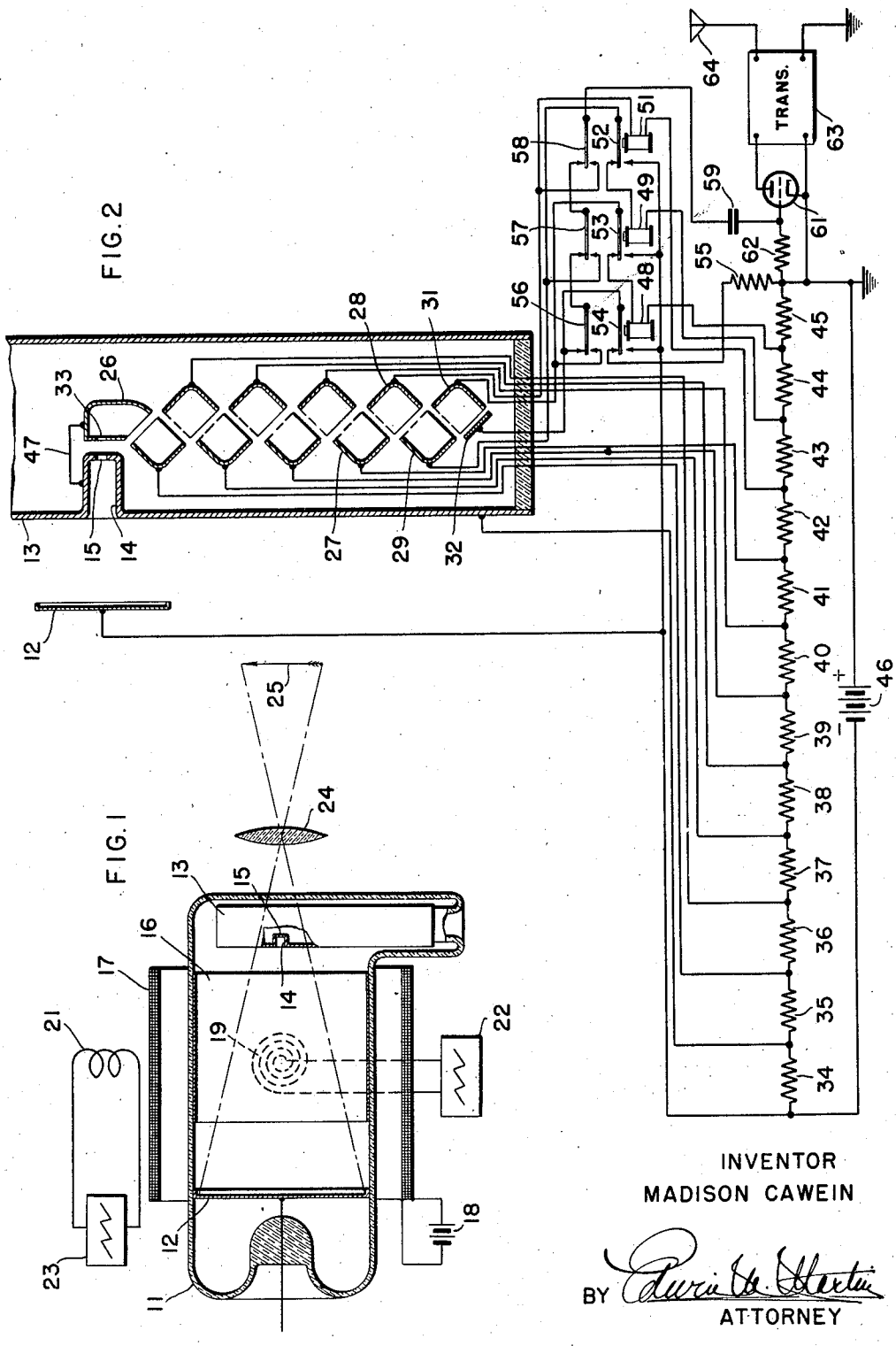
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VARIABLE GAIN ELECTRON MULTIPLIER

