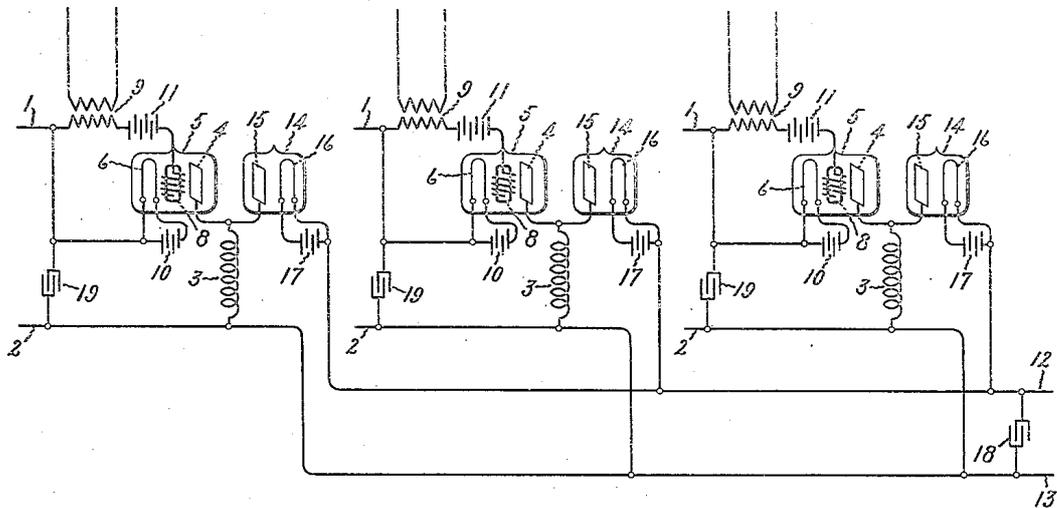


I. LANGMUIR.
MEANS FOR TRANSFORMING DIRECT CURRENT.
APPLICATION FILED DEC. 29, 1913.

1,273,626.

Patented July 23, 1918.
2 SHEETS—SHEET 2.

Fig. 3.



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UNITED STATES PATENT OFFICE.

IRVING LANGMUIR, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR TRANSFORMING DIRECT CURRENT.

1,273,626.

Specification of Letters Patent.

Patented July 23, 1918.

Application filed December 29, 1913. Serial No. 809,247.

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 Means for Transforming Direct Current, of which the following is a specification.

My invention relates to the transformation of a direct current of a given voltage into a direct current of a different voltage.

In carrying my invention into practice I make use of an energy storing device arranged in coöperative relation with electron discharge tubes. By the term "electron discharge tube" I mean to imply the use of a highly exhausted envelop containing at least two electrodes one of which is provided with means for causing it to emit electrons. A device of this nature when connected to a source of current operates selectively in such a manner as to allow current to flow between the electrodes in only one direction; that is, there will be a flow of negative electricity from the electron emitting electrode to the other electrode or electrodes, but no flow in the opposite direction. In order that this result may be obtained when a potential of more than 20 or 30 volts is applied it is necessary to have the highest possible exhaustion of the envelop. Otherwise there will be a heavy ionization of the gas present and this will render the device useless for my purpose. By improved methods of exhausting the envelop, however, such a high vacuum may be secured that for any voltage which is applied there is no appreciable gas ionization but the flow of current is the result of a pure electron discharge and is entirely independent of any gas conductivity.

If a negatively charged conducting body is placed in the proximity of the electrodes in such an envelop the flow of current will be impeded, and if the negative potential is made high enough the flow may be stopped altogether. By associating an electron discharge tube having a conducting body interposed between the electrodes and one without such conducting body, with an

energy storing device, I have produced an organization such that the current interrupting action and the selective action of the electron discharge tubes so control the storing and restoring of energy of the energy storing device as to produce in one of the circuits of the system a direct current potential differing from that of the original source.

The novel features which I believe to be characteristic of my invention I have pointed out with particularity in the claims appended hereto. The invention itself, however, both as to the details of its organization and its mode of operation will be better understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 shows diagrammatically one way in which my invention may be carried into effect; Fig. 2 shows a modification thereof, and Fig. 3 shows a system made up of a plurality of transforming devices like that shown in Fig. 1.

