

Oct. 26, 1943.

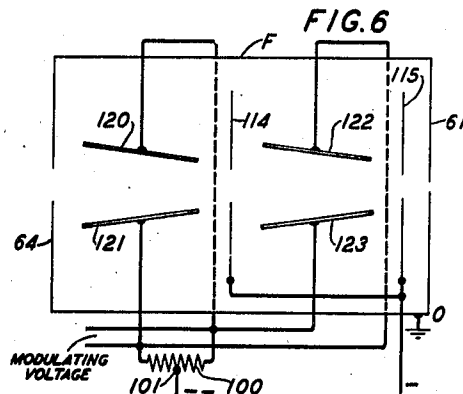
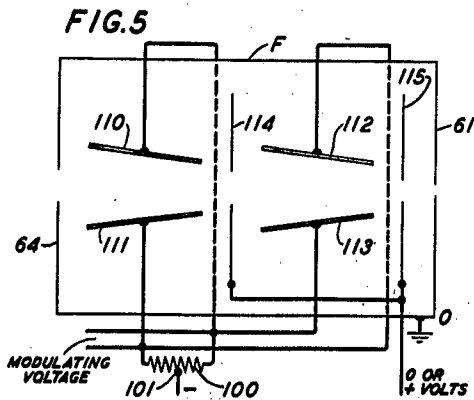
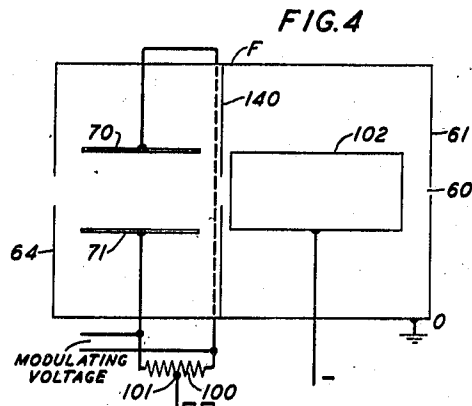
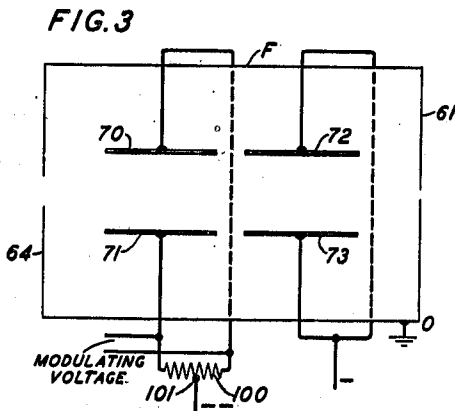
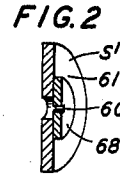
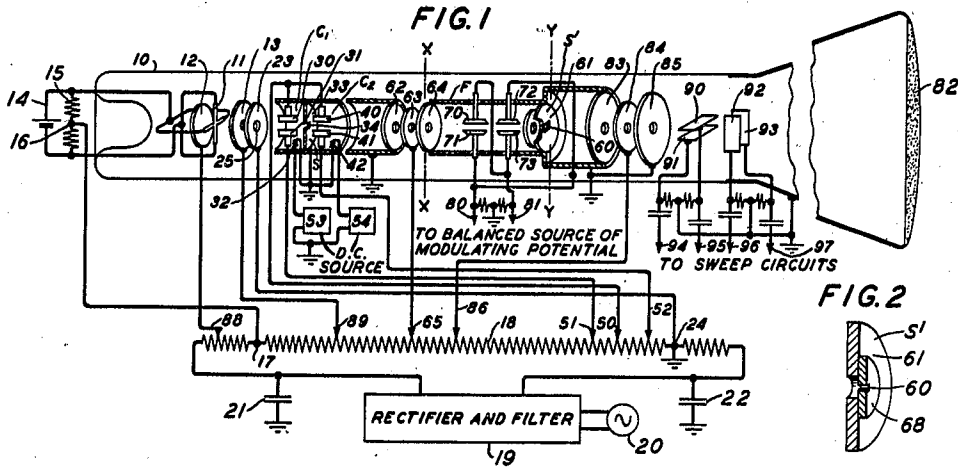
C. J. CALBICK

2,332,622

ELECTRON DISCHARGE DEVICE

Filed Oct. 11, 1941

3 Sheets-Sheet 1



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2,332,622

ELECTRON DISCHARGE DEVICE

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FIG. 7

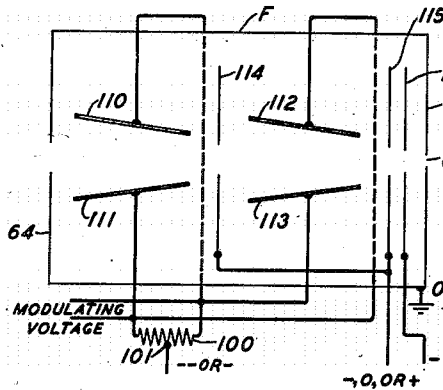


FIG. 8

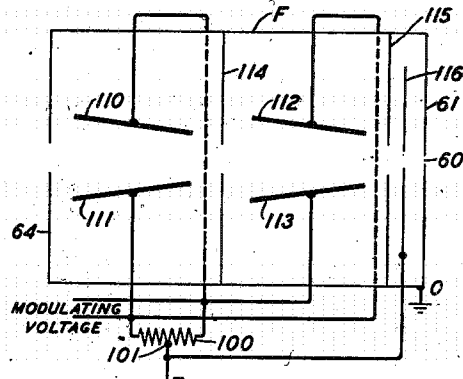


FIG. 9

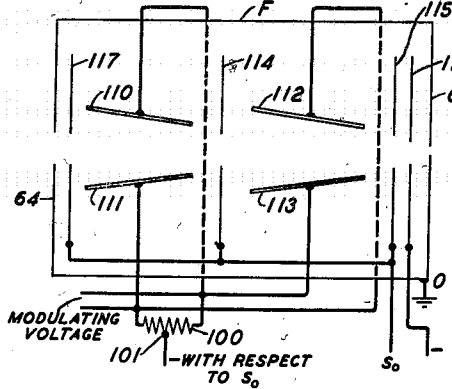


FIG. 11

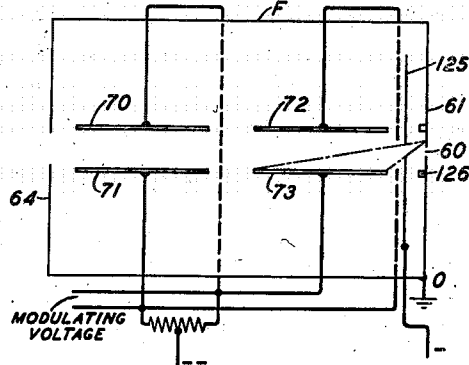
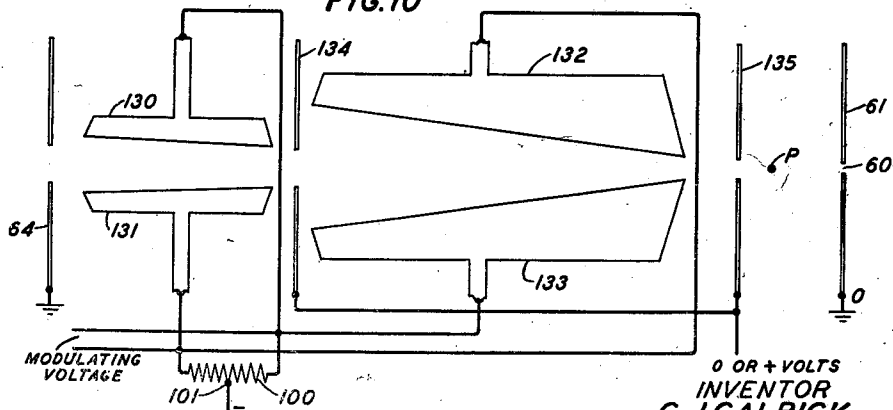


