I. LANGMUIR.

SYSTEM FOR AMPLIFYING VARIABLE CURRENTS.

APPLICATION FILED MAR. 2, 1915.

1,297,188. Patented Mar. 11, 1919.

Fig. 1.

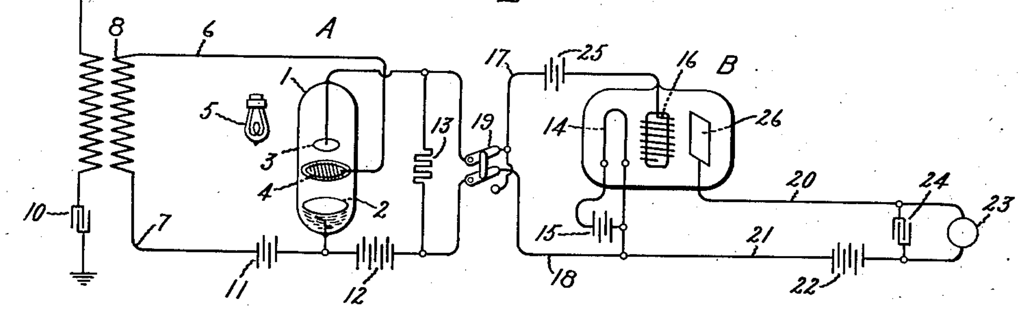


Fig. 2.

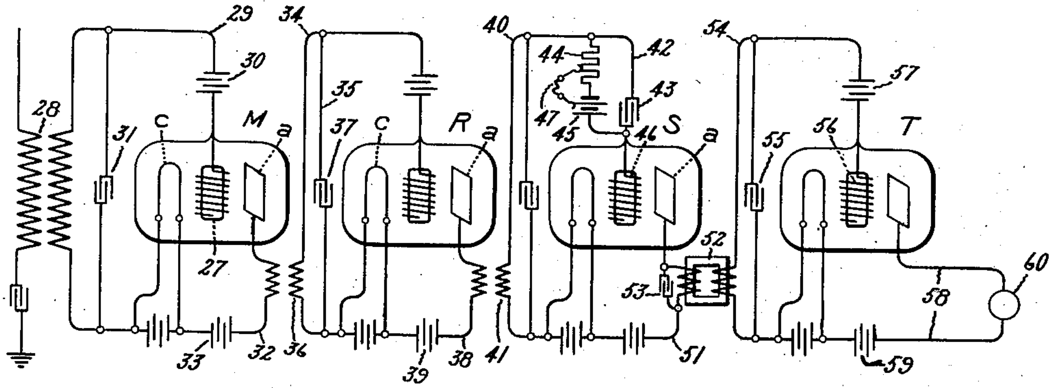
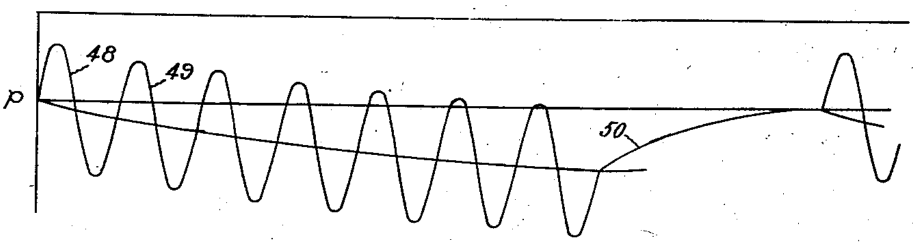


Fig. 3.



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UNITED STATES PATENT OFFICE.

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SYSTEM FOR AMPLIFYING VARIABLE CURRENTS.

1,297,188. Specification of Letters Patent. **Patented Mar. 11, 1919.**

Original application filed October 29, 1913, Serial No. 797,985. Divided and this application filed March 2, 1915. Serial No. 11,512.

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 Systems for Amplifying Variable Currents, (division of my application filed October 29, 1913, Serial No. 797,985,) of which the following is a specification.

The present invention relates to electrical discharge apparatus utilizing an electron discharge and comprises novel systems of connection whereby weak variable currents may be reproduced as stronger currents. My invention also includes means for securing selectivity in detecting signals, for example, for receiving systems in radio-telegraphy.

The electron-discharge device preferably utilized in accordance with my invention comprises an incandescent, or other electron-emitting cathode, a coöperating gas-free anode and a discharge-controlling conductor, commonly called the grid, and an inclosing envelop, the space in the envelop being evacuated below the pressure at which appreciable gas ionization by collision with electrons can occur, but it is to be understood that my invention is not limited to this particular apparatus.

My invention includes a combination of two or more electron discharge devices connected in cascade, the electrode circuit of one device being connected to a resistance, a reactance or transformer across which is connected the grid circuit of a second device. My invention also includes other novel features, such as means for integrating high frequency wave trains into impulses or waves of lower frequency, tuning both for group frequency as well as wave frequency, and other features pointed out with greater particularity in the appended claims.

