

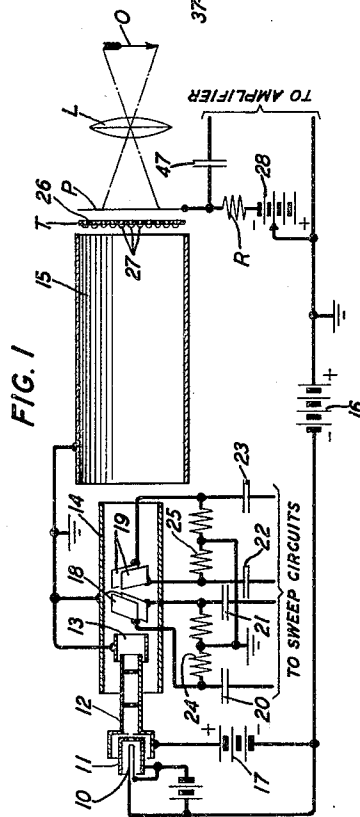
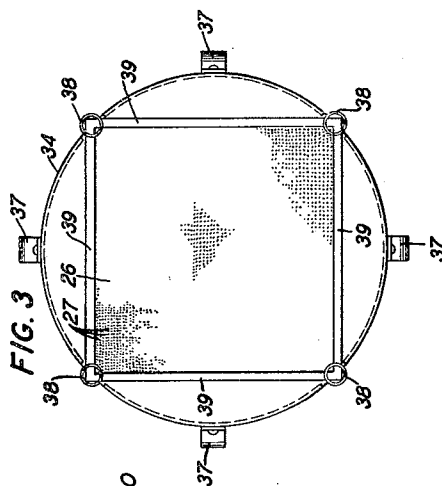
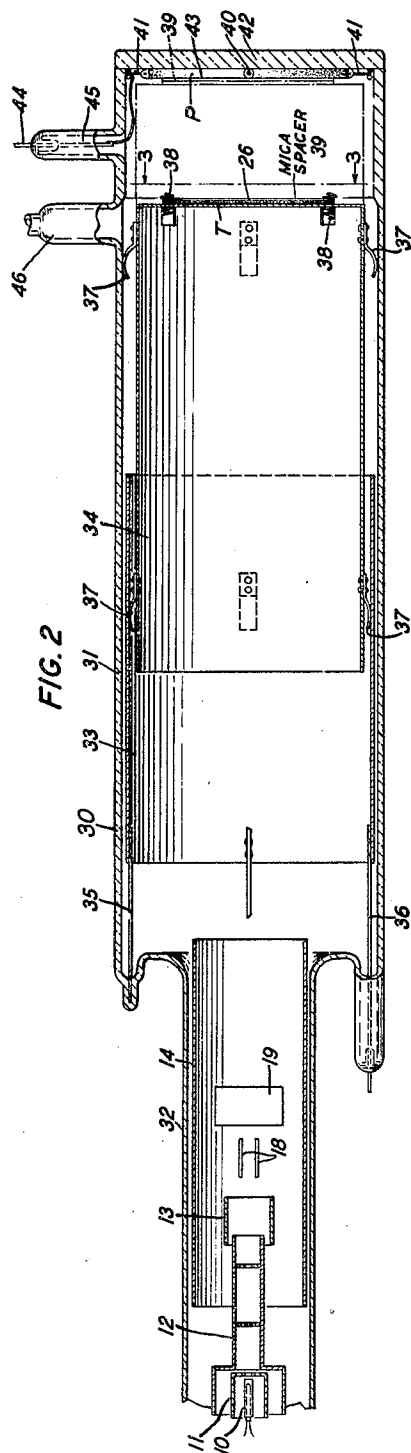
July 29, 1941.

C. J. DAVISSON

2,250,927

ELECTRON DISCHARGE DEVICE

Filed May 2, 1939



INVENTOR
C. J. DAVISSON
BY *C. J. Sprague*
ATTORNEY

UNITED STATES PATENT OFFICE

2,250,927

ELECTRON DISCHARGE DEVICE

Clinton J. Davisson, Short Hills, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application May 2, 1939, Serial No. 271,295

4 Claims. (Cl. 250—153)

This invention relates to electron discharge devices and more specifically to electron camera tubes for television.