FIG. 10



0 OR + VOLTS
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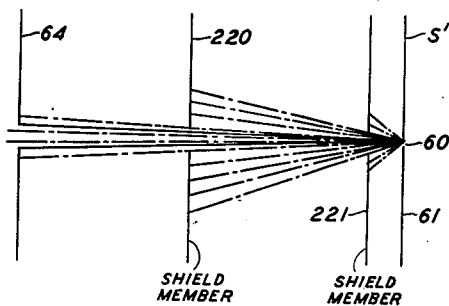
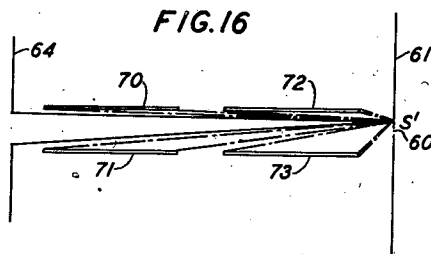
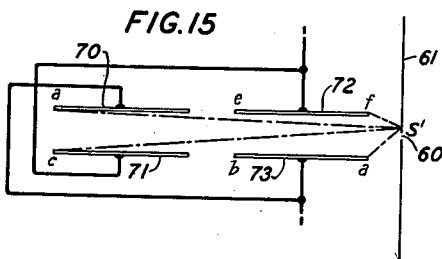
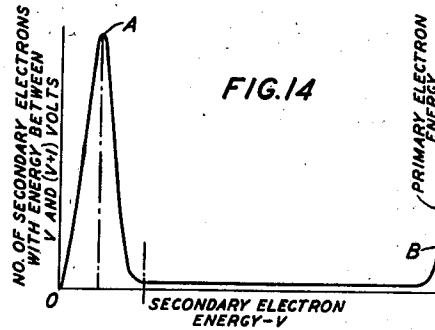
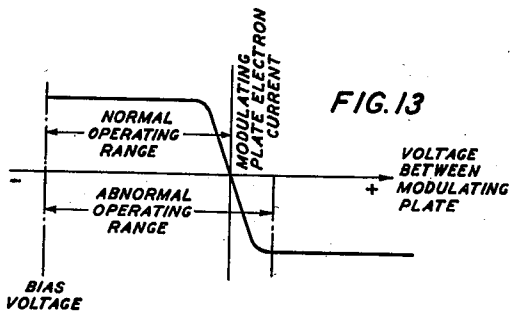
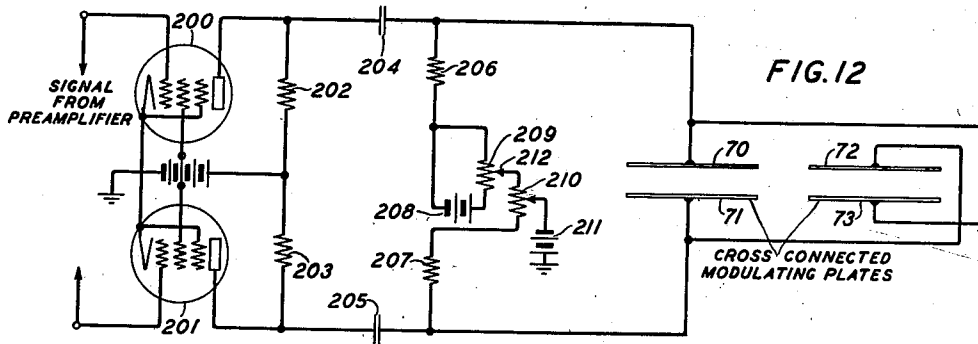
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ELECTRON DISCHARGE DEVICE

Filed Oct. 11, 1941

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2,332,622

ELECTRON DISCHARGE DEVICE

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Application October 11, 1941, Serial No. 414,621

27 Claims. (Cl. 250-27)

This application relates to electron discharge devices and more specifically to electrode arrangements in cathode ray tubes.

It is an object of this invention to provide a novel method of and means for reducing the flow of electron currents to certain electrodes in electron discharge devices.

In Patent 2,217,198 issued October 8, 1940 to C. J. Davisson there is disclosed a cathode ray television receiving tube of very high quality. In this tube electrons emitted from a cross-shaped filament are brought to a focus at an aperture in a first diaphragm (the S-plane) and an image of this aperture is projected upon an aperture in a second diaphragm (the S'-plane) an image of this latter aperture being projected on a fluorescent screen. Two pairs of cross-connected modulating plates are arranged near the second diaphragm on the side thereof nearer the cathode, to which plates are applied modulating potentials to vary the position of the beam with respect to the second apertured diaphragm in order to vary the number of electrons which pass through said aperture and hence reach the fluorescent screen. Due to the fact that the aperture in the first diaphragm selects a portion of the beam which is of substantially uniform cross section and projects an image of this portion on the second diaphragm, the final spot on the fluorescent screen has a very uniform cross-sectional intensity distribution.

In a typical input circuit for a tube of the type described in the preceding paragraph, (a somewhat similar circuit being described in greater detail in Patent 2,168,760 issued September 8, 1939 to C. J. Calbick), the signal amplifier terminates in a pair of push-pull output tubes working into two resistances of, for example, 50,000 ohms each. The signals appearing on the plates of these tubes are transmitted through coupling condensers to the modulating plates of the cathode ray tube, which in the Davisson arrangement, are cross-connected. It is necessary to connect across the modulating plates balanced resistances in order that a biasing direct current voltage may be applied between the plates and that the average potential of the modulating plates may be fixed. It was found that when the two resistances in the plate circuit of the amplifier supplying the plates are large the operation of the circuit is seriously affected. There was evidence that this might be due largely to electron current flowing between the modulating plates and when this was investigated it was found that a modulating plate current exists

which tends to be constant over a considerable range of values of modulating plate voltage (potential difference applied to the plates) and to decrease rapidly and reverse its direction within a relatively very narrow range of modulating plate voltages in the region of the sign reversing point of this voltage. A simple method of eliminating the effect of ordinary slow speed secondary electrons by forcing them to return to the electrode which emits them, by proper electric gradient, is described in Patent 2,168,760 issued September 8, 1939 to C. J. Calbick. This method, however, did not solve the problem. It seemed possible (and experimentation has made it apparent) that some of the high speed secondary electrons which have high energy strike the more negative ones of the four modulating plates and cause the emission of tertiary electrons which are drawn across to the more positive plates by the electric fields between each of the pairs of modulating plates to constitute modulating plate currents. These high energy secondary electrons are probably predominantly "full-speed" electrons which have had their direction nearly reversed at the apertured plate to which the primary beam is directed. From the circuit design standpoint this electron current between the deflecting plates has an effect in the signal modulating circuit of a varying resistance in shunt to the deflecting plates. As will be pointed out more fully below, the equivalent resistance between the modulating plates, as a function of applied signal voltage developed across the plates of the last pair of tubes in the signal amplifier, may have any value from minus infinity to plus infinity, and, furthermore, it is not constant over the operating range. From a circuit standpoint, the output tubes of the video signal amplifier must drive a circuit whose impedance varies greatly both with frequency and amplitude of the impressed signal. By proper equalization in the preamplifier a flat frequency response can be obtained in a circuit of the type discussed above, provided the resistance in parallel with the reactance, that is, the amplifier output tube plate resistances in series, in parallel with the equivalent modulating plate resistance and with the resistance (of the order of 2 megohms in practice) necessary for the application of direct current potential and biasing voltage to the modulating plates, is substantially constant and not more than a few times the minimum reactance. This can be achieved by making the amplifier output tube plate resistances small compared to the variable modulating plate resistance. For exam-

ple, if these amplifier plate resistances are 1,500 ohms each (adding up to 3,000 ohms in series), the equivalent modulating plate resistance can vary greatly, so long as it remains greater than, say, 100,000 ohms. This, for a circuit actually constructed for use with the Davisson tube, corresponds to modulating plate currents somewhat less than about 100 microamperes. However, in many cases, it is desired to use higher output tube plate resistances (greater than 10,000 ohms, adding up in series to more than 20,000 ohms). To provide a reasonably flat signal response curve, it is necessary to reduce modulating plate currents to less than 10 microamperes and correspondingly increase the equivalent resistance of the modulating plates to a relatively large value; and even smaller values are felt to be highly desirable. The prior art does not suggest any means to reduce modulating plate currents to such a low value.

It is, accordingly, another object of this invention to provide a method of and apparatus for substantially decreasing the modulating plate currents in cathode ray tubes employing modulation by deflection.

The low speed group of secondary electrons can always be forced, by appropriately disposed small electric gradients, to return to the electrode which emits them, and can thus be eliminated as a cause of modulating plate currents. The secondary electrons in the high speed group, on the other hand, pursue trajectories which are only slightly affected by these small electric gradients introduced for the purpose of eliminating the low speed group. Furthermore, their trajectories are only slightly affected by the transverse electric fields between the modulating plates themselves, so that a considerable number of them which strike the more negative of the modulating plates give rise to tertiary electrons which are accelerated by the transverse electric gradient of the modulating electric field, and finally are collected by the more positive of the modulating plates, thus constituting a modulating plate current. The number of high speed secondary electrons striking the more negative ones of the modulating plates depends upon the solid angle subtended by these plates with respect to the point or area of emission of the secondary electrons, which is the area within which the primary electron beam impinges upon the second apertured diaphragm. This area is in the immediate vicinity of the aperture in the diaphragm. Various methods of reducing this angle constitute different embodiments of the invention.

