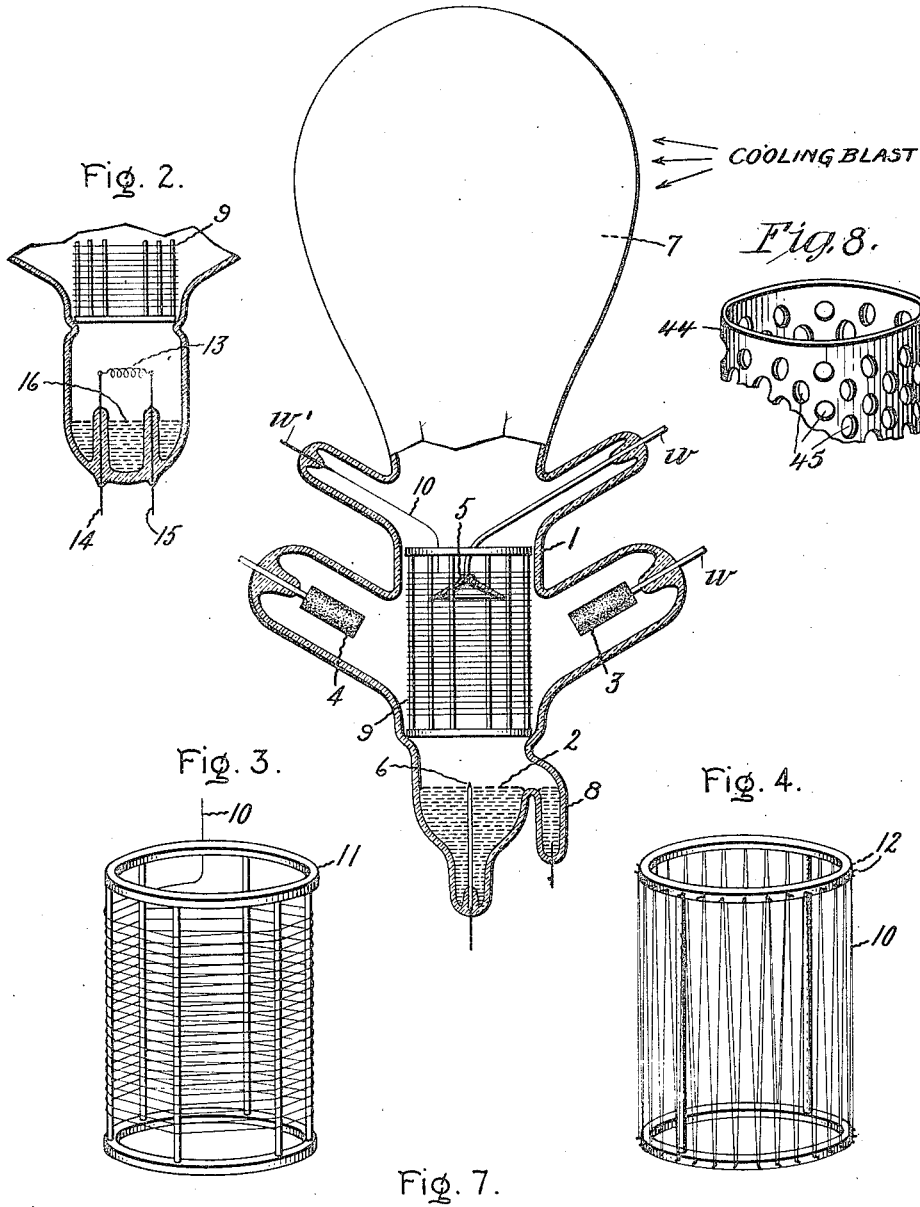


I. LANGMUIR.
 ELECTRIC DISCHARGE CONTROLLING DEVICE AND METHOD OF OPERATING THE SAME.
 APPLICATION FILED NOV. 6, 1914.

1,289,823:

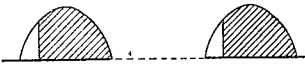
Patented Dec. 31, 1918.
 2 SHEETS—SHEET 1.

Fig. 1.