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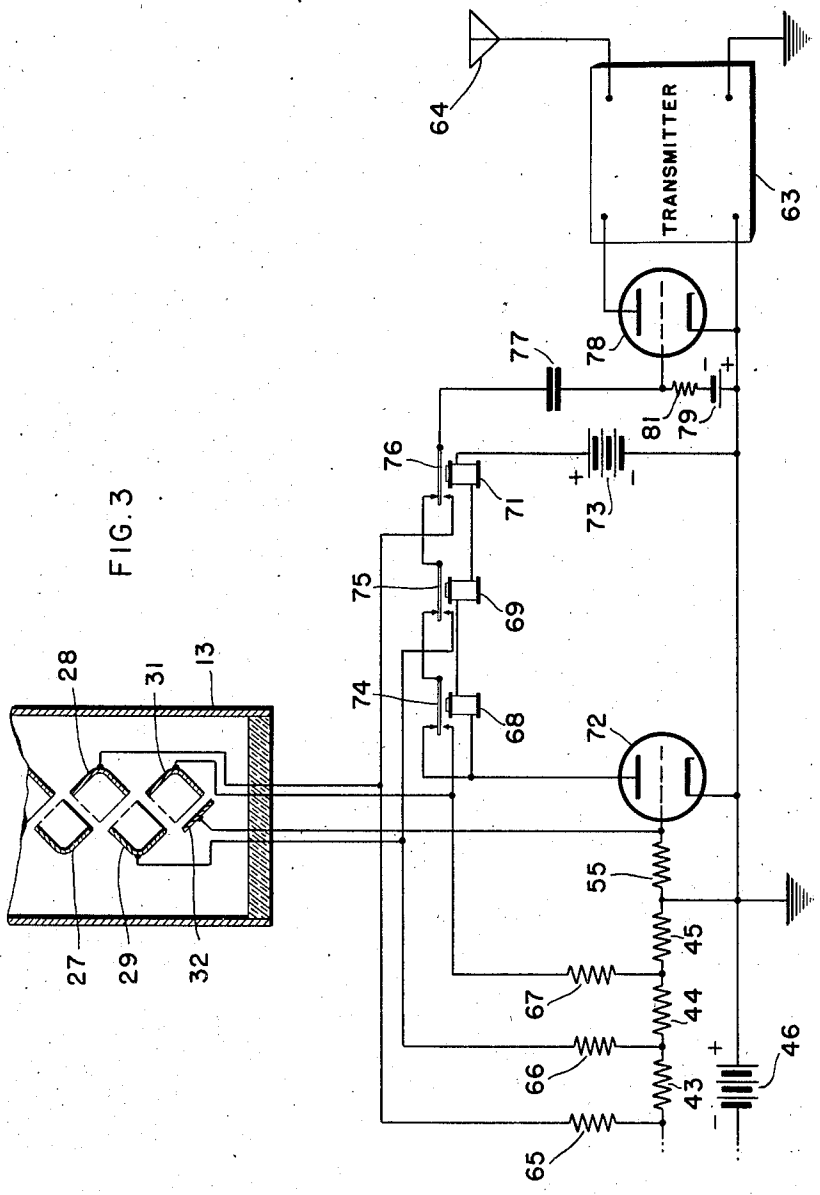


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VARIABLE GAIN ELECTRON MULTIPLIER

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FIG. 3




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2,416,376

## VARIABLE GAIN ELECTRON MULTIPLIER

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Application January 14, 1944, Serial No. 518,223

19 Claims. (Cl. 179—171)

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This invention relates to electron multipliers and particularly to automatic gain control apparatus therefor.

A conventionally employed multistage electron multiplier is capable of amplifying electron streams of varying concentrations in a substantially linear manner; that is, the voltages developed in the output circuit of such a multiplier are substantially proportional to the electron concentrations in the primary electron streams from which they are developed. The voltages are related to the corresponding electron stream concentrations by the multiplication factor of the multiplier. The overall multiplication factor of the multiplier is a function of the number of multiplying stages.

It is well known in the art that an electron multiplier of this character, when employed with apparatus for producing electron streams varying in concentration throughout a substantial range of values, will develop voltages varying between maximum and minimum limits, which frequently are beyond the range that may be usefully employed. It, therefore, is desirable to provide apparatus to operate a multistage electron multiplier in such a manner that the range of output circuit voltages is prevented from exceeding a predetermined value.

It, therefore, is an object of the present invention to provide control apparatus responsive to the electron concentrations in an electron multiplier for automatically controlling the multiplication ratio thereof in a manner to prevent the voltage derived from the multiplier from exceeding a predetermined maximum value.

In accordance with the invention, there is provided an electron multiplier having a plurality of secondary electron emissive electrodes and a collector electrode connected to an output circuit. Associated with one or more of the electrodes is switching apparatus which is rendered operative in response to predetermined voltages developed in the output circuit to vary the number of operative electrodes whereby to correspondingly vary the multiplication factor of the device.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings:

Fig. 1 is a diagrammatic representation of a dissector tube embodiment of the invention;

Fig. 2 is a schematic wiring diagram showing

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the electrical interconnections of the pertinent components of a dissector tube drawn to an enlarged scale; and,

Fig. 3 is a fragmentary schematic diagram showing a modified form of the invention.

Having reference now to Fig. 1 of the drawings, there is illustrated a sectional view of a dissector tube provided with an evacuated envelope 11. Mounted within and adjacent to one end of the envelope is a photoelectric cathode 12. Also, within the envelope and adjacent to the end opposite the cathode there is mounted a multistage electron multiplier housed within a metallic shielding anode 13. The anode is provided with a recessed portion 14 at the end of which is formed a primary scanning aperture 15 which is disposed substantially centrally with respect to the cathode 12 and faces the cathode. An accelerating anode is provided in the form of an interior wall coating 16 between the cathode 12 and the anode 13.