In carrying out my invention as illustrated in Fig. 1 the direct current, the voltage of which is to be changed is supplied by the direct current mains 1 and 2. The energy storing device which I use consists of an inductance coil 3 which is connected to the main 2 having a positive potential and the anode 4 of the electron discharge tube 5. The cathode 6 of this tube is connected to the main 1, which has a negative potential. Interposed between the anode and the cathode is a conducting body 8, preferably in the form of a grid, which is connected to an alternating current source of potential 9. The cathode is preferably of filamentary form and is provided with heating means consisting of a local battery 10. While the heating of the cathode is the means preferably employed for causing it to emit electrons, other methods may be used to accomplish the same result. If the cathode 6 is heated and the grid 8 is at zero potential there will be a flow of negative electricity from the cathode to the anode. If the grid is given a positive charge this flow will increase, while if the grid is given

a negative charge the flow will be cut down or interrupted entirely depending upon the voltage applied to the device and the value of the negative charge on the grid. In some cases it will be found desirable also to employ an extra battery 11 in order to impose an extra negative potential on the grid. For a further description of the causes for and the nature of this phenomenon reference is had to my copending applications Ser. No. 795,609, filed October 16, 1913, renewed as application Serial No. 84,241 on March 14, 1916, and 795,610 filed Oct. 16, 1913, renewed as application Serial No. 84,242 on March 14, 1916.

The inductance coil 3 is also connected to the conductors 12 and 13 of a second circuit which includes the electron discharge tube 14. This electron discharge tube has an anode 15 and a cathode 16 with a local battery 17 for heating the same.

The operation of my device as shown in Fig. 1 is as follows: If the potential supplied to the grid 8 is positive, current will start to flow through the circuit 2-3-4-1 and energy will be stored up in the medium surrounding the coil 3. If comparatively low frequencies are employed for the source 9 this medium may consist partly or entirely of iron. Before the current builds up to its maximum value however, the alternating current source 9 changes the potential of the grid 8 to negative and the current is interrupted. The energy stored up in the medium surrounding the coil 3 is then returned and is discharged into the circuit 12-14-3-13. The energy thus given to the second circuit cannot return to the first, as current can flow in only one direction through the electron discharge tube 14. It will be seen that by this means a succession of impulses of current is delivered to the second circuit. The frequency of these impulses will depend upon the frequency of the source 9, but they will all be in the same direction. By giving these impulses a high enough frequency and by inserting a condenser 18 between the conductors 12 and 13, I am able to secure a unidirectional and continuous current of constant voltage in the second circuit. The voltage of the current delivered to the second circuit will depend upon the resistance of that circuit. It will also be apparent that by connecting several transforming devices in parallel as shown in Fig. 3 and utilizing alternating current sources 9 which differ slightly in phase relation I may deliver a practically continuous succession of current impulses to the second circuit. In order to decrease the time required for the current in the coil 3 to build up to the desired value a condenser 19 may be connected across the supply mains 1 and 2.

In Fig. 2 I have shown a modification of

the means used for interrupting the flow of current in the first circuit. In place of the alternating current source used for exciting the grid 8 I may employ a battery 20, the positive terminal of which is connected to the grid through a high resistance 21 and the negative terminal of which is connected to the grid by means of a key 22. An intermediate point of the battery is also connected to the cathode 6. When the key 22 is open the grid 8 will be charged with a positive potential and current will flow through the tube. As soon as the key 22 is closed, however, the grid is connected directly to the negative pole of the battery and the current through the tube is immediately interrupted. In some cases this mode of operation will be more desirable than the one shown in Fig. 1 because of the fact that the interruption of the current may be accomplished more quickly than when an alternating current source is employed for exciting the grid. It will of course be understood that in place of the battery 20 I may use any source of direct current of the desired voltage and also that in practice some form of automatic make and break device will be used instead of the key 22. The high resistance 21 is used to prevent the short-circuiting of the battery when the key is closed.

While I have shown only two forms of a system for transforming direct current from one voltage to another it will be apparent that many modifications thereof may be made without departing from the scope of my invention; for example, I may use a second inductance in the second circuit, placed in inductive relation to the coil 3 for delivering the stored up energy to the second circuit. Other forms of electron discharge tube than those indicated may be employed in carrying out my invention; for example a tube having a plurality of anodes and a plurality of grids such as that shown and described in my copending application Ser. No. 797,986, filed Oct. 27, 1913.

Certain novel features of electron discharge devices and their operation are described and claimed by me in the above-mentioned applications, and in application Serial No. 876,432, filed December 10, 1914. Although certain aspects of the invention described and claimed in the applications mentioned are also described in the present application, I desire to make no claim there- to in the present application.