Witnesses:

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Inventor:

Irving Langmuir,
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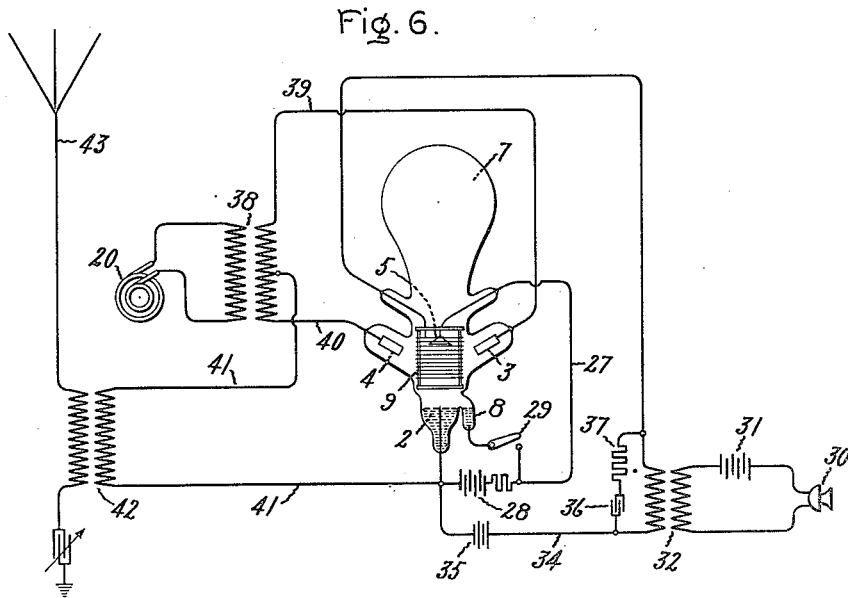
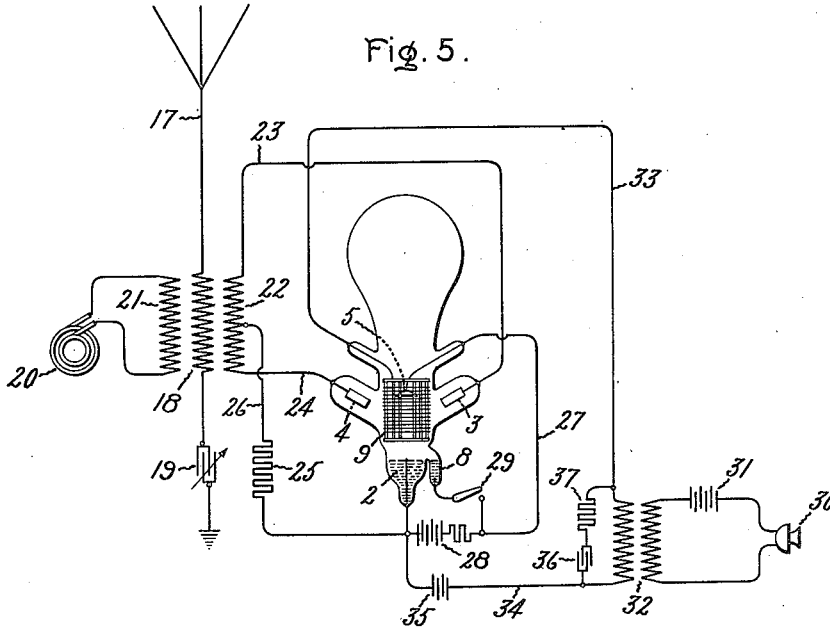
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2 SHEETS—SHEET 2.



Witnesses:

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UNITED STATES PATENT OFFICE.

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

ELECTRIC-DISCHARGE-CONTROLLING DEVICE AND METHOD OF OPERATING THE SAME.

1,289,823.

Specification of Letters Patent.

Patented Dec. 31, 1918.

Application filed November 6, 1914. Serial No. 870,598.

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 Electric-Discharge-Controlling Devices and Methods of Operating the Same, of which the following is a specification.

The present invention relates to apparatus for controlling electrical currents, particularly high frequency alternating currents, and comprises a novel electrical discharge apparatus and systems of connections suitable for utilizing the same in electric signaling, such as aerial telephony.

It is the object of my invention to provide a current controlling apparatus capable of passing relatively large amounts of energy, and to enable very feeble currents, as for example, the variable current of a telephone transmitter, to directly control and vary a powerful oscillating current.

In accordance with my invention an alternating current, or other variable current periodically falling to a potential too low to support an arc is employed to operate a succession of arcs and the starting of the successive arcs is timed in accordance with the potential of an electrical field established in the path of the arcs and varying in accordance with the variations of the current to be amplified. One embodiment of my invention comprises an electric arc device provided with excitation means, such as a continuously operating arc, main electrodes between which the successive arcs operate and a conducting body for establishing an electric field to act upon and time the duration of each successive arc. My invention also includes systems of connections for an aerial signal system supplied with high frequency alternating current and containing a control device constructed and operated in accordance with my invention.

