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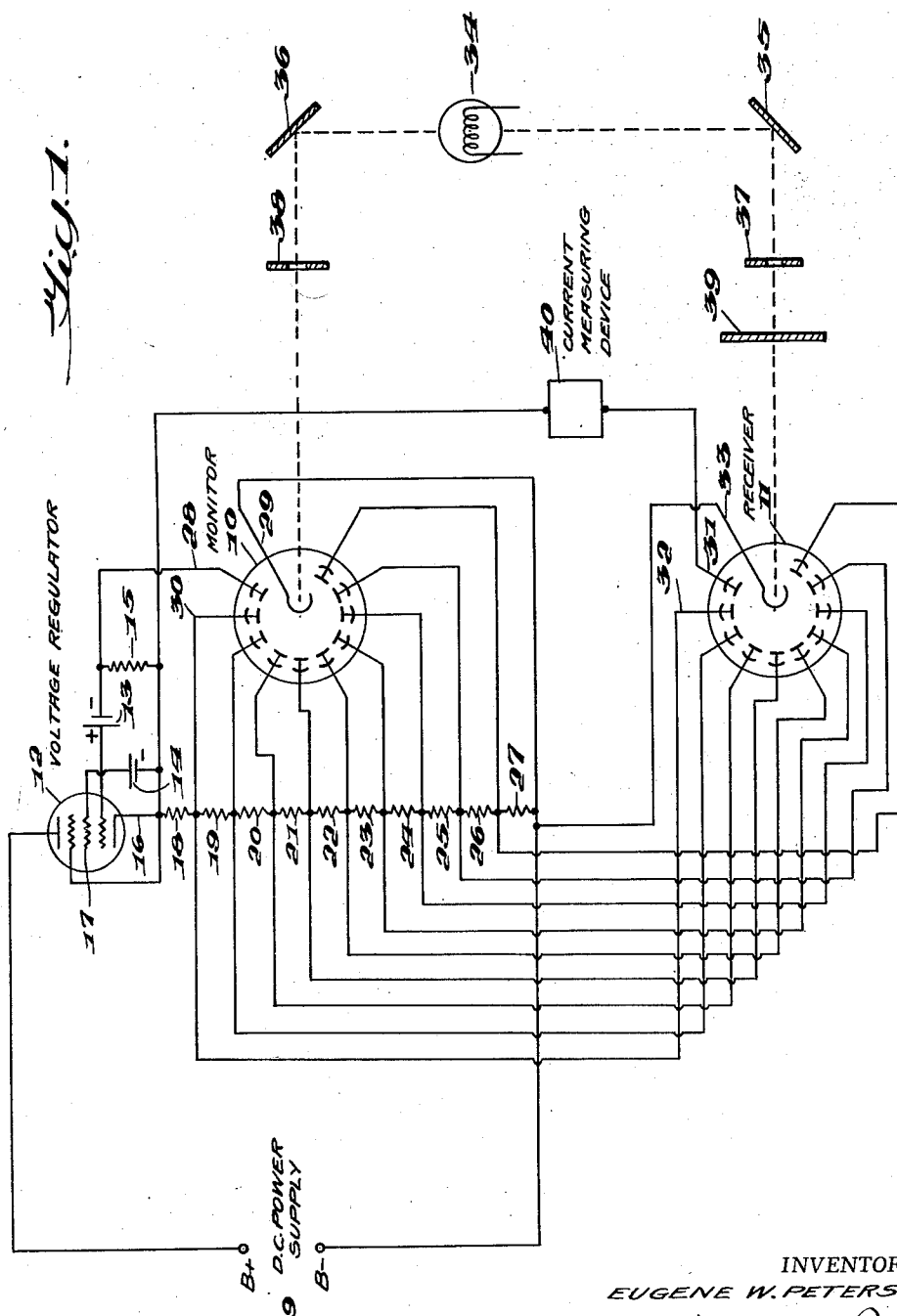
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STABILIZED ELECTROOPTICAL SYSTEM