In British Patent 369,832 to Zworykin, March 31, 1932, there is disclosed an electron camera tube for television transmission comprising an evacuated envelope having at one end thereof means for generating a beam of electrons and at the other end thereof a screen structure comprising, in the simplest embodiment shown, a mesh screen, a metallic plate having a plurality of apertures therein, each of said apertures being filled with an insulating insert pierced by a metallic plug member having a globular-shaped head, and a second mesh screen which is covered with photoemissive material. Radiations from an object or field of view are applied to the mesh screen which is covered with photoemissive material to cause the emission of electrons from the screen to the metallic plug members where charges are stored because of the capacity between each of the plugs and the metallic plate, the insulating inserts being used as dielectrics. The plugs are scanned through the first mesh screen to remove these charges and to set up an image current.

It is an object of this invention to provide an electron camera tube of the general type disclosed in the British patent but which by using a screen structure which is much simpler to construct and which embodies fewer parts, is a much more simple and satisfactory tube.

It is another object of this invention to provide an electron camera tube in which the capacity between a conducting photoemissive screen and a plurality of metallic plugs carried in an insulating plate is utilized for the storage of charges.

Other and ancillary objects and features of this invention will be apparent from the description below and from the appended claims.

In accordance with this invention there is provided, for example, a television transmitter tube comprising a cathode ray device on the end wall of which is a translucent conducting photoemissive surface. Parallel and very close to the photoemissive surface is a mosaic of small metallic conducting buttons which are supported and insulated from one another by a perforated plate of insulating material, such as glass, the conducting elements extending through the plate from side to side. An electron gun is provided for generating a beam of electrons and the anode portion of said gun near the photoemissive surface is connected to ground. The photoemissive

surface is connected to ground through a resistance and a source of potential which maintains it at a potential of 50 to 100 volts negative with respect to ground. The buttons of the mosaic are similar and their ends have a coefficient of secondary emission which is for electrons of the speed of those in the scanning beam (from 1000 to 1500 volts) appreciably greater than 1, that is, for practical purposes, not less than 1.5.

The operation of the electron camera tube of this invention is as follows: With the transmitter operating, normally the "dark potential" of the mosaic is at or near earth potential. The photo-plate on the end wall of the tube is 50 to 100 volts negative with respect to earth. Each element of the mosaic, that is, each metallic button, then has a certain "dark charge" which is positive and which is greater the greater the capacity between the photo-plate and the mosaic, and which is proportional to the negative potential applied to the photo-plate, the minus 50 or minus 100 volts. The effect of the photo-current which flows from the photo-plate to each of the plug elements during the scanning period is to discharge this elementary condenser. The action of the scanning beam is thus to restore the elementary condenser to its fully charged condition. It is important that the photo-currents from even the most brightly illuminated parts of the plate shall not completely discharge the associated elementary condenser in the time of one scanning period. The signal from an element is proportional to the extent to which the elementary condenser is discharged. If an elementary condenser were completely discharged in the scanning period for some intermediate plate brightness then it would be completely discharged for all greater brightnesses and all brightnesses above the critical brightness would give signals of the same strength; that is, all parts of the object above the critical brightness would appear in the picture as of the same brightness. The capacity between the photo-plate and the mosaic must be large enough so that none of the elementary condensers is ever completely discharged. If this condition is not satisfied the high-lights of the image are flattened out. If this condition is satisfied the transmitter is operative and increasing the capacity or lowering the plate voltage further has no effect. If this capacity is large enough, it is not necessary that any metallic element be placed in capacitive relation to the metallic button of the mosaic, as is the case in the British patent de-

scribed above. Thus it is possible to make use of a greatly simplified target plate.

An important feature of the present invention has to do with the strong and definite field which is provided for transporting photoelectrons from the photo-plate to the elements of the mosaic, that is, the 50 to 100-volt field between plate and mosaic. Due to the closeness of the photo-plate and the mosaic, preferably of the order of from one to ten thousandths of an inch, the voltage gradient between these two members is very large and this field insures that every photo-electron emitted by the plate is transferred to and stores on its proper element. A weak feature of the well known iconoscope is that no positive means is provided for carrying off the photo-emission from the element, this objectionable feature not being present in the instant invention. In the arrangement shown in the British patent (where the plugs serve to attract electrons from the photoemissive mesh screen) there are metallic elements between the various plug members, which metallic elements will attract certain of the electrons from the photo-emissive screen and thus prevent these electrons from going to the plug members. In the present invention there are no metallic elements in the mosaic target other than the plug members so there is nothing to prevent the photoelectrons from going directly across to the plug members.

