

I. LANGMUIR.
 METHOD OF AND MEANS FOR CONTROLLING ELECTRIC CURRENTS OR POTENTIALS.
 APPLICATION FILED FEB. 5, 1914.

1,273,627.

Patented July 23, 1918.

Fig. 1.

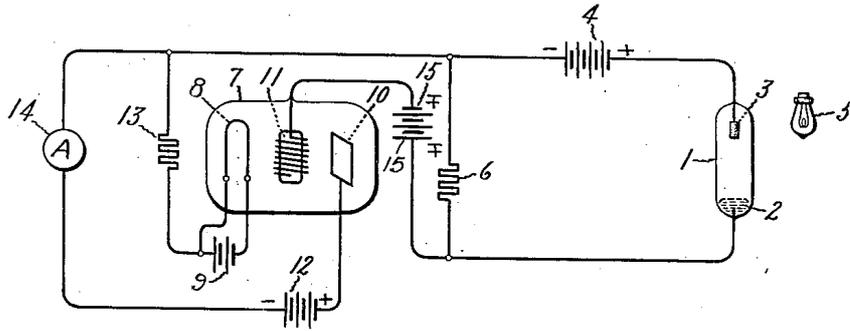


Fig. 2.

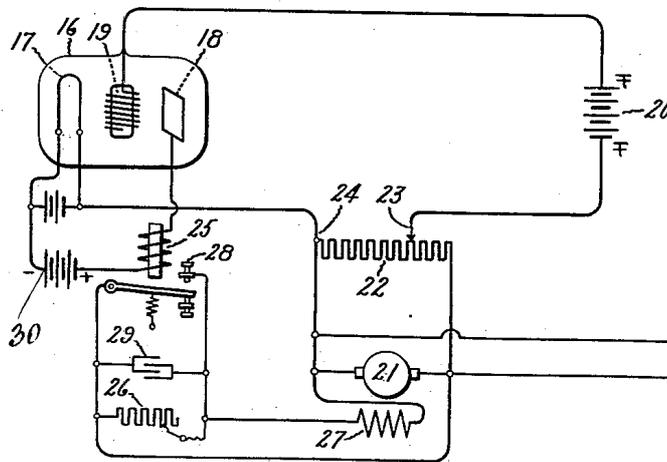
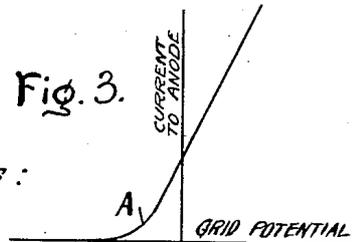


Fig. 3.



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UNITED STATES PATENT OFFICE.

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METHOD OF AND MEANS FOR CONTROLLING ELECTRIC CURRENTS OR POTENTIALS.

1,273,627.

Specification of Letters Patent.

Patented July 23, 1918.

Application filed February 5, 1914. Serial No. 816,836.

To all whom it may concern:

Be it known that I, IRVING LANGMUIR, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Methods of and Means for Controlling Electric Currents or Potentials, of which the following is a specification.

My present invention relates to means for controlling and regulating electric currents or potentials. I employ various and diverse agencies in such a way that variations of potential or current of one circuit are utilized to produce desired changes in the potential or current of another circuit suitably coupled with the first.

In one modification this effect may be employed in a system for controlling the value of a direct current of constant or slowly varying amplitude in the second circuit by means of a current of the same nature in the first circuit, in contra-distinction to the large class of devices which are in common use and which accomplish this result only in the case of alternating currents or pulsating direct currents.

In another modification variations in the potential of a source of electromotive force are utilized to produce variations in the current flow from another source. The variable current flow thus produced may be utilized in turn to operate suitable regulating means to maintain a constant potential in the first source.

In carrying my invention into effect I make use of some form of electron discharge apparatus arranged in coöperative relation with the source of potential or current which is to be controlled or regulated. I am not limited to the use of any particular form of electron discharge apparatus.