Filed June 30, 1949

2 Sheets-Sheet 1



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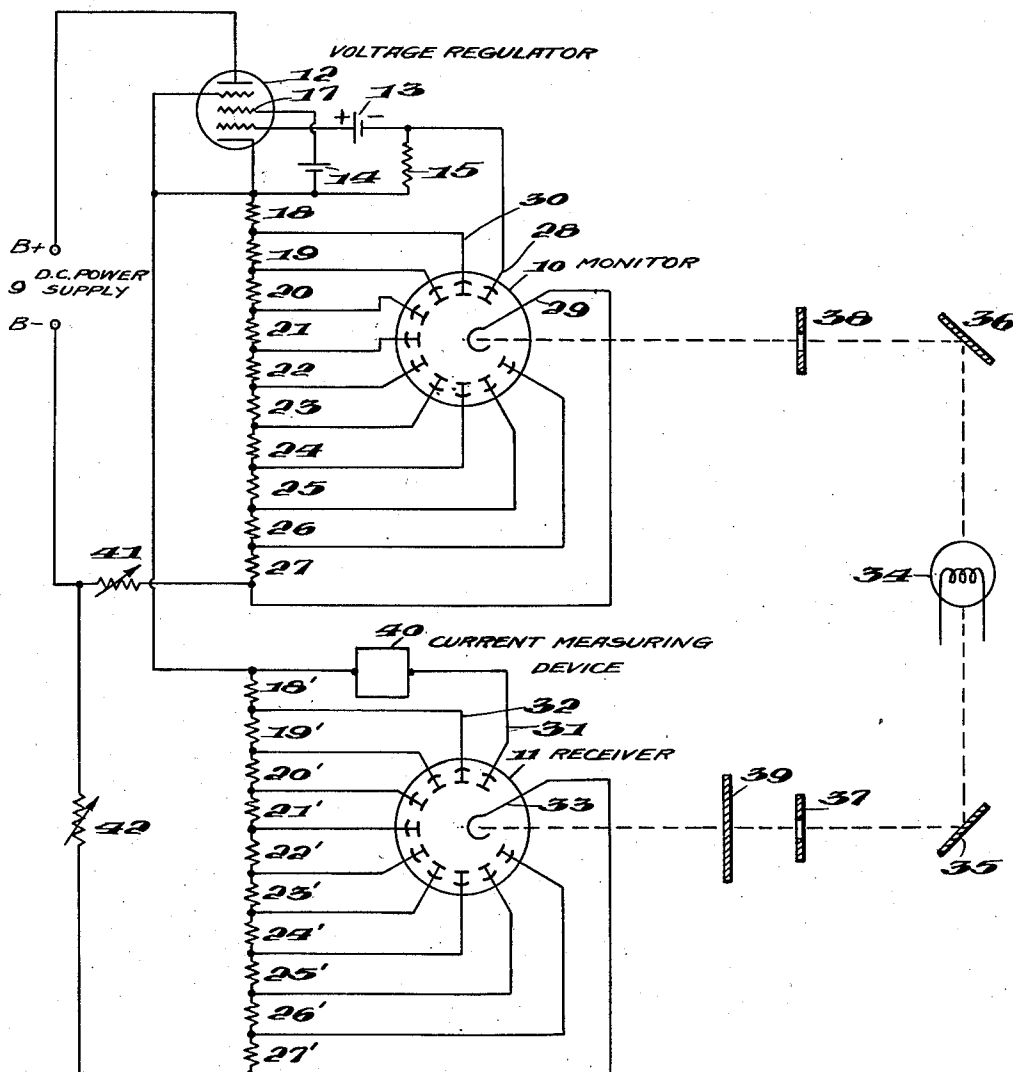
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Fig. 2.



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STABILIZED ELECTROOPTICAL SYSTEM

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15 Claims. (Cl. 250—207)

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This invention relates to electron multiplier systems, and more particularly to means for stabilizing such systems against variations in the potential of the voltage sources of such systems, and against variations in the intensity of the exciting light source.