In the accompanying drawings Figure 1 shows in longitudinal section one type of control device embodying my invention; Fig. 2 is a longitudinal section of the cathode and of a modification containing an incandescent cathode; Figs. 3, 4, and 8 illustrate in perspective three types of construction suitable for the field-controlling member; Figs. 5 and 6 illustrate radio sending systems containing control devices made in

accordance with my invention; and Fig. 7 shows diagrammatically how the amount of energy passing through the device is varied.

The device shown in Fig. 1 comprises an envelop 1 consisting of glass, quartz, or the like, and containing a body of easily vaporizable material 2, for example, mercury, constituting the cathode of the device, and main anodes 3, 4, consisting of graphite, tungsten, molybdenum or other highly refractory material, current being conveyed to all these electrodes in the usual manner by leading-in-wires *w*, sealed into the wall of the container. Above the cathode 2 is provided an anode 5 from which an arc is constantly running to the cathode during the operation of the device the arc being maintained steady by the conductor 6 consisting of platinum or copper, and projecting above the surface of the mercury. This anode 5 is located equal distance from the two main anodes. Above the arcing space is provided a condensing chamber 7, the size of which is adjusted to give the proper mercury pressure for the best operation of the device. In some cases the device may be externally cooled, as indicated in the drawing. The arc is started by a small side branch electrode 8, or in any other convenient manner.

A charge-controlling member 9 hereinafter known as a grid is located between the arc operating between the electrodes 5 and 2 and the anodes 3 and 4. While this grid may assume various forms two suitable constructions are shown in Figs. 3 and 4. As here illustrated the grid consists of a wire 10, preferably tungsten wire, wound on the periphery of the cylindrical or polygonal frame 11, Fig. 3, or strung back and forth upon supports 12 embedded in the top and bottom of the frame, as shown in Fig. 4. External connection is made to the grid wire 10 by a leading-in conductor *w'* in the same manner as the electrodes. Various other grid constructions for example a metal plate 44 having perforations 45 as shown in Fig. 8, or other open work devices may be used, depending on the specific character and uses of the control device.

Instead of using a vapor arc having its seat at an easily vaporizable cathode, an arc in a suitable gas may be used which emanates from a non-consuming refractory cathode operating at incandescence, of the type described, for example, in Meikle Pat-

ent No. 1,182,290. The cathode 13 of the device shown in Fig. 2 consists preferably of a highly refractory material, such as tungsten, and is heated by a current introduced by conductors 14, 15. In close proximity to the heated cathode is a quantity of mercury 16 which is vaporized and ionized by the cathode 13. The mercury body in this figure has been shown as illustrative of one of the ionizable substances in which an arc may be operated.

The operation of the device may be best understood by reference to the wireless sending systems shown in Figs. 5 and 6. In Fig. 5 the usual antenna 17 is shown containing an inductive coil 18 and a grounded condenser 19. Electrical energy is supplied by a high frequency alternator 20 connected to a coil 21 located in inductive relation to the antenna coil 18. The coil 22 is also located in inductive relation with the coil 21 and has its terminals connected by conductors 23, 24, to the anodes 3, 4, of a control device constructed as described in connection with Fig. 1. The cathode 2 is connected in series with the resistance 25 by a circuit conductor 26, carrying rectified current, to a point of intermediate potential on the coil 22. The circuit represented by conductor 27 connecting the cathode 2 and the anode 5 contains a battery 28 for supplying energy to continuously maintain an arc between these electrodes. This same battery may also be used to initially start the device by completing a circuit to the auxiliary electrode 8 by the closure of the switch 29.

When the arc between the electrodes 5 and 2 is normally operating energy is supplied by the alternator 20, and successive arcs would ordinarily pass from the anodes 3 and 4 to the cathode in the usual manner of operation of a mercury arc rectified. When, however, the grid 9 is negatively electrified to a sufficiently high potential the starting of these arcs is prevented. In order to take advantage of this fact a variable negative potential may be impressed upon the grid thereby causing variable amounts of energy to be passed by the arc device and as this energy is consumed in the resistance 25 it is subtracted from the energy available for the antenna and thus desired signals may be transmitted. For example, a signaling device, such for example, as a telephone transmitter 30 containing a local source of energy such as battery 31, is connected to the primary of a transformer 32, the secondary of which is connected by its negative terminal by the conductor 33 to the grid 9. The positive terminal of the secondary is connected by a conductor 34 in series with the battery 35 to the cathode 2. The battery 35 is not absolutely essential but is desirable as it maintains the grid at a

