

Sept. 18, 1923.

1,468,116

I. LANGMUIR

METHOD OF AND MEANS FOR AMPLIFYING POTENTIAL VARIATIONS

Filed Dec. 10, 1914

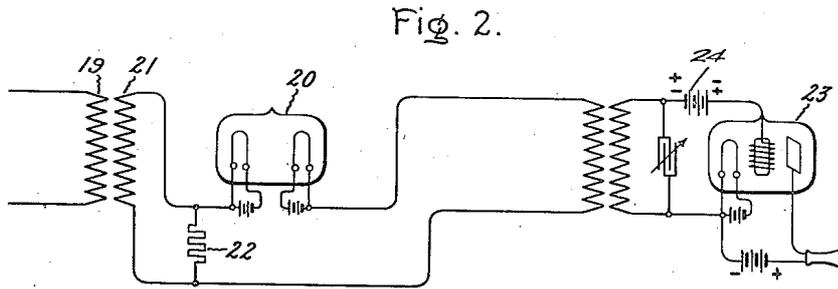
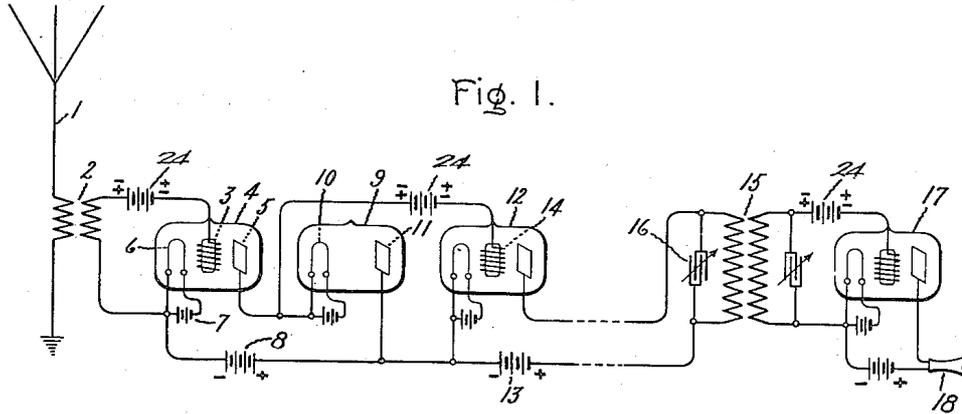


Fig. 3.

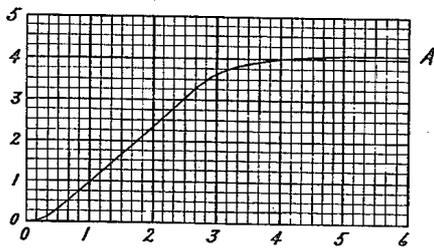
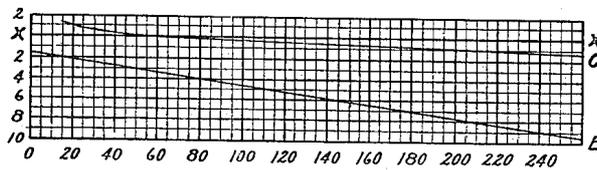


Fig. 4.



Witnesses:

George H. Tilden
J. Ellis Glenn

Inventor:

Irving Langmuir,
by *Albert H. Davis*
His Attorney

UNITED STATES PATENT OFFICE.

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

METHOD OF AND MEANS FOR AMPLIFYING POTENTIAL VARIATIONS.

Application filed December 10, 1914. Serial No. 376,432.

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 Amplifying Potential Variations, of which the following is a specification.

My present invention relates to the amplification of potential variations and more especially to the utilization in a wireless receiving system of devices having certain peculiar current limiting characteristics.

One of the objects of my invention is to provide a simple and efficient means for amplifying the potential variations of received waves of radiant energy. A further object of my invention is to provide a system in which all of the electrical impulses received by an antenna may be amplified and the wave shape of the original impulses may be maintained substantially the same up to a desired point in the amplification. Still another object of my invention is to provide a system in which the effects upon the receiving apparatus of the atmospheric condition known as "static" may be greatly reduced.