An object of the invention is to provide an improved electron multiplier system for use in photometers, sound reproducers and similar systems for converting light signals into highly accurate electrical signals.

Electron multiplier tubes have been widely utilized in recent years as light receptors in various electro-optical systems. Such tubes consist essentially of a photocathode, a plurality of secondarily emissive dynodes and an anode. The stream of electrons emitted by the illuminated photocathode is electrostatically focused on the first dynode. Upon striking the surface of the first dynode, the electrons cause emission of a new and greater stream of electrons which are in turn focused on the second dynode. This process is repeated until the multiplied stream is collected at the anode. For a more detailed description of the construction and operation of such electron multipliers reference is made to articles by Zworykin et al. appearing in the Proceedings of the I. R. E., volume 24, for March 1936, at pages 351 to 375 and volume 27 for September 1939, at pages 558 to 566.

The energizing voltages for the electrodes of the electron multiplier tube are supplied from progressively higher potential taps of a voltage dividing resistor network which is connected in series with the primary voltage source. Since the amplification of the tube is dependent on these exciting voltages, it is obvious that such voltages must be maintained extremely constant in order to insure accurate reproduction of the light signals impressed upon the photocathode.

It is accordingly a special object of this invention to provide simple means for maintaining these voltages constant irrespective of variations in the primary voltage source.

A further difficulty encountered in all electro-optical systems is that of maintaining constant the intensity of the exciting light source. Since the electro-optical system is designed to accurately reproduce modulations of the intensity of this light, it is essential that the system either be supplied by a constant exciting light source or that it be compensated for variations thereof. It is difficult, if not impossible, to obtain a light source of the requisite constant intensity, especially when a source such as a mercury arc or

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a gas discharge is required; in addition, constant voltage sources and controls for the light source are apt to be cumbersome pieces of apparatus.

It is accordingly an object of this invention to provide a highly accurate and simplified system for automatically compensating for variations in the intensity of such light.

Among the other objects of this invention are: to provide an electron multiplier system in which the output of one electron multiplier tube is utilized to control the amplification of a second electron multiplier; to provide an inverse feedback control system in combination with a plurality of electron multiplier tubes in parallel circuit relation; to provide means for matching the amplification factors of the electron multiplier tubes; and to provide an extremely accurate electro-optical measuring system.

These and other objects of the invention will be more readily apparent from reference to the following detailed description, appended claims and drawings, of which:

Fig. 1 is a schematic wiring diagram illustrating one embodiment of the invention, and

Fig. 2 is a schematic wiring diagram illustrating a second embodiment of the invention.

Generally speaking, this invention contemplates the use of two or more electron multiplier tubes connected in parallel electrical circuit relation in such a manner that one tube, herein referred to as the monitor, views the light source directly and automatically compensates for variations in light source intensity and in line voltage, while the other tubes, herein referred to as the receivers, receive modulated light from the same source and provide output currents which are measures of the desired light quantities.

The parallel voltage networks for the electrodes of the said tubes are energized thru a thermionic amplifier connected in series circuit relation with said parallel networks and with the line source of potential. The output of the monitor tube is connected to the control grid of the amplifier in inverse feedback relation. Therefore, any change in the line voltage, or in light source intensity, or in the amplification characteristics of the thermionic amplifier will cause a corresponding change in the output of the monitor tube. This change in turn varies the gain of the thermionic amplifier, whose output is thereby varied to apply a corrected voltage to the voltage divider network supplying the electrodes of the electron multipliers. Since each of the multiplier tubes has substantially identical gain versus dynode voltage characteristics and the voltages

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supplied to each tube are the same, the outputs of the receiver tubes will be accurately compensated. The present system further provides variable resistor means for matching the amplification factors of the electron multiplier tubes.

Referring to Fig. 1 of the drawings, 10 is the monitor electron multiplier tube, and 11 is the receiver electron multiplier tube. Such tubes might be one of the several commercially available types, such as RCA 931A, 1P21, 1P22 or IP28, depending on the light level and wave lengths at which they are to be used. The gain of the tube must be sufficiently high to produce a current much larger than dark current when its dynode voltages are somewhat below their maximum safe value with the light source available.