A focusing coil 17 is disposed on the outside of the tube envelope 11 in a manner to surround substantially completely the space within the tube between the cathode and the anode. A battery 18 or other suitable source of electrical energy is connected to the focusing coil for the energization thereof to establish the desired focusing field within the tube envelope whereby an electron image is formed substantially in the plane of the anode 13. The tube also is provided with horizontal and vertical scanning coils 19 and 21, respectively. Each of these coils is energized by respective sources 22 and 23 of appropriate saw-toothed wave form voltages.

In conjunction with the dissector tube there also is provided an optical system represented by a lens 24, whereby an optical image of a subject 25 is focused into the plane of the photoelectric cathode 12.

Referring now to Fig. 2 of the drawings, a more detailed description of the electrical connections to the photoelectric cathode, the electron multiplier and the switching apparatus will be given. The multiplier which is housed within the anode shield 13 comprises a plurality of box-like electrodes such as 26, 27, 28, 29 and 31. In the case of a so-called eleven stage multiplier, as illustrated herein, the device includes eleven of such box-like electrodes. The inner surfaces of the electrodes are treated with material such as caesium, for the purpose of producing a relatively large number of secondary electrons by the bombardment of the surfaces with a relatively small number of primary electrons. Adjacent the out-

let of the eleventh stage electrode 31 is located an electron collecting electrode of suitable form such as a plate 32. The first stage electrode 26 is provided with a secondary scanning aperture 33 in alignment with the primary scanning aperture 15 formed in the anode shield 13. The secondary aperture ordinarily is smaller than the primary aperture, being of substantially the same size as the desired elemental scanning area.

Suitable accelerating potentials are impressed upon the multiplier electrodes and the photoelectric cathode by appropriate connections to taps on a voltage divider which, as illustrated, comprises the series connection of resistors 34 to 45, inclusive. A source of relatively high potential unidirectional energy such as a battery 46 is connected to the terminals of the voltage divider. The negative terminal of the battery 46 is connected to the photoelectric cathode 12. The junction point between resistors 34 and 35 is connected to the shielding anode 13 and also, by means of an internal connection such as represented by a conductor 47, to the first multiplier electrode 26. Thus, the anode shield and the first stage electrode are operated at the same positive potential with respect to the anode 12. Similarly, the electrodes comprising multiplier stages 2 to 8 inclusive, the latter of which comprises the electrode 27, are connected directly to other respective taps on the voltage divider in a manner to impress increasingly higher positive potentials on succeeding multiplier electrodes.

The ninth, tenth and eleventh stage electrodes 28, 29 and 31 respectively, are connected to the remaining taps on the voltage divider through switching circuits controlled by three relays 48, 49 and 51. It is contemplated to be within the scope of the invention that the switching circuits be controlled by equivalent electronic relays in a suitable manner. The continuity of these connections is determined by the operative or inoperative conditions of the relays. Normally, with all relays in their unoperated positions, the connections between the last three multiplier electrodes are substantially the same as those for any of the other electrodes. The ninth stage electrode 28 is connected through the winding of relay 51 to the junction point between voltage divider resistors 42 and 43. The tenth stage electrode 29 is connected through the back contact associated with armature 52 of relay 51 and the winding of relay 49 to the junction point between the divider resistors 43 and 44. The eleventh stage electrode 31 is connected through the back contact associated with armature 53 of relay 49 and the winding of relay 48 to the junction point between the divider resistors 44 and 45. The collector electrode 32 is connected through the break contact associated with armature 54 of relay 48 and an output circuit resistor 55 to the grounded positive terminal of the battery 46. The collector electrode also is connected through the serially arranged break contacts associated with armatures 56, 57 and 58 of relays 48, 49 and 51 respectively, and a coupling condenser 59 to the control grid of an amplifier tube 61. A leak resistor 62 also is connected between the control grid of the tube and ground. The output circuit of the amplifier tube 61, which includes the anode and the grounded cathode, is connected to the input circuit terminals of a transmitter 63. The output terminals of the transmitter are connected to a suitable transmission channel which may include a radiator 64.

Armatures 52, 53 and 54, respectively, of relays 51, 49 and 48 are connected to electrodes 29, 31 and 32 of the multiplier so that these electrodes may be switched in a manner and for a purpose to be described in a subsequent portion of the specification. The make contacts associated with these armatures are connected to a negative potential point such as the negative terminal of the battery 46. The armatures 56, 57 and 58 respectively, of relays 48, 49 and 51 are interconnected in a manner to switch the input circuit of the amplifier tube 61 to any one of the multiplier electrodes 28, 29, 31 or 32.