In the accompanying drawings in which Figure 1 shows diagrammatically one way in which my invention may be utilized for the amplification of electric currents, Fig. 2 shows a second modification thereof adapted to the operation of a constant potential regulator, and Fig. 3 shows a characteristic current curve of an electron discharge device which may be employed.

1 indicates a photo-electric cell having a cathode 2 of sodium, potassium or other metal which gives off electrons when subjected to the influence of light, and an anode

3. A battery 4 is placed in circuit with this cell and the current which passes through the cell when exposed to the influence of a light source 5 is caused to flow through the high resistance 6. In conjunction with this source of small currents I employ an electron discharge tube 7 comprising a cathode 8 of filamentary form provided with means for heating, consisting of a battery 9, an anode 10 and a conducting body 11 in the form of a grid interposed between the cathode and the anode. In circuit with the cathode and anode is placed a battery or other source of current 12 and a resistance 13, the value of which bears a given ratio to that of the resistance 6. In this circuit I may also place a suitable measuring instrument 14 for the purpose of measuring the amplified current.

The curve shown in Fig. 3 illustrates the relation between current between cathode and anode and grid potential in an electron discharge device which is suitable for my purpose. From this it will be seen that with a certain negative potential on the grid no appreciable current will flow between the electrodes. As this negative potential becomes less, current starts to flow and increases with decrease in the negative potential. Beyond a point A the curve becomes a straight line, that is, the change in current is directly proportional to the change in the grid potential and small changes in the grid potential produce large changes in the current.

Considering now the system shown in Fig. 1 and assuming that no current is flowing through the photo-electric cell 1, if current flows through the tube 7 there will be a drop of potential through the resistance 13 and this will cause the grid 11 to become negative with respect to the cathode 8. The greater the current the greater the drop in potential in the resistance 13 and the greater the difference in potential between the grid and cathode. Thus as the current increases the grid becomes more negative until a current value is reached at which further increase is prevented by the negative potential on the grid. The circuit should preferably be so adjusted that this value of the current will be small but will fall upon the straight portion of the current curve at some value above that represented by the point A. In order to keep the current in the tube at the

value desired it may sometimes be necessary to employ a battery 15 to impose an extra potential on the grid 11 though if the tube is properly designed this may not be necessary.

If now current starts to flow through the photo-electric cell there will be a drop in potential through the high resistance 6 and this difference of potential will oppose that through the resistance 13; that is, the potential of the grid 11 will become less negative or positive with respect to that of the cathode 8. As a result more current will flow through the tube. This increased current in turn causes an increased drop in potential through resistance 13. A point is finally reached at which further increase in current is limited by the grid potential. When this point is reached the increase in the drop through resistance 13 is substantially equal to the drop through the resistance 6 and the increase in current through resistance 13 will bear a fixed ratio to the current through resistance 6, which ratio is approximately the same as the ratio between the resistances. Assume for example that the drop through resistance 6 is 25 volts. If the current curve of the device were perfectly vertical the current through resistance 13 would increase until the drop therethrough had increased 25 volts so that the grid potential would be the same as before. Since, however, the current curve has a certain slant the current may increase only to a point where the increased drop through resistance 13 is 24 volts, making the grid 11 one volt less negative or more positive than before. It will be apparent that the ratio between the current through resistance 6 and the increase in current through resistance 13 will be substantially the same as the ratio of resistance 13 to the resistance 6. If now the current through the photo-electric cell is increased so that the drop through resistance 6 increases to 50 volts the current through resistance 13 will increase until the drop therethrough has increased 48 volts from what it was originally and the grid will be two volts less negative or more positive than before. It will be apparent that there will be the same proportionality between the two currents as before and that this ratio will remain the same as long as the current falls on the straight portion of the curve.

If the system is to be used for photometric purposes the measuring device 14 may be calibrated to read directly in candle power or any suitable unit desired. It will of course be understood that this form of my invention is by no means limited to the measuring of currents derived from the photo-electric cell but will be useful in many cases for amplifying or measuring small electrical currents derived from other

sources. It will also be apparent that many modifications of the system shown may be made without departing from the scope of my invention.