All of the electron multiplier tubes must have the same or nearly the same voltage amplification characteristics if substantially perfect compensation is to be obtained. Means for matching the amplification characteristics is provided by the circuit arrangement of Fig. 2, as described below in more detail.

Photomultiplier 10 includes a photocathode 29, an anode 28 and a series of intermediate dynodes 30. In like manner, photomultiplier 11 includes a photocathode 33, an anode 31 and a series of intermediate dynodes 32.

The operating potentials applied to the electrodes of the tubes 10, 11 are obtained from a voltage divider resistance network 18—27 connected in series circuit relation with a source of voltage 9 and a variable impedance 12. The power supply 9 is preferably a substantially constant potential source of direct current, although the circuit will compensate correctly with a power supply having relatively wide variations in potential.

The variable impedance voltage regulator device 12 is illustrated as a pentode amplifier having its plate connected to the positive side of the voltage source, and its cathode 16 connected to the voltage divider network 18 through 27. The tube circuit includes the usual connection between the cathode and suppressor grid. A source of potential 14 is connected between the cathode and the screen grid. This source is indicated in the drawings as a battery, but for some purposes could be a glow discharge tube or other substantially constant source. The value of said potential 14 is dependent on tube choice and current requirements. A grid biasing resistor 15 is connected between the cathode 16 and the control grid 17. To increase circuit sensitivity, a second battery 13 is connected to the control grid 17 to supply a positive bias thereto. It is understood that, while a pentode amplifier is shown, variable impedance 12 may be a triode thermionic amplifier, or any other suitable device known in the art.

The cathode 16 of amplifier 12 is connected to one side of the voltage divider network which consists of a series of resistances 18 through 27. Resistance 18 is preferably of such a value as to maintain the last dynode of each series of dynodes 30 and 32 from 50 to 250 volts negative with respect to anodes 28 and 31 over the operating range of the system. The remaining resistances, 19 through 27, are substantially equal in value so as to provide equal voltage increments, e. g. around 100 volts, between successive dynodes. The values of these resistances are not critical and they need not be exactly matched.

Parallel circuit connections are made from the junction of resistances 18 and 19 to the dynode

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30 closest to anode 28 of tube 10 and the corresponding dynode 32 of tube 11, and from the junction of resistances 19 and 20 to the second dynode of the tube 10 and the second dynode of tube 11; similar connections are made from each of the remaining taps to corresponding dynodes of each tube. The negative side of the network is connected to photocathodes 29 and 31 and to the negative or B- side of the power supply 9. The overall value of the resistance network should be of such a magnitude that the current through the network is large compared to the current through tubes 10 and 11.

The anode 28 of monitor tube 10 is connected to the control grid 17 of the voltage regulator amplifier 12, and hence to resistor 15. This resistor, therefore, serves as the main load resistor for the anode current of monitor tube 10. Its value may vary over wide limits, but, to avoid dark current and fatigue effects, should be of such magnitude as to cause an anode current in the range of 10^{-7} to 10^{-5} amperes, and this current must produce sufficient biasing voltage across the resistance to oppose the voltage of battery 13 and drive the control grid 17, preferably within the linear portion of its operating range. Where the tubes are refrigerated, anode currents as low as 10^{-10} amperes are operable.

The anode output of receiver 11 is fed to a current measuring device 40 connected in series with anode 31 and cathode 16 of amplifier 12. Hence, current measuring device 40, indicates the anodic current of the receiver 11. Where the electron multiplier system is a component of a photometer the current responsive device may be a galvanometer or a vacuum tube meter. In the case of a sound reproducer, it would be an audio amplifier and speaker.

In the particular embodiment illustrated, the electron multiplier system is utilized in a photometer. Light from source 34 is reflected by mirror 36 through variable shutter 38 onto photocathode 29 of monitor 10. Light from the same source 34 is reflected by mirror 35 through variable shutter 37 and through sample 39 onto photocathode 33 of receiver 11. The variation in the intensity of the light striking photocathode 33 caused by sample 39 produces a corresponding variation in the anodic current of receiver 11, whose magnitude is indicated by current measuring device 40.