The invention will be more readily understood from the following description taken in connection with the accompanying drawing forming a part thereof, in which:

Fig. 1 shows schematically an electron camera tube and associated circuits in accordance with the invention;

Fig. 2 is a sectional view of a complete tube embodying the invention showing the mosaic target before it has been put into position closely adjacent the photoemissive plate member on the wall of the tube; and

Fig. 3 is an end view of a portion of the tube shown in Fig. 2.

Referring more particularly to the drawing, Fig. 1 shows schematically a cathode ray television transmitter in accordance with the invention. The transmitter preferably comprises an evacuated container enclosing an electron gun for generating and focussing a beam of electrons, a target assembly T, means for causing the beam to scan every elemental area in turn of a field on the target assembly T and a conducting translucent photoemissive layer P upon which radiations from an object or field of view are projected. The envelope surrounding the electron gun deflecting system and target assembly is, for simplicity, not shown in this figure but is shown in Fig. 2.

The electron gun assembly comprises an equipotential cathode 10, heated by a suitable heater, a shield electrode 11, a first anode 12 and a second anode comprising three coaxial cylinders 13, 14 and 15 all of which are placed at the same potential, which potential is preferably ground. The cathode 10 is placed at a potential from 1000 to 1500 volts below ground by means of a source 16. The first anode 12 is placed at a potential about 600 volts positive with respect to the cathode by means of the source 17. The various elements in the electron gun system cooperate in a manner well known to those skilled in electron optics to form a beam of small cross-section at the target T.

In order to cause the electron beam generated by

the electron gun apparatus described above to scan every elemental area of the field of view on the target T in turn, suitable deflecting plates such as, for example, two pairs of electrostatic deflecting plates 18, 18 and 19, 19, the normals to whose surfaces are located at right angles to each other, are provided. To the deflecting plates 18, 18 are applied deflecting voltages at line scanning frequency, (5760 cycles per second, for example) and of saw-toothed wave form to produce the horizontal deflection, while deflecting voltages of framing frequency (24 cycles per second, for example) and of saw-toothed wave form are applied to the deflecting plates 19, 19 to produce vertical deflection of the beam. Any appropriate sweep circuit (not shown) may be used to generate the horizontal and vertical deflection voltages. For example, reference may be made to Patent 2,178,464, issued October 31, 1939, to M. W. Baldwin, Jr., which discloses suitable balanced sweep circuits for this purpose. Connections may be made from the balanced sweep circuits to the pairs of deflecting plates 18, 18 and 19, 19 by means of coupling condensers 20, 21 and 22, 23, respectively, of about 1 microfarad capacity each. Coupling resistances 24 and 25 of the order of 20 megohms each are respectively connected across the pairs of plates 18, 18 and 19, 19. The mid-points of the resistances 24 and 25 are connected to ground so that the average of the potentials of the deflecting plates does not deviate more than slightly from the potential of the second anode elements 13, 14 and 15. This relationship is maintained to avoid changes in the sensitivity of the deflecting system, and the consequent distortion of the image which would otherwise result. For a fuller description of the advantages of balanced sweep circuits for use with cathode ray television tubes, reference may be made to the above-mentioned Baldwin patent and also to Patent 2,209,199, issued July 23, 1940, to Frank Gray.

The target T comprises an insulating plate 26 comprising a thin film of glass about .002 inch thick supported by a thicker border of glass (not shown), the thin center portion having therein a multiplicity of small holes regularly spaced and of uniform size. These holes are filled with locked-in metallic buttons 27. The mosaic plate is preferably prepared by coating one surface of a glass plate with a plurality of wax dots through a mesh screen, removing the screen, melting the wax so that only small spaces of the plate between the dots are left uncovered, dipping the plate in an etching solution until the acid almost etches through to the side which is not covered by the wax, etching from the other side until the acid etches through to the apertures, washing the plate, and then depositing metallic plugs in the apertures from a suitable metallic plating solution. Large heads are then put on the plugs to cause them to be locked in place. For a fuller description of targets of the type disclosed herein and for a method of making them, reference may be made to Patent 2,217,334, issued October 8, 1940, to B. A. Diggory and G. K. Teal.

