Oct. 13, 1959 P. K. WEIMER 2,908,835

PICKUP TUBE AND TARGET THEREFOR

Filed Oct. 4, 1954 4 Sheets-Sheet 1

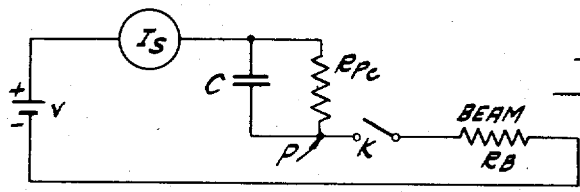

Fig-1

EQUIVALENT CIRCUIT OF A CONVENTIONAL SERIES-TYPE TARGET.

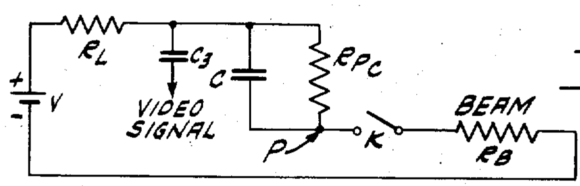

Fig-2

CIRCUIT FOR EXTRACTING THE SIGNAL CURRENT FROM A SERIES-TYPE TARGET.

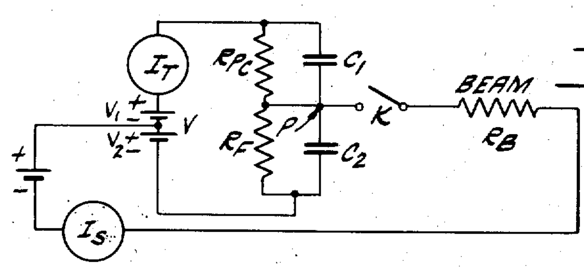

Fig-3

EQUIVALENT CIRCUIT OF A BRIDGE TYPE TARGET.

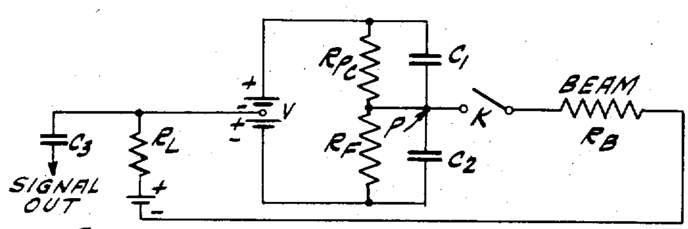

Fig-4

CIRCUIT FOR EXTRACTING SIGNAL FROM A BRIDGE-TYPE TARGET.

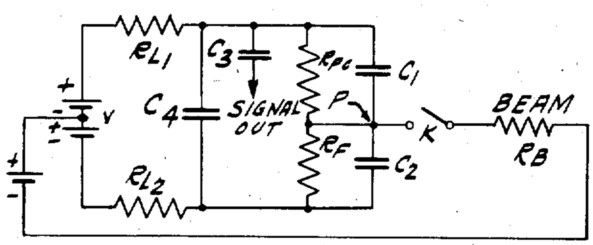

Fig-5

CIRCUIT FOR EXTRACTING SIGNAL FROM A BRIDGE-TYPE TARGET.

INVENTOR.
PAUL K. WEIMER
BY
William A. Zalesak
ATTORNEY

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Fig. 6

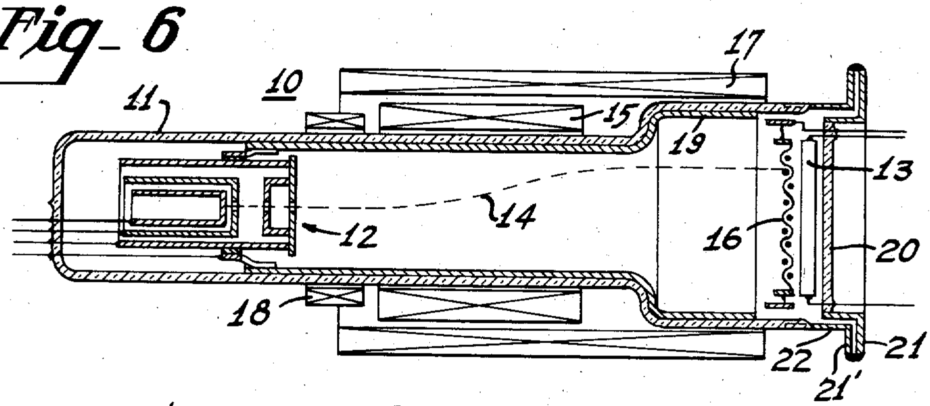


Fig. 7

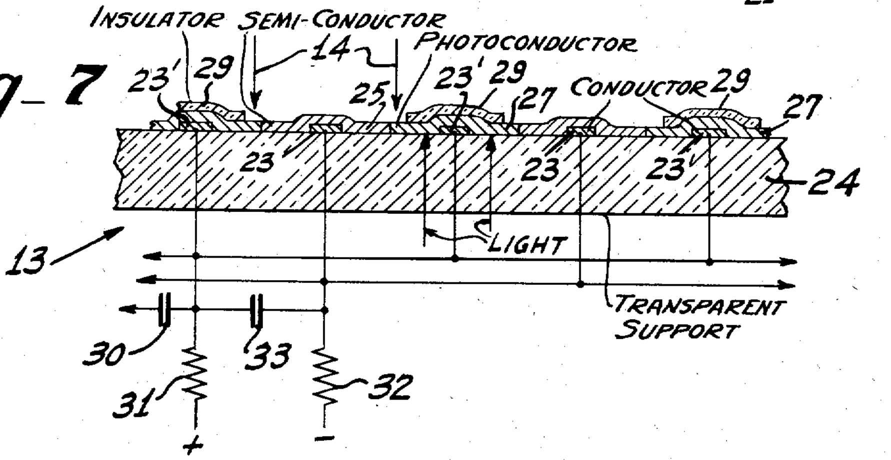
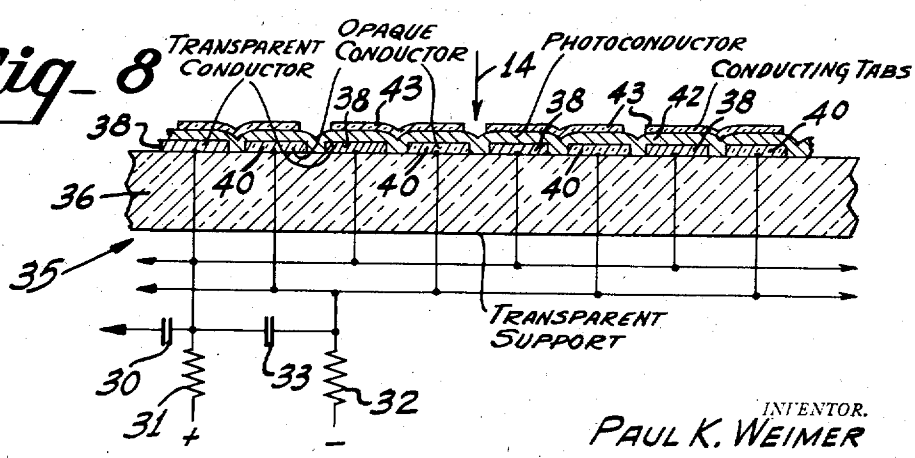