Referring now to the operation of the apparatus of Figs. 1 and 2 embodying the present invention, assume that initially the maximum intensity of the light reflected from the subject 25 is relatively small. In this case the maximum concentration of any of the electron streams from the photoelectric cathode 12 which are admitted to the multiplier is not in excess of that required to develop an output voltage of a predetermined maximum tolerable value. In this case all of the switching relays 48, 49 and 51 are in their unoperated positions as shown. The collector electrode 32 thus is connected through the break contact associated with armature 54 to the normal output circuit resistor 55. In this case the flow of current through this resistor resulting from the collection of electrons by the electrode 32 develops signal voltages in the resistor which are impressed by the circuit including the break contacts associated with armatures 56, 57, and 58 and the coupling condenser 59 upon the input circuit of the amplifier tube 61. At the same time, by reason of the described electron accelerating potential connections to the ninth, tenth and eleventh multiplier stages 28, 29 and 31 respectively, there is produced a current flow through the operating windings of the relays 48, 49 and 51. The magnitudes of the respective currents is a function of the electron current flow to the respective electrodes and this current flow is dependent upon the electron concentrations at the respective electrodes. Thus, the maximum current traverses the winding of relay 48 while currents of lesser magnitudes traverse the windings of relays 49 and 51.

If now the reflected illumination from the subject 25 increases so as to effect an increase in the electron concentration of the stream representative of one of the brighter elemental areas of the subject, there will be effected an increase in the electron collection by the electrode 32. Consequently, the greatest voltage developed in the output resistor 55 will exceed the predetermined maximum tolerable value. In this case there also will be proportional increases in the magnitudes of the currents traversing the windings of relays 48, 49 and 51. Under these conditions the relays are adjusted so that the current then traversing the winding of relay 48 will be sufficient to actuate this relay, thereby moving its associated armatures 54 and 56 into engagement with their respective make contacts.

The circuit from the output resistor 55 to the collector electrode 32 is opened at the break contact associated with armature 54. At the same time this electrode is connected by the make contact associated with this armature to an electron repelling voltage such as the negative terminal of the battery 46. The normal eleventh stage multiplier electrode 31 remains connected through the winding of relay 48 to the voltage divider. This electrode also is now connected through the make contact associated with arma-

ture 56 and the break contacts associated with armatures 57 and 58 to the coupling condenser 59.

It is seen, therefore, that the normal collector electrode 32 is disconnected from the normal output resistor 55 and at the same time is connected to a negative potential point for the purpose of rendering it inoperative for the attraction thereto of electrons from the preceding stage. At the same time the normal eleventh stage electrode 31, by reason of its normal connection through the impedance represented by the winding of relay 48 is rendered operative as a collector electrode to develop signal voltages across the impedance of the winding of relay 48. Also, by reason of the switching of this electrode to the input circuit of the amplifier tube 61 the signal voltages developed in the manner described are impressed upon the amplifier.

It is noted that the normal voltage of the electrode 31, when acting as the eleventh stage of the multiplier, is 180° out of phase with the voltage developed at the electrode 32 when acting as the electron collector of the multiplier. When the described switching operation has been performed the phase of the voltage developed at the electrode 31 is the same as the normal voltage developed at the electrode 32. This result is obtained by rendering ineffective in the manner described the electrode 32 to attract electrons from the electrode 31. The latter electrode then functions as an electron collector and consequently develops voltages of the same phase as the normal collector voltages.

It is seen, therefore, that after the described switching operation has been performed one electron multiplying stage is eliminated from the multiplier. Consequently, the voltage developed across the winding of relay 48 will be of considerably less magnitude than the voltage developed across the resistor 55 just prior to the performance of the switching operation. By this means then the maximum signal voltage which is impressed upon the input circuit of the amplifier tube 61 is prevented from exceeding the predetermined maximum tolerable value.

If now, as a result of a still further increase in the maximum reflected illumination from the subject 25 the voltage developed at the acting electron collector electrode 31 reaches the predetermined maximum tolerable value for impression upon the amplifier tube 61, the electron current flow through the winding of relay 49 to the normal tenth stage multiplier electrode 29 will be increased sufficiently to effect the actuation of the relay armatures 53 and 57. The electrode 31 is disconnected at the break contact associated with armature 53 from its normal tap on the voltage divider and instead is connected by the make contact associated with this armature to the negative terminal of the battery 46. In this manner the electrode 31 is rendered ineffective for the attraction thereto of electrons from the preceding electrode 29. At the same time the electrode 31 is disconnected at the break contact associated with armature 57 from the amplifier coupling condenser 59. The electrode 29 is maintained in connection with its normal tap on the voltage divider through the winding of relay 49. It also is connected by the make contact associated with armature 57 to the coupling condenser 59. Thus, the normal tenth stage multiplier electrode 29 is connected in a manner to function as an electron collector whereby to develop signal voltages across the impedance comprising the winding of relay 49. These voltages



are impressed, by means of the described connection to the coupling condenser 59, upon the input circuit of the amplifier tube 61. Again, by reason of rendering electrode 31 ineffective to attract electrons from the electrode 29, the electrons are collected by the latter electrode and these signal voltages are in phase with the corresponding voltages previously impressed upon the amplifier by either of the electrodes 31 or 32 when the latter were serving as collectors.

If the illumination reflected from the subject 25 again increases sufficiently to raise the signal voltage developed across the winding of relay 49 to the maximum tolerable value, the electron current flow through the winding of relay 51 to the normal ninth stage multiplier electrode 28 will be increased sufficiently to operate this relay, causing the actuation of its armatures 52 and 58.