In accordance with one embodiment of the invention, the cross-connection of the four plates in a tube of the Davisson type is eliminated. Instead, the first pair (that is, the pair near the cathode) is used for modulation by deflection, and the second pair (that is, the pair farthest removed from the cathode), is used as a shield. This pair is placed at a minimum fixed potential of, for example, about 22½ volts negative with respect to the second apertured diaphragm. This minimum value is determined by two factors: (1) few of the low speed group of secondaries have energy exceeding about 10 volts, and (2) the signal applied to the modulating plates may be sufficient to cause one or more of the modulating plates to assume a potential positive by several volts (of the order of 10 volts maximum at a primary electron energy of 5,000 volts) with respect to the average potential of the modulat-

ing plates. The signal voltage in a given geometry of modulating plates depends upon the primary electron energy (that is, a relatively large signal voltage is required if the primary electron energy is large) and consequently the second factor varies with the primary electron energy. In various arrangements one or both factors may be operating to fix the minimum negative potential. The second pair of plates in this embodiment thus acts as a shield to force the group of low speed secondary electrons to return to the diaphragm. It is also evident that the solid angle subtended by the more negative of the modulating plates has been greatly reduced as compared with the conditions prevailing with cross-connection, since only one instead of two plates is now acting as a source of tertiary electrons, and that plate is the more remote from the point of emission of the secondary electrons. With this arrangement, the current between the plates of the first pair, which now are the only pair, of modulating plates, becomes small enough so that a very large input resistance may be used.

The above-described arrangement may be modified by placing a diaphragm or other shield member in the region between the second pair of modulating plates and the second apertured diaphragm, this shield being placed at a negative potential with respect to the apertured diaphragm. The second pair of modulating plates now serves no useful purpose and can be eliminated. The shield can take the form of a hollow metallic cylinder extending from the vicinity of the second apertured diaphragm back to the first pair of plates.

If, however, it is desired to retain the advantages of cross-connection of the four modulating plates, the solid angle subtended by the plates with respect to the aperture in the second apertured diaphragm may be reduced greatly by inclining the inner surfaces of the modulating plates away from the central axis, the distance between the plates of each pair decreasing in the direction of primary electron flow, and by interposing two diaphragm shield members, one positioned between the two pairs of plates and the second placed between the second pair of plates and the second apertured diaphragm. In addition, a third diaphragm shield member may be placed between the second diaphragm shield member and the second apertured diaphragm, and a fourth may be placed on the cathode side of the first pair of plates.

Although the two pairs of inclined plates may be similar pairs, an increase of modulation sensitivity is obtained by making the first pair shorter than the second.

If the degree of inclination is properly chosen and the diaphragm shield members are properly positioned, substantially all of the high speed secondary electrons are intercepted by the shields, and none are incident upon the modulating plates. In consequence, the tertiary electrons are emitted by the diaphragm shield members, and it is only necessary to arrange the electric potentials in such a way that these tertiary electrons are forced to return to the members themselves, and are therefore not drawn to the modulating plates, to insure that the modulating plate currents shall be substantially zero and hence that large input resistances can be used.

When two diaphragm shield members are used, they may be conductively connected together and

their potential made negative with respect to the second apertured diaphragm, in order to eliminate the low speed group of secondary electrons, and positive with respect to the average potential of the four modulating plates. Alternatively, the shield members may be conductively connected to the second apertured diaphragm, and the average potential of the modulating plates made negative with respect to the shield members. In this second arrangement the low speed secondary electrons are eliminated in essentially the manner described in the above-mentioned Patent 2,168,760. This arrangement is, however, not as effective as the first in reducing the modulating plate currents.

Still more complete suppression is obtained if a third shield member conductively connected to the other two, is provided at the cathode end of the first pair of modulating plates. Finally, most complete suppression is achieved if a fourth shield member, not electrically connected to the other three, is placed adjacent the second apertured diaphragm and operated at a potential negative to that of the second apertured diaphragm to eliminate the low speed secondary electrons, the other three conductively connected shield members being made positive with respect to the second apertured diaphragm and the average potential of the modulating plates made negative with respect to that of the three conductively connected shield members.

Each of the various arrangements described briefly above illustrates the general principle that in order to eliminate effects caused by tertiary electrons due to high speed secondary electrons, the following arrangements are, in general, necessary: (1) metallic shields must be placed in the trajectories of high speed secondary electrons proceeding to electrodes in whose vicinity there are more positive electrodes, and (2) these shields must be made more positive than any neighboring electrodes, so that tertiary electrons emitted by the shields are forced to return to the shields.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof in which:

Fig. 1 shows a cathode ray tube of the prior art (the Davisson type television receiver) employing modulation by deflection;

Fig. 2 shows an apertured diaphragm member in the tube of Fig. 1;

Figs. 3 to 11, inclusive, show various arrangements for reducing modulating currents in the tube of the general type of that shown in Fig. 1;

Fig. 12 is a diagram of a typical input circuit which may be used with a tube of the type embodying this invention; and

Figs. 13 to 17 inclusive, are diagrammatic and graphical representations to aid in explaining the invention.

Referring more specifically to the drawings, Fig. 1 shows a cathode ray tube 10 which is more fully described in the C. J. Davisson patent mentioned above. A brief description of this tube is given at this point in order to provide a proper framework for a clearer understanding of the present invention. Briefly stated, the electrode structure of the television receiving tube 10 is as follows:

The cross-shaped filament 11 serving as a cathode is located between and parallel to a back electrode 12 and an accelerating electrode 13, in the form of an apertured diaphragm, constituting the first member of a condenser lens system. A

positive potential with respect to that of the cathode 11 is applied to the first member 13 of the condenser lens system through tap 89 of the potentiometer resistor 18 and a negative potential with respect to the cathode 11 is applied to the back electrode 12 from the tap 88 and so adjusted that a uniform field is produced between the back electrode 12 and the first condenser lens member 13 the effect of which is to cause the electrons emitted from the four arms of the cross-shaped filament 11 to traverse paths which are substantially parallel to the axis of the tube. Heating current for the filamentary cathode 11 is obtained from a source 14 across which is connected a resistor 15 the mid-tap 16 of which is connected to a tap 17 of the potentiometer resistor 18. The resistor 18 is connected across a rectifier and filter (represented by the block 19) which in turn is connected to a suitable source of oscillations 20. Two spaced apart points of the potentiometer resistance 18 are connected to ground through suitable condensers 21 and 22.

An apertured diaphragm 23 adjacent the first condenser lens member 13 constitutes the second member of the condenser lens system and the potential of this second condenser lens member 23 is made positive with respect to that of the first condenser lens member 13. The member 23 is connected to the tap 24 on the potentiometer resistance 18 and this tap is also connected to ground (the frame potential). Frame potential is also the potential of many of the other electron lens members to be described below. The cathode is thus highly negative with respect to the potential of the second condenser lens member 23 and hence with respect to the earth or frame potential.

Proceeding along the axis of the tube, a first collimator unit C_1 is provided to produce electric and magnetic fields normal to the tube axis and parallel to each other. The collimator unit C_1 comprises a pair of electrostatic plates 30 and 31 and magnetic coils 32. The function of the first collimator unit is to deflect the electrons after they pass through the aperture in the second condenser lens member 23 in such a manner as to place the maximum electron intensity at any desired point in the S-plane (that is, the plane formed by the member 33 having a slit 34 therein). The slit in the S-plane in the preferred embodiment is .006 inch wide and is parallel to the pair of plates 30, 31 of the first collimator unit C_1 .

A second collimator unit C_2 similar to the first collimator unit C_1 is placed on the side of the S-plane remote from the cathode 11. The collimator unit C_2 comprises a pair of electrostatic plates 40, 41 and magnetic coils 42. The collimator units C_1 and C_2 receive potentials for their electrostatic members from taps or terminals 50, 51 and 52 of the potentiometer resistance 18, all of these taps being shown at a potential which is negative with respect to the frame potential, although in practice it is possible that they may be slightly positive instead of slightly negative or some may be positive and others negative. The plates 30 and 40 are shown connected together although they need not be so connected in all cases. The currents for the magnetic coils 32 and 42 are obtained from the direct current sources 53 and 54. The function of the second collimator unit C_2 is to change the direction of motion of electrons so that they are once more proceeding approximately parallel to the tube axis, thus compensating for any angular deviation which the first collimator unit C_1

may have given them when it displaced the maximum intensity point of the beam to the correct place on the slit in the S-plane.