A more detailed understanding of my invention may be had from the following description taken in connection with the accompanying drawings, which show for the purpose of illustration my invention as applied to receiving systems of wireless telegraphy. Figure 1 illustrates a system containing a device having an illuminated cathode; Fig. 2 illustrates a tuned system containing a condenser for integrating oscillations, and Fig. 3 is a diagram illustrating an integrating effect secured with a condenser with the grid circuit.

In Fig. 1 an electron discharge device A comprises a gas-tight envelop 1 which may consist of quartz or glass, preferably material pervious to ultra-violet light, and into which are sealed in the usual manner an electron-emitting cathode 2, a coöperating anode 3 and a discharge-controlling grid 4 ordinarily located between the cathode and anode. The cathode in this case consists of potassium, sodium, or other metal which emits electrons when illuminated by means of a source of light 5, which may be an incandescent lamp as illustrated or a suitable arc lamp. A monochromatic source of light, such as mercury vapor arc in a quartz or glass envelop is advantageous in giving electrons of uniform velocity. The anode preferably consists of tungsten and is deprived of gas by electron bombardment during the exhausting process, the envelop being sealed when the anode has been thoroughly freed from gas and the pressure in the envelop has been reduced to a value at which no appreciable gas ionization can occur. The grid 4 and the cathode 2 are connected respectively by conductors 6 and 7 to the secondary of a transformer 8, the primary of which is located in circuit with an antenna 9. In the antenna circuit there may be located a grounded condenser 10 but the antenna connections and structure may be the usual ones forming no part of my present invention. In the grid circuit 7, there is preferably included a source of potential 11, such as a battery which preferably is connected to maintain the grid at a definite negative potential, but in some cases the grid may be maintained at a positive potential.

In the circuit connecting the cathode and the anode, also known as the "plate circuit," is included a local source of energy, such as a battery 12, having its negative terminal connected to the cathode, and also a resistance 13. In place of this resistance a sufficiently high inductance may be used, its value depending on the frequency. The grid consists of a frame-work upon which is wound preferably very fine wire, for example, wire having a diameter of about .0004 inch, the turns being closely spaced. To the terminals of the resistance is connected a second electron-discharge device B, having a cathode 14, adapted to be heated to incandescence by means of a battery 15, or other convenient source. The grid 16 and the cathode 14 are connected to the resistance 13 respectively by conductors 17 and 18, through a reversing switch 19. In the electrode circuit 20, 21, of the device B is included a local source of energy 22 and an electrical detecting device 23, such as any of the known forms of electro-magnetic recorders or a telephone. In shunt therewith may be placed a condenser 24. In some cases a battery 25 or other source of potential may be included in the grid circuit 17.

In the system described the discharge device A, which may have relatively large distances between the grid and the electrodes, is made very sensitive to changes of grid voltages. The fact that the electrons are emitted by the cathode at uniform velocity contributes to its sensitiveness. A comparatively feeble impulse received from the antenna 8 will be accompanied by a change in the current from the local source 12 through the resistance 13. The current increases when a positive wave is superimposed on the negative grid potential. The current flowing through the resistance 13 will be greater than the current received from the antenna, and, therefore, will produce greater variations in the static charge of the grid 16 of the device B than were originally received by the grid 4 of the device A. Hence, these potentials may be used to produce greatly amplified signal current. In other words, the stronger currents flowing in the electrode circuit of the device A can be used to vary the flow of electron discharge current between the cathode 14 and the anode 26 of the discharge device B which is adapted to control relatively a greater amount of energy than the device A although not necessarily so sensitive to minute voltage changes as the device A. When the switch 19 is set so as to connect the positive terminal of the resistance 13 to the grid circuit 17, containing means for making the grid 16 negative, an increase of plate current of device A will produce an increase in the plate current of device B. The converse is the case when the connections are reversed. The variations in the electrode or plate circuit constitutes further amplification of the original signal currents and may be made of great enough to operate an electromagnetic instrument 23, such as a telegraph relay, or in any convenient way to indicate the signals. In some cases an ordinary telephone may be connected to the terminals of the conductors 20, 21, to detect the amplified signals.

The system shown in Fig. 2 is in some respects similar to the system shown in Fig. 1, for example, in the character of the discharge device used, and therefore need not be again described in detail. Each device has a heated cathode *c* and an unheated anode *a*, both of which may consist of tungsten. In the system shown in Fig. 2 a number of discharge devices have been shown connected in cascade and one of the devices is provided with means for integrating the high frequency oscillations of the wave trains so as to transmit in its plate circuit variable current which when transformed to an alternating current will correspond in frequency with the group frequency of the wave trains. Such a system permits progressive tuning in each grid circuit whereby the receiving system will select only signals having both a predetermined oscillation frequency and group frequency. This method of operation will be better understood by first considering the connections and then tracing through the method of operation.

