A. W. HULL.

MEANS FOR PRODUCING ALTERNATING CURRENTS.

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1,313,188.

Patented Aug. 12, 1919.

Fig. 1.

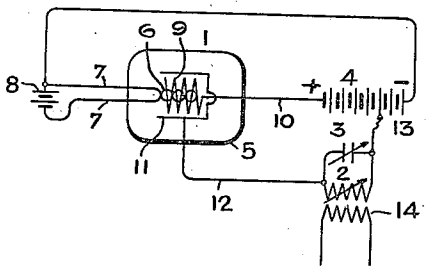
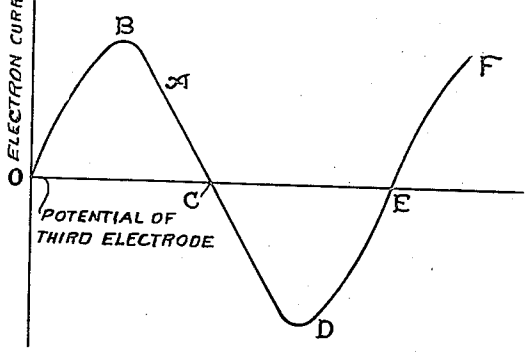


Fig. 2.



Inventor:
Albert W. Hull,
by
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UNITED STATES PATENT OFFICE.

ALBERT W. HULL, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR PRODUCING ALTERNATING CURRENTS.

1,313,188. Specification of Letters Patent. Patented Aug. 12, 1919.

Application filed November 8, 1915. Serial No. 60,402.

To all whom it may concern:

Be it known that I, ALBERT W. HULL, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Means for Producing Alternating Currents, of which the following is a specification.

The object of my present invention is to provide a means for producing alternating currents of any frequency desired from a source of direct current.

In carrying my invention into effect I make use of a negative resistance device in a circuit containing positive resistance, inductance and capacity and a source of direct current. I am aware that systems have heretofore been used in which the negative resistance effect of an arch has been employed. In this case the effect is brought about by gas ionization and as a result there is an appreciable lag in the action. In the present case, however, I make use of a negative resistance device in which the current both increases and decreases inversely with changes in the potential applied thereto, independently of any gas ionization and without any lag in its action.

The novel features of my invention I have pointed out with particularity in the appended claims. The invention itself however both as to its construction and method of operation together with further objects and advantages, will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 shows one system of connections which may be used in carrying my invention into effect; Fig. 2 shows the current characteristics of one of my negative resistance devices.

In the arrangement shown in Fig. 1 a negative resistance device 1 is connected in series with a variable inductive resistance 2 and a condenser 3 and a portion of the battery 4 is included in the circuit to furnish the energy from which the alternating currents are produced.

The negative resistance which I utilize in the present case is one which is described and claimed in my prior application, Serial No. 47,938, filed August 30, 1915, and which consists of a highly evacuated envelop 5 provided with a tungsten filament cathode 6 connected to leading-in conductors 7 for supplying current from the battery 8 for heating it to incandescence. This cathode is preferably surrounded by a cylindrical wire grid 9 which serves as an anode and which is connected to leading-in wire 10. Surrounding the cathode and anode is a third electrode consisting of a metal cylinder 11 connected to leading-in wire 12. This cylinder is preferably fairly close to the anode. The relative positions of the three electrodes may be varied in order to vary the operating characteristics of the device. The envelop 5 should preferably be exhausted to such a degree of vacuum that when potentials of the magnitude desired for the operation of the device are applied to the electrodes there will be no visible manifestations of gas ionization such as blue glow.

If a positive potential is impressed upon the anode 9 there will be a flow of electrons from cathode to anode. If the third electrode 11 is at the same potential as the cathode no electrons will be received thereby. If, however, a small positive potential is applied to the third electrode a portion of the electrons which pass through the grid anode will strike it and it will receive a current of negative electricity. The velocity with which the electrons will strike the third electrode will depend upon the difference of potential between it and the cathode. If this difference of potential is increased the velocity will increase until the electrons striking the third electrode are able by their impact to liberate secondary electrons. These secondary electrons leaving the third electrode will be attracted to the more positive anode. As the potential is increased a point will finally be reached at which the number of secondary electrons leaving the third electrode is just equal to the number of primary electrons that strike it. That is, each electron that strikes liberates on an average one secondary electron. No current will then be received by the third electrode. If the potential of the third electrode is further increased the number of secondary electrons given off becomes greater than the number of primary electrons received and as a result the third electrode loses electrons, thereby supplying current to the anode instead of receiving current.

