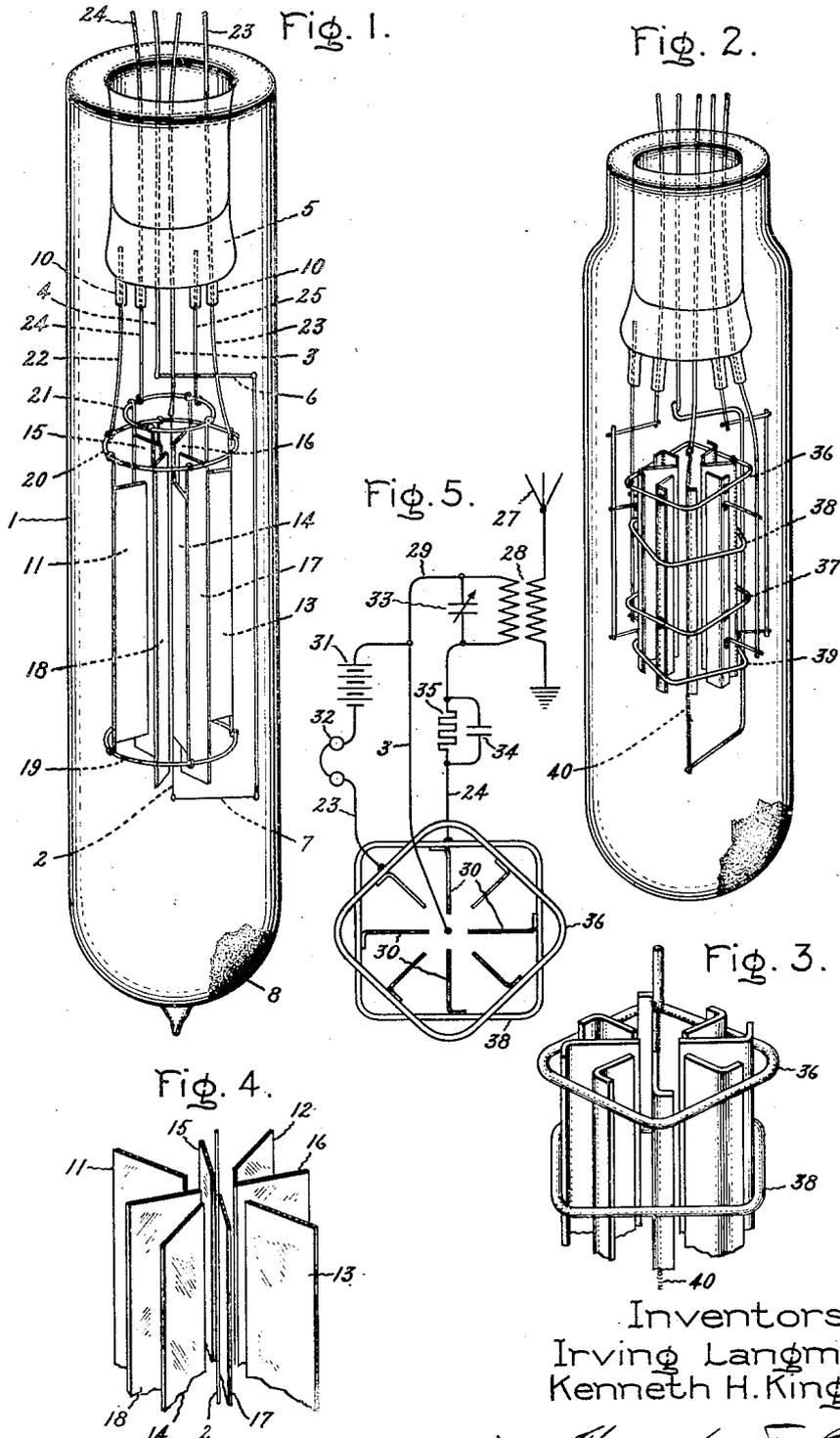


Dec. 27, 1932.