Where permissible it is desirable to utilize a monochromatic light source to avoid mismatch of tubes 10 and 11 due to spectral differences caused by colored samples. Shutters 37 and 38 should be adjusted so that the system is balanced. Since the position of the light beams on the photocathodes greatly influences their gain, the geometrical relationship between the photocathodes and the light beams must be fixed. In some instances it is desirable to place a frosted glass or quartz plate about $\frac{1}{4}$ inch in front of each tube envelope to scatter the light striking the photocathodes and thus reduce tube positional sensitivity. Of course, focusing lens systems may be used in conjunction with the present system. In any event, it is necessary to protect the entire optical system and the electron multiplier tubes from stray illumination.

In operation, assume a decrease in the intensity of light source 34. The output current of monitor tube 10 will decrease, causing a decrease in the negative bias applied to control grid 17 of amplifier 12. The output of amplifier 12 will, therefore, be increased, increasing the potential across the voltage divider network. This in-

creased voltage is applied equally to all of the dynodes 30, 32 of monitor 10 and receiver 11, causing an increase in the amplification factors of both tubes which is sufficient to exactly compensate for the variation in light intensity.

In similar fashion, a decrease in the voltage of the source of potential will cause a decreased anodic current output of monitor tube 10. This decreased current will increase the gain of amplifier 12 to exactly compensate the voltages supplied to each of the electrodes of tubes 10 and 11 for the decrease in line potential. The same resulting compensation will follow a variation in the amplification characteristic of voltage regulator 12. The outputs of receiver 12 and current responsive device 40 are, therefore, maintained substantially independent of light or voltage source fluctuations.

While only one receiver tube has been shown and described in the foregoing discussion, it is obvious that a plurality of receiver tubes may be utilized in the system of the present invention. Each additional electron multiplier receiver tube would have each of its electrodes connected in parallel relation with the corresponding electrode of receiver 11. Each additional receiver would also have a separate current measuring device connected between its anode and the cathode 16 of amplifier 12, and would have a separate beam of light from source 34 directed upon its photocathode. Such additional receivers and current measuring devices would be compensated against variations in light intensity and applied potential in a manner exactly corresponding to the above described compensation of receiver 11.

It is here pointed out that the system of the invention is highly superior to a comparable system employing a simple photocell as a monitor. The amplification response of the simple photocell to variations in light intensity and in applied voltage intensity does not correspond over any wide range with the amplification response of an electron multiplier. Hence a photocell monitor will produce good compensation only over the very narrow range of light level for which the device is adjusted. Additionally, a simple photocell is not as responsive to minute variations in light intensity and applied voltage intensity.

The present invention is also superior to comparable systems wherein the voltage of a single dynode is varied as a means of compensation. For good performance over a wide range of applied voltage and of light intensity, and for long tube life, it is necessary that the potential drop between successive dynodes of the electron multiplier remain substantially equal. Therefore, if compensating voltages are applied to a single dynode, they must either be restricted to a narrow range in value or the resulting tube amplification will be inaccurate, and tube life will be shortened.

For many purposes, the voltage amplification characteristics of the several electron multiplier tubes will be sufficiently matched providing they are of the same type and manufacture. However, where excellent compensation must be obtained, more accurate matching is required. The embodiment of the invention illustrated in Fig. 2 shows a means for accomplishing this matching.

The circuit of Fig. 2 has essentially the same components as those previously described with regard to Fig. 1. A monitor electron multiplier 10, having an anode 28, a photocathode 29 and a

plurality of intermediate dynodes 30 views light directly from source 34. Its output is connected to the grid biasing resistor 15 of amplifier 12 to vary the gain thereof. Amplifier 12 has the identical circuit connections described above. One or more receiver electron multipliers 11 receives light signals from source 34 and its output current is measured by current measuring device 40.