It has been discovered that if two electrodes provide a simple and efficient means for causing it to emit electrons, are enclosed in an envelope exhausted to such a degree that the passage of current between the electrodes produces substantially no gas ionization, irrespective of the voltage employed, the flow of current is dependent upon certain conditions. In case a heated cathode is used the current with constant temperature of the cathode, will, between certain limits, vary as the $3/2$ power of the voltage impressed on the anode. As the voltage is increased, however, a point which may be termed the "saturation" point, is finally reached at which the current becomes constant. By varying the temperature of the cathode the impressed voltage at which the current becomes constant may be varied and the value of the saturation current may be varied. Devices of this type are described and certain broad features thereof are claimed in my copending application, Serial No. 84,242, filed March 14, 1916, which is a continuation of my application Serial No. 795,610, filed October 16, 1913.

If a negative electrostatic field is set up

within the envelope of an electron discharge device in which the current has not reached the saturation point, by impressing a negative potential upon a conducting grid interposed between the electrodes the flow of current will be decreased, and if the negative potential used is great enough with respect to the potential impressed on the anode the flow of current may be stopped altogether. On the other hand if a positive potential is impressed upon the grid the flow of current may be increased. In controlling the current in this way if the anode is maintained at a constant potential a small variation in the potential of the grid will cause a very large change in the current between the electrodes. This property of such devices has been made use of by impressing upon the grid the potential of the very feeble current impulses of waves of radiant energy such as are received by the antenna of a wireless station, thereby producing a current flow between the electrodes which varies in accordance with the variations in the received current, but which is of much greater amplitude. If on the other hand, it is desired to cause a constant current to flow through the device the anode potential required to produce that current will vary in accordance with the variations in the potential of the grid. In carrying my invention into effect I make use of this last property in such a way as to amplify the potential variations of the received waves instead of the current variations and by so doing secure a high degree of amplification. In accomplishing this result I may also make use of the current saturation effect of a second electron discharge device to prevent the current through the amplifier from exceeding a certain amount, irrespective of the voltage impressed upon the grid.

In the operation of a receiving system arranged in accordance with my invention all of the potential variations of the received waves of radiant energy on a strongly damped antenna may be amplified in their proper proportions. The amplified potential variations thus obtained may be impressed upon a current limiting device which will eliminate all of the current impulses above a predetermined value and in this way the effect of heavy static discharges may be avoided. After the large impulses have thus been removed suitable tuning appara-

tus may be employed to select the impulses of the frequency sent by the station from which it is desired to receive.

Before proceeding further with the description of my invention it may be well to explain briefly the nature of the disturbances, the effect of which upon the receiving apparatus I desire to reduce as much as possible. A receiving antenna in addition to its function of serving as a collector for the waves of radiant energy sent out from other stations also serves as a path to the ground for atmospheric electricity commonly known as "static." This may be collected by the antenna merely by contact with charged atmosphere. The greatest interference with the receiving of the desired waves is, however, due to electromagnetic waves produced by atmospheric discharges accompanying thunder storms at a distance. When receiving from a station sending out strong signals and not too far away, the energy of these waves produced by atmospheric discharges which reach the antenna is usually so small in comparison with that of the signaling waves that there is practically no interference with the signals which it is desired to receive. On the other hand when an attempt is made to receive signals which are so weak when they reach the antenna that amplification is necessary for receiving, the amplitude of these waves produced by static discharges may become much greater than that of the signals which are to be received. If the antenna is tuned to the frequency of the waves to be received, oscillations of the same frequency but of much greater amplitude than the received waves will be set up therein by the waves produced by static discharges. The duration of these oscillations is comparatively short but if, in order to receive the signals desired, amplification is necessary the waves produced by static will be amplified to the same extent as the other waves. As a result the amplified static oscillations will produce such a loud noise in the telephone ordinarily used as a receiver as to completely drown out the desired signals over a much greater period. If the antenna is strongly damped no oscillations will be set up therein but the energy of the wave produced by static will pass to earth as a single rush of current. With such an antenna the received signals are weaker than when the antenna is tuned, while the amplitude of the static impulse remains substantially the same. As a result the amplitude of the signaling waves becomes much less with respect to the static impulses than when a tuned antenna is used for receiving. If then a device is placed in the receiving system, either before or after amplification, which limits the current which can reach the receiver to a value approximately that of the waves to be received