I. LANGMUIR ET AL
ELECTRICAL DISCHARGE DEVICE
Original Filed Oct. 1, 1924

1,892,244



Inventors:
Irving Langmuir,
Kenneth H. Kingdon,
by *W. J. Lunt*
Their Attorney.

UNITED STATES PATENT OFFICE

IRVING LANGMUIR AND KENNETH H. KINGDON, OF SCHENECTADY, NEW YORK, ASSIGNORS TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

ELECTRICAL DISCHARGE DEVICE

Application filed October 1, 1924, Serial No. 740,998. Renewed October 30, 1931.

This application is a continuation in part of our application filed November 6, 1923, Serial No. 673,165 and on which U. S. Patent 1,648,312 was granted November 8, 1927.

5 The present invention relates to the construction of electrical discharge devices having in addition to the cathode a plurality of cooperating electrodes, one which serves as an input or grid electrode whereby the current in the device is electrostatically controlled.

Heretofore, in the construction of radio detectors, electric amplifiers, oscillators and similar electron devices, the grid commonly has been constituted by a wire coil or screen which was interposed between the cathode and a surrounding anode.

15 In accordance with our invention, we have provided an improved device of this character in which the anode as well as the input or grid electrode consists of plate-shaped members which are arranged in interleaved relation with the members of the anode, the members constituting the input electrode being in closer electrostatic relationship to the cathode than the members constituting the anode. This construction is of particular advantage in a device containing a cathode sensitive to positive ion bombardment, as the positive ions are attracted to the grid instead of the cathode.

25 The novel features of our invention will be set forth with greater particularity in the accompanying claims, while details of our invention will be described in the following specification taken in connection with the accompanying drawing.

30 In the drawing, Fig. 1 is a side elevation of a three-electrode amplifier tube embodying our invention; Fig. 4 illustrates in perspective the relation of the grid and anode members, the supports being omitted for the sake of clearness; Figs. 2 and 3 illustrate a modification, and Fig. 5 is a diagram of a radio receiving system in which a tube embodying our invention may be employed as a radio detector and amplifier, the elements of the tube in this figure being shown in horizontal section.

50 Our invention will be described with par-

ticular reference to an electron discharge device containing a substance such as caesium or rubidium, which is capable of increasing the electron emission of a thermionic cathode by the formation upon the cathode of an adsorbed film, as described in detail and claimed in our prior application Serial No. 673,165, of which this application constitutes a continuation.

60 The device shown in Fig. 1 comprises as usual, an exhausted container 1, consisting of glass or other convenient material and containing a filamentary cathode 2, which preferably should have a substantially rectilinear extension. The cathode 2 is supported from the leading-in conductors 3 and 4, which are sealed into a stem 5, as usual. Between the leading-in conductor 4 and the end of the cathode remote from the stem 5 is a supporting structure 6, which terminates in a spring 7 in order to maintain the cathode taut. Provided within the container 1 also is a quantity of metallic caesium, as indicated at 8. The caesium may be introduced from a side tube (not shown) containing a mixture of caesium chloride and calcium which when heated yields caesium.

75 In these tubes containing alkali metals, care should be taken to avoid condensation of metal on the stem as such condensation will cause electrical leakage between wires passing through the stem. Condensation of this kind is particularly apt to occur on those places where caesium oxide is present. The stem should be freed from condensed caesium by heating, and the parts where caesium has deposited should be cooled sufficiently to avoid perceptible vapor pressure of caesium when the oxygen is introduced. To reduce electrical leakage, it is advantageous to surround the electrode leads with short glass tubes spaced away from the leads as shown in both figures of the drawing. (See Fig. 1.)

85 In the prior application above mentioned we have described particularly the property of an electron discharge device containing in addition to caesium or the like a layer of adsorbed material on the cathode, preferably an oxygen film which has the property of

causing the cathode surface to more tenaciously hold the caesium bound thereon than would a clean unoxidized cathode surface. While the present invention is not to be understood as being limited to this particular form of device, we will describe for the sake of completeness the preparation of the entire device, including the oxidation of the cathode surface. Although the described structure has particular advantages in a device having a cathode sensitive to positive ion bombardment, it should be understood, of course, that the structure covered by our present application can be used in other forms of discharge devices.