However, in this embodiment of the invention, the dynodes 30, 32 and photocathodes 29, 33 of the multiplier tubes 10, 11 are not directly connected. Instead, each tube is supplied from a separate voltage divider resistance network, which networks are connected in parallel circuit relation. Thus, one such network, consisting of resistors 18 through 27 and connected to the cathode 16 of amplifier 12, has taps thereon which are connected to each of the dynodes 30 and to photocathode 29 of monitor 10. A second network, consisting of resistors 18' through 27', and connected in parallel circuit relation with the first network to cathode 16 of amplifier 12, has taps thereon which are connected to each of the dynodes 32 and to photocathode 33 of receiver 11.

The negative side of first network 18—27 is connected through a variable resistance 41 to the negative or B- terminal of power supply 9. In like manner, the negative side of second network 18'—27' is connected through a second variable resistor 42 to the negative terminal of power supply 9 in parallel relation to first network 18—27. Resistance 18 may be equal in ohmic value to resistance 18' and resistances 19 through 27 and 19' through 27' may all be substantially equal in ohmic value. Similarly, variable resistance 41 may be equal in ohmic value to variable resistance 42. However, the circuit will function correctly if the values of the various resistances are so chosen that the ratios of each resistance in the first network to the corresponding resistance in the second network are all equal, i. e., if the ratio of 18 to 18' is equal to the ratio of 19 to 19', etc. Preferably, resistances 19 through 27 are all equal in ohmic value, and resistances 19' through 27' are all equal in ohmic value. Variable resistors 41 and 42 serve as a means for adjusting the relative voltages applied to the electrodes of tubes 10 and 11 and hence for matching the amplification factors thereof.

As previously described, monitor tube 10 is part of a feedback loop, and, by designing the loop to have a high gain, a relatively small change in its anode current will cause a large change in its amplification factor, providing excellent compensation.

Even if this is attained, the system still might not provide good compensation of the receiver tubes. In order to achieve as good compensation of the receiver as of the monitor, the voltage amplification characteristics of the tubes must resemble each other over their entire operating range so that

$$(1) \quad \frac{\Delta A_{10}}{A_{10}} = \frac{\Delta A_{11}}{A_{11}}$$

where A_{10} and A_{11} are the amplification factors of the tubes and ΔA_{10} and ΔA_{11} are changes therein. This relation will never be strictly true for all operating voltages. However, by selecting tubes of the same type and manufacture, the relation will be reasonably satisfied.

Resistances 41 and 42 are adjusted so that

$$(2) \quad V_{10} = kV_{11}$$

where V_{10} and V_{11} are the operating voltages applied to tubes 10 and 11, and k is a constant slightly greater or less than unity. By proper adjustment of the resistances, Equation 1 may be satisfied at a particular voltage. By selecting this voltage as the middle voltage of the system operating range, extremely close matching of the amplification factors of tubes 10 and 11 will be accomplished. This selected voltage will be of a value such that the slopes of the amplification curves of the tubes at this voltage are equal, and preferably will be at a point in the center of the linear portions of these curves. This insures highly accurate compensation of the receiver tube.

While only one receiver tube is shown and described, it is obvious that the system may include a plurality of such tubes. Each additional tube would be provided with a separate network and variable resistance identical with network 18'—27' and resistance 42. Each additional network and variable resistance would be connected in series relation, and this combination would be connected in parallel circuit relation with the series combination of network 18'—27' and resistance 42.

For many purposes, either resistance 41 or resistance 42 may be fixed in value, variation of one of these resistances being sufficient to accomplish the desired tube matching.

I claim:

1. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes each having an anode, a photocathode and one or more intermediate dynodes; a source of unidirectional voltage; a variable impedance; parallel connections between said electron multiplier tubes, said parallel tube circuit being connected in series circuit relation with said source and said impedance; and a connection between the output of said first electron multiplier tube and said impedance to vary said impedance, whereby the output of said remaining electron multiplier tubes is maintained constant irrespective of variations of the intensity of said light source and of said voltage source.