the effect of the static charge on the receiver may be so reduced as to be practically negligible.

The novel features of my invention are pointed out with particularity in the appended claims. The invention itself, however, 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 Fig. 1 illustrates diagrammatically a receiving system; Fig. 2 illustrates the application of a current limiting device to reduce the effect of static disturbances; Fig. 3 shows a curve illustrating the current saturation effect of an electron discharge device, and Fig. 4 shows the relation between the anode potential and grid potential of an electron discharge device with a constant current.

As indicated in Fig. 1 the antenna 1 is inductively connected by means of the transforming device 2 to the grid 3 of an electron discharge device 4. This device comprises in addition to the grid 3 an anode 5 which preferably is plate shaped, and a cathode 6 of filamentary form which is provided with a battery 7 for heating to incandescence. For convenience of description I term the circuit which comprises the grid 3, the secondary of the transformer 2, and the cathode 6, the grid circuit. The envelope within which these electrodes are placed is preferably exhausted to such a high degree of vacuum that the passage of current between the electrodes is accompanied by substantially no gas ionization irrespective of the voltage employed. In series with the electrodes of this device a source of energy 8 is placed and a second electron discharge device 9 is also included in the circuit which for convenience of description I designate as the plate circuit. This second device is similar to the first with the exception that the grid may be omitted. This device, however, should be so designed that with the ordinary temperature at which the cathode 10 is best adapted to operate the current will reach its maximum value when the voltage impressed upon the anode 11 is considerably less than that of the source of energy 8. The two devices should be so related and the potential of the source 8 should be so adjusted that normally the saturation current of the device 9 will be less than that which would pass through the device 4 when the grid 3 is at the normal potential. If then the grid potential be varied the current through the device 4 will tend to vary. Inasmuch, however, as this current is kept constant by the current limiting device 9 no variation in the current through the device 4 is possible. As the grid potential is varied, however, the difference in potential between the cathode 6 and the anode 5 will vary and consequently

the potential difference between the cathode 10 and the anode 11 of the current limiting device 9 will vary. The variations thus produced, however, will be many times greater than the variations of the potential of the grid 3. These amplified potential variations may be impressed upon the grid of a third electron discharge device 12 similar to the first one. Since the variation in potential between the cathode 6 and the anode 5 is equal to that between the cathode 10 and the anode 11 of the current limiting device 9 the potential variations between cathode 6 and anode 5 may be impressed on the grid of the device 12 with the same result. If the connection is made in this way it will be possible to use a somewhat variable source of energy in place of battery 8 since variations in the potential of the source will have no effect on the potential between cathode 6 and anode 5 as long as the potential of the source 8 is greater than that required to produce saturation current.

In this case the variations in potential of the source 8 will be all taken up by the device 9. While the variations in potential between 6 and 5 will differ from those between 10 and 11 by an amount equal to the variations of the source 8 this will not affect the operation of the device as the potential variations between 6 and 5 will always be proportional to the changes in potential of grid 3. The plate circuit of the device 12 may in addition to the source of energy 13 include a second current limiting device, and the potential variations impressed upon the grid 14 may be again amplified as in the first case. As many of these devices may be connected in series as is necessary to secure the desired degree of amplification. When the potential variations have been amplified as much as desired they may be used to control the current through the last electron discharge device of the series, thereby producing in the plate circuit of that device a current which varies in accordance with and is many times greater than the current received in the antenna.