These characteristics can best be understood by reference to the curve shown at A in Fig. 2 in which the ordinates represent

the electron current flowing to or away from the third electrode and the abscissæ represent the potential of the third electrode. The part O B represents the increasing electron current reaching the third electrode as the potential is increased. When the potential of the third electrode increases beyond that corresponding to the point B, the rate of increase in the emission of secondary electrons exceeds the rate of increase in the primary electrons received and the current begins to decrease. When the potential of the third electrode reaches the point C it loses as many electrons as it receives and the current becomes zero. From C to D the number of secondary electrons given off continues to increase and the electron current from the third electrode to the anode increases. The point D is finally reached however at which the potential of the third electrode so closely approaches that of the anode that the number of secondary electrons lost by the third electrode begins to decrease because of the fact that the difference of potential between anode and third electrode is not great enough to attract as many electrons to the anode as before. This continues until the point E is reached where the number of secondary electrons which leave the third electrode and do not return is equal to the number of primary electrons which strike it and the current again becomes zero. From this point the electron current received by the third electrode increases with increase in its potential as indicated by the part E F of the curve. The part B D of the current curve throughout the greater portion of its length is approximately straight and the straight portion may be represented by the equation

$$I = I_0 - \frac{E}{R}$$

where E is the potential of the third electrode, I_0 and R are constants, depending upon the characteristics of the particular device, and I is the electron current flowing to or away from the third electrode as

$$I_0 - \frac{E}{R}$$

is positive or negative. R corresponds to the resistance of an ordinary circuit except in this case it is a negative resistance. Thus it will be seen that there is a certain range through which the device may be operated in which the current received by the third electrode will vary inversely as the potential applied thereto. In the description which follows and in the claims the term "negative resistance" is used to designate a device having this characteristic.

In the system shown in Fig. 1, battery 4 furnishes a constant potential for the anode 9. The portion 13 of this battery supplies the potential which is applied to the third electrode 11. When the system is connected in this way and the capacity and inductance are properly proportioned the current in inductance 2 will vary, becoming either an alternating current or a pulsating direct current. In either case an alternating current will flow in a circuit connected to inductance 14 which is coupled to inductance 2. The frequency of this current may be varied by varying the capacity or inductance. It is also dependent to some extent upon the resistance 2 and the value of the negative resistance. In order that the system may oscillate, the product of the two resistances should be numerically less than the ratio of inductance to capacity. The alternating current obtained in the manner which I have described may be utilized for any desired purpose; for example, inductance 14 might be connected to an antenna and by the use of suitable signal producing apparatus the current be employed for transmitting wireless signals. In the above description and in the claims which follow I have used such expressions as "current flow from cathode to third electrode" to designate the net electron current received by the third electrode, or the current which will flow in the external circuit between cathode and third electrode.

While I have shown and described the preferred embodiment of my invention, various modifications therein may be made without departing from the scope of the appended claims; for example, the capacity instead of being placed in parallel with the inductive resistance may equally well be connected in parallel with the negative resistance.

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

1. Means for producing alternating currents comprising a circuit which includes capacity and inductance and a device having a plurality of electrodes inclosed in a receptacle evacuated to such a degree that the device is operable independently of gas ionization, and sources of potential of such values applied to the electrodes that the device has a working range over which the current flow therethrough increases and decreases inversely as the potential applied thereto.

2. Means for producing alternating currents comprising a circuit which includes capacity and inductance, and a device having an electron emitting cathode and electrodes coöperating therewith, and sources of potential of such values applied to the electrodes that the device has a working range over which the current flow therethrough varies inversely as the potential applied thereto, said device being operable over said working range independently of any gas ionization.

3. Means for producing alternating cur-

rents comprising a circuit which includes capacity and inductance and a device having an electron emitting cathode, an anode and a third electrode inclosed in a highly evacuated envelop, and sources of potential of such values applied between the cathode and other electrodes that the device has a working range over which the current flow from the cathode to the third electrode varies inversely as the potential applied thereto.

4. Means for producing alternating currents comprising a device having an electron emitting cathode, an anode and a third electrode inclosed in a highly evacuated envelop, and having a working range over which the current flow from cathode to third electrode varies inversely as the potential applied thereto, an external circuit between said cathode and third electrode comprising inductance and capacity and means for impressing a constant potential on said anode.

5. Means for producing alternating currents comprising a circuit which includes capacity, inductance and both positive and negative resistance, the negative resistance having a definite working range over which the current flow therethrough increases and decreases inversely as the potential applied thereto independently of any changes in temperature or gas ionization, and being so constructed that the current therethrough is carried entirely by the flow of negative electrons through an evacuated space.

6. Means for producing alternating currents comprising a circuit which includes capacity and inductance and a device having a definite working range over which the current flow therethrough increases and decreases inversely as the potential applied thereto independently of any changes in temperature or gas ionization, and which is so constructed that the current therethrough is carried entirely by the flow of negative electrons through an evacuated space.

7. Means for producing alternating currents comprising a circuit which includes capacity, inductance and both positive and negative resistance, the negative resistance having a definite working range over which the current flow therethrough increases and decreases inversely as the potential applied thereto independently of any changes in the temperature, the current through said negative resistance being carried entirely by the flow of negative electrons through an evacuated space, and the product of the two resistances being numerically less than the ratio of the inductance to the capacity.

8. Means for producing alternating currents comprising a device having an electron emitting cathode, an anode and a third electrode inclosed in a highly evacuated receptacle, means for impressing a constant positive potential upon said anode, means for impressing a smaller positive potential upon said third electrode of such value that the device has a working range over which the current flow from cathode to third electrode varies inversely as the potential applied thereto, and inductance and capacity included in an external circuit between said cathode and third electrode.

In witness whereof I have hereunto set my hand this 6th day of November, 1915.

ALBERT W. HULL.