Proceeding along the axis after the electrons have passed through the second collimator unit, an electron image of the slit in the S-plane is formed at the S'-plane (which includes a rectangular or square aperture 60 in a diaphragm 61) by the modulator lens system which comprises three apertured diaphragms 62, 63 and 64, the two outside diaphragms 62 and 64 being placed at earth or frame potential and the inside diaphragm 63 being connected to a potential obtained from the potential tap 65 which is negative with respect to earth. Between the modulator lens system and the S'-plane is the modulating system consisting of four plates 70, 71, 72 and 73 which in the Davisson arrangement (see Figs. 1 and 12) are cross-connected in order to produce a displacement of the image without angular deviation of the electrons. Variation of the modulating voltage will vary the number of electrons incident upon the aperture 60 in the S'-plane which aperture is preferably .005 or .006 inch square. Since this aperture is uniformly "illuminated" only in a direction parallel to the modulating plates, it is advisable that this direction should be perpendicular to the lines of the television image. To produce modulation of the beam, the image of the slit 34 in the S-plane is moved across the square aperture 60 in the S'-plane in accordance with the signal voltages applied between the modulating plates by a balanced circuit, not shown, which is connected to the terminals 80 and 81.

Between the S'-plane and the fluorescent screen 82 is the projector lens system preferably comprising three apertured diaphragms 83, 84 and 85, the two outside diaphragms 83 and 85 being placed at frame potential and the inner diaphragm 84 being connected to a potential which is obtained from the tap 86 which is negative with respect to earth.

The purpose of the projector lens system is to project an electron image of the square aperture in the S'-plane upon the fluorescent screen 82. Between the projector lens system and the fluorescent screen are located two pairs of electrostatic deflecting plates 90, 91 and 92, 93 to which are applied deflecting voltages, the purpose of which is to so deflect the beam that it scans every elemental area of the field of view on the screen 82 in turn within the period of persistence of vision. To each of the pairs of deflecting plates is applied a voltage of sawtooth wave form of the proper frequency to produce this result. Preferably balanced sweep circuit arrangements are employed and these sweep circuits are connected to terminals 94, 95 and 96, 97. Any suitable sweep circuits may be used; for example, reference may be made to Patent 2,178,464 issued October 31, 1939 to M. W. Baldwin, Jr. which shows satisfactory circuits for this purpose. For a more complete description of the tube described above, reference may be made to the above-mentioned Davisson patent.

The Davisson tube has been in successful operation in circuits in which the input circuit to the modulating plates has a resistance of about 3,000 ohms. With this resistance modulating currents (not including the signal current) of up to around 100 microamperes may be tolerated. As explained above, however, it is highly desirable that input resistances of much higher value be used which requires, for proper circuit match-

ing, that the equivalent resistance of the modulating plates be also high (i. e., that the modulating plate currents be low). Reference will now be made to a typical input circuit which may be used with a tube of the type embodying this invention in order to make plain the reason that it is necessary to reduce modulating plate currents.

Fig. 12 shows a typical input circuit for balanced signals. The signal amplifier terminates in a pair of push-pull output tubes 200 and 201 working into resistances 202 and 203 of 50,000 ohms each (this value may be varied considerably and is merely illustrative). The signal appearing on the plates of the tubes 200 and 201 is transmitted through coupling condensers 204 and 205 to the modulating plates 70, 71 and 72, 73 which are shown cross-connected as in the Davisson arrangement of Fig. 1.

It is necessary, however, to connect across the modulating plates balanced resistances such as the resistors 206 and 207 of one megohm each in order that (1) a biasing direct current voltage may be applied between the plates which is achieved by connecting the battery 208 across the potentiometer 209 of, for example, 500 ohms, the variable tap 212 of which is connected to ground through the resistor 210 and the source of potential 211, and (2) the average potential of the modulating plates may be fixed, as for example at a potential of minus 22½ volts, by the source of potential 211. In actual circuits, the batteries 208 and 211 are not used as the required differences in potential are supplied by drops across resistances through which currents are flowing, the currents originating in properly disposed alternating current rectifiers.

It is clear that the existence of a large electron current between the modulating plates 70, 71 and 72, 73 will seriously affect the operation of the circuit. If this current could be represented by a simple resistance connected in parallel with the condenser consisting of the modulating plates themselves, whose capacity so connected is, in an arrangement actually constructed, about 12 micromicrofarads, it would be possible to tolerate electron currents equivalent to a resistance approaching the 100,000 ohms of the two plate resistances in series as shown (resistors 202 and 203). But, for reasons stated above, the electron current is decidedly not proportional to the voltage applied between the modulating plates. Rather it tends to be constant for a considerable range of values of modulating plate voltage and to decrease and reverse its direction within a very narrow range of modulating plate voltage in the region of the point of reversal in sign of the voltage between the modulating plates. This is shown in Fig. 13. In practice, the voltage between the modulating plates is biased, as shown in Fig. 12, and the normal operating range is such that the modulating plate current remains reasonably constant except when the signal voltage across the plates is near to or at its maximum value, corresponding to voltages between the modulating plates in the range adjacent zero value and hence maximum or near maximum beam current through the apertures. However, because of geometric variations in the assembly of the electrode structure, the operating range may be extended to produce a range designated "abnormal" in Fig. 13.

Furthermore, it should be noted that, because of the negative bias applied to the plates as shown in Fig. 12, a positive signal amplitude is

giving rise to an electron current which is negative. This leads to the result that the circuit element equivalent to the modulating plate current may be a negative resistance of value approximately proportional to the modulating signal voltage and increasing negatively to a value of minus infinity as the end of the operating range (maximum signal voltage across the plates) is approached. There exists in some tubes the abnormal operating range, as a result of which the equivalent resistance first increases with the signal voltage, then becomes infinite when the voltage difference between the modulating plates goes to zero, and finally becomes positive. There is also another mode of operation in which the bias is adjusted to the other end of the operating range than that shown in Fig. 13. In this case, over the normal operating range the equivalent resistance is positive and roughly proportional to the signal voltage while in tubes whose geometrical departure from symmetry produces an "abnormal" operating range, the equivalent resistance is at first negative and increases to negative infinity, reverses sign to positive infinity and thereafter remains positive, decreases to a minimum, and finally increases again, as the signal voltage is increased.

It is thus clear that the equivalent resistance as a function of applied signal voltage developed across the plates of the last pair of tubes 200 and 201 in the signal amplifier, may have any value from minus infinity to plus infinity, and that it is not constant over the operating range. From the circuit standpoint, the output tubes of the video signal amplifier must drive a circuit whose impedance varies greatly both with frequency and amplitude of the impressed signal. The reactance of the capacity of the modulating plates is about

$$\frac{1.3 \times 10^{10}}{f}$$

where f is the frequency, and since f varies from low values up to more than a megacycle, the reactance varies from thousands of megohms down to a few thousand ohms. By proper equalization in the preamplifier, a flat frequency response can be obtained in a circuit such as that shown in Fig. 12 provided the resistance in parallel with the reactance, that is the amplifier output tube plate resistances in series with each other and in parallel with the equivalent modulating plate resistance and with the resistance (2 megohms as illustrated in Fig. 12) necessary for the application of direct current potential and biasing voltage to the modulating plates, is substantially constant and not more than a few times the minimum reactance. This can be achieved by making the amplifier output tube plate resistances small compared with the variable modulating plate resistance. For example, if these resistances were 1,500 ohms each, adding up to 3,000 ohms in series, the equivalent modulating plate resistance could vary greatly, so long as it remained greater than say 100,000 ohms. This would correspond to modulating plate currents somewhat less than about 100 microamperes. However, as pointed out above, it is frequently necessary to use higher output tube plate resistances (that is, greater than 10,000 ohms adding up in series to more than 20,000 ohms). As a matter of fact, it is sometimes necessary and desirable to use an input resistance of as high as 300,000 ohms and more. To provide a reasonably flat signal response curve, it is necessary

to reduce modulating plate currents to less than 10 microamperes; and even smaller values are felt to be highly desirable. The present invention discloses various ways in which the modulating plate currents can be reduced.

In order to clearly understand just what it is attempted to do by the shielding arrangements of Figs. 3 to 11, inclusive, it seems advisable to define what is meant by "low" and "high" energy electrons. The distribution-in-energy curve of secondary electrons is shown in Fig. 14. The secondary electrons consist of a large group (usually about 90 per cent of all secondary electrons) of low energy secondary electrons, a group (usually about 5 per cent) with an almost uniform distribution-in-energy, corresponding to the long horizontal portion of the curve shown in Fig. 14 and a small group (2 per cent to 5 per cent) of full speed electrons, which are assumed to be reflected primary electrons, because of the electron diffraction phenomena they exhibit, under certain control conditions. The peak A in the curve of Fig. 14 is, for example, at about 3 volts, but this varies for different surfaces and primary energies between, for example, 1 and 10 volts. Beyond about 10 volts and up to about 100 volts the curve is very flat but the ordinates are not quite zero. The hump B is due to full speed secondaries which are usually regarded as reflected primary volts. For the purpose of this description, therefore, the low speed secondary electrons can be defined as those secondary electrons possessing energies of less than 10 volts, or less than 5 per cent of the primary electron energy, whichever is greater. The high energy secondary electrons amenable to control by the method of this invention are those whose energy is greater than about 20 per cent of the primary voltage or about 20 volts, whichever is greater.