The grid 27 of the discharge tube M is connected to the secondary of the loosely coupled air core transformer 28. The primary of the transformer is included in a grounded antenna similar to that shown in Fig. 1. In the grid circuit 29 is included a source of potential 30 and across the transformer secondary is connected a condenser 31, which preferably is made adjustable. By properly proportioning the inductance of the transformer secondary and the capacity of the condenser, the oscillating circuit constituted thereby may be made resonant to a desired frequency and therefore will be largely opaque to disturbances. Hence the grid will be influenced only to a slight extent by frequencies differing from the desired predetermined frequency. As already explained the variations in the grid potential, which is preferably negative, produced by the impressed oscillations result in oscillations in the plate circuit 32 similar to those in the grid circuit. These oscillations having been produced by a local source of current 33 may be stronger than the received oscillations. They are impressed on another oscillating circuit 34, 35, by means of an air core transformer 36. The circuit 34, 35, is likewise adjusted to be opaque to undesired oscillations by properly adjusting the condenser 37. The oscillations produced in the plate circuit 38 of the device R by a local source of energy 39 are again transmitted to another local oscillating circuit 40 which is also tuned, by an air core transformer 41. It will be noted that by thus tuning successive circuits the undesired oscillations are reduced in each case in geometric proportion.

In the present case, I secure as a novel feature tuning for both oscillation frequency and group frequency, as will be explained. The grid circuit 42 of the discharge tube S contains a condenser 43 which is shunted by a high resistance 44 and battery 45 which preferably has its negative terminal connected to the grid 46. Both the resistance and the battery are provided with an adjustable shunt 47 so that the potential of the battery and amount of resistance may be both varied or, in fact, entirely eliminated. Even when the grid 46 is not maintained at a predetermined potential it will assume some negative potential as it receives electrons from the cathode c and its potential is determined by the surface of the grid 46 and the rate at which the charge may leak off from the condenser plates. When the grid is positively charged it will take up electrons at a rate varying with the degree of positive charge and when the grid is negatively charged the rate at which it absorbs electrons decreases with the degree of negative charge until a value is reached at which no more electrons are taken up. The condenser charge will come to an equilibrium when the rate of leakage is equal to the rate of charging by the electrons absorbed. This grid potential may be assumed to have a negative value represented by the line p in Fig. 3 which represents a diagram in which the ordinates are grid potentials and the abscissa represents time. The actual number of oscillations in each group, of course, will be much greater than indicated in Fig. 3. When the oscillations are superimposed on the grid, assuming its potential to be p, Fig. 3, a positive wave 48 will cause it to take up more electrons, which are not discharged during the succeeding negative wave. Each successive wave adds its increment to the negative charge which thus accumulates on the grid and the plate of the condenser connected to it. After a certain number of oscillations have thus been received the grid has received such a negative charge that it no longer takes up more electrons than it loses. When the wave train ceases, the added negative charge leaks off as indicated by the line 50, until the grid potential again assumes its original value p. The capacity of the condenser 43, the potential of the battery 45, if one is used, and the resistance 44 should be so chosen that the grid 46 will have resumed its equilibrium charge before the next wave train is impressed on it.

As the current in the plate circuit 51 of the tube S is determined by the grid charge, a variable current will tend to flow therein having a frequency equal to the group frequency of the signals received from the antenna and also having a high frequency component. The high frequency component of this current may be eliminated by making the circuit responsive or resonant only to the low frequency. This may be done by providing the transformer 52 with an iron core so as to introduce considerable inductance into the circuit 51 and also by shunting the primary circuit of the transformer with a condenser 53. A relatively smooth low frequency alternating current will flow in the secondary circuit 54 which may be tuned for the frequency to be selected by an adjustable condenser 55.

The selectivity of the system thus is made very great as it is opaque not only to disturbances having a different frequency than the oscillations to be received but is also opaque to aerial signals having a different group frequency. The number of circuits connected thus in series or in cascade may be increased to any desired number.

In the system illustrated the oscillations of the circuit 54 are impressed on a grid 56, in circuit with which preferably is a source of potential 57. The currents in the plate circuit 58 produced by a local source 59 are varied as already explained by variations of grid potential. The amplified and selected signals may be recorded or detected by any suitable form of device as indicated at 60.

The grids of tubes M and R may consist of fine wire, closely spaced, the grid of the device S of coarse wire, more widely spaced, and the grid 56 of tube T of fine wire widely spaced but these relations are not essential.

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

1. The combination in an amplifying system of an electron discharge device having grid and plate circuits, means for supplying currents to be amplified to the grid circuit, a second electron discharge device having plate and grid circuits and a non-inductive resistance which is included in the plate circuit of the first device and the grid circuit of the second device.

2. The combination in an amplifying system of an electron discharge device having grid and plate circuits, means for supplying currents to be amplified to the grid circuit, a source of current and a non-inductive resistance in the plate circuit, a second electron discharge device having plate and grid circuits, and means for supplying the potential variations between the terminals of said resistance to the grid circuit of the second electron discharge device.

3. The combination in an amplifying system of an electron discharge device having grid and plate circuits, means for supplying currents to be amplified to the grid circuit a source of current and a non-inductive resistance in the plate circuit, a second electron discharge device having plate and grid circuits and means for supplying potential variations produced in the plate circuit of the first device by reason of changes in current through said resistance to the grid circuit of the second device.

In witness whereof, I have hereunto set my hand this 1st day of March, 1915.

IRVING LANGMUIR.

Witnesses:
EDWARD F. HENNELLY,
HELEN ORFORD.