Fig. 8



INVENTOR.
PAUL K. WEIMER

BY William A. Zalesak
ATTORNEY

Oct. 13, 1959 P. K. WEIMER 2,908,835

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Fig-9

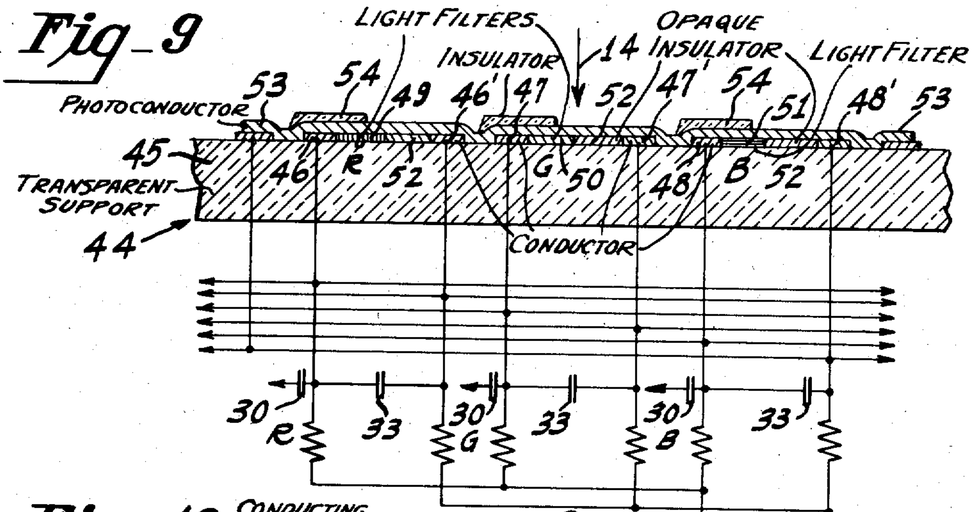


Fig-10

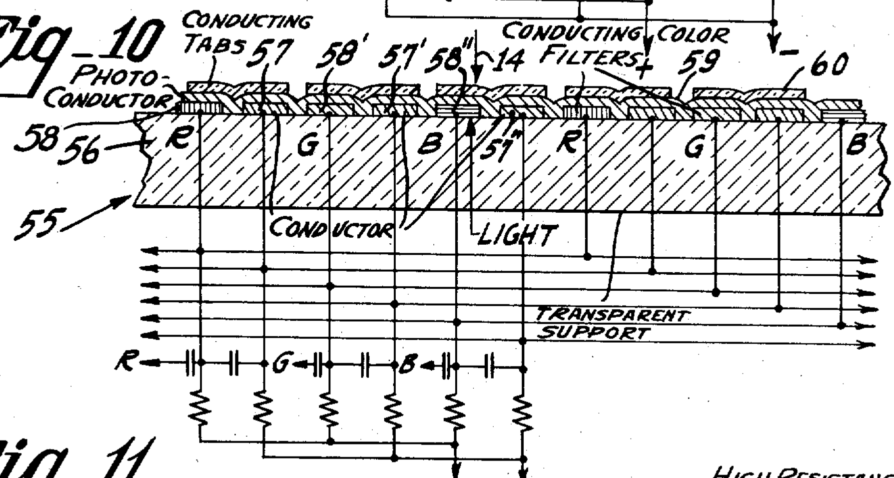
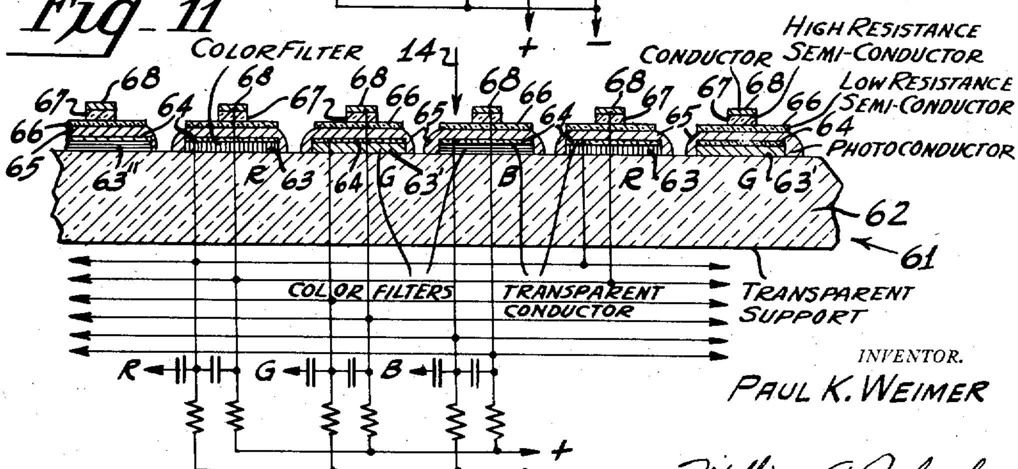


Fig-11



INVENTOR.

PAUL K. WEIMER

BY William A. Zalesak

ATTORNEY

Oct. 13, 1959 P. K. WEIMER 2,908,835
PICKUP TUBE AND TARGET THEREFOR
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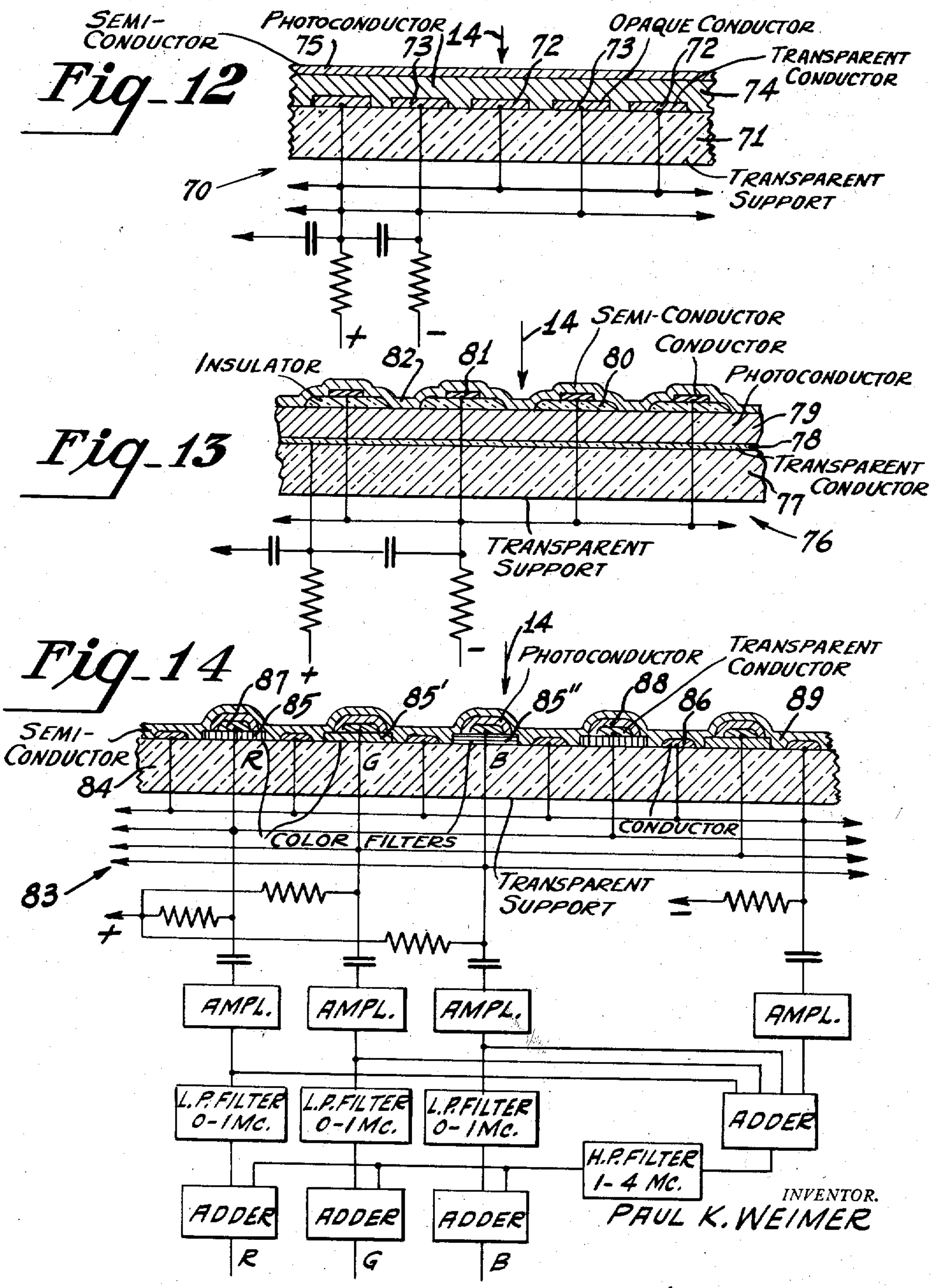

INVENTOR.
PAUL K. WEIMER

BY William A. Zalesak
ATTORNEY

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PICKUP TUBE AND TARGET THEREFOR

Paul K. Weimer, Princeton, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 4, 1954, Serial No. 459,971

19 Claims. (Cl. 313—65)

This invention relates to television camera tubes and particularly to improved television camera, or pickup, tubes having a novel target structure.