It is evident that practically speaking, it is not very important just where along the flat part of the distribution curve the dividing line is drawn; especially since there is a gap, at least for higher primary energy, of the order of several kilovolts, between which neither method (that is, the method of this application of controlling the high speed secondaries or the method of controlling the low speed secondary electrons of the above-mentioned Calbick patent) is very applicable. The reasons for this are: (1) the method of control of low speed secondaries results in electron optical aberrations which increase approximately as the square of the retarding voltage employed. This limits the magnitude of the retarding voltage which determines just where on the flat part of the curve the method of the above-mentioned Calbick patent ceases to be effective. (2) The method of control of high speed secondaries depends on shielding for assumed linear or nearly linear trajectories of the high speed groups. The lower the energy, the more the trajectories will, in local fields such as those between the modulating plates, deviate from linear trajectories. In consequence, the lower the energy the less effective is the shielding. The energy expressed (as a fraction of primary energy) at which a particular shield or method of shielding will lose its effectiveness depends upon geometrical factors and the secondary emissive properties of the surfaces involved.

In Figs. 3 to 11, inclusive, various shielding arrangements are shown in which the modulating currents are greatly reduced, thus making it possible to use a higher input resistance than before. In each of these figures there is shown a diagram-

matic representation of the modulating space in the tube shown in Fig. 1 between the lines XX and YY, or in other words between the apertured diaphragms 64 and 61. These two diaphragms are mounted in a metal cylinder F which is placed at frame or ground potential. No attempt has been made in these figures to draw the various elements and spaces between them to scale, they being merely drawn schematically to illustrate the features of novelty of this invention.

In each of the arrangements shown in Figs. 3 to 11, inclusive, the modulating plates are located between the diaphragm 64 of the modulating lens system and the diaphragm 61 in the S'-plane. The electron beam, entering from the left from the last collimator lens, is converging to form, upon the plane of the .006 inch square aperture 60 at the right of the figure, an image of the slit 34 in the S-plane through which slit the beam has previously passed. Plates 70 and 71 form the first pair of modulating plates and plates 72 and 73 form a similar and second pair of modulating plates. In the arrangement shown in Fig. 1, that is, in the usual mode of operation of the Davisson type cathode ray television receiver tube, the plates are cross-connected; that is, plates 70 and 73 are electrically connected and plates 71 and 72 are electrically connected, the modulating signals being applied between the pairs so connected. This cross-connection results in the beam approaching the S' plane traveling in the same direction as when it entered the modulating space through the diaphragm 64 but displaced laterally. The optical analogue is that of a beam of light passing through a piece of plane-parallel glass at other than normal incidence whereas the optical analogue of a beam of electrons passing between a single pair such as between plates 70 and 71 where-across a potential difference exists is a beam of light passing through a prism.

The electron beam converges to an image of the slit 34 and is incident, for example, upon a piece of thin tungsten through which has been punched a hole .006 inch times .006-inch. This tungsten sheet is clamped against a thin piece of molybdenum through which has been bored a hole about .020 inch in diameter; thus the beam finds the tungsten sheet at the bottom of the hole in the molybdenum plate. Fig. 2 shows this diaphragm construction, the tungsten sheet 68 being clamped to the molybdenum diaphragm 61. When the beam is incident centrally on the hole 60 about half of the electrons of the beam pass through and proceed on to form, after passing through the projecting lens system, an electron image of the hole 60 upon the screen 82 of the tube. This image is the "spot" of the television tube. When the modulating voltage is not such as to cause the image of the slit 34 in the S-plane to be central upon the hole 60, the latter is only partially "illuminated" by electrons and fewer electrons pass through. More of the beam is now incident upon the tungsten sheet 68 and if V_m , the voltage difference between the modulating plates, is sufficiently large, no electrons will pass through the hole but all will be incident upon the tungsten plate 68 or the molybdenum plate 61. As V_m is further increased, the beam becomes entirely incident upon the molybdenum plate 61; any further increase will cause it to strike one of the modulating plates. As the beam does these various things, the modulating plate currents will vary. Up to those values of V_m sufficient to cause the beam to strike the

modulating plates themselves, the modulating plate current is due to secondary electrons; a distinction should be made between two groups of secondary electrons, that is between low speed and high speed secondary electrons. Probably the latter group is made up predominantly of "full speed" reflected electrons, but it also includes electrons scattered with various but incomplete energy losses. These high speed secondaries are apparently equal in number to about 10 per cent of the primary electrons, and give rise to several effects which ordinary methods of secondary electron control based upon the low speed, and more numerous group, fail to eliminate.

In the arrangement shown in Fig. 3, the cross-connection of the four modulating plates is eliminated. Instead the first pair 70, 71 is used for modulation by deflection and the second pair 72, 73 is placed at a fixed potential of about 22½ volts negative with respect to the second apertured diaphragm although it is to be understood that this value may vary from a very few volts up to about 200 volts negative with respect to the plane potential. The maximum value of this potential is fixed by the following considerations. Placing a negative potential on the second pair of plates introduces into the path of the primary beam a cylindrical electron lens which causes astigmatism in the electron image of the slit S in the first apertured diaphragm 33 which the modulating lens is forming in the plate of the second apertured diaphragm 61. This astigmatism reduces the maximum beam current which can be passed through the slit or hole S' and has also other undesirable effects which are not so important. So long as the cylindrical electron lens is weak, the reduction of the maximum beam current is small, but as its strength increases with increase of the negative potential being applied to the second pair, a point is reached when the negative potential is about 4 per cent of the primary electron energy, at which the reduction becomes appreciable. It is clear that the preferable mode of operation is close to the minimum value of the negative potential. It should be observed that when the second pair of plates is made into a hollow metallic cylinder, geometrical arrangements are possible which completely eliminate the cylindrical end effects and hence that the hollow cylindrical lens can be operated very negative indeed, although still it cannot be made to approach cathode potential, because of electron optical aberration. The second pair of plates 72, 73 acts as a shield to force the group of low speed secondary electrons to return to the diaphragm 61. It is also evident that the solid angle subtended by the more negative of the modulating plates 70, 71 has been greatly reduced as compared with the conditions prevailing in Fig. 1, that is, in an arrangement where cross connection is used, since only one instead of two plates is now acting as a source of tertiary electrons and that plate is more remote from the point of emission of the secondary electrons, i.e., the diaphragm 61. The modulating plates 70, 71 are preferably connected to the terminals of the high resistance 100, the mid-point 101 of which is connected to a potential which is negative with respect to the potential of the plates 72, 73. Thus if the potential of the plates 72, 73 is made 22½ volts negative with respect to the potential of the diaphragm 61, the potential of the mid-point 101 would be about 45 volts negative with respect to the frame potential. This

value of 45 volts is not very critical and, in fact, only a slight reduction of modulating plate currents is achieved by making the average potential of the first pair negative with respect to the fixed potential of the second pair. The high speed secondary electrons incident upon the second pair cause the emission of tertiary electrons, practically all of which are repelled from the first pair by making its average potential about $22\frac{1}{2}$ volts less than that of the second pair (which itself is $22\frac{1}{2}$ volts negative). As the potential of the first pair approaches that of the second pair, tertiary electrons emitted by the latter begin to be drawn across to the more positive plate of the first pair, constituting a modulating plate current. If the average potential of the first pair is made positive with respect to that of the second pair (as for example by making it zero or frame potential), a very considerable current of tertiaries from the second pair to the first pair results. With the arrangement shown in Fig. 3, the current between the plates of the first pair 70, 71 which now are the only pair of modulating elements, becomes small enough so that a very large input resistance 100 may be used.

The arrangement shown in Fig. 3 may be supplemented by a diaphragm or other shield member placed between the second pair of modulating plates 72, 73 and the second apertured diaphragm 61, this shield being placed at a negative potential with respect to the apertured diaphragm 61. The second pair of plates 72, 73 now serves no useful purpose and it can be eliminated entirely. With the elimination of the plates 72, 73, the shield can be made into a hollow metallic cylinder 102, as shown in Fig. 4, extending from the vicinity of the second apertured diaphragm 61 back to the vicinity of the first pair of plates 70, 71. The member 102 is preferably placed at the same potential as the plates 72, 73 in the arrangement of Fig. 3. It is necessary that the hollow metallic cylinder 102 and its immediate vicinity should have axial symmetry. This can be most easily achieved by a single shielding plate 140 between the cylinder and the pair of plates 70, 71, this plate having a circular aperture at its center and being connected to the frame. The function of this plate 140 is to separate the region of planar symmetry, represented by the deflecting plates 70, 71 from the region of axial symmetry represented by the cylinder 102. With this arrangement the cylinder could be operated at 4000 volts negative (for primary beam energy of 5000 volts) before electron optical aberration would begin to have undesirable effects. Such a system eliminates a considerable fraction of the group of high speed secondary electrons by turning back to the diaphragm 61 all secondary electrons having less energy than four-fifths of the primary electron energy, and would not be eliminated as a source of modulating plate currents.