If the antenna 1 is strongly damped all of the waves of radiant energy received thereby will be amplified to the same degree and if none of the circuits connecting the amplifiers are resonant the wave shapes of the various impulses received will be amplified with little variation. By passing the amplified current thus obtained through a tuned circuit consisting of an inductance 15 and variable condenser 16, it will be possible to select the amplified waves of the frequency which it is desired to receive. The waves thus selected may then be impressed upon the grid circuit of another electron discharge device 17 and the received signals may be detected in the telephone receiver 18 connected to the plate circuit of the detector 17.

In the drawing I have shown only one potential amplifying device, but have indicated by dotted lines the point in the system at which additional potential amplifying devices may be connected.

In the system thus far described no provision has been made for eliminating the heavy static impulses which are received on the antenna. An arrangement for accomplishing this is indicated in Fig. 2 in which current from a device controlled by amplified potential variations is caused to flow through the coil 19. The current thus obtained may comprise received waves from a plurality of stations and in addition may contain impulses from static charges of much greater amplitude than the signaling waves. To eliminate all of these impulses of an amplitude greater than that of the signaling waves, a current limiting device 20 having two incandescent electrodes, in order to allow the passage of current in either direction, may be included in the circuit of the coil 21 which is coupled with coil 19. The signaling waves will pass through this current limiting device without difficulty. As soon as a wave of high amplitude due to a static impulse is induced in the circuit the current limiting action of the device takes effect and only a small portion of the wave is allowed to pass through. The energy of the wave which does not pass through the current limiting device may be absorbed in the resistance 22. Having thus eliminated the heavy static impulses the current may be reproduced in the tuned grid circuit of the detector 23 in order to select and detect the waves of a desired frequency. While I have indicated the current limiting device as being connected in the system after the desired potential amplification has been obtained it will be apparent that it may be located at any point in the system where the current value of the received waves does not differ greatly from the saturation current of the device. In the operation of electron discharge devices having a controlling grid it will be found desirable to adjust the normal potential of the grid to a value at which the device has the greatest sensitiveness to variations in the grid potential. In order to do this a battery 24 of the desired potential may be connected to the grid. In some cases the positive terminal may be connected to the grid while in other cases it will be found desirable to connect the negative terminal of this battery to the grid.

The curve A of Fig. 3 which is drawn with current as ordinates and the impressed voltage on the anode as abscissae shows the relation between these two quantities. It will be seen that when the current reaches a certain value further increase in voltage has no effect. The temperature of the cathode in this case is constant. If the temperature

should be increased the value of the saturation current would also increase. In any case, however, there will be a point at which further increase of voltage will produce no increase in the current.

In Fig. 4 I have illustrated the relation between the grid potential and anode potential of a device, such as 4 in Fig. 1. In this case the ordinates represent the grid potentials, those below the axis, X—X representing negative grid potential, and the abscissæ represent the anode potential necessary to maintain constant current with varying grid potential. The lower curve B represents the relation between the two potentials when no current passes through the device, and the upper curve C represents the same relation for one particular value of the current. In the device of which this is a characteristic curve it will be seen that a variation of one volt in the grid potential corresponds to a variation of practically 150 volts in anode potential, thus it will be seen that 150 fold amplification may be secured with this particular device by the method which I have described. The slope of the constant current curve will depend upon the construction and arrangement of the electrodes and grid, and I have found it possible to construct devices of this character by means of which a greater degree of amplification than 150 may be secured.

While I have described my method of amplification with special reference to a system in which a strongly damped antenna is employed it is also adapted for use with a tuned antenna as well. It will also be apparent to one skilled in the art that many variations in the arrangement of the different devices employed and in the characteristics of the connecting circuits may be made without departing from the scope of the appended claims, and I do not wish to be limited to the particular arrangement described. Neither do I wish to be limited to the use of apparatus which operates with a pure electron discharge, as amplification according to the method described may be successfully carried on with any controlling device in which the flow of current or the potential between two electrodes may be varied by varying the potential on a conducting body interposed between or placed in the neighborhood of the electrodes, or with any current limiting device in which an increase in voltage above a certain point does not produce an increase of current.