definite negative potential so that the variations impressed by the signaling current vary the grid potential to values above or below the battery potential. High frequency current in the circuit 33, 34 is damped out by a condenser 36 and the resistance 37. When in the arrangement described a voice or other audible signal produces variation in the conductivity of the transmitter 30 a resultant variable current in the transformer 32 is stepped up in potential superimposed upon the battery potential 35 and thus varies the charge on the grid. The grid in accordance with the degree of its negative charge delays the starting of the wave impulses from the anodes as shown diagrammatically in Fig. 7, the shaded portions of the waves indicating the energy transmitted through the control device. In that manner a variable current is drawn off from the antenna thereby varying the energy radiated into space from the antenna.

Instead of withdrawing energy from the antenna by the control device it may be directly transmitted to the antenna from the high frequency source through the control devices as shown in Fig. 6. In this figure the high frequency alternator 20 is connected with the primary of the transformer 38, the secondary of which is connected by conductors 39, 40, to the anodes 3, 4 of the arc control device. The cathode 2 is connected by a conductor 41 in series with the primary of a transformer 42 to a point of intermediate potential of the transformer 38. The other connections of the control device are similar to those already described. When a variable potential is impressed on the grid 9 by the telephone 30 or other transmitting device, variable portions of the wave impulses from the high frequency supply are transmitted by the arcs and impressed as rectified current impulses on the transformer 42, the secondary of which is included in series with the antenna 43. A high frequency current having double the frequency of the source 20 is generated in the antenna varying in amount in accordance with the variations of the signaling current.

Various modifications and substitutions may be made within the scope of my invention in the apparatus and system above described.

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

1. The method of controlling the duration of an arc discharge in a gas which consists in rendering conductive the arc path, establishing in the arc path a negative electric field having a potential high enough to prevent the starting of an arc, and at the desired instant lowering the potential of said field to permit an arc to start.

2. The method of varying an alternating

current in accordance with the variations of another electric current which consists in impressing the current to be varied on a continuously ionized arc path in a gas and producing in the arc path a negative electric field varying in accordance with said independent current, thereby timing the starting of electric arcs by the arc-suppressing effect of said field.

3. The combination of a source of current periodically falling to zero, an electric control device comprising a vaporizable cathode, an anode, and conductive means located between said electrodes for establishing an electric field, connections from the negative and positive terminals of said source to the cathode and anode of said device, means for varying at will the potential of said conductive means, and means for continuously maintaining an auxiliary arc from said vaporizable cathode.

4. The combination of a source of alternating current, a vapor arc device comprising a mercury cathode, an anode, and a grid located between said electrodes, electrical connections between the terminals of said source and the cathode and anode of said vapor device, means for establishing and varying at will an electrical field about said grid, means for utilizing a variable current passed between said main electrodes, and means for maintaining an ionizing electrical discharge in said device.

5. The combination of a source of high frequency current a control device comprising an envelop, arc-sustaining electrodes, means for continuously ionizing the same, and a means for establishing and varying at will an electric field in the arcing path between said arc-sustaining electrodes, electrical connections from said high frequency source to said electrodes, a circuit between the cathode of said control device and said high frequency source, and means in said

cathode circuit for utilizing rectified wave impulses for the transmission of signals.

6. In a system of communication, the combination of a source of high frequency pulsating current, a vapor electric arc device in circuit therewith, means within said arc device for continuously ionizing gas within the apparatus, an electrostatic member within the apparatus for timing the starting of successive arcs therein by said high frequency current, electrical connections for varying the electrical charge of said member in accordance with signals to be sent, and means for utilizing the energy of the variable current conducted by said device for the transmission of signals.

7. The combination of a source of alternating current, a vapor arc device having a cathode and an anode operatively connected to said source, a grid coextensive transversely with the arcing space between said electrodes, means for producing a varying electrical charge on said grid for timing the starting of successive arcs between said arcing electrodes in accordance with signals to be transmitted, and means for utilizing the energy of said successive arcs for the generation of electromagnetic waves.

8. The method of controlling the duration of an arc discharge sustained by an intermittent current falling periodically below the value necessary to sustain an arc which consists in setting up in the arc path a negative electrostatic field having a value high enough to delay the starting of an arc and varying said field in accordance with the variations desired in said arc.

In witness whereof, I have hereunto set my hand this 5th day of November, 1914.

IRVING LANGMUIR.

Witnesses:

MARY E. CHRISTIE,
HELEN ORFORD.