Closely adjacent the surface of the target T remote from the electron gun is a conducting photoemissive surface (photo-plate) P. This surface is connected through a signal resistance R and at least a portion of source 28 to ground. The photoemissive layer P is preferably maintained at a potential of about 50 or 100 volts negative with respect to ground.

The buttons 27 of the mosaic target T are sim-

ilar and their ends have a coefficient of secondary emission which is, for electrons of the speed of those in the scanning beam, appreciably greater than 1—not less, for example, than 1.5.

The currents within the tube are as follows: With the photo-plate P dark (that is, with no radiations being projected upon the photo-plate P from the object O through the lens L) and the scanning beam sweeping the mosaic T, the system attains a dynamic equilibrium in which the net current to the mosaic will be zero. The current of electrons flowing to the mosaic T from the scanning beam is balanced by an equal current of secondary electrons flowing from the mosaic to the secondary anode member 15. The equilibrium results from an adjustment of potentials which reduces the number of escaping secondaries (those passing from the mosaic T to the anode member 15) to an average of 1 per primary electron. The nature of this and similar equilibria will be considered more fully below.

If the beam current is switched off and the photo-plate P uniformly illuminated, photoelectrons will flow from the plate P to the mosaic target T. This continues until the potential of the target T falls sufficiently far below that of the plate P to reduce the photo-current to zero.

Considering now that the scanning beam is switched on but at an extremely low current, so low that the total secondary emission from the surfaces of the metallic buttons 27 near the scanning beam is small compared to the total photo-emission from P, the mean potential of the mosaic T will rise until a photo-current equal in magnitude to the total secondary emission minus the beam current flows from the photo-plate P to the mosaic target T. An equilibrium is established in which the beam current plus the photo-current (a part only of the total photo-emission) is equal to the total secondary emission. The potential of the mosaic differs only slightly from that of the photo-plate P.

If the beam current is increased, the total secondary emission also increases and the mean potential of the mosaic rises still more, but still only slightly to maintain the type of equilibrium just described. This continues with continuously rising beam current until the total secondary emission is equal to the beam current plus the total photo-emission. When this condition is reached the equilibrium is unstable. The system is in equilibrium for any mean potential of the mosaic which is sufficiently above that of the photo-plate P to saturate the photo-emission and sufficiently below that of the secondary anode member 15 to allow all secondary electrons to escape.

For still greater beam current, equilibrium is attained with the mean potential of the mosaic near that of the secondary anode member 15. The total secondary emission is greater than the beam current plus the total photo-emission. The potential of the mosaic target T rises until the current of escaping secondary electrons is just equal to the sum of these two currents flowing into the mosaic. It is this latter type of equilibrium only which is of interest—that which results when the total secondary emission is greater than the beam current plus the photo-current. It will be assumed in what follows that this condition is always satisfied.

It will now be considered what it is that happens when the illumination of the photo-plate P is constant in time but non-uniform in distribution—that is, when some portions are illuminated

more brightly than others by radiations from an object O to be televised. The current of photoelectrons flowing from the plate P to the mosaic T is constant; so also is the beam current. The current of secondary electrons flowing from the mosaic T to the second anode member 15 is, however, not constant. As regards a single element of the mosaic T the equilibrium is one in which the element receives photoelectrons at a constant rate from the portion of the photo-plate P which it faces and then once each scanning period, while the beam is passing over it, receives electrons at a high rate from the beam and at the same time loses secondary electrons to the second anode member 15 at an even higher rate. The element receives, for example, n photo-electrons during the scanning period and then, while the beam sweeps it, receives N electrons from the beam and loses $(N+n)$ to the secondary anode member 15. The current to the secondary anode member 15 is greater when the beam is sweeping elements which face brightly illuminated portions of the photo-plate P than when it is sweeping elements which face less brightly illuminated areas. In fact, the secondary current minus the beam current is at every instant proportional to the brightness of that portion of the photo-plate P opposed to the elements being swept by the beam. The secondary current is not at every instant equal to the beam current plus the total photo-current. This equality holds only for the average value of the secondary current taken over the complete scanning period.