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

1. The combination in a wireless receiving system of an electron discharge device comprising an evacuated envelope having therein an electron emitting cathode, an anode and a grid, means for impressing re-

ceived waves upon the grid circuit of said device, a source of energy in the plate circuit of said device, a current limiting device in series with said source of energy which prevents any increase of current in the plate circuit above a certain amount irrespective of the voltage applied thereto, a second electron discharge device similar to the first, and means for impressing upon the grid circuit of the second electron discharge device the potential variations between the terminals of said current limiting device.

2. The combination in a wireless receiving system of a strongly damped antenna, means for amplifying all of the waves of radiant energy received by said antenna, means for limiting the amplitude of said amplified waves to a predetermined value which is independent of the voltage of the source by which they are produced, means for selecting from said amplified waves of limited amplitude those of a desired frequency and means for detecting the waves thus selected.

3. The combination in a wireless receiving system of a plurality of electron discharge devices each having an electron emitting cathode, a cooperating anode and a conducting grid, means comprising a non-resonant circuit for causing variations in the potential of the grid of one of said devices corresponding to received waves means comprising a second non-resonant circuit for amplifying these potential variations and impressing them on the grid of a second device, thereby producing amplified waves in the plate circuit of that device, means for limiting the current in the second non-resonant circuit to a predetermined value irrespective of the voltage therein, a tuned circuit in operative relation to said second device for selecting from the amplified waves those of a desired frequency, and means for detecting the waves thus selected.

4. The combination with an electron discharge device comprising an evacuated envelope having therein an electron emitting cathode, an anode and a grid, of means for impressing a variable potential upon said grid, a source of energy in the plate circuit of said device, a current limiting device in series with said source of energy which prevents any increase of current in the plate circuit above a certain amount irrespective of the voltage applied thereto, a second electron discharge device similar to the first and means for impressing upon the grid of the second device the potential variations between the terminals of said current limiting device.

5. The combination in a wireless receiving system of an antenna, means for amplifying the waves of radiant energy received by said antenna and means for limiting the amplitude of said amplified waves to a pre-

determined value which is independent of the voltage by which they are produced.

6. The combination in a wireless receiving system of an antenna, means for amplifying the waves of radiant energy received by said antenna, and means for absorbing all of the energy of said amplified waves above that corresponding to a current of a certain predetermined value.

7. The combination in a wireless receiving system of an antenna, means for amplifying the waves of radiant energy received by said antenna, detecting apparatus operatively connected to said antenna and means for absorbing all of the energy of said amplified waves above that corresponding to a current of a predetermined value before they reach the detecting apparatus.

8. The combination in a wireless signaling system of an antenna, means for amplifying the waves of radiant energy received by said antenna, detecting apparatus operatively connected to said antenna and means for limiting the amplitude of the received and amplified waves to a predetermined value which is independent of the voltage producing them before they reach the detecting apparatus.

9. The combination in a wireless receiving system of an antenna, means for amplifying the potential variations of the waves of radiant energy received by said antenna, means for producing a current which varies in accordance with said amplified potential variations, means for limiting the amplitude of said current to a predetermined value which is independent of the voltage by which it is produced, means for selecting from said variable current waves of a desired frequency, and means for detecting the waves thus selected.

10. The combination in a wireless receiving system of an electron discharge device comprising an evacuated envelope having therein an electron emitting cathode, an anode and a grid, means for impressing received waves upon the grid circuit of said device, a source of energy in the plate circuit of said device, a second electron discharge device adapted to limit the current in the plate circuit of the first device to a predetermined value irrespective of the voltage applied thereto, a third electron discharge device similar to the first, and means for impressing upon the grid circuit of the third device the potential variations between the terminals of said second device.