The electrode 29 thereby is disconnected at the break contact associated with armature 52 from its normal tap on the voltage divider and instead is connected through the make contact associated with this armature to the negative terminal of battery 46. The electrode 29 thus is rendered inoperative for the attraction of electrons thereto from the preceding electrode 28. Also, the electrode 29 is disconnected at the break contact associated with armature 58 from the amplifier coupling condenser 59. At the same time the electrode 28 is maintained in connection with its normal point on the voltage divider through the winding of relay 51. This electrode also is connected through the make contact associated with armature 58 to the coupling condenser 59. In this manner the signal voltages developed in the impedance comprising the winding of relay 51, with the associated multiplier electrode 28 acting as an electron collector, are impressed upon the input circuit of the amplifier tube 61.

It will be noted that, as each of the switching relays 49 and 51 is operated, the preceding relays 48 and 49 respectively, are released. For example, the circuit through the winding of relay 48 is opened at the break contact associated with armature 53 when the relay 49 is operated. Similarly, the continuity of the circuit to the winding of relay 49 is broken at the break contact associated with armature 52 of relay 51. However, this does not affect in any way the described functioning of the apparatus. When the relay 49 is operated, for example, the normal eleventh stage multiplier electrode 31 is rendered inoperative by the connection of a negative potential thereto. Thus, it is of no consequence that a result of the release of relay 48 is the reconnection of the normal collector electrode 32 to the output resistor 55. This may be appreciated by considering that the negative potential connected to the electrode 31 prevents the passage of electrons beyond the preceding electrode 29. Thus, there is no possibility of electrons reaching the collector electrode 32 to develop a voltage in the resistor 55. In like manner the reconnection of any of the multiplier electrodes to their normal taps on the voltage divider, after having been rendered inoperative with respect to the preceding multiplier electrode, will not adversely affect the functioning of the apparatus as described.

If it is desired to switch the output circuit of a multistage electron multiplier to still earlier stage electrodes, additional relays connected similarly to those shown and described may be employed. Such an arrangement is contemplated to

be within the scope of the instant invention.

Of course, a decrease in the intensity of the subject illumination will cause the successive functioning of the relays 48, 49 and 51 in a reverse sequence to that described. For example, when relay 51 is operated to employ electrode 28 as a collector and there is effected a decrease in the number of collected electrons as a result of a decrease in the subject illumination, the current flow through the winding of relay 51 will be insufficient to maintain this relay operated. In this case the armatures 52 and 58 are disengaged from their respective make contacts and reengaged with their respective break contacts. In this manner a circuit through the winding of relay 49 is reestablished through the break contact associated with armature 52 to the multiplier electrode 29, thereby effecting the operation of this relay. Connections are established as previously described from the electrode 29 to the input circuit of the amplifier tube 61. In a similar manner, relay 48 is reoperated in the event that the illumination is still further decreased.

Reference now is made to Fig. 3 which shows a modification of the invention. In this case only the higher multiplier stages and their associated connections are illustrated. Apparatus which is the equivalent of corresponding apparatus shown in Fig. 2 is represented by similar characters of reference. The ninth, tenth and eleventh multiplier stages 28, 29 and 31 respectively are connected to appropriate taps on the voltage divider through the respective resistors 65, 66 and 67. These multiplier electrodes also are connected to the make contacts of the switching relays 68, 69 and 71. The collector electrode 32 is connected through an output resistor 55 to the grounded positive terminal of the battery 46. This electrode also is connected to the control grid of a phase shifting vacuum tube 72 which also has a cathode which is connected to ground. Space current for the tube is provided by a source of unidirectional energy such as a battery 73 having its negative terminal connected to ground and its positive terminal connected through the windings of relays 68, 69, and 71, arranged in series, to the anode of the tube. The output circuit of the phase shifting tube 72 is derived from the anode which also is connected through the break contacts associated respectively with armatures 74, 75 and 76 of relays 68, 69 and 71 respectively, to a coupling condenser 77. This condenser is connected to the control grid of an amplifier tube 78 having its cathode connected to ground. A suitable biasing and leak circuit for the grid of the tube 78 is provided by a source of unidirectional energy such as a battery 79 and a resistor 81.

The output circuit of the amplifier tube 78 is derived from the anode and cathode thereof and is connected to the input circuit of the transmitter 63 as in the previously described modification of the invention.

Referring now to the operation of the modification of the invention shown in Fig. 3, assume that the average subject illumination intensity is such to effect the development of output voltages in the resistor 55 which do not exceed in magnitude the predetermined maximum tolerable value when the entire multiplier structure is in operation. In this case, all of the switching relays 68, 69 and 71 are in their unoperated positions as shown. The ninth, tenth and eleventh multiplier stages then are all disconnected from the output circuit at the respective make contacts associated with armatures 76, 75 and 74 respectively. Electrons collected by the electrode 32 produce a current flow through the output resistor 55 whereby to develop a control voltage for the phase shifting tube 72. The voltage which is developed at the anode 72 is 180° out of phase with the control voltage impressed upon the grid of the tube by reason of the inherent phase reversing characteristic of the vacuum tube. The anode voltage of this tube is impressed by means of the circuit including the break contacts associated with armatures 74, 75 and 76 of relays 68, 69 and 71 respectively, and the coupling condenser 77 upon the control grid of the amplifier tube 78.