Conventional television camera tubes of the Vidicon type normally consist of an elongated envelope enclosing an electron gun in one end of the envelope. In the other end of the envelope is provided a transparent electrode, which is referred to as a signal plate. On the transparent electrode there is deposited a thin layer of photoconductive material. During operation, an electron beam from the electron gun scans the photoconductor to establish a charge thereon. When exposed to light, electron flow occurs between the two faces of the target through the photoconductive layer at the illuminated areas in accordance with the light intensity. This action produces a signal which can be used to transmit the scene picked up. While this arrangement makes a fairly simple target for television camera tubes, certain improvements result by using target structures made in accordance with this invention.

In the conventional television camera tubes which utilize a target including a photoconductive material, there is a limitation upon the materials which may be used as the photoconductor due to a requirement that the photoconductor be a material having a relatively high volume resistivity. This requirement occurs due to the fact that, when using the standard methods of operating camera tubes, the charge released by the photoconductor being exposed to light must be stored for the period of time occurring between successive scans by the electron beam. Since the scanning period is $\frac{1}{30}$ of a second, the volume resistivity of the photoconductor must be high enough to store charges for this period of time. The lower limit on the volume resistivity of the photoconductive materials which can be used in conventional targets is approximately 10^{11} ohm-centimeters. Several known photoconductive materials have extremely high sensitivities but have resistivities that are lower than the 10^{11} ohm-centimeters requirement and thus cannot be used in conventional target structure. Since these highly sensitive materials cannot be used, prior to this time, a compromise has been made between a lower sensitivity and a higher resistivity in selecting a photoconductive material.

Furthermore, when using conventional target structures, a storage time as long as $\frac{1}{30}$ of a second has certain disadvantages. As an example, in certain types of television transmission, it is often desirable to transmit pictures of rapidly moving objects. When the storage time is $\frac{1}{30}$ of a second blurred images occur in attempting to televise these rapidly moving objects.

Still further, in tubes utilizing conventional target structures and when utilizing a low velocity electron beam, the capacity of the target, i.e. the capacity between the signal plate and the photoconductor, must be kept below several thousand micro-micro-farads for the beam to discharge the target in one scan. When objectionable capacity lag occurs, i.e. capacity lag longer than the $\frac{1}{30}$ of a second scanning period, signals from one frame are carried over into the next frame resulting in a poor reproduction of the scene. In other words, objectionable capacity lag occurs when the target is not discharged by one scan of the electron beam. In order to keep the capacity small in prior art targets, the photoconductor must be made thicker than would otherwise be desirable for maximum sensitivity.

It is therefore an object of this invention to provide a novel target structure for television camera tubes which permits the use of photoconductive materials having relatively low volume resistivities but which nevertheless provides the high sensitivity required in tubes of this type.

It is a further object of this invention to provide a novel target structure for television camera tubes which eliminates capacity lag effects and thus permits more effective transmission of rapidly moving objects.

A further object of this invention is to provide a new and more sensitive target for television camera tubes wherein it is not necessary for the electron beam to completely discharge the target in a single scan.

A still further object of this invention is to provide an improved camera tube having improved sensitivity.

These and other objects, applicable to television camera tubes of the monochrome type or the tri-color type, are accomplished in accordance with this invention by providing a television camera tube having a novel and an improved photoconductive type of target. In the various embodiments of the target shown and described, the photoconductive material functions in conjunction with a plurality of spaced apart signal output electrodes in a manner such that the resistance of the photoconductor forms one arm of a bridge while a fixed resistance forms a second arm of a bridge resulting in a bridge type equivalent circuit. The bridge type target may be incorporated into targets having the conventional transverse electron flow or in targets having lateral electron flow which will be described below.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself will best be understood by reference to the following description taken in connection with the accompanying four sheets of drawings and in which:

Fig. 1 is an equivalent circuit diagram of a conventional series type target;

Fig. 2 is the equivalent circuit diagram of Fig. 1 modified to illustrate a method of extracting the signal from the circuit of Fig. 1;

Fig. 3 is an equivalent circuit diagram of a bridge type target made in accordance with this invention;

Figs. 4 and 5 are equivalent circuit diagrams of Fig. 3 modified to illustrate methods of extracting the signal from the circuit of Fig. 3;

Fig. 6 is a longitudinal sectional view of a camera tube utilizing a target in accordance with this invention;

Fig. 7 is an enlarged fragmentary sectional view of a target of the lateral current flow bridge-type in accordance with this invention for use in a monochrome type pickup tube as shown in Fig. 6;

Fig. 8 is an enlarged fragmentary sectional view of a modification of a target of the transverse flow bridge type in accordance with this invention for use in a monochrome camera tube such as the tube shown in Fig. 6;

Figs. 9 through 11 inclusive are enlarged fragmentary sectional views of modifications of target structures in accordance with this invention for use in a tri-color pickup tube such as the tube shown in Fig. 6;

Figs. 12 and 13 are enlarged fragmentary sectional views of modifications of target structures in accordance with this invention for use in a monochrome type of camera tube such as the tube shown in Fig. 6; and,

Fig. 14 is an enlarged fragmentary sectional view of a modification of a target structure in accordance with this invention for use in a tri-color type of camera tube such as the tube shown in Fig. 6.

Referring to Fig. 6 there is shown a pickup or camera, tube **10** comprising a vacuum tight envelope **11** having an electron gun **12** mounted in one end thereof. The electrodes of the electron gun **12** include the usual cathode, control electrode, and one or more accelerating anodes which are connected to lead-in means in the well-known manner. An electron beam **14** from the gun **12** is directed upon a target **13** at the other end portion of envelope **11**. Means are provided for focusing the electron beam **14**, and scanning the beam **14** over target **13** to form a raster. These means may include a focus coil **17**, a deflection yoke **15**, and an alignment coil **18** as shown. An electrode **16** is positioned adjacent to the target **13** and, in operation, together with focus coil **17** cooperates to insure that the electron beam **14** in its final approach to the surface of target **13** is normal thereto. A final accelerating electrode **19** may take the form of a conductive coating on the interior of envelope **11**. Fingers mounted on the gun **12**, but insulated therefrom, serve to connect conductive coating **19** to one of the lead-in pins.

Target **13** is conventionally supported adjacent to a transparent window **20** and has terminal pins sealed therethrough as shown. The transparent window **20** is supported in the end of the envelope **11** by means of a hollow metallic member **21** which is in turn welded to a similar hollow metallic member **21'** that is sealed to the body portion of envelope **11**.

The various elements of camera tube **10** that are referred to above are conventional. In a conventional tube the target **13** comprises a transparent conductive electrode, or signal plate supported adjacent to the window **20**, and a photoconductive layer on the signal plate. The elements of a target electrode that are normally included in a conventional tube are not shown in detail.

Referring now to Fig. 1 there is shown schematically an equivalent circuit of a conventional photoconductive pickup tube. This circuit is shown for the purpose of more clearly explaining applicant's invention and forms no part of this invention. In this circuit R_{PC} and C represent the elemental photoconductive resistance and capacitance respectively, which exists between the scanned surface of the photoconductive layer and the signal plate. The light sensitive target element is connected at point P, i.e. where the beam strikes the target, in series with a voltage supply V and an electron beam through a switch K which is normally open but which is closed momentarily each $\frac{1}{30}$ of a second for a period of

$$\frac{1}{30}\cdot\frac{1}{N}$$

seconds, where N is the total number of picture elements. The beam resistance R_B has a value of approximately 10 megohms for low velocity scanning.