11. The combination with an electron discharge device comprising an evacuated envelope having therein an electron emitting cathode, an anode, and a grid, of means for impressing a variable potential upon said grid, a source of energy in the plate circuit of said device, a second electron discharge device adapted to limit the

current in the plate circuit of the first device to a predetermined value irrespective of the voltage of the source of energy therein, a third electron discharge device similar to the first, and means for impressing upon the grid of the third device the potential variations between the terminals of said second device.

12. The combination in a wireless receiving system of an antenna, means for amplifying waves of radiant energy received by said antenna without any substantial variation in the wave shape, means for limiting the amplitude of said amplified waves to a predetermined value which is independent of the voltage by which they are produced, and means for detecting said amplified waves of limited amplitude.

13. The combination in a wireless receiving system, of means for amplifying the potential variations of the received waves comprising a controlling device having at least two electrodes and a controlling grid, a source of energy connected to said electrodes and having in series therewith a device adapted to prevent the current between said electrodes from exceeding a predetermined value irrespective of the voltage impressed thereon from said source, means for impressing the potential variations of the received waves upon the controlling grid, and means for impressing the amplified potential variations upon the grid of a second controlling device.

14. Means for amplifying potential variations comprising a controlling device having at least two electrodes and a controlling grid, a source of energy connected to said electrodes having in series therewith a device adapted to prevent the current between the electrodes from exceeding a predetermined value irrespective of the voltage impressed thereon from said source, and means for impressing the potential variations to be amplified on the controlling grid.

15. The combination with a controlling device having at least two electrodes and a controlling grid of a source of energy connected to said electrodes and having in series therewith a device adapted to prevent the current between the electrodes from exceeding a predetermined value irrespective of the voltage impressed thereon from said source, and means for impressing a variable potential on the controlling grid.

16. The combination in a wireless receiving system of means for amplifying the potential variations of the received waves comprising a controlling device having at least two electrodes and a controlling grid, a source of energy connected to said electrodes and having in series therewith a device adapted to prevent the current between said electrodes from exceeding a predetermined value irrespective of the volt-

age impressed thereon from said source and means for impressing the potential variations of the received waves on the controlling grid.

17. The method of amplifying potential variations which consists in causing a constant current to flow in a circuit comprising two separated electrodes having interposed between them a controlling grid and at the same time impressing the potential variations which are to be amplified on the controlling grid, thereby producing potential variations between the electrodes similar to the potential variations impressed on the grid but of much greater amplitude.

18. The combination of a repeating circuit comprising an electron discharge device having two windings in series therewith, means for inducing an alternating potential from a selected source together with disturbing potentials in one of said windings, and a second circuit having a winding therein operatively related to the second winding, said electron discharge device being so constructed and the saturation current thereof having such a value that the current flowing in the second winding cannot exceed the maximum value of the current derived from the selected source irrespective of the value of the disturbing potential induced in the first winding.

19. The combination of a repeating circuit comprising an electron discharge device having two electrodes and two windings in series therewith, and means for inducing an alternating potential from a selected source together with disturbing potentials in one of said windings, the saturation current of said electron discharge device having such a value that the current flowing in the second winding cannot exceed the maximum value of the current from the selected source irrespective of the value of the disturbing potential induced in the first winding.

20. In a repeating system the combination of an electron discharge device comprising an evacuated container having two electrodes enclosed therein provided with means for heating to incandescence, said device being so constructed and the temperature of the electrodes being so chosen that the current passing between said electrodes cannot exceed a predetermined desired value irrespective of the voltage applied thereto.

21. The combination of a repeating circuit comprising an electron discharge device having two electrodes, at least one of which is provided with means for heating to incandescence and means for impressing upon said circuit an alternating potential from a selected source together with disturbing potentials, said electron discharge device being so constructed and the temperature of the incandescent electrode being so chosen that the current flowing in the

circuit cannot exceed the maximum value of the current derived from the selected source irrespective of the value of the disturbing potentials impressed upon the circuit and will vary between this maximum value and a substantially zero value with variations in the amplitude of the alternating potential from the selected source.

