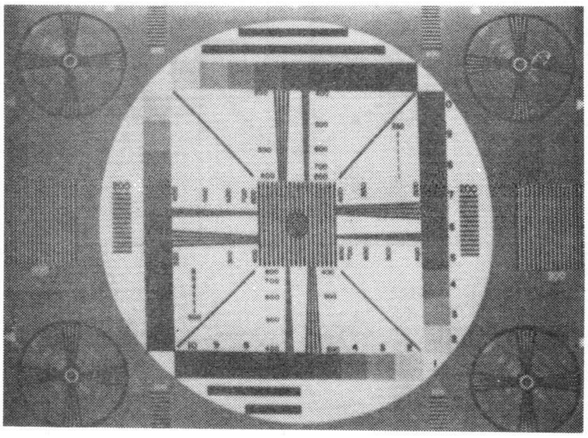

Fig. 13 Extension of the Test Pattern Image to the Edges of the Scanned Area on TV Monitor.

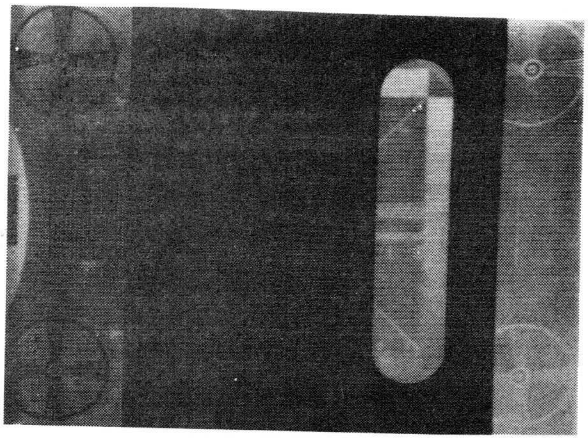

Fig. 14 Video Display when Target Voltage is below the Optimum Value. (Notice negative after image on the right)

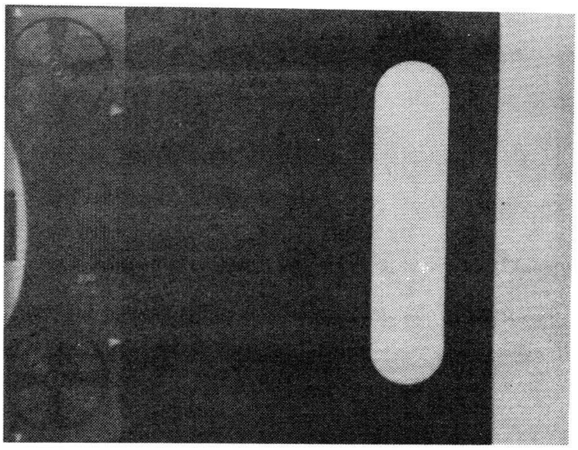

Fig. 15 Video Display when the Target Voltage is just the Optimum Value. (Notice that the negative after image is not seen on the right)

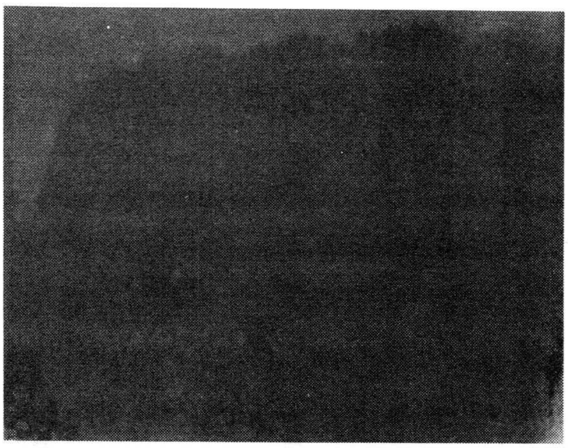

Fig. 16 Video Display with Deteriorated Picture Quality under the Dark when Target Voltage is exceedingly over the Optimum Value.

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