There is one other current which should be considered. This is the current of electrons which flows into the photo-plate P through the resistance R and which serves to compensate or balance the flow of photoelectrons from the photo-plate P to the mosaic target T. It is conceivable that this current is constant like the total photo-current or that it is variable like the secondary current. As a matter of fact it is variable like the secondary circuit. It is not strictly equal at every instant to the secondary current minus the beam current, but when certain circuit conditions are satisfied, it duplicates this current difference with high, though not perfect, fidelity.

It follows that when these conditions are satisfied the potential across the resistance R is closely proportional at every instant to the brightness of the photo-plate P opposite the mosaic element upon which the scanning beam is playing. This voltage constitutes the television signal.

Referring now to Fig. 2, a cathode ray device 30 is shown in which the present invention is used. The device 30 comprises a large tube 31 and a smaller tube 32. The smaller tube 32 includes the cathode 10, shield 11, first anode 12, the first and second members 13 and 14 of the second anode member, and the deflecting plates 18, 18 and 19, 19. The larger tube 31 contains cylindrical members 33 and 34, forming together the third member of the second anode member, the mosaic member T and the photo-plate P. It is to be understood, of course, that any other suitable electron gun system may be used instead of the one specifically described above.

The cylinder 33 is preferably supported within the envelope 31 by means of support and contact wires 35 and 36, while the inner cylinder 34 is slidingly supported by means of sliding contact members 37 which serve both to hold the cylinder 34 in position with respect to the longitudinal axis of the tube and also to make contact with the

cylindrical member 33. Thus electrically the cylinders 33 are one member.

The mosaic target T is supported from the cylinder 34 by means of small springs 33 (see Fig. 3). Mica spacers 39 are also used under the springs 38 to space the mosaic target T the proper distance from the photoelectric plate P, when the target T is moved up to its operating position (see the dotted line position, Fig. 2). In practice, this distance should be from one to ten thousandths of an inch.

The photo-plate P comprises a glass plate 39 which has four glass beads 40 around the periphery thereof, from which wires 41 extend to serve as supporting members for the plate P. The glass plate 39 is thus mounted contiguous to a glass plate 42 which serves as the end wall of the cathode ray 30. The glass plate 39 is coated with platinum and then silver, the silver being oxidized and coated with caesium to form a photoemissive layer on the plate 39. Thus a conducting photoemissive surface 43 is formed on the side of the photo-plate P adjacent the mosaic layer T. A contact 44 is made to the photoelectric surface 43 by means of one of the wires 41 extending through the seal 45.

The spacing between the photo-plate P and the mosaic target T is one of the factors determining the capacity between these elements. This capacity must be sufficiently large to insure that none of the elementary condensers of the mosaic is completely discharged (by the emission of photoelectrons from the photo-plate P) during the scanning period—even those opposite the most brightly illuminated plate areas. This capacity has, however, another function for which it is desirable that the capacity be as large as possible, or at any rate quite high. The signal current which flows into the plate P through the signal resistance R is not precisely or identically that due to the charges which flow onto the parts of the plate P opposite the elements of the mosaic T when the elements are discharged. These induced plate charges which account for the signal current are always somewhat less than the element charges, but the discrepancy between them is less, the greater the plate to mosaic capacity. This capacity should be great enough to make these charges substantially equal, or nearly so, if the signals are to be as strong as possible. It is desirable also that the plate to mosaic separation be as small as possible to insure that the emission from the part of the plate opposite the given element reaches this element and not to any appreciable extent the neighboring elements. This requirement also leads incidentally to a high capacity from plate to mosaic.

In assembling the tube the cap 42 is sealed on the end of the tube 31 and the cylinder 34 is shaken down so that the spacers 39 adjacent the mosaic target T rest against the photo-plate P. Thus there is a spacing of only a small fraction of an inch, as stated above a few thousandths of an inch, between the end of the plugs 27 and the photoemissive surface 43. The tube 32 is then sealed into the larger tube 31. The glass plate 39 has a coating of platinum previously applied thereto and a coating of silver placed thereon. Oxygen is admitted to the tube and a spark coil placed close to the tube until silver oxide is formed. The oxide is then photosensitized by firing a caesium pill in the side tube 46. Due to the presence of the platinum layer the photoemissive surface 43 is conducting and connected

by means of a connecting wire 44 to the resistance R which is connected to the input circuit of a suitable amplifier by means of a coupling condenser 47 (see Fig. 1), for example.