22. The method of eliminating disturbing effects in a signaling system comprising an electron discharge device having a plurality of electrodes, at least one of which is provided with means for heating to incandescence, the temperature of said heated electrode being so chosen that the current passed by said device cannot exceed a given desired value irrespective of the applied voltage, which consists in producing in the system by means of the maximum energy from a selected source a signaling voltage approximately equal to that required to produce maximum current in the device and applying this voltage together with any voltages which may be produced in the system by means of the energy of disturbing agencies to said device and thereby producing in the system currents which will vary only between the maximum value of the current produced by the selected source and a substantially zero value.

23. The method of transferring electrical energy of a selected source from one circuit to another by means of an intermediate circuit, which consists in limiting the current in the intermediate circuit to a value substantially equal to the maximum value of current which can be derived from the selected source irrespective of the voltage applied thereto while maintaining the continuity of the intermediate circuit.

24. In a receiving system for radio communication, a current limiting device comprising an electron discharge device, an electrical circuit connected to electrodes of said device, a wave responsive device associated with said circuit and means for impressing upon the electrodes of said device currents produced by signaling waves together with currents produced by disturbing agencies, the electron producing means of said device being so adjusted that the current carried by the produced electrons cannot appreciably exceed in value the current produced in the circuit by the signaling waves.

25. The combination in a signaling system which is subject to abnormal potentials of an electron discharge device, an electrical circuit arrangement which includes two windings in series with said device and means for inducing a signaling potential from a selected source in one of said windings, said electron discharge device being so constructed and the saturation current thereof adjusted to such a value that the

current flowing in the second winding can only vary in value between the maximum value of current derived from the selected source and a substantially zero value, irrespective of the value of any abnormal potentials which may be induced in the first winding.

26. The combination in a signaling system which is subject to abnormal potentials of an electron discharge device, an electrical circuit arrangement which includes two windings in series with said device and means for inducing a signaling potential from a selected source in one of said windings, said electron discharge device being so constructed and the saturation current thereof adjusted to such a value that the current flowing in the second winding will vary between a maximum and a substantially zero value with variations in the signaling potential and cannot appreciably exceed in value the maximum value of the current produced by the signaling potential.

27. The method of operating an energy transmission system, which is subject to abnormal energy conditions and which comprises a circuit containing a device which permits of current flow therethrough in both directions and which is adjusted to limit the current flowing in that circuit to a predetermined value irrespective of the voltage applied thereto without interrupting the continuity of the circuit, which consists in producing by means of the normal energy in the system a voltage of substantially the value required to produce the maximum possible current in the circuit, applying this voltage to the circuit, together with any other voltages which may be produced in the system by abnormal energy, and thereby limiting the rate at which abnormal energy is transmitted to a value substantially equal to the rate at which the normal energy in the system is transmitted.

28. The method of eliminating disturbing effects in a signaling system comprising an electron discharge device having a plurality of electrodes, at least one of which is provided with means for heating to incandescence, the temperature of said heated electrode being so chosen that the current passed by said device cannot exceed a given desired value irrespective of the applied energy, which consists in producing in the system by means of the normal energy from a selected source a variable signaling voltage, the maximum value of which is approximately equal to that required to produce a current of a value equal to the maximum current which can be passed by said device and applying to the device this voltage together with any voltages which may be produced in the system by means of the energy of disturbing agencies and there-

by limiting currents produced in the system by the disturbing agencies to a value which is substantially equal to that of the maximum currents produced by the variable signaling voltage.

29. The combination in a signaling system which is subject to abnormal potentials of an electron discharge device, an electrical circuit which includes two windings in series with said device, and means for inducing a signaling potential from a selected source in one of said windings, said electron discharge device being capable of permitting current to flow in both directions through said windings and being so constructed and the saturation current thereof adjusted to such a value that the current flowing in the second winding cannot appreciably exceed in value the current produced therein by the signaling potential from the selected source irrespective of the value of any abnormal potentials which may be induced in the first winding.