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

1. The method of transforming direct current from one voltage to another which consists in causing unidirectional current of one voltage to flow between electrodes in a vacuum in a circuit containing inductance, interrupting the flow between said electrodes and

discharging the stored up energy of the inductance into a second circuit as unidirectional current at a different voltage.

2. The method of transforming direct current from one voltage to another which consists in causing current of one voltage to flow between electrodes in a vacuum in a circuit containing inductance, interrupting the flow between said electrodes by imposing a negative potential upon a grid placed between them and discharging the stored up energy of the inductance into a second circuit at a different voltage.

3. The method of transforming direct current from one voltage to another which consists in causing a direct current of a given voltage to flow in a circuit comprising an energy storing device and an electron discharge tube, alternately applying positive and negative potentials to a grid placed between said electrodes to intermittently store up energy in the energy storing device and delivering said energy to a second circuit as a unidirectional current of a different voltage.

4. Means for transforming direct current from one voltage to another comprising an inductance common to two circuits, an electron discharge tube in one circuit, means for producing a flow of current through said tube and thereby storing up energy in the inductance, means for interrupting the flow of current through said tube, and means for discharging the stored up energy of the inductance into the second circuit.

5. Means for transforming direct current from one voltage to another comprising an inductance common to two circuits, two electrodes in the first circuit in a highly evacuated envelop, a conducting body interposed between said electrodes, means for imposing negative and positive potentials upon said conducting body, means for storing up energy from the first circuit in the inductance and discharging said stored up energy in the second circuit, and means to prevent energy discharged into the second circuit from returning to the first.

6. The combination of a source of direct current of a given voltage, an electron discharge tube in circuit with said source and means cooperating with said device for producing a direct current of a voltage different from that of the source.

7. The combination of a source of direct current of a given voltage, an energy storing device, an electron discharge tube in circuit with said source and means cooperating with said energy storing device and said tube for producing a direct current of a voltage different from that of the source.

8. The combination of a source of direct current of a given voltage, an energy storing device, an electron discharge tube, a grid

between the electrodes of said tube, means for imposing positive and negative potentials on said grid and means cooperating with said energy storing device and said tube for producing a direct current of a voltage different from that of the source.

9. Means for transforming direct current from one voltage to another comprising an inductance common to two circuits, an electron discharge tube in one circuit, means for interrupting the flow of current through said tube and a device in the second circuit having asymmetric conductivity through which stored up energy of the inductance may be discharged into the second circuit.

10. Means for transforming direct current from one voltage to another comprising an inductance common to two circuits, an electron discharge tube in one circuit, means for interrupting the flow of current through said tube and an electron discharge device in the second circuit through which stored up energy of the inductance may be discharged into the second circuit.

11. Means for transforming direct current from one voltage to another comprising an inductance common to two circuits, an electron discharge tube in the first circuit comprising an anode, a cathode and a conducting body interposed between anode and cathode inclosed in a highly evacuated envelop, means for imposing alternately positive and negative potentials upon said conducting body, and a device in the second circuit having asymmetric conductivity through which stored up energy of the inductance may be discharged into the second circuit.

12. Means for transforming direct current from one voltage to another comprising an inductance common to two circuits, an electron discharge tube in the first circuit comprising an anode, a cathode and a conducting body interposed between anode and cathode inclosed in a highly evacuated envelop, means for imposing alternately positive and negative potentials upon said conducting body and an electron discharge device in the second circuit.

13. The combination of a source of direct current of a given voltage, an energy storing device, an electron discharge tube comprising an anode, a cathode and a conducting body interposed between said anode and cathode inclosed in a highly evacuated envelop, means for impressing positive and negative potentials upon said conducting body and means cooperating with said energy storing device and said tube for producing a direct current of a voltage different from that of the source.

14. The combination of a source of direct current of a given voltage, an energy storing device and an electron discharge tube in a circuit with said source, said electron dis-

charge tube comprising a cathode, an anode
and a conducting body interposed between
anode and cathode, means for impressing
positive and negative potentials upon said
5 conducting body, and a second circuit com-
prising the energy storing device and a
second electron discharge tube.

In witness whereof, I have hereunto set
my hand this 27th day of December, 1913.

IRVING LANGMUIR.

Witnesses:

WILLIAM C. WHITE,
BENJAMIN B. HULL.