The current flow in the output circuit of the phase reversing tube 72 is a function of the number of electrons collected by the multiplier electrode 32. This current also traverses the windings of relays 68, 69 and 71, all of which have marginal operation characteristics. The relay 68, for example, is adjusted to operate at a relatively small current. The relay 69 is adjusted so that it will not operate at the relatively small operating current required for the relay 68 but will respond to a somewhat greater current. Similarly, the relay 71 is adjusted to remain unoperated when energized by the minimum currents required to operate relays 68 and 69 but will respond to relatively large currents. In the case where the voltage developed in the output resistor 55 is not in excess of that required to produce, at the output circuit of the amplifier tube 78, a voltage greater than the predetermined maximum tolerable value none of the switching relays are traversed by a current of sufficient magnitude to cause their operation.

If now the subject illumination intensity increases somewhat, the current flow in the output circuit of the phase reversing tube 72 and through the windings of the switching relays will be increased sufficiently to cause the operation of relay 68. The anode of the tube 72 is disconnected from the input circuit of the amplifier tube 78 at the break contact associated with armature 74 of the operated relay. At the same time the eleventh multiplier stage electrode 31 is connected through the make contact associated with armature 74 to the input circuit of the amplifier tube 78.

It is noted that in this form of the invention the multiplier electrode which is switched away from the output circuit is not rendered inoperative with respect to the other multiplier electrodes. In this case the collector electrode 32 is maintained in connection with the normal circuit resistor 55 so that it has impressed thereon a higher positive potential than the eleventh stage electrode 31. Consequently, the electron flow through the multiplier to its normal output circuit is not materially affected by the described switching operation. With respect to the development of the desired signal voltage the only difference is that, instead of utilizing the voltage developed in the normal output resistor 55, the voltages developed in the resistor 67 connected to the eleventh stage electrode 31 are employed. It is by reason of the use of these different types of resistors that the use of the phase shifting tube 72 is required in the one case but not in the other.

In the functioning of a multistage electron multiplier there is a net loss of electrons at each of the secondary emissive electrodes. The electrodes thus tend to increase in positive polarity

with an increase in the electron concentrations supplied to the multiplier. On the other hand there is a net gain of electrons by the collector electrode 32. Consequently, the potential of this electrode tends to become increasingly negative with an increase of the electrode concentrations. Thus, it is apparent that the voltages developed at any of the multiplier electrodes are 180° out of phase with respect to the voltages developed at the collector electrode. Therefore, when the output circuit of the multiplier is switched from the collector electrode to any of the secondary emissive electrodes, it is necessary to effect a phase shift in the output circuit. In the present instance this is accomplished by including the phase shifting tube 72 between the normal output circuit derived from the collector electrode and the amplifier 78. When the output circuit is derived from any of the other secondary emissive electrodes, the phase shifting tube 72 is not included between the electrode and the amplifier 78.

If now the illumination intensity increases still further, the relay 69 will be operated to connect at the make contact associated with armature 75 the tenth stage multiplier electrode 29 to the input circuit of the amplifier tube 78. At the same time the eleventh stage multiplier electrode 31 is disconnected at the break contact associated with this armature from the amplifier.

Similarly, an additional increase of the subject illumination will produce a current flow through the windings of the switching relays of sufficient magnitude to effect the operation of relay 71. The electrode 29 thereby is disconnected at the break contact associated with armature 77 from the input circuit of the amplifier tube 78 and the ninth stage multiplier electrode 28 is connected in place thereof by the make contact associated with this armature.

As in the previously described embodiment of the invention, additional relays, as desired, may be connected to still other multiplier electrodes in a manner similar to those illustrated.

A change of the subject illumination in the opposite sense will effect the successive releases of the switching relays in a sequence opposite to that in which they are operated.

While there has been described what, at present, are considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. Electron multiplying apparatus comprising, a plurality of electrodes, a utilization circuit, and means responsive to signal current derived from one of said electrodes for switching said utilization circuit from one to another of said electrodes, whereby to prevent the development in said circuit of voltages exceeding a predetermined maximum value.

2. Electron multiplying apparatus comprising, a plurality of electrodes, a utilization circuit normally connected to one of said electrodes, and switching means responsive to currents derived from one of said electrodes to disconnect said utilization circuit from said normally connected electrode and to connect said utilization circuit to another of said electrodes, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.