30. In a receiving system for radio communication, a current limiting device comprising an electron discharge device having a cathode adapted to be heated to incandescence to serve as a source of electrons and an anode, an electrical circuit connected to the electrodes of said device, a wave responsive device associated with said circuit, and means for impressing upon the electrodes of said device currents produced by signaling waves together with currents produced by disturbing agencies, the temperature of said cathode being so adjusted that the current carried by the electrons emitted thereby cannot appreciably exceed in value the current produced in the circuit by the signaling waves.

31. The combination in an energy transmitting system which is subject to abnormal energy conditions of an electron discharge device having two electrodes, both of which are provided with means for heating to incandescence, an electrical circuit connected between said two electrodes, and means for impressing upon said circuit a voltage produced by the normal energy from a selected source together with voltages produced by abnormal energy conditions, said electron discharge device being so constructed and the temperature of the incandescent electrode being so chosen that the current in the circuit cannot appreciably exceed in value the current produced therein by the voltage produced by the normal energy from the selected source.

32. The method of eliminating disturbing effects in a signaling system comprising an electron discharge device having a plurality of electrodes, at least one of which is provided with means for heating to incandescence, the temperature of said heated electrode being so chosen that the current passed

by said device cannot exceed a given desired value irrespective of the applied voltage, which consists in producing in the system by means of the normal energy from a selected source a signaling voltage approximately equal to that required to produce maximum current in the device, and applying this voltage together with any voltages which may be produced in the system by means of the energy of disturbing agencies to said device and thereby limiting currents produced in the system by the disturbing agencies to a value which is substantially equal to that of the currents produced by the signaling voltage.

33. The combination in a signaling system which is subject to abnormal potentials of an electron discharge device, an electrical circuit arrangement which includes two windings in series with said device, and means for inducing a signaling potential from a selected source in one of said windings, said electron discharge device being so constructed and the saturation current thereof adjusted to such a value that the current flowing in the second winding cannot appreciably exceed in value the current produced therein by the signaling potential from the selected source irrespective of the value of any abnormal potentials which may be induced in the first winding.

34. The method of operating an energy transmission system, which is subject to abnormal energy conditions and which comprises a circuit arrangement containing a device which is adjusted to limit the current flowing in that circuit arrangement to a predetermined value irrespective of the voltage applied thereto without interrupting

the continuity of the circuit arrangement, which consists in producing by means of the normal energy in the system a voltage of substantially the value required to produce the maximum possible currents in the circuit arrangement, applying this voltage to the circuit arrangement, together with any other voltages which may be produced in the system by abnormal energy, and thereby limiting the rate at which abnormal energy is transmitted to a value substantially equal to the rate at which the normal energy in the system is transmitted.

35. The combination in an energy transmitting system which is subject to abnormal energy conditions, of an electron discharge device having a plurality of electrodes, at least one of which is provided with means for heating to incandescence, an electrical circuit arrangement connected with said electrodes, and means for impressing upon said circuit arrangement a voltage produced by the normal energy from the selected source together with voltages produced by abnormal energy conditions, said electron discharge device being so constructed and the temperature of the incandescent electrode being so chosen that the current in the circuit arrangement cannot appreciably exceed in value the current produced therein by the voltage produced by the normal energy from the selected source.

In witness whereof, I have hereunto set my hand this 9th day of December, 1914.

IRVING LANGMUIR.

Witnesses:

WILLIAM C. WHITE,
BENJAMIN B. HULL.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,468,116, granted upon the application of Irving Langmuir, of Schenectady, New York, for an improvement in "Methods of and Means for Amplifying Potential Variations," an error appears in the printed specification requiring correction as follows: Page 1, line 30, strike out the words "provide a simple and efficient means for" and insert instead the syllable and words *-trodes, one of which is provided with means*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23d day of October, A. D., 1923.

[SEAL.]

WM. A. KINNAN,
Acting Commissioner of Patents.