While in the arrangement of Fig. 3 the plates 72, 73 serve no purpose as modulating elements, in some ways this arrangement may be preferred to the arrangement shown in Fig. 4 as it should be noted that it may be desired to operate a tube of the Davisson type under diverse conditions so that it may not be desirable to eliminate the second pair of plates even though in a particular circuit, such as that in Fig. 3, they serve no useful purpose.

If it is desired to retain the advantages of cross-connection of the four modulating plates, the solid angle subtended by the plates with re-

spect to the aperture in the second apertured diaphragm 61 may be reduced greatly by inclining or tapering the inner surfaces of the modulating plate away from the central axis, the distance between the plates of each pair decreasing in the direction of primary electron flow, and by providing two diaphragm shield members 114 and 115, one positioned between the two pairs of plates 110, 111 and 112, 113 and the second placed between the second pair of plates 112, 113 and the second apertured diaphragm 61. Such an arrangement is shown in Fig. 5. In this arrangement the shielding diaphragms 114 and 115 prevent high speed secondary electrons from striking the modulating plates. They are placed at a potential which is equal to or more positive than the potential of the diaphragm 61 in order that secondary electrons emitted by the shields are forced to return to the shields. In this arrangement, the mid-point 101 of the resistance 100 is placed at a potential which is negative with respect to the frame, as for example $22\frac{1}{2}$ volts, although it may have any value less than a few hundred volts.

The arrangement in Fig. 6 is the same as that shown in Fig. 5 except that the diaphragms 114, 115 are placed at a negative potential, of for example $22\frac{1}{2}$ volts but which may be more or less than this value, with respect to the potential of the second apertured diaphragm 61 while the mid-point 101 of the resistor 100 is placed at a potential which is more negative than the potential of the diaphragms 114 and 115. The functions of diaphragm 115 are (1) to turn back the low speed group of secondaries and (2) to intercept the group of high speed secondaries. Diaphragm 114 also intercepts certain of the high speed secondaries.

It should be noted that in the arrangements of Figs. 5 and 6, there is no need for a shield diaphragm near the diaphragm 61. This is because, since the average potential of the first pair of plates 110 and 111 is negative with respect to the diaphragm member 61, the tertiary electrons emitted by the diaphragm 61 by the high speed secondary electrons incident thereon encounter a negative electric gradient and are forced to return to the member 61 and hence do not give rise to modulating plate currents. It should also be noted that in the arrangement shown in Fig. 5, if the shield diaphragms are placed at zero potential, they may be mechanically and therefore electrically connected inside the tube to the frame (diaphragms 64, 61 and the cylinder F) and there is no necessity to bring out extra leads. Although this last-mentioned arrangement is not as satisfactory as the arrangement of Fig. 6 in the elimination of secondary electrons, the mechanical simplicity would make it a preferred arrangement in some cases.

Fig. 7 shows a structure which differs from that of Figs. 5 and 6 in the addition of a third shielding diaphragm 116 between the diaphragms 115 and 61. In this arrangement, the requirement is that the average potential of the modulating plates shall be negative with respect to the two connected shielding diaphragms 114 and 115. The third shielding diaphragm 116 is always at a negative potential with respect to the frame potential to eliminate the low speed secondary electrons. The diaphragms 114 and 115 are placed at either negative, zero or positive potential, thus corresponding to Figs. 5 and 6, but the potential of the mid-point 101 of the re-

sistance 100 is in all cases negative with respect to the potential of the plates 114 and 115.

In a tube of the Davisson type, a preferred arrangement from the standpoint of simplicity is to connect the first two shields 114 and 115 mechanically (and electrically) to the frame F as shown in Fig. 8. Thus, they are always at zero or frame potential. The third insulated shielding diaphragm 116 is the only member which requires that an extra lead be brought out of the tube and it may be connected to the average potential point 101 of the modulating plates.

A fourth shielding diaphragm 117 may be added as shown in Fig. 9. This diaphragm is placed between the diaphragm 64 and the first pair of plates 110 and 111 and is electrically connected to the diaphragms 114 and 115. A separate lead is also required for the diaphragm 116, which is always placed negative with respect to the frame in order to eliminate low speed secondary electrons. The shield potential S_0 (the shield comprising the three connected diaphragms 117, 114 and 115) may be of any desired value although the potential of the mid-point 101 of the resistor 100 is always made negative with respect to the shield potential S_0 . The shield formed by the members 117, 114 and 115 furnishes an electrically independent space within which the tapered plates 110, 111 and 112, 113 are located. To eliminate tertiary electrons it is only necessary that the average potential of the modulating plates, that is the potential of the mid-point 101 of the resistor 100, should be negative with respect to the potential S_0 .

The only advantage of the arrangement of Fig. 9 over that shown in Figs. 7 and 8 is that it is possible to set the average modulating plate potential at any desired value with respect to the frame whereas in the arrangement of Figs. 7 and 8, it is essential that it be negative with respect to the frame. From the standpoint of elimination of the secondary and tertiary electrons, the arrangements of Figs. 7, 8 and 9 are equally good.

Although the cross-connection is shown in all the arrangements of Figs. 5 to 11, inclusive, it should be noted that the elimination of secondary and tertiary electrons is independent of the cross-connection and signals applied to the four modulating plates. The only electrical requirement is that at no time during operation does the potential of any of the four modulating plates become positive with respect to its immediate surroundings; the geometrical requirement is that the four plates all be shielded from the approximately linear trajectories of the high speed secondary electrons emitted from the center of the aperture 60 in the diaphragm 61.

Any of the shielding arrangements shown in Figs. 5 to 9, inclusive, can be used either with similar pairs of tapered plates as shown in these figures or with two dissimilar pairs as shown in Fig. 10. In the arrangement of this figure, which is electrically connected as shown in Fig. 5, the modulating plates 120 and 121 constituting a first pair are shorter than the plates of the second pair 122 and 123. It has been noted that a gain of sensitivity of about 10 per cent can be achieved by the use of such dissimilar pairs. This is because the minimum taper, which reduces the angle subtended by the surfaces of the plates to zero, is less for the first pair of plates than it is for the second, since the latter are nearer the source of high speed secondary electrons at the second apertured diaphragm. In consequence the first pair can have greater sensitivity for de-

flection of the primary beam per unit length of plate. But it is required that the total sensitivity of each pair be the same in order to achieve the principle represented in the cross-connection. Therefore, if maximum sensitivity is desired, the first pair is tapered less and made shorter than the second pair. Extensions of the taper lines of the four plates preferably all intersect at the axis in a common point P. While the electrical hook-up of Fig. 10 is similar to that of Fig. 5, it is to be understood that the principle of providing dissimilar pairs of tapered plates may be also applied to any of the arrangements shown in Figs. 5 to 9, inclusive.

In the arrangement of Fig. 11, parallel plates are shown as in Figs. 1, 3 and 4. These parallel plates have a considerable advantage of sensitivity over the tapered plates and it is possible to retain the cross-connection and still greatly reduce the tertiary electrons by the introduction of the diaphragm 125 which is always placed at a potential which is negative with respect to the frame potential to eliminate the low speed secondary electrons but is positive with respect to the average potential of the modulating plates (and preferably with respect to the potentials of all the modulating plates) in order to oppose the flow of tertiary electrons from this element to the modulating plates. In the arrangement of Fig. 11 assume that the primary electron beam is deflected upward and that the plates 71 and 72 are electrically connected as shown, and at a given instant are negative with respect to plates 70 and 73 which are also connected together and driven positive by the deflecting voltage. This results in an upward deflection of the primary beam as shown in Fig. 11. The dotted lines show that when the primary beam is sufficiently deflected, the high speed secondary electrons are restricted by the diaphragm shield to incidence upon the plate 73; since this plate is positive with respect to the plate 72, the tertiary electrons it emits are forced back to it and hence do not constitute a modulating plate current. At lesser degrees of deflection, some high speed secondary electrons strike plate 71 and give rise to tertiary electrons which are accelerated by the electric field between the plates 70 and 71 and are collected by plate 70, thus constituting a modulating plate current, but since the plate 71 is considerably removed from the region of emission of high speed secondary electrons on the aperture diaphragm 61, it subtends a relatively small angle and consequently the modulating plate current is greatly reduced as compared to what it is in the absence of the diaphragm 125 when the plate 72 which subtends a relatively large angle is also exposed to the high speed secondary electrons, giving rise to tertiary electrons which are drawn across to the plate 73. By properly proportioning the size of the opening in diaphragm 125 to the distance between it and the plate 61, diaphragm 125 can be made a shield equivalent to that obtained by abandoning the cross-connection and connecting the second pair of modulating plates as a shield in the manner previously described in connection with Fig. 3. The size of the opening is fixed by the requirement that no electrons in the primary beam can be allowed to strike the diaphragm 125. Thus in the arrangement of Fig. 11, the greater sensitivity of the parallel plate system may be utilized, including the advantages of the cross-connection, with a great reduction but not complete elimination of the modulating

plate currents. In many signal input circuits, this reduction may be adequate. If desired, a small cylinder 126 may be electrically and mechanically connected to the plate 61 surrounding the aperture 60 in any of the figures described above to increase the shielding effect.