While my invention as illustrated in Fig. 1 is especially suitable for the amplification of feeble currents the principle involved in carrying it into effect may equally well be applied to the operation of a device for constant potential regulation. In Fig. 2 I have illustrated an organization whereby such a result may be accomplished. In this case I provide an electron discharge tube 16 with the usual cathode 17 and anode 18, and in circuit with the grid 19 of this tube may be connected two equal and opposing sources of electromotive force. The first of these, 20, consists preferably of a battery of standard cells the electromotive force of which is constant. The second source of electromotive force is the generator 21, the potential of which it is desired to maintain at a constant value. It may be desirable in some cases to use enough standard cells so that the constant electromotive force of the source 20 is substantially equal to the electromotive force of the generator 21. If this is not expedient, however, a resistance 22 may be connected across the terminals of the generator and a portion of this resistance shunted in such a way that the drop of potential between the shunt connections 23 and 24 is normally equal to the electromotive force of the source 20. As long as the drop in potential through the shunted resistance is equal to the electromotive force of the source 20 the current flow through the plate circuit of the electron discharge tube from a battery 30 will be constant. As soon, however, as this drop in potential varies there will be a change in the potential of the grid 19 with respect to the cathode 17. If the positive pole of battery 20 is connected to the grid more or less current will flow in the plate circuit of the tube according as to whether the drop of potential decreases or increases. If the negative pole of battery 20 is connected to the grid, an increase in the electromotive force of the generator will cause an increase in the plate current and vice versa. While it is not necessary that the electromotive force of the battery 20 should have the same value as the drop of potential in the shunted resistance 22, it should preferably have very nearly the same value in order that the grid 19 may normally be at substantially zero potential. In this case variations in the voltage of the generator 21 above or below normal produce corresponding positive or negative potentials on the grid 19 and a small change of potential will cause a large variation in the current flowing through the plate circuit of the tube. If, however, the value of the electromotive force of the battery 20 was ap-

preciably greater or less than that of the normal potential drop through the shunted resistance 22 the grid 19 would normally have an appreciable voltage impressed thereon and the effect of small voltage variations of the generator 21 would be much less proportionally than before. This current variation may readily be caused to operate upon any suitable regulating means by means of a relay 25 in the plate circuit of the tube.

While my invention is not limited to any particular form of regulating device, I have indicated one simple way in which the regulation of the generator may be accomplished. A variable resistance 26 is normally in series with the shunt field 27 of the generator 21. The apparatus is so arranged, however, that when the voltage of the generator falls below the desired value the current through the plate circuit of the electron discharge tube increases, enabling the relay 25 to pick up its armature and make contact with the upper stop 28, thereby short circuiting all of the resistance and thus increasing the field strength of the generator. A condenser 29 may be connected across the relay contacts to prevent sparking when the relay drops its armature, by reason of the increase in voltage of the generator and the corresponding decrease in the current in the plate circuit.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. The combination of an electron discharge tube having therein a cathode, an anode and a conducting grid, two sources of electromotive force connected in opposition to each other in an external circuit between the grid and the cathode, and means cooperating therewith whereby the two forces are maintained substantially equal to each other.

2. The combination of an electron discharge tube having therein a cathode, an anode and a conducting grid, two sources of electromotive force connected in opposition to each other in an external circuit between the grid and the cathode, and means cooperating therewith rendered operative by a change in one of the electromotive forces whereby the two forces are maintained substantially equal to each other.

3. The method of operating an electron discharge device comprising a cathode, anode and conducting grid which consists in causing current to flow in an external circuit between the anode and cathode of said device, applying two substantially equal and opposing potentials to the conducting grid, varying one of the potentials and utilizing the resulting current variations in the external circuit to maintain the two potentials substantially equal to each other.

4. Means for amplifying small unidirectional electric currents, comprising an electron discharge tube having grid and plate circuits, a resistance which is included in both of said circuits, and means cooperating therewith whereby an increase of current is produced in the plate circuit of an amount substantially equal to a given multiple of the value of the current to be amplified.