Two conditions must be satisfied for charge storage type of operation of conventional photoconductive pickup tube targets, ie. those of a type schematically shown in Fig. 1. These conditions are: (1) the time constant for storage purposes, which is given by the product of R_{PC} times C, must exceed $\frac{1}{30}$ of a second for frame storage, or $\frac{1}{15000}$ of a second for line storage; and (2) the time constant for discharge purposes, which is given by R_B times C, must be less than

$$\frac{1}{30\,N}$$

seconds in order for the beam to discharge the target in one scan.

These two conditions can be expressed in terms of the total resistance and the capacity of the entire target. When so expressed, for frame storage, condition (1) above is $R_{PCT}.C_T$ must be greater than $\frac{1}{30}$ of a second.

While condition (2) above, when so expressed is $R_B.C_T$ must be less than $\frac{1}{30}$ of a second.

where: R_{PCT} is the parallel resistance of the entire scanned surface.

Condition (1) above establishes a lower limit on the volume resistivity of the photoconductor which can be used in a conventional tube. For conventional targets, operating with transverse flow and frame storage, the volume resistivity must be 10^{11} ohm-centimeters or greater. Lateral flow targets, i.e. where current flow is substantially parallel to the target, permit the resistivity to be as low as 10^9 ohm-centimeters. For line storage these values are each reduced by a factor of 500.

Condition (2) above establishes an upper limit of several thousand micro-micro-farads on the total capacity of the target in a conventional tube for a beam resistance of 10 megohms. A practical lower limit of the capacity is set by the amount of stored charge required to give a signal sufficiently large for an adequate signal-to-noise ratio.

The signal current I_S, which flows in the series circuit shown schematically in Fig. 1, could be measured and utilized in two ways. One method consists of inserting a load resistor R_L in series with the signal plate and coupling the resulting voltage fluctuation into an amplifier as shown in Fig. 2.

Alternatively, the load resistor may be omitted and the signal current fluctuation may be measured indirectly by collecting and amplifying the fraction of the electron beam which fails to be deposited on the target. Both of these methods of extracting a signal are conventional and form no part of the present invention, and are shown merely to illustrate the principles of this invention.

In principle, conventional series type photoconductive pickup tube targets wherein the photoconductor has a resistivity which is too low for charge storage operation can be operable. However, such targets have never performed satisfactorily in the past. The reason for this is that the high dark current places severe demands on the uniformity on the secondary emission on the conductivity of the target. Thus, from a practical standpoint, charge storage for at least line time and preferably for frame time is necessary. The present invention permits satisfactory operation without requiring charge storage.

Referring now to Fig. 3 there is shown an equivalent circuit, for a picture element, of a tube, such as tube **10** shown in Fig. 6, utilizing a bridge type target, such as the target shown in Fig. 7, and in accordance with this invention. In this instance, the photoconductive resistance R_{PC} forms one arm of a potentiometer bridge circuit, instead of the series connected circuit of Fig. 1. The other arm of the bridge comprises a fixed resistance R_F. A potenital difference V_1+V_2 is applied across the elemental bridge. The scanning beam makes contact, at point P, with the target by closing switch K at the junction of the light-sensitive resistance R_{PC} and the fixed resistance R_F. The resistance and voltages are so chosen that, in the absence of light, the bridge balances at the dark potential required by the scanning beam. For low velocity scanning the dark potential may equal the gun cathode potential. When light falls on the target, the variable resistance R_{PC} decreases and the point P assumes a different potential, which depends upon the new value of the ratio of R_{PC} to R_F. For low velocity scanning the maximum light potential may be several volts above the potential of the gun cathode. The fraction of the beam deposited at point P, which depends upon the potential of point P, provides the signal current. As will be explained hereinafter both the fixed resistance R_F and photoconductive resistance R_{PC} may be obtained from the photoconductive material by shielding portions of the photoconductor from the light to result in a fixed resistance. Alternatively, the fixed resistance can be obtained from a non-photoconductive semi-conductor.

An important feature of the bridge type targets in accordance with this invention, is that the conditions (1) and (2) which have been set forth above, no longer have the same significance. The charge storage time constant of the bridge type target is given by the expression

$$\frac{R_{PC}R_F}{R_{PC}+R_F}\cdot(C_1+C_2)$$

A significant difference of the bridge type target, as compared to conventional targets, is that satisfactory output signals can be generated using photoconductors in which this time constant is considerably less than that necessary for storage purposes in conventional targets. For a very fast photoconductor, i.e. one having a time response much less than $\frac{1}{30}$ of a second, this means a slight reduction in sensitivity but a great improvement in the definition obtainable when televising rapidly moving objects. If the photoconductor has a time response of approximately $\frac{1}{30}$ of a second, a low resistivity will not limit the sensitivity of the target nor will it have any effect on the sharpening of the resolution of moving objects. The lower limit on the resistivity of a photoconductor in a bridge type target in accordance with this invention, is probably established by the current carrying capabilities of the target structure, and by the sensitivity of the photoconductor which must be more sensitive for lower resistivities in order to provide adequate potential variations to effectively modulate the beam. The dark current through the bridge circuit does not appear in the output signal and does not have to be carried by the beam.

The condition, set forth above, for discharge purposes to avoid lag in conventional tubes, is not necessary in tubes utilizing bridge type targets in accordance with this invention, provided the frame storage time constant is less than $\frac{1}{30}$ of a second. Under these conditions, the target is self-discharging when the light is removed and does not require the beam for discharge. A consequence of this feature is that the capacity of the target can be larger than would be permissible if it were necessary to satisfy the the second condition set forth above. Thus, the photoconductor can be made thinner than is possible when utilizing conventional series type targets. The thin photoconductor makes possible improved sensitivity and, when desired, larger target areas.

Referring now to Fig. 4 there is shown a method of inserting load resistors in the equivalent bridge type circuit shown in Fig. 3. The voltage fluctuations produced by the load resistance R_L are coupled to a video amplifier (not shown) by means of coupling capacitor C_3. An alternative method is shown in Fig. 5. The load resisotrs R_{L_1} and R_{L_2} are connected to the opposite branches of the bridge circuit. The external capacitor C_4 may be inserted to insure that the complete video signal is obtained. In practice capacitor C_4 may be unnecessary because its function is accomplished by the internal series capacity C_1 and C_2. The total video signal is coupled to an amplifier (not shown) through the coupling capacitor C_3. As an alternative of the methods of obtaining the output signal from a tube having a bridge type target, the signal may be obtained from the return beam which is collected and directed into an electron multiplier. In this case the load resistors R_{L_1} and R_{L_2} may be omitted. It should be understood that in the equivalent circuit diagrams of Figs. 3–5 that the light sensitive resistance may be the negative arm of the bridge, rather than the positive arm of the bridge as shown, in which case an inverted polarity signal results. Also, the mean potential of the bridge may be raised considerably above gun cathode potential for high velocity scanning.

The tolerance of high capacity and high dark current in the bridge type target in accordance with this invention makes this type of target especially suitable for use with P–N junctions as the light sensitive resistance. Such photosensitive barriers have intrinsically fast response and good sensitivity, but are difficult to make for the conventional series type targets because of their high dark current and high capacity per unit of target area.