The angle relationships determining modulating currents will now be considered with reference to Figs. 15 to 17, inclusive. By way of illustration, consider first the parallel plates with no shields, cross-connected, as in Fig. 15, and at an average potential such that the low speed group is eliminated. Assume voltages such that the plates 71 and 72 are slightly positive with respect to the plates 70 and 73. The beam is then slightly deflected upward. The modulating plate currents may be considered as having two principal components: (1) High speed secondary electrons incident upon plates 71 and 72. These are substantially those emitted within the angle $cS'b$ and $eS'f$. There will be some slight displacement of these angles due to the fields between the plates 72 and 73 and the plates 70 and 71. Thus a secondary electron (dependent on its energy) may have left S' in a direction headed for b , and end by striking plate 71, because of the field between the plates 72 and 73. However, because the distribution-in-angle of the emitted secondaries is not very far from a cosine distribution, the principal effect of the curved trajectories between plates 72 and 73 is to decrease slightly the secondary electrons striking the more negative plates and increase those striking the more positive plates. (2) Tertiary electrons due to high speed secondaries emitted within angle $bS'a$ and $dS'e$, which strike the more negative plates 70 and 73. Once again, the exact effective angles of emission of high speed secondaries are difficult to define exactly, because of the curved trajectories due to the electric field between the plates 70 and 71, and that between plates 72 and 73. These trajectories are approximately parabolic, with the curvature in the opposite sense between the two pairs of plates; but the radius of curvature is so large for secondary electrons with energies more than 20 per cent of primary electron energy that they may be represented by segments of circles of very large radius.

It can be shown that if shields are interposed between the source of the high speed secondary electrons at S' and the four plates in such a way that no linear trajectories strike the more negative plates, then also none of the curved trajectories strike the more negative plates. Essentially this is because of the fact that the electrons are always deflected toward the more positive plates. Thus by proper shielding and geometry of the modulating plates as, for example, in Fig. 5, it is possible to completely eliminate tertiary electrons as a source of modulating plate currents.

The shields inserted to eliminate the tertiary electrons as sources of modulating plate currents also intercept most of the secondary electrons in group 1 (those striking the more positive plates directly). Due to the curved trajectories a small part of this group still strikes the more positive plates, that is, they pass by the edges of the shields and are then deflected towards the more positive plates, but the number doing this is small compared to the number intercepted by the shields. This residual modulating plate current can be further decreased by increasing the in-

clination of the plates beyond that given by the radial lines centering at the slit S' .

But these direct secondary electrons constitute only a small part of the total modulating plate current, since the tertiary electrons whose sources are the more negative ones of the modulating plates constitute the major part (in the absence of shields). This is because of the high secondary emission factor associated with almost glancing incidence of the high speed secondary electrons upon the more negative plates.

Thus the shields reduce modulating plate currents to a few per cent of their value in the absence of shields. By appropriate inclination of the plates modulating plate currents can be reduced as much as desired but, of course, at the expense of reduced sensitivity associated with increased inclination or taper. It is also possible to decrease the residual modulating plate current by increasing the plate separation, so that the plates are set back behind the edges of the apertures in the shielding member. This, of course, also results in decreased modulation sensitivity.

Finally, as mentioned above, it is essential that the shielding system be operated at a potential positive compared with more positive modulating plates, in order that low speed tertiary electrons from the shielding members themselves shall not be drawn across to the modulating plates and constitute a modulating plate current. The diagram shown in Fig. 16 and Fig. 17 shows angle relationship based upon linear trajectories for the high speed secondary electrons. As mentioned above, these are not the actual trajectories but, despite this, the linear diagram represents very nearly an optimum shielding arrangement for the reduction of modulating plate current. The diagram of Fig. 16 shows the flow, by means of dotted lines, of high speed secondary electrons from a source at the edge of the aperture 60 in the apertured diaphragm 61. When the primary beam, indicated by full lines, is thus deflected so that a considerable part of it is not passing through the aperture 60 but instead is being intercepted by the apertured diaphragm 61, this part of the primary electron beam gives rise to secondary electrons including the high speed group.

If the cross-connection is used, plates 70 and 73 are positive with respect to plates 71 and 72 for the primary beam deflection shown. Those high speed secondary electrons (it has been assumed the low speed group has been eliminated by the method of the above-mentioned Calbick patent) which strike plates 70 and 73 constitute a small part of the modulating plate current, the major part of which is furnished by tertiary electrons set free at plates 71 and 72 by the high speed group of secondary electrons incident thereon. The diagram shown in Fig. 17 shows the assumed linear trajectories of high speed secondary electrons with a shielding system inserted, but with no modulating plates shown. The primary beam is shown solid while the high speed secondary trajectories are dotted.

It is clear from Fig. 17 that there exist regions between the diaphragm 64 and the first shield member 220 and between the two shield members 220 and 221, within which there are no high speed secondary electron trajectories, and hence that if the modulating plates are placed in these regions, that there will be no modulating plate currents because no high speed secondaries strike the modulating plates. Actually, because the trajectories are not linear, but curved by the

transverse modulation field, the modulating plate currents are not reduced to zero if the modulating plates are located just inside the trajectory-free region of Fig. 17. However, the residual current will be quite small, and can be reduced to any desired degree, at the expense of sensitivity, by moving the modulating plates farther away from the regions of high speed secondary electron trajectories, that is, by increasing the separation, or inclination, or both separation and inclination, of the modulating plates. Obviously, designs similar to the above can be drawn for any proposed shielding system, and the modulating plates located within the trajectory-free region as deeply as is consistent with the desired sensitivity and with the specified degree of freedom from modulating plate currents.

The various arrangements described above illustrate the general principle that, in order to eliminate effects caused by tertiary electrons due to high speed secondary electrons, the following steps are in general necessary; (1) metallic shields must be placed to intercept the trajectories of high speed secondary electrons leading to electrodes in whose vicinity there are more positive electrodes, and (2) these shields must be made more positive than any neighboring electrode so that tertiary electrons emitted by the shields are forced to return to the shield, although partial elimination may take place by using only one of these steps. In certain types of electron beam switching tubes, cross-talk between channels due to high speed secondary electrons takes place and in such tubes shielding means embodying the above principles may be used to eliminate such cross-talk.

Various other changes may be made in the embodiments above described without departing from the spirit of the invention, as indicated in the appended claims.

What is claimed is:

1. A cathode ray tube comprising main electrodes for generating a cathode beam, a beam receiving element, a beam-control electrode forming the terminal of an external control circuit, an additional element within the tube and outside the path of said beam adapted to emit electrons under impact of high speed electrons, said control electrode and said additional element having at certain times at least during the operation of the tube respective potentials such that electrons emitted from a surface of said additional element will flow to said control electrode, and a shield for shadowing said surface from any high speed electrons traveling toward said surface in substantially straight paths from the immediate vicinity of that portion of said beam receiving element to which the beam is directed.

2. In a cathode ray device, means for generating a beam of electrons, a beam receiving member, means for focussing said beam to a small spot at said member, a pair of modulating plates between said member and said beam generating means and spaced apart one on each side of the central longitudinal axis of said beam, said plates being so positioned that when portions of said beam of electrons strike said member electrons are normally deflected to at least one of said plates, and means interposed in the paths of said deflected electrons for shielding said plates from electrons proceeding from said member.

3. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm of metallic material, means for focussing said

beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, and a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm.

4. In a cathode ray device, means for generating a beam of primary electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, the distance between said plates decreasing in the direction of primary electron flow whereby electrons deflected from said diaphragm when struck by portions of said beam tend not to reach said plates, and means for applying a biasing potential between said apertured diaphragm and said pair of plates of such polarity that the average potential of said plates is at all times negative with respect to said diaphragm.

5. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and beam generating means and spaced apart one on each side of the longitudinal axis of said device, the inside surface of each of said plates being inclined outwardly in a direction opposite to the direction of travel of the beam whereby electrons deflected from said diaphragm when struck by portions of said beam do not reach said plates, means for applying a biasing potential between said apertured diaphragm and said pair of plates of such polarity that the average potential of said plates is at all times negative with respect to said diaphragm, and a second apertured member between said beam generating means and said pair of plates for intercepting at least a portion of said deflected electrons.

6. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, and means for cross-connecting the plates of said first pair with the plates of said second pair, the inside surface of each of the plates of said first and second pairs of plates being inclined outwardly in a direction opposite to the direction of travel of the beam.

7. The combination of elements as in claim 6 but being further characterized in that the plates of said second pair are longer than the plates of said first pair of plates.

8. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm of metallic material, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, and a third apertured diaphragm between said first pair of plates and said second pair of plates.

9. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, a third apertured diaphragm between said first pair of plates and said second pair of plates, and means for placing said second and third diaphragms at the same potential.

10. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, a third apertured diaphragm between said first pair of plates and said second pair of plates, means for applying modulating voltages between said cross-connected pairs of plates, and means for placing the average potential of said cross-connected plates at a value which is negative with respect to the potential of said second and third apertured diaphragms.

11. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike

said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, a third apertured diaphragm between said first and second pairs of plates, and a fourth apertured diaphragm between said second apertured diaphragm and said first apertured diaphragm.

12. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, a third apertured diaphragm between said first and second pairs of plates, a fourth apertured diaphragm between said second pair of plates and said second apertured diaphragm, and means for placing said third and fourth apertured diaphragms at the same potential.

13. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, a third apertured diaphragm on the side of said first pair of plates remote from said second pair of plates, a fourth apertured diaphragm between said first pair of plates and said second pair of plates, and a fifth apertured diaphragm between said second pair of plates and said second apertured diaphragm, and means for placing said third, fourth and fifth apertured diaphragms at a common potential.

14. In a cathode ray device, means for generating a beam of electrons, an apertured diaphragm, means for focussing said beam to a small spot in the region of the aperture in said diaphragm, a pair of modulating plates between said diaphragm and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, said plates being so positioned that when portions of said beam of electrons strike said diaphragm electrons are normally deflected to at least one of said plates, a second pair of spaced plates positioned between said first pair of plates and said apertured diaphragm, means for cross-connecting the plates of the first pair

with the plates of the second pair, a second apertured diaphragm between said second pair of spaced plates and said first apertured diaphragm, said plates of each pair being parallel to each other, means for placing said second apertured diaphragm at a negative potential with respect to said first apertured diaphragm, and means for placing the average potential of said cross-connected plates at a value which is negative with respect to that of said second apertured diaphragm.

15. In a cathode ray device having two electrode members therein between which, at least at certain times, a difference of potential exists and between which, in the absence of preventing means, there is a flow of current due to low speed electrons caused by relatively high speed electrons striking the more negative of said electrode members, the method of substantially reducing said flow of current comprising the step of intercepting the high speed electrons with an element which is more positively polarized than at least the more negative of said electrode members.

16. In a cathode ray device, two electrode members, means for creating a difference of potential between said electrode members, means for generating a stream of relatively high velocity electrons which, in the absence of preventing means, would strike the more negative of said electrode members, and means for substantially preventing said high speed electrons from striking said more negative electrode member, said means comprising shielding means so positioned as to intercept certain at least of said high speed electrons, and means for applying a potential to said shielding means which is positive with respect to the potential of the more negative of said electrode members.

17. A cathode ray tube comprising a source of a beam of electrons, an electron receiving element in the path of the beam, means for causing said beam to impinge upon a surface of said element within a small area thereof during at least the major portion of the time said tube is in operation, whereby certain of the electrons of said beam have their general direction of travel reversed and move at high velocity away from said area in substantially straight paths lying within a cone having said area as its apex, a pair of control means for said beam positioned respectively on opposite sides thereof within said cone between said source and said surface, each of said control means having a surface facing said beam and so disposed as to lie outside the straight paths of said deflected electrons which pass by the boundaries of said surface nearest said electron receiving element, and means for applying a biasing potential between said electron receiving element and said pair of control means of such polarity that the average potential of said control means is at all times negative with respect to said electron receiving element.

18. A cathode ray tube comprising a source of a beam of electrons, an electron receiving element in the path of the beam, means for causing said beam to impinge upon a surface of said element within a small area thereof during at least the major portion of the time said tube is in operation, whereby certain of the electrons of said beam have their general direction of travel reversed and move at high velocity away from said area in substantially straight paths lying within a cone having said area as its apex, a pair of control means for said beam positioned respectively on opposite sides thereof within said

cone between said source and said surface, each of said control means having a surface facing said beam and so disposed that any straight line passing through a boundary thereof and through said area will lie substantially within said surface, and means for applying a biasing potential between said electron receiving element and said pair of control means of such polarity that the average potential of said control means is at all times negative with respect to said electron receiving element.

19. A cathode ray tube comprising a source of a beam of electrons, an electron receiving element in the path of the beam, means for causing said beam to impinge upon a surface of said element within a small area thereof during at least the major portion of the time said tube is in operation whereby certain of the electrons of said beam have their general direction of travel reversed and move at high velocity away from said area in substantially straight paths lying within a cone having said area as its apex, a pair of control means for said beam positioned respectively on opposite sides thereof within said cone between said source and said surface, each of said control means having a surface facing said beam and generally inclined toward the axis thereof in the direction away from said source and so disposed as to lie outside the paths of said deflected electrons which pass by the boundaries of said surface nearest said area, and an apertured diaphragm member between said pair of control means and said electron receiving element.

20. The combination of elements as in claim 19 in further combination with means for applying a biasing potential between said pair of control means and said apertured diaphragm member of such polarity that the average potential of said control means is at all times negative with respect to said diaphragm.

21. The combination of elements as in claim 19 in further combination with means for applying a biasing potential between said pair of control means and said electron receiving element of such polarity that the average potential of said control means is at all times negative with respect to said electron receiving element.

22. In a cathode ray device, a first pair of spaced electrode members one on each side of the longitudinal axis of the device, means for forming a stream of electrons at least some of which are caused to pass between said members, and a second pair of spaced electrode members arranged on the side of said first pair remote from said means, the intersection of the inside surface of each of the members of said first and second pairs with a single plane passing through said axis and bisecting at least the members of one of the pairs being inclined outwardly in the direction of flow of said electron stream.

23. In a cathode ray device, a first pair of spaced electrode members one on each side of the longitudinal axis of the device, means for forming a stream of electrons at least some of which are caused to pass between said members, and a second pair of spaced electrode members arranged one on each side of said axis and on the side of said first pair remote from said means, the intersection of the inside surface of each of the members of said first and second pairs with a single plane passing through said axis and bisecting at least the members of one of the pairs being inclined outwardly in the direction of flow of said electron stream, the angle of said in-

clination of the first pair being less than the angle of said inclination of the second pair.

24. In a cathode ray device, a first pair of spaced plates one on each side of the longitudinal axis of the device, means for forming a stream of electrons at least some of which are caused to pass between said plates; and a second pair of spaced plates arranged one on each side of said axis and on the side of said first pair remote from said means, the inside surface of each of the plates of said first and second pairs of plates being inclined outwardly in the direction of flow of said electron stream, the angle of inclination of the inside surfaces of the plates of the first pair with the longitudinal axis of the device being less than the angle of inclination of the inside surfaces of the plates of the second pair, the plates of all four of the inside plate surfaces intersecting said axis at the same point.

25. In a cathode ray device, means for generating a beam of electrons, a beam receiving element, means for focussing said beam to a small spot at said element, and two electrode members between said element and said beam generating means and spaced apart one on each side of the longitudinal axis of said device, the distance between said members decreasing in the direction of flow of electrons in said beam, whereby electrons deflected from said element when struck by portions of said beam tend not to reach said members, the inclination of the intersection of the inside surface of each of the two members and the longitudinal axis of the device, with respect to the adjacent boundary surface of the beam, being such that the sensitivity of the two members is less than for a pair of parallel plates spaced apart by a distance equal to the smallest

distance between the members of the inclined pair.

26. A cathode ray tube comprising means for generating an electron beam, a beam receiving element, an electrode member, an additional element within the tube and outside the path of said beam adapted to emit electrons under impact of other electrons, said electrode member and said additional element having at certain times at least during the operation of the tube respective potentials such that electrons emitted from a surface of said additional element will flow to said electrode member, and a shield for shadowing said surface from any high speed electrons traveling toward said surface in substantially straight paths from the immediate vicinity of that portion of said beam receiving element to which the beam is directed.

27. In a cathode ray tube, electron deflecting means having portions extending along the tube axis on opposite sides thereof and symmetrically arranged with respect to said axis, the opposed inner surfaces of said portions being inclined away from said axis in the same direction therealong, a source of electrons positioned beyond that end of said electron deflecting means at which said surfaces are nearest said axis, the size of said source, its distance from said electron deflecting means, the minimum distance between said surfaces, and the inclination of said surfaces all being such that no electron traveling in a straight path from said source can reach said surfaces, and shielding means for preventing electrons from said source directed toward other parts of said electron deflecting means from reaching said means.

CHESTER J. CALBICK.