2. An electro-optical system comprising, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a source of unidirectional voltage; a variable impedance; parallel circuit connections between said electron multiplier tubes, said parallel tube circuit being connected in series circuit relation with said source and said impedance; means to substantially match the amplification factors of said tubes; a connection between the output of said first electron multiplier tube and said impedance to vary said impedance, whereby the output of said remaining electron multiplier tubes is maintained constant irrespective of variations of the intensity of the light source and of the voltage source.

3. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more dynodes; separate variable resistors in series circuit relation with one or more of said multiplier tubes; parallel circuit connections between said electron multiplier tubes; a source of unidirectional voltage; a second variable impedance; said parallel tube

circuit being connected in series circuit relation with said voltage source and with said second variable impedance; a connection between the output of said first electron multiplier tube and said second impedance to vary said impedance, whereby the output of said remaining electron multiplier tubes is maintained constant irrespective of variations of the intensity of said light source and of said voltage source.

4. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a separate voltage dividing network for each of said tubes having connections to each of the electrodes of said tube, said networks being connected in parallel circuit relation; a source of potential; a variable impedance; series circuit connections between said source, said impedance, and said parallel circuit; and a connection between the output of said first tube and said variable impedance to vary said impedance, whereby the output of the remaining electron multiplier tubes is automatically compensated for variations in the intensity of said light source and of said voltage source.

5. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a separate voltage dividing network for each of said tubes having connections to each of said electrodes of said tube; a variable resistor in series circuit relation with each of said networks, said first network and said first variable resistor being connected in parallel circuit relation with the series circuits of each of said remaining networks and variable resistors; a source of potential; a variable impedance; said voltage source, said variable impedance and said parallel circuit being connected in series circuit relation; and a connection between the output of said first tube and said variable impedance to vary said impedance, whereby the output of the remaining electron multiplier tubes is automatically compensated for variations in the intensity of said light source and of said voltage source.

6. An electro-optical system comprising, in combination, a light source; two electron multiplier tubes each having an anode, a photocathode and one or more intermediate dynodes; a separate voltage dividing network for each of said tubes having connections to each of said electrodes of said tube; a variable impedance in series circuit relation with one of said networks; parallel circuit connections between said first network and said variable impedance, and said second network; a source of potential; a second variable impedance; said parallel circuit being connected in series relation with said voltage source and said second variable impedance; and a connection between the output of said first tube and said second variable impedance to vary said second impedance, whereby the output of said second electron multiplier tube is automatically compensated for variations in the intensity of said light source and of said voltage source.

7. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes each having an anode, a photocathode, and one or more intermediate dynodes; a voltage dividing resistance network

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having taps thereon; separate parallel connections between each of said taps and a corresponding electrode of each of said tubes; a source of potential; a variable impedance; said source of potential, said variable impedance, and said network being connected in series circuit relation; and a connection between the output of said first electron multiplier tube and said variable impedance, whereby the outputs of said remaining electron multiplier tubes are automatically compensated for variations in the intensity of said light source and of said voltage source.

8. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said electron multiplier tubes having an anode, a photocathode and one or more intermediate dynodes; a voltage dividing resistance network having taps thereon; connections between said first of said taps and the first dynode of each of said tubes; similar separate connections between each of said remaining taps and a corresponding electrode of each of said electron multiplier tubes; a source of potential; a variable impedance; said source of potential, said variable impedance and said resistance network being connected in series circuit relation; and a connection between the output of said first electron multiplier tube and said variable impedance, whereby the outputs of said remaining electron multiplier tubes are maintained substantially independent of variations in the intensity of said light source and of said source of potential.

9. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a separate voltage dividing network for each of said tubes having connections to each of said electrodes of said tube, said networks being connected in parallel circuit relation; a source of potential; a thermionic amplifier having its output connected in series circuit relation with said source of potential and said parallel circuit; and a connection between the output of said first electron multiplier tube and said thermionic amplifier to vary the amplification of said amplifier, whereby the outputs of the remaining electron multiplier tubes are maintained constant irrespective of variations in the intensity of said light source and of said source of potential.