When radiations from an object O are projected upon the photoemissive surface 43 by means of a suitable lens system L and the plugs 27 are each scanned in turn by means of the electron beam generated by the electron gun, a television signal current appears in the resistance R which is amplified by suitable means and which may be transmitted over wire or carrier channel to a television receiving station.

What is claimed is:

1. A television camera tube comprising means for generating a beam of electrons, a photoemissive screen, a continuous plate of insulating material having a multiplicity of metallic conductors therethrough, each of said conductors being separated from adjacent conductors solely by insulating material, said plate being placed between said screen and said beam generating means, means for subjecting said screen to radiations to cause emission of electrons from said screen to the ends of the conductors in said plate near said screen, and means for causing said beam of electrons to repeatedly scan the ends of said metallic conductors remote from said screen, said photoemissive screen and said insulating plate being substantially parallel to each other and separated by a distance of from one to ten thousandths of an inch.

2. A television camera device comprising a gas-tight container, means in said container for generating a beam of electrons, a photoemissive screen remote from said beam generating means a plate of insulating material having a multiplicity of elemental metallic plug conductors therethrough, each of said conductors being separated from adjacent conductors solely by insulating material, said plate being placed between said screen and said beam generating means, means including apparatus for causing said beam to repeatedly scan the ends of the conductors in said insulating plate remote from said screen to charge every plug to a positive equilibrium potential with respect to the potential of said screen, and means for applying radiations from an object or field of view to said photoemissive screen to cause the emission of electrons from the various elemental areas thereof to the ends of the metallic conductors in the insulating plate near said screen to partially remove the charges on said plugs, the degree of removal of the charge on any plug being proportional to the light-tone value of the corresponding elemental area of the object or field of view, said screen and said insulating plate being separated by a distance of from one to ten thousandths of an inch.

3. A television camera device comprising a gas-tight container, means in said container for generating a beam of electrons, comprising a cathode and a plurality of anodes, a conducting photoemissive screen remote from said beam generating means, a plate of insulating material having a multiplicity of elemental metallic plug conductors therethrough, each of said conductors being separated from adjacent conductors solely by insulating material, said plates being placed between said screen and said beam generating means, means for placing said photoemissive screen at a potential of from 50 to 100 volts negative with respect to the anode of said beam generating means nearer said plate of insulating material,

means including apparatus for causing said beam to scan repeatedly the ends of the conductors in said insulating plate remote from said screen to charge every plug to a positive equilibrium potential with respect to the potential of said screen, means for applying radiations from an object or field of view to said photoemissive screen to cause the emission of electrons from the various elemental areas thereof to the ends of the metallic conductors in the insulating plate near said screen to partially remove the charges on said plug, the degree of removal of the charges on any plug being proportional to the light-tone value of the corresponding elemental area of the object or field of view, and spacers for separating said screen and said insulating plate by from one to ten thousandths of an inch.

4. A television camera tube comprising means for generating a beam of relatively high velocity electrons, a target for said beam comprising a continuous plate of insulating material having a multiplicity of metallic conductors therethrough, each of said conductors being free to swing in potential and each being separated from adjacent conductors solely by insulating material, a photoemissive screen, all portions of which are at the same potential, positioned closely adjacent said target and facing the side thereof remote from said beam generating means, means for subjecting said screen to radiations from an object or field of view to cause the emission of photoelectrons from the various elemental portions

thereof, means for providing an accelerating field for the photoelectrons emitted from said photoemissive screen, said last mentioned means including means for causing said beam of relatively high velocity electrons to scan in succession the end of each of the metallic conductors in said target remote from said screen to cause the emission of secondary electrons therefrom to an extent which makes the potential of each of said conductors swing in a positive direction, to an equilibrium potential, with respect to the potential of the photoemissive screen, said photoelectrons causing the lowering of the potential across and thus the partial discharge of each of the elemental capacities between a metallic conductor and the photoemissive screen in an amount proportional to the light-tone value of the corresponding elemental area of the object, and means including a conductive element passing through the envelope of said tube and which is connected to said photoemissive screen for passing an image current formed when the beam of electrons returns the conductors to their equilibrium potential, said screen and said plate being placed so close together that the capacity therebetween is so great that none of the elemental condensers is ever completely discharged by the passage of photoelectrons from said screen to said conductors, whereby said conductors are at all times at a positive potential with respect to said screen.

CLINTON J. DAVISSON.