3. Electron multiplying apparatus comprising, a secondary electron emissive electrode, an electron collecting electrode, a utilization circuit normally connected to said collecting electrode, and switching means responsive to current derived from one of said electrodes to disconnect said collecting electrode from said utilization circuit and to connect in place thereof said secondary emissive electrode, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

4. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, a utilization circuit normally connected to said collecting electrode, and switching means responsive to currents derived from one of said electrodes to disconnect said collecting electrode from said utilization circuit and to connect in place thereof any one of said secondary emissive electrodes, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

5. Electron multiplying apparatus comprising, a secondary electron emissive electrode, an electron collecting electrode, a utilization circuit, a relay having contacts connected to said utilization circuit and to said collecting and secondary emissive electrodes, and an operating winding for said relay responsive to current derived from one of said electrodes for actuating the contacts of said relays to disconnect said collecting electrode from said utilization circuit and to connect in place thereof said secondary emissive electrode, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

6. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, an amplifier having input and output circuits, a plurality of relays having contacts connected to the input circuit of said amplifier and to said collecting and secondary emissive electrodes, and operating windings for said relays responsive to currents derived from said electrodes for actuating the contacts of said relays to disconnect said collecting electrode from the input circuit of said amplifier and to connect in place thereof one of said secondary emissive electrodes, whereby to prevent the development in the output circuit of said amplifier of voltages exceeding a predetermined maximum value.

7. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, an amplifier having input and output circuits, a plurality of relays having contacts connected to the input circuit of said amplifier and to said collecting and higher stage secondary emissive electrodes, and operating windings for said relays connected for response to currents derived from said electrodes for actuating the contacts of said relays in response to derived currents of a predetermined magnitude to disconnect said collecting electrode from the input circuit of said amplifier and to connect in place thereof any one of said higher stage secondary emissive electrodes, whereby to prevent the development in the output circuit of said amplifier of voltages exceeding a predetermined maximum value.

8. Electron multiplying apparatus comprising, a secondary electron emissive electrode, an elec-

tron collecting electrode, a utilization circuit, a relay having an operating winding and circuit switching contacts, the winding of said relay being connected to said secondary emissive electrode, means including contacts of said relay operable to connect either said electron collecting or said secondary emissive electrode to said utilization circuit, and means including contacts of said relay operable to impress a negative potential upon either of said electrodes, said relay being operable in response to current of a predetermined magnitude to disconnect said collecting electrode from said utilization circuit and to connect in place thereof said secondary emissive electrode and simultaneously to impress a negative potential upon the disconnected electrode, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

9. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, a plurality of voltage sources of different magnitudes, an amplifier having input and output circuits, a plurality of relays each having an operating winding and circuit switching contacts, the windings of said relays being connected between respective voltage sources and said secondary emissive electrodes, connections including contacts of said relays establishable between said electron collecting and said secondary emissive electrodes and the input circuit of said amplifier, and other connections including contacts of said relays establishable between said electrodes and one of said voltage sources of a relatively low order of magnitude, said relays being operable respectively in response to currents of a predetermined magnitude to disconnect said collecting electrode from the input circuit of said amplifier and to connect in place thereof any one of said secondary emissive electrodes and simultaneously to connect the disconnected electrode to said voltage source of a relatively low order of magnitude, whereby to prevent the development in the output circuit of said amplifier of voltages exceeding a predetermined maximum value.

10. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, a voltage divider having a plurality of taps, an amplifier having input and output circuits, a plurality of relays each having an operating winding and circuit switching contacts, the windings of said relays being connected between respective voltage divider taps and said secondary emissive electrodes, connections including some of said relay contacts establishable between said electron collecting and said secondary emissive electrodes and the input circuit of said amplifier, and connections including the others of said relay contacts establishable between said electrodes and a negative tap of said voltage divider, said relays being operable respectively in response to currents of a predetermined magnitude to disconnect said collecting electrode from the input circuit of said amplifier and to connect in place thereof any one of said secondary emissive electrodes and simultaneously to connect the disconnected electrode to said negative tap of said voltage divider, whereby to prevent the development in the output circuit of said amplifier of voltages exceeding a predetermined maximum value.

11. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, a voltage divider having a plurality of taps, an amplifier having input and output circuits, a plurality of relays each having an operating winding and two sets of circuit switching contacts, the windings of said relays being connected between respective voltage divider taps and higher stage secondary emissive electrodes, connections including one set of said relay contacts establishable between said electron collecting and higher stage secondary emissive electrodes and the input circuit of said amplifier, and connections including the other set of said relay contacts establishable between said electrodes and the negative terminal of said voltage divider, said relays being operable respectively in response to currents of a predetermined magnitude to disconnect said collecting electrode from the input circuit of said amplifier and to connect in place thereof any one of said higher stage secondary emissive electrodes and simultaneously to connect the disconnected electrode to an electron repelling voltage tap of said voltage divider, whereby to prevent the development in the output circuit of said amplifier of voltages exceeding a predetermined maximum value.

12. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, a voltage divider having a plurality of taps for impressing electron accelerating potentials upon said secondary emissive electrodes, means including the winding of one of a plurality of relays to connect taps on said voltage divider to respective ones of the higher stage secondary emissive electrodes, means including the circuit switching contacts of one of said relays to connect said voltage divider to said collecting electrode, an amplifier having an input circuit normally connected by contacts of said relays to said collecting electrode and connectable by operations of said relays to any one of said higher stage secondary emissive electrodes, means including the windings of said relays responsive to an electron current flow therethrough in excess of a predetermined value for operating said relays whereby to substitute for the normal connection of said collecting electrode to said amplifier the connection of one of said higher stage secondary emissive electrodes, and means controlled by the contacts of an operated relay to impress upon the electrode disconnected from the amplifier a sufficiently negative voltage to render the disconnected electrode ineffective for the attraction thereto of electrons from the preceding electrode.

13. Electron multiplying apparatus comprising, a secondary electron emissive electrode, an electron collecting electrode, respective circuits connected to said electrodes for the development of voltages of different magnitudes, a utilization circuit, and means responsive to voltage changes in said collecting electrode circuit to switch said utilization circuit between said electrode voltage developing circuits.

14. Electron multiplying apparatus comprising, a secondary electron emissive electrode, an electron collecting electrode, respective circuits connected to said electrodes for the development of voltages of opposite phase, a utilization circuit, means responsive to voltage changes in said collecting electrode circuit to switch said utilization circuit from one of said electrode voltage developing circuits to another, and means for reversing the phase of the voltage developed in one of said electrode circuits.

15. Electron multiplying apparatus comprising,

a secondary electron emissive electrode, an electron collecting electrode, respective circuits connected to said electrodes for the development of voltages of different magnitudes and opposite phase, a utilization circuit, means responsive to voltage changes in said collecting electrode circuit to switch said utilization circuit from one of said electrode voltage developing circuits to another, and means for reversing the phase of the voltage developed in said collecting electrode circuit.

16. Electron multiplying apparatus comprising, a secondary electron emissive electrode, an electron collecting electrode, impedance devices connected to said electrodes, a utilization circuit, a relay having circuit switching contacts, a phase reversing device having input and output circuits, the input circuit of said phase reversing device being connected to said collecting electrode and the output circuit thereof being connected through the contacts of said relays to said utilization circuit, connections from said secondary emissive electrode to contacts of said relay, and a winding for said relay responsive to a current flow in excess of a predetermined magnitude in the output circuit of said phase reversing device for effecting the operation of said contacts to disconnect the output circuit of said phase reversing device from said utilization circuit and to connect in place thereof said secondary emissive electrode, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

17. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, resistance elements connected to said collecting electrode and to said secondary emissive electrodes, a utilization circuit, a plurality of relays each having an operating winding and circuit switching contacts, a phase reversing device having input and output circuits, the input circuit of said phase reversing device being connected to said collecting electrode and the output circuit thereof being connected to the windings of said switching relays, the output circuit of said phase reversing device also being connected through the contacts of said relays to said utilization circuit, connections from said secondary emissive electrodes to contacts of said relays, and means responsive to a current flow in excess of a predetermined magnitude in the output circuit of said phase reversing device for effecting operations of said relays to disconnect the output circuit of said phase reversing device from said utilization circuit and to connect in place thereof one of said secondary emissive electrodes, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

18. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, means including resistance elements for impressing electron accelerating potentials upon said secondary emissive electrodes, a utilization circuit, a plurality of marginal relays each having an operating winding and circuit switching contacts, a vacuum tube having input and output circuits, the input circuit of said vacuum tube being connected to said collecting electrode and the output circuit thereof being connected to the windings of said switching relays, the output circuit of said vacuum tube also being connected through the contacts of said relays to said utilization circuit, connections from said secondary emissive electrodes to respective contacts of said relays, and means responsive to current flows in excess of predetermined magnitudes in the output circuit of said vacuum tube for effecting the successive operations of said relays to disconnect the output circuit of said vacuum tube from said utilization circuit and to connect in place thereof one of said secondary emissive electrodes, whereby to prevent the development in said utilization circuit of voltages exceeding a predetermined maximum value.

19. Electron multiplying apparatus comprising, a plurality of secondary electron emissive electrodes, an electron collecting electrode, a voltage divider having a plurality of taps for impressing electron accelerating potentials upon said secondary emissive electrodes, resistance elements connecting respective taps on said voltage divider to said collecting electrode and to a plurality of higher stage secondary emissive electrodes, an amplifier having input and output circuits, a plurality of marginal relays each having an operating winding and circuit switching contacts, a phase reversing tube having input and output circuits, the input circuit of said phase reversing tube being connected to said collecting electrode and the output circuit thereof being connected to a series arrangement of the windings of said switching relays, the output circuit of said phase reversing tube also being connected through the contacts of said relays to the input circuit of said amplifier, connections from said higher stage multiplier electrodes to respective normally open contacts of said relays, and means responsive to current flows in excess of predetermined magnitudes in the output circuit of said phase reversing tube for effecting the successive operations of said relays to disconnect the output circuit of said phase reversing tube from the input circuit of said amplifier and to connect in place thereof any one of said higher stage multiplier electrodes, whereby to prevent the development in the output circuit of said amplifier of voltages exceeding a predetermined maximum value.

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