Referring now to Figs. 6 and 7 there is shown a new and improved pickup tube **10** in accordance with this invention. Certain elements of tube **10**, which are conventional, have been previously described. However, in accordance with this invention a target **13**, which is shown more clearly in Fig. 7, comprises a support, or backing, plate **24** which may be of a material such as glass. The support plate **24** may be omitted when desired and the balance of the target **13** may be supported directly on the transparent window **20**, shown in Fig. 6, which then also serves the same function as support plate **24**. There is provided on the surface of the support plate **24**, which is normally scanned by the electron beam **14**, a plurality of spaced apart conducting signal strips **23** and **23'**. In contact with, and extending on each side of each of the signal strips **23'**, is a strip of photoconductive material **27**. In contact with, and extending on each side of signal strip **23** is a non-photoconductive strip of semi-conducting material **25**. The semi-conductive material **25** extends along the support member **24** and is in contact along its edges with the photoconductor strips **27**. On the exposed surface of photoconductive material **27**, i.e. the surface upon which beam **14** lands, there is provided a plurality of strips of insulating material **29**. As can be seen from the drawing each of the strips of insulating material **29** is adjacent one of the signal strips **23'**. It should be understood that the insulating strips **29** are optional and may be omitted if the benefits of the coplanar grid effect are desired.

Connected to each of the plurality of signal strips **23'** is a resistor **31** (R_{L_1} of Fig. 5). Connected to each of the plurality of signal strips **23** is a resistor-capacitor circuit which includes a load resistor **32** (R_{L_2} of Fig. 5) and a capacitor **33** (C_4 of Fig. 5), the latter of which is connected to the junction between resistor **31** and capacitor **30**. As shown in the drawings, the other end of the resistors **31** is connected to the positive side of a potential source while the other end of resistor **32** is connected to the negative side of a potential source. The other side of capacitor **30** is connected with the first amplifier stage (not shown) after the camera tube.

In the embodiment shown in Fig. 7 the fixed resistance (R_F of Fig. 3) is obtained by means of the resistance of the semi-conductor **25**, while the variable resistance (R_{PC} of Fig. 3) of the bridge comprises the photoconductor **27** which is exposed to light, i.e. the areas adjacent the signal strips **23'**.

As shown in the drawings, the lead-ins for the signal strips **23** and **23'** extend through the support plate **24**. This method of illustration is utilized merely for ease of illustrating the appropriate connections. In actual practice, the ends of the conducting strips **23** and **23'** would be connected together inside the envelope **11** and each set would have a common lead extending through the walls of envelope **11**.

The support plate **24** may be constructed of any transparent material such as glass, mica, or quartz, and may be of any thickness ranging from more than ⅛ inch down to less than one-thousandth of an inch. As an alternative to the materials mentioned for the support plate **24**, the support plate may be made of a thin transparent membrane such as aluminum oxide stretched on a rigid frame (not shown). Still further, the transparent window **20** may serve as the support plate. Alternatively, the photoconductor sheet or the signal strips may be made sufficiently rigid that the entire target structure can be self-supporting inside the tube without contact to any support plate. A still different method of supporting the target, which is not illustrated, is to use a thin sheet of semi-conducting material or a support plate on the beam side of the target. A thin sheet of lime glass about 5 microns thick has the proper resistivity to conduct the signal current through the glass without loss of resolution by lateral leakage.

The signal strips **23** and **23'** may be composed of some highly conductive material such as aluminum, gold, or tin oxide, and may be of a width ranging from substantially ½ mil. to several mils. The number of signal strips **23** and **23'** for any given target **13** will be determined by the definition required in the picture to be reproduced, and generally should be from about 500 to several thousand for a high quality picture. The signal strips **23** and **23'** may be thin strips of conducting material approximately 100 to 1000 Angstrom units thick applied to the support plate **24** by well-known means such as evaporation, or they may be metallic strips of metal heavy enough to support the entire target.

The photoconductive material **27** may be any of the well-known highly sensitive photoconductive materials such as antimony sulfide, cadmium selenide, cadmium sulfide, or selenium. The photoconductive material **27** may be of a thickness within the range of approximately 1000 Angstrom units thick to several microns. The resistivity of the photoconductive material **27** may vary over a wide range and may be as low as 10^6 ohm-centimeters. The photoconductive layer may be deposited by evaporation, crystallization, chemical reaction, or other well-known means.

The insulating strips **29** may be any of the well-known goods insulators such as zinc sulfide, magnesium fluoride or aluminum oxide. The thickness of insulator strips **29** should be of a thickness that is sufficient to insulate the junction between a signal strip **23'** and the photoconductor sheet **27** from bombardment by the electron beam **14**. An insulator of approximately 1 micron in thickness is usually sufficient.

The semi-conductive strips **25** may be any semi-conductive material which is not a photoconductor. One example of such material is germanium. The thickness and the resistivity of the semi-conductor should be so chosen so that with reasonable applied voltages the exposed areas of photoconductor **27** will balance to ground in the dark, and further, that leakage along the semi-conductor **25**, parallel to the strips **23**, will not be great enough to deteriorate resolution.

The target **13** may be oriented in any desired manner within the tube **10**. For example, the signal strips **23** and **23'** may be arranged parallel or perpendicular to the direction of scan. The pickup tube **10** may be operated in several ways and both low and high velocity operation of the electron beam is suitable.

During operation of the tube **10**, potentials are applied to the various electrodes to form an electron beam **14** which is directed toward the target **13**. The electron beam **14** is scanned across the surface of target **13** in a rectangular raster by magnetic deflecting fields produced by the deflecting yoke **15**. The deflection yoke **15** normally consists of two pairs of magnetic coils with the coils of each pair connected in series and positioned on opposite sides of the envelope **11**. The pairs of coils are arranged so that the field produced by one pair is substantially normal to the field produced by the other pair of coils. Each pair of coils is connected to appropriate sources of voltages (not shown) to produce both horizontal deflection and vertical deflection of the electron beam **14** in a conventional manner to provide a rectangular scansion raster. The means for producing this type of scansion raster is well-known and is not considered further as it is not a part of this invention.

Electrons from the beam **14** will be deposited upon the exposed areas of the photoconductor sheet **27**, and upon the strips of insulating material **29**, until the potential of the insulating strips is driven substantially to the potential of the cathode of the electron gun **12**. The electron beam **14** lands on the target **13** and the charge deposited is determined by the potential existing on the storage area of the photoconductor **27**. These charged

storage areas comprise the portion of the photoconductor sheet that is between an end of an insulating strip **29** and an adjacent insulating strip **25**. The target **13** has two separate resistance elements. One of these resistance elements is the resistance of the photoconductor which is beneath an insulator strip **29**. The resistance of the photoconductor which is underneath an insulating strip **29** is the variable resistance which is described in connection with Figs. 3 through 5 as R_{PC}. The other resistance of target **13** is the resistance of the semi-conductor **25**. The resistance of the areas of semi-conductor **25** is the fixed resistance which is described in connection with Figs. 3 through 5 as R_F. When the elemental areas of the target **13** are not illuminated by a scene to be reproduced, the fixed and variable resistances are substantially equal. When an elemental area of the target **13** is illuminated, the variable resistance is decreased and the potential of an elemental area of the photoconductor rises a few volts. When the electron beam **14** scans over an elemental area which has a potential that is slightly positive, electrons are deposited in the storage areas of the photoconductor and a video signal is generated in the signal strips **23** and **23'** by virtue of the target capacity existing between the strips and the storage area. This signal is coupled to the first tube of the video amplifier (not shown) by means of the capacitors **30** and **33**.

As can be seen from Fig. 7, the capacity of the target **13** is a parallel combination of the capacity existing between the storage area and the adjacent signal strips **23** and **23'**. This parallel combination is illustrated by capacitors C_1 and C_2 in the equivalent circuit of Figs. 3, 4 and 5. Since these capacitors are shunted by the variable, or photoconductor resistance R_{PC}, and by the fixed resistance R_F, the target capacity does not need to be discharged completely by a single scan of the beam **14** to avoid capacitive lag. In other words, when an image is removed from the target, the elemental storage areas return to zero or dark potential regardless of whether the elemental area is scanned or not simply by flow of current in the bridge formed by the fixed and the variable resistances.

There is no objectionable lag in target **13** if the RC time constant of the target is substantially less than the $\frac{1}{30}$ of a second scanning period. Since the RC time constant is the product of the parallel combination of the fixed and the variable resistances and the parallel combination of the capacitors C_1 and C_2, the RC time constant may be varied by varying the resistivity and thickness of the photoconductor or by varying the spacing of the signal strips.