10. An electro-optical system comprising, in combination, a light source; two electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a separate voltage dividing network for each of said tubes having connections to each of said electrodes of said tubes; a variable resistor in series circuit relation with said first network, said first network and said variable resistor being connected in parallel circuit relation with said second network; a source of potential; a thermionic amplifier having its output connected in series circuit relation with said source of potential and said parallel circuit; and a connection between the output of said first electron multiplier tube and said thermionic amplifier to vary the gain of said second electron multiplier tube is automatically compensated for variations in the intensity of said light source and of said voltage source.

11. An electro-optical system comprising, in

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combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said electron multiplier tubes having an anode, a photocathode and one or more intermediate dynodes; a voltage dividing resistance network having taps thereon; connections between the first of said taps and the first dynode of each of said tubes; similar separate connections between each of said remaining taps and a corresponding electrode of each of said electron multiplier tubes; a source of potential; a thermionic amplifier having its output connected in series circuit relation with said source of potential and said network; and a connection between the output of said first electron multiplier tube and said thermionic amplifier to vary the gain of said amplifier, whereby the outputs of said remaining electron multiplier tubes are automatically compensated for variations in the intensity of said light source and of said voltage source.

12. An electronic measuring system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a source of unidirectional voltage; a variable impedance; parallel connections between said electron multiplier tubes, said parallel tube circuit being connected in series circuit relation with said voltage source and said impedance; a connection between the output of said first electron multiplier and said impedance to vary said impedance; one or more current responsive devices connected to the outputs of said remaining electron multiplier tubes, whereby the outputs of said current responsive devices are maintained substantially independent of variations of the intensity of said light source and of said voltage source.

13. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a source of unidirectional voltage; a variable impedance; parallel circuit connections between said electron multiplier tubes, said parallel tube circuit being connected in series circuit relation with said source and said impedance; means to match the amplification factors of said tubes; a connection between the output of said first electron multiplier tube and said impedance to vary said impedance, whereby the outputs of said remaining electron multiplier tubes are maintained constant irrespective of variations of the intensity of the light source and of the voltage source; and a separate current responsive device connected to the output of each of said remaining electron multiplier tubes.

14. An electronic measuring circuit comprising, in combination, a light source; two electron multiplier tubes each having an anode, a photocathode and one or more intermediate dynodes; a separate voltage dividing network for each of said tubes having connections to each of said electrodes of said tube; a variable impedance in series circuit relation with one of said networks; parallel circuit connections between said first network and said variable impedance, and said second network; a source of potential; a second variable impedance; said parallel circuit being connected in series circuit relation with said voltage source and said second variable impedance; a connection between the output of said first tube and said second variable impedance to vary said sec-

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ond impedance, whereby the output of said second electron multiplier tube is automatically compensated for variations in the intensity of said light source and of said voltage source; and a current measuring device connected to the output of said second electron multiplier.

15. An electro-optical system comprising, in combination, a light source; a plurality of electron multiplier tubes excited by said light source, each of said tubes having an anode, a photocathode and one or more intermediate dynodes; a voltage dividing resistance network having taps thereon; connections between one of said taps and the photocathodes of each of said tubes; connections between a second tap and the first dynode of each of said tubes; similar connections between each of the remaining taps and the remaining corresponding dynodes of each of said tubes; a source of unidirectional voltage; a thermionic amplifier having its plate connected to the positive side of said voltage source and its cathode connected to the positive side of said resistance network; a biasing resistor connected between said cathode

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and the control grid of said tube; a source of constant biasing potential for said tube; a connection between said control grid and the anode of said first electron multiplier tube; a separate current responsive device connected between said cathode and each of the anodes of said remaining electron multiplier tubes; and a connection between the negative side of said voltage source and said photocathodes and the negative side of said resistance network, whereby the outputs of said remaining electron multiplier tubes are automatically compensated for variations in the intensity of said light source and of said voltage source.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,198,233	Snyder, Jr.	Apr. 23, 1940
2,412,423	Rajchman et al.	Dec. 10, 1946