5. Means for amplifying small electric currents, comprising an electron discharge tube, a resistance in series therewith, and means cooperating with the tube and resistance to cause an increase in current flowing through the tube, which increase bears a predetermined definite ratio to the current which is to be amplified, which ratio is substantially independent of the operating characteristic of the tube.

6. Means for amplifying small electric currents, comprising an electron discharge tube and a resistance in series therewith, a second resistance through which the current to be amplified may be caused to flow, and means cooperating with the tube and resistances to cause an increase in the current flowing through the tube having a ratio to the current to be amplified substantially equal to the ratio of the second resistance to the first.

7. Photometric means comprising a photoelectric cell and an amplifying device electrically associated with and cooperating therewith whereby an increase in a normally small current in said device is produced of an amount equal to a given multiple of the value of the current flowing through the photoelectric cell.

8. Photometric means comprising a photoelectric cell, an electron discharge tube and means electrically associated with and cooperating therewith whereby an increase in current is produced in the tube of an amount equal to a given multiple of the value of the current in the photoelectric cell.

9. Means for amplifying small electric currents comprising an electron discharge tube, a resistance through which the current to be amplified may be caused to flow, and means cooperating with the resistance and the tube whereby an increase in current is produced in the tube of an amount equal to a predetermined given multiple of the value of the current to be amplified, which multiple is substantially independent of the operating characteristic of the tube.

10. Means for amplifying small electric currents comprising an electron discharge device having grid and plate circuits, a resistance which is included in both of said circuits, and a second resistance through which the current to be amplified may be caused to flow, and which is also included in said grid circuit.

11. Means for amplifying small electric currents comprising an electron discharge

device having grid and plate circuits, a resistance which is included in both of said circuits, and a second resistance through which the current to be amplified is caused to flow, said second resistance being included in the grid circuit in such a way that the drop in potential between its terminals opposes the drop in potential between the terminals of the first resistance when current is flowing therein.

12. Means for amplifying small electric currents comprising an electron discharge device having grid and plate circuits, a resistance which is included in both of said circuits, and a second resistance through which the current to be amplified may be caused to flow and which is also included in said grid circuit, said resistances being so related to each other that when the current to be amplified flows through the second resistance it will cause an increase in current through the first resistance of an amount equal to a given multiple of the value of the current to be amplified.

13. An electrical amplifying system comprising an electron discharge device having an incandescent cathode, an anode and a grid inclosed in an evacuated envelop, an external circuit connecting said cathode and said anode, a second external circuit connecting said cathode and said grid, means for impressing potential variations produced by the current to be amplified upon the second circuit and connections for impressing upon the second circuit potential variations produced by current changes in the first circuit, said connections being so arranged that the two sets of potential variations act in opposition to each other.

14. Means for amplifying electric currents comprising an electron discharge device having grid and plate circuits, means for impressing upon the grid circuit potential vari-

ations produced by the current to be amplified and a coupling between the two circuits whereby potential variations produced by changes in the current in the plate circuit act in opposition to the potential variations impressed upon the grid circuit by means of the current to be amplified.

15. Means for amplifying electric currents comprising an electron discharge device having a cathode adapted to be heated to incandescence, an anode and a grid inclosed in an evacuated receptacle, an external circuit connecting the cathode and grid, means for impressing a potential upon this circuit which is produced by the current to be amplified, and a second external circuit connecting the cathode and anode, and an ohmic resistance which is common to both circuits whereby current changes in the second circuit are effective in producing potential variations in the first circuit.

16. Means for amplifying small unidirectional currents comprising an electron discharge device having plate and grid circuits and an ohmic resistance included in the grid circuit through which the unidirectional current to be amplified is caused to flow.

17. The method of operating an electron discharge device comprising a cathode, anode and conducting grid which consists in causing current to flow in an external circuit between the anode and cathode of said device, and causing a small unidirectional current which is to be amplified to flow through an ohmic resistance which is included in an external circuit between the cathode and grid of said device.

In witness whereof I have hereunto set my hand this 4th day of February, 1914.

IRVING LANGMUIR.

Witnesses:

WILLIAM C. WHITE,
BENJAMIN B. HULL.