Although some photocurrent is wasted by leaking off of the charge from the elemental storage areas, through the fixed resistor, this loss of photocurrent is more than compensated for by the freedom given the tube designer in being able to operate with a target time constant that is less than $\frac{1}{30}$ of a second. Due to the fact that it is possible to operate with an RC time constant of less than $\frac{1}{30}$ of a second, photoconductive materials having lower volume resistivities may be utilized. In fact, volume resistivities of the photoconductor as low as 10^6 ohm-centimeters are usable. Furthermore, due to the fact that the storage time may be reduced below $\frac{1}{30}$ of a second, the images of rapidly moving objects will be sharp discreet images.

Referring now to Fig. 8, there is shown a partial sectional view of a modification of this invention. The target **35** comprises a support plate **36** having on the beam side thereof, a plurality of spaced apart transparent conducting strips **38**. On the surface of the support plate **36** and spaced in between each of the signal strips **38** is a strip of opaque conducting material **40**. The plurality of transparent conducting strips **38** and the opaque conducting strips **40** function as the signal strips for the target **35**. The strips of transparent conducting materials **38** are connected together and to an output circuit comprising a coupling capacitor **30** and a load resistor **31**, while the opaque conducting strips **40** are connected together and to a circuit comprising a coupling capacitor **33** and a load resistor **32** as was described above.

Covering the exposed areas of the opaque conducting strips **40**, and the transparent conducting strips **38**, is a sheet of photoconductive material **42**. Covering the exposed surfaces of the photoconductive material **42**, over each pair of transparent signal strips **38** and opaque signal strips **40**, is a plurality of short conducting tabs **43**. The photocurrent through the bridge circuit of target **35** is substantially from the transparent signal strips **38** through the photoconductor to the conducting tab **43**, then parallel to the surface along the tab to an area above an opaque strip, then through the photoconductor to the underlying opaque strip **40**. This flow of current in the photoconductor is substantially transverse to the target, whereas in Fig. 7 the photocurrent was substantially parallel to the target surface. The fixed resistance (R_F of Figs. 3 through 5) of the bridge is the resistance of the photoconductor **42** in the areas over the opaque strips **40** while the variable resistance (R_{PC} of Figs. 3 through 5) of the bridge is the resistance of the photoconductor in the illuminated areas.

The short conducting tabs **43** may be of any highly conductive material such as aluminum, gold, or tin oxide and each covers a rectangular area of one to three thousandth of an inch on a side and may be of a thickness of 100 to 1000 Angstroms. The other materials shown in the modification of the target structure described in connection with Fig. 8 are similar to those set forth above in connection with Fig. 7 and further description thereof is not deemed necessary at this time.

Referring now to Fig. 9 there is shown an enlarged fragmentary view of an embodiment of a target structure in accordance with this invention for use in a tri-color, lateral flow, bridge type target. The target **44**, which may be inserted in tube **10** shown in Fig. 6, comprises a support plate **45** having on the beam side thereof a plurality of spaced apart conducting signal strips **46** and **46′** for the red, **47** and **47′** for the green, and **48** and **48′** for the blue. Arranged on the surface of the support plate **45** between each respective pair of signal strips, and contiguous to one of the signal strips, is an insulating light filter strip **49** for the red, **50** for the green, and **51** for the blue. A plurality of opaque insulator strips **52** is provided each of which is arranged in between a respective filter strip and conducting signal strip, and on the surface of the support plate **45**. Covering the exposed surfaces of the signal strips, the color filter strips, the opaque insulating strips, and the remainder of the support sheet **45** is a thin sheet of photoconductive material **53**. Covering each of the areas of photoconductive sheet **53** which is adjacent to a junction of a signal strip and a color filter strip, i.e., signal strip **46** and red filter **49**, for example, is a protective insulator strip **54**.

The materials utilized in target **44** may be similar to those that have been described heretofore as may be the size and numbers of each. The color filter strips **49**, **50** and **51** are preferably made from some type of multi-layer interference filter. These color filter strips are normally made of alternate layers of high index materials such as zinc sulfide, and low index materials such as magnesium fluoride with the thickness of each layer chosen to give the desired color. Other materials may be utilized as the insulating material in the multi-layer interference filter such as kryolite and zinc selenide. It should be understood that other types of insulating color filter strips may also be utilized to derive the various color signals.

It should be noted that the insulating color filter strips **49**, **50** and **51** are arranged in the conventional red, green, blue arrangement with signal strips **46** and **46′**, **47** and **47′**, and **48** and **48′** respectively. The output connections for the various signal strips are connected so that

there is provided coupling capacitors **30** and **33** for each of the individual colors. The video signal corresponding to each of the primary colors can be fed through these capacitors to separate color channels as is well-known in the art.

The opaque insulating strips **52** may be of any opaque insulating material such as black aluminum oxide, or an opaque metal covered with an insulating film. The insulating strips **52** may be substantially the same thickness and width as the conducting signal strips **46** and **46′**.

During operation of the target **44**, current flow is laterally through the photoconductor, i.e., similar to Fig. 7, and occurs only when a light signal to be reproduced is passed through a particular color filter **49**, **50** or **51**. As can be seen from Fig. 9, the resistance and capacitance of the target **44** is a parallel combination of resistances and capacitances as has been described hereinabove. In target **44**, the fixed resistance (R_F of Figs. 3 through 5) of the target occurs in the areas of photoconductor directly over an opaque insulating strip **52**; while the variable resistance (R_{PC} of Figs. 3 through 5) occurs in the area of photoconductor directly over a color filter strip **49**, **50** or **51**.

Referring now to Fig. 10, there is shown an enlarged fragmentary sectional view of a modification of a target structure of the transverse current flow, bridge type in accordance with this invention for use in a tri-color camera tube such as tube **10** shown in Fig. 6. The target **55** comprises a support plate **56** having on the beam side thereof a plurality of spaced apart opaque conducting strips **57**, **57′** and **57″** for the red, green and blue signals respectively. Spaced intermediate each of the opaque conductive strips is a conducting color filter strip **58**, **58′** and **58″** for the red, green, blue respectively. Covering the opaque signal strips, and the conducting filter strips, is a sheet of photoconductive material **59**. Covering the areas of the photoconductive material **59** which are adjacent pairs of color filter strips and opaque conducting strips, as well as the photoconductor therebetween, is a plurality of short conducting tabs **60**. Each of the color filter strips and its associated opaque conducting strip, is connected to a respective ouput circuit to provide an output signal in each of the primary colors as was described above.

The materials, and sizes, for the elements of target **55** are similar to those described in connection with Fig. 9. The conducting filters referred to here may be of the Fabry-Perot type consisting of two thin layers of metal separated by a thin transparent dielectric. Alternatively, the previously described insulating multi-layer interference filters may be used provided they are each covered with a different thin sheet of transparent conducting metal such as evaporated gold. The operational difference between target **55** and target **44** is that current flow occurs transversely through the target **55** which is similar to the current flow in the monochrome type target described in connection with Fig. 8.

Referring now to Fig. 11, there is shown an enlarged fragmentary sectional view of a modification of a target structure of the transverse current flow, bridge type in accordance with this invention. The target **61**, which may be utilized in tube **10**, comprises a support plate **62** having on the beam side thereof a plurality of spaced apart color filter strips **63**, **63′** and **63″** for the red, green and blue respectively. Covering each of the color filter strips **63**, **63′** and **63″** is a conducting strip of thin transparent metal **64**. This layer may be omitted if the filter strips themselves are conducting as are the Fabry-Perot type described for Fig. 10. A strip of photoconductive material **65** is deposited over each of the conducting signal strips and the adjacent portions of the exposed surface of the support plate **62**. Individually covering each of the photoconductor strips **65** is a strip of semiconducting material **66** which extends over the photoconductor strips in the areas directly over each of the color filter strips **63**, **63′** and **63″**. The thin semi-conductor **66** provides the storage area at which the beam makes contact to the target. A narrow semi-conducting strip **67**, of somewhat higher resistivity than semi-conductor **66**, is deposited over the thin semi-conductor **66**. Over the top of the semi-conductor strip **67** a narrow conducting signal strip **68** is deposited. The potential difference across the bridge is applied to the upper and lower signal strips **68** and **64**, respectively. The applied potential may have the polarity shown or may have the reverse polarity.

Each of the conducting signal strips **64** is connected to an output circuit for the red, green and blue signals. Each of the conducting strips **68** is also connected to the output circuit. The fixed resistance (R_F of Figs 3 through 5) is obtained by the resistance of the semi-conductor **67** while the variable resistance (R_{PC} of Figs. 3 through 5) is the resistance of the photoconductor strips **65** directly over a conducting color filter strip. The filter materials utilized in target **61** may be similar in size and material to those previously described. The thin semi-conducting strips **66** may be of a material such as germanium evaporated to a thickness of about a hundred Angstroms. The narrow semi-conductor strips **67** should have a relatively high resistivity and may be evaporated material such as lead oxide, or zinc oxide. As can be seen, Fig. 11 discloses a tri-color transverse flow bridge type target, the operation of which is similar to the operation of target **55** shown in Fig. 10. Alternatively, the target of Fig. 11 may be operated with a high velocity beam.

Referring now to Fig. 12, there is shown an enlarged fragmentary sectional view of a monochrome, transverse flow, bridge type target utilizing a thin layer of semi-conductor material in accordance with this invention. The target **70**, which may be utilized in tube **10**, comprises a glass support member **71** having a plurality of transparent conductive strips **72** spaced apart on the side of the support member **71** adjacent to the electron beam. Spaced in between each of the plurality of transparent conducting strips **72** is an opaque conducting strip **73**. Covering all of the plurality of transparent conducting strips **72**, and all of the plurality of opaque conducting strips **73**, is a continuous sheet of photoconductor **74**. Covering the exposed surface of the photoconductor **74** is a continuous sheet of semi-conducting material **75**.

The materials utilized in target **70** may be substantially the same as those that have previously been described. With the semi-conducting material **75** being a material such as a thin layer of evaporated germanium. The operation of target **70** is such that the fixed resistance (R_F of Figs. 3 through 5) is obtained from the areas of photoconductor material **74** adjacent to an opaque conducting strip **73**; with the variable resistance (R_{PC} of Figs. 3 through 5) being obtained from the areas of photoconductor material **74** adjacent to the transparent conducting strips **72**. The target **70** is substantially a transverse flow, bridge type target for use in the monochrome television as has been described. This structure is equivalent to that described in Fig. 8 except that the conducting tabs of Fig. 8 are replaced by a thin semi-conducting sheet **75** having a resistivity chosen to give proper operation without loss of resolution.

Referring now to Fig. 13 there is shown an enlarged fragmentary sectional view of a modification of this invention comprising a target **76** including a support member **77** having on the beam side thereof a continuous layer of transparent conductive material **78**. On the exposed surface of the transparent conductive material **78** is provided a sheet of photoconductive material **79**. Spaced apart on the exposed surface of the photoconductor material **79** is a plurality of insulating strips **80**. Substantially centrally disposed upon each of the insulating strips **80** is a conducting strip **81**. Covering each of the conducting strips **81**, the exposed portions of the insulating strips **80**, and the balance of the photoconductor sheet **79** is a continuous semi-conducting material **82**.

In target **76**, which may be utilized in tube **10**, the lateral conductivity of the thin semi-conducting layer **82** is used as the fixed resistance (R_F of Figs. 3 through 5) of the bridge. The positive terminal is the underlying transparent conductive coating **78** on which is deposited the uniform layer of photoconductor **79**. The negative terminal comprises the conducting strips **81** which are insulated from the underlying photoconductor by means of insulating strips **80**. The semi-conducting layer **82** connects the exposed areas of the photoconductor **79** to the conducting strips **81** thus providing the variable resistance (R_{PC} of Figs. 3 through 5) of the bridge. The reverse potential may be applied giving a video signal having opposite polarity, if desired. Also, the conducting strips **81** may be on the beam side of semi-conductor **82** and the target **76** will bear substantially the same electrical properties as that shown. Due to the thinness of semi-conductive layer **82**, the coplanar grid effect may be utilized in either instance.

The materials utilized in target **76** may be substantially the same as those that have previously been described with the continuous transparent conducting layer **78** being a material such as tin oxide although any suitable transparent conductive material may be utilized. The thickness and the resistivity of the semi-conducting layer **82** should be chosen so that, with reasonable applied voltages, the exposed areas of photoconductor **79** will balance to ground potential in the dark, and further, that leakage along the semi-conductor **82**, parallel to the strips **81**, will not be great enough to deteriorate resolution. Target **76** is a target of the transverse flow, bridge type, for use with monochrome television pick-up tubes, the operation of which has previously been described.

Referring now to Fig. 14, there is shown an enlarged fragmentary sectional view of a tri-color, transverse flow, bridge type target structure in accordance with a modification of this invention. The target **83**, which may be utilized in tube **10**, comprises a support member **84** having a plurality of spaced apart color filter strips **85**, **85′** and **85″** for the red, green and blue signals respectively. Spaced in between each of the color filter strips **85**, **85′** and **85″** is a conducting strip **86** which may be either opaque or transparent. Supported substantially centrally on each of the color filter strips **85**, **85′** and **85″** is a transparent conducting strip **87**. Substantially covering each of the transparent conducting strips **87**, and the balance of each of the color filter strips **85**, **85′** and **85″**, is a strip of photoconductive material **88**. Substantially covering all of the conducting strips **86**, all of the photoconductive strips **88**, as well as the balance of each of the color filter strips **85**, **85′** and **85″** is a continuous semi-conducting layer **89**.

As can be seen from the drawings, the negative terminal strips **86** fall between each of the color signal strips **85**, **85′** and **85″** and serve as a shield between color strips in addition to their function as part of the bridge. Some monochrome signal will be picked up by the strips **86** and to obtain maximum signal to noise ratio in the mixed-high channel output from the camera, it may be desirable to add higher frequency components of this signal to the mixed-high signal obtained from the three sets of color strips **88**.

A suitable photoconductor material for target **83** would be a photoconductor such as evaporated antimony sulfide or evaporated cadmium sulfide or selenide doped with one or more impurities to give a satisfactory red response and a volume resistivity of approximately 10^9 to 10^{11} ohm-centimeters. Satisfactory thickness for the photoconductor material **88** would be approximately 1 micron.

A typical semi-conductor would be tin oxide having a resistivity of about 10^3 ohm-centimeters deposited in a layer less than 1 micron thick. Alternatively, a much thinner layer of evaporated germanium has been found to be suitable. The conducting strips may be gold or aluminum evaporated to a thickness of approximately .05 micron.

As can be seen from Fig. 14 there is provided a tricolor, transverse flow, bridge type target where in the variable resistance (R_{PC} of Figs. 3 through 5) is obtained from the transverse flow of current through the photoconductor over the signal strips **87**. The fixed resistance (R_F of Figs. 3 through 5) is obtained from the lateral conductivity of the semi-conductor between conducting strips **86** and the area over the photoconductor.

Although certain examples of geometry of photoconductive materials, semi-conductive materials, and color filter materials are shown, these are merely examples and it should be understood that it is within the contemplation of this invention to utilize strips or tabs of photoconductive material or semi-conductive material in the various embodiments shown. Also, since this invention contemplates tubes having bridge type targets utilizing either lateral flow, or transverse flow, for either the variable resistance or the fixed resistance, and certain examples of these targets are shown, it should be understood that the invention should not be limited to these examples, but should include all such targets as come within the scope of the appended claims.

What is claimed is:

1. An electron discharge device including an envelope containing means for supplying a stream of electrons along a path, a target positioned in said path, said target comprising a transparent support member, a plurality of conducting signal strips supported by means of said support member, alternate ones of said signal strips being electrically coupled to substantially fixed resistances in said target, intermediate ones of said signal strips being electrically coupled to variable resistances in said target, the junctions between a fixed resistance and a variable resistance being directly exposed to said stream of electrons, and the magnitude of the resistance of said variable resistances varying in response to light directed onto said target.

2. An electron discharge device as in claim 1 further comprising color filter means whereby the magnitude of said variable resistances varies in response to light of different colors.

3. An electron discharge device including an envelope containing means for supplying a stream of electrons along a path, a target positioned in said path, said target comprising a transparent supporting member, a plurality of signal electrodes supported by means of said supporting member, photo-conductive means electrically coupled to said signal electrodes, a part of said photoconductive means being shielded from light whereby the resistance of said part is substantially fixed, a second part of said photoconductive means being exposed to light whereby the resistance of said second part varies in response to light, and the junction between said parts being directly exposed to said stream of electrons.

4. An electron discharge device as in claim 3 further comprising color filter means.

5. An electron discharge device comprising an envelope containing means for supplying a stream of electrons along a path, a target positioned in said path, said target comprising a support member, a plurality of spaced apart conductive elements supported by said support member, a photoconductive means electrically coupled to the alternate of said conductive elements, semi-conductive means electrically coupled to the intermediate of said conductive elements whereby the alternate of said conductive elements are electrically coupled to resistances that vary in response to light and the intermediate of said conductive elements are electrically coupled to substantially fixed resistances, and the junctions between said resistances that vary in response to light and said fixed resistances being exposed directly to said stream of electrons.

6. An electron discharge device including an envelope containing means for supplying a stream of electrons along a path, a target positioned in said path and including a transparent support member, a plurality of transparent conductive elements supported by means of said member, a plurality of opaque conductive elements supported by means of said member, and photoconductive means electrically coupled to said pluralities of conductive elements with the opaque conductive members shielding said photoconductive means from light whereby the resistance of said photoconductor adjacent to said opaque members is substantially fixed.

7. A television pickup tube comprising an electron gun for producing an electron beam, a target electrode including a supporting member, a plurality of spaced apart conductive elements supported by means of said member, photoconductive means electrically coupled to said conductive elements, a plurality of portions of said photoconductive means being shielded from light whereby said portions of said photoconductive means have a substantially fixed electrical resistance, a second plurality of portions of said photoconductive means being exposed to light whereby the resistance of said portions of said photoconductor varies in response to light, and a direct current path between said gun and a junction between a fixed resistance and a variable resistance.

8. A television pickup tube as in claim 7 further comprising color filter means.

9. A television pickup tube as in claim 7 wherein each of said fixed resistances is in electrical parallel relation with one of said variable resistances.

10. A television pickup tube comprising an electron gun for producing an electron beam, a target in the path of said beam and comprising a support member, a plurality of spaced apart conductive elements supported by said support member, photoconductive means electrically coupled to the alternate of said conductive elements, semi-conductive means other than said photoconductive means electrically coupled to the intermediate of said conductive elements whereby the alternate of said conductive elements are electrically coupled to resistances that vary in response to light and the intermediate of said conductive elements are electrically coupled to substantially fixed resistances, and said semi-conductive means comprising a part of a direct current path between said gun and a junction of a fixed resistance and of a variable resistance.

11. A target as in claim 10 further comprising color filter means.

12. A target for a television camera tube comprising, a transparent support member, a first plurality of spaced apart conductive strips on one surface of said support member, a second plurality of spaced apart conductive strips on said one surface of said support member, each of said first plurality of strips being spaced in between a pair of said second plurality of strips, a photoconductor supported by means of said support member, means including each of said first plurality of strips for shielding portions of said photoconductor from light whereby the resistance of said portions is substantially fixed.

13. A target for a television camera tube comprising a transparent support member, a plurality of transparent conductive strips spaced apart on one surface of said support member, a plurality of opaque conductive strips spaced apart on said one surface of said support member and each spaced between an adjacent pair of said transparent strips, a continuous layer of photoconductive material covering said strips and the exposed areas of said support member therebetween, and a plurality of conductive tabs spaced apart on said photoconductive material, each of said tabs being disposed adjacent to one

of said transparent strips and an adjacent one of said opaque strips.

14. A television camera tube comprising an electron gun for producing an electron beam, a target in the path of said beam and comprising a transparent support member, a plurality of pairs of signal strips spaced apart on one surface of said member, a plurality of opaque insulator strips and a plurality of color filter strips supported on said one surface of said support member, one of said opaque insulator strips and one of said color filter strips being supported between each pair of said signal strips, a continuous sheet of photoconductive material covering all of said strips and the portion of said support member exposed therebetween the portions of said photoconductive material over said opaque strips comprising a substantially fixed resistance, the portions of said photoconductive material over said color filter strips comprising a variable resistance, the junctions between a fixed resistance and a variable resistance being directly exposed to said electron beam, and a plurality of strips of insulating material supported on said photoconductor and one adjacent to each of said color filter strips and the signal strip contiguous thereto.

15. A television pickup tube comprising an electron gun for producing an electron beam, a target in the path of said beam and comprising a transparent support member, a plurality of sets of signal output electrodes spaced apart on one surface of said support member, each of said sets including a signal strip, a color filter strip, an opaque insulator strip and a second signal strip continguously arranged and in that order, a photoconductor spanning said sets and the exposed surface of said support member therebetween, the portions of said photoconductive material over said opaque strips comprising a substantially fixed resistance, the portions of said photoconductive material over said color filter strips comprising a variable resistance, the junctions between a fixed resistance and a variable resistance being directly exposed to said electron beam, and a plurality of insulating strips each supported on said photoconductor adjacent to a color filter and the contiguous signal strip.

16. A target for a television pickup tube comprising a support member, a plurality of sets of signal output electrodes spaced apart on said support member, each of said sets including a conductive color filter strip and an opaque conductive strip, the strips in each of said sets being spaced apart, a photoconductor covering said sets and the exposed areas of said support member therebetween, and a plurality of conductive tabs each supported on said photoconductor adjacent to one of said sets.

17. A television camera tube comprising an electron

gun for producing an electron beam, a target in the path of said beam and comprising a transparent support member, a plurality of sets of signal output electrodes spaced apart on one surface of said support member, and each of said sets comprising a layered unit of a color filter strip, a signal strip, a photoconductive strip, a semi-conducting strip, a narrow semi-conducting strip, and a conducting strip in that order each of said photoconductive strips comprising a variable resistance, each of said narrow semi-conducting strips comprising a substantially fixed resistance, and each of said semi-conducting strips comprising a portion of a direct current path between said electron gun and a junction between a fixed resistance and a variable resistance.

18. A television pickup tube comprising an electron gun for producing an electron beam, a target in the path of said beam and comprising a transparent support member, a plurality of pairs of conducting strips spaced apart on one surface of said support member, each of said pairs including one transparent strip and one opaque strip, a photoconductor spanning said pairs and the exposed areas of said support member therebetween, the portion of said photoconductor over each of said opaque strips comprising a substantially fixed resistance, the portion of said photoconductor over each of said transparent strips comprising a variable resistance a sheet of semi-conductive material on said photoconductor and said sheet of semi-conductive material comprising a portion of a direct current path between said electron gun and a junction between a fixed resistance and variable resistance.

19. A television camera tube comprising an electron gun for producing an electron beam, a target in the path of said beam and comprising a transparent insulating support member, a conductive layer on a surface of said support member, a photoconductive layer on the exposed surface of said conductive layer and comprising a variable resistance, a plurality of insulating strips spaced apart on said photoconductive layer and each comprising a fixed resistance, a plurality of conductive signal strips each arranged on one of said insulating strips, a semi-conductive layer spanning said signal strips and the exposed areas of insulating strips and photoconductor therebetween, and said semi-conductive layer comprising a portion of a direct current path between said gun and a junction between a fixed resistance and a variable resistance.

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