When the cathode is to be provided with an oxygenous layer, the envelope of the device first is evacuated thoroughly and the filament heated to a high temperature to free its surface of impurities and to remove occluded gas. In the case of a tungsten cathode this temperature should be about 2500° Kelvin. Oxygen then is admitted to the container to a pressure of about 20 to 30 microns (0.02-0.030 mm.) the filament preferably being heated to a temperature of about 1400 to 1500° K. for a few seconds, which causes the formation of a thin layer of adsorbed oxygen upon the cathode. The remaining oxygen then is pumped out and a quantity of caesium or rubidium is distilled into the container, which may form a condensate on the wall, as shown at 8, as preferably enough of the metal is introduced to provide a surplus of unevaporated caesium at any desired operating temperature.

In some cases after the caesium has been introduced an additional amount of oxygen is admitted to oxidize part of the caesium and preferably in addition to the oxygen about half as much hydrogen (by volume) as the amount of oxygen is introduced and allowed to "clean-up". The tube finally is sealed off with the exhaust pump operating. After the tube is sealed off, the cathode should be heated for a few seconds at about 1300 to 1500° K. to get rid of deleterious substances on the oxygen layer.

When the device prepared as above described by the admission of gaseous oxygen is operated with the cathode at a temperature of about 900° K., the bulb as a whole being at a temperature of 30° C. (303° K.), an electron emission from the cathode of the order of about 200 to 300 milliamperes per sq. cm. of surface is obtained. This emission is of the same order of magnitude as the emission from a tungsten filament operating in a vacuum in the absence of caesium or similar activating substances at a temperature of about 2500° K., but the energy required is much less.

Both the control electrode and the anode in the device shown in the drawing consist of flat plate-shaped members which are radially positioned with respect to the cathode,

the cathode being axially positioned in the envelope 1. The anode consists of set of plates 11, 12, 13 and 14 and the control electrode consists of plates 15, 16, 17 and 18. It should be noted that the set of plates constituting the control electrode are located somewhat more closely to the cathode than the anode plates and therefore are in closer electrostatic relation to the cathode than the anode plates. By this construction the electron current passing during operation from the cathode to the anode can be controlled, so as to secure relatively large changes of current by small change of the potential of the grid or control electrode plates. As shown in Fig. 1 the control electrode plates may be somewhat longer than the anode plates, but this is not essential. The spacing of the anode and grid plates from the cathode may easily be chosen to give an amplification constant of about 4.5 to 5. The anode plates are connected to one another as shown in Fig. 1 by rings 19, 20 to prevent displacement, and the control electrode plates are connected together by a single ring 21. The rings 20 and 21 are supported respectively from the stem 5 by the wires 22, 23 and 24, 25. The wires 23 and 24 are continued through the stem and project from the outside of the device to permit of electrical connection.

In a tube of this construction the positive ions are almost entirely formed in the space between the anode and control plates and not between the filament and the plates. The ions, therefore, are produced at points where the electric field draws them to the grid, and they are thus prevented from striking the cathode. Moreover, it is evident that inasmuch as a general movement of the positive ions formed at the surface of the anode is in a direction substantially normal to that surface and toward the grid member, the cathode is shielded from ion bombardment.

It is also apparent that while control and anode members of flat form and positioned in the plane of the filament lend themselves particularly well from the manufacture, assembly and operation standpoint for the purposes stated, it is to be understood that our invention is not limited to electrodes of this configuration and arrangement, since the electrodes may take any suitable shape, individually or as a whole, and may be positioned in any relation with respect to the cathode and with respect to one another as will cause the electrostatic lines of force between the control and anode members to be directed substantially away from the filament without departing from our invention. These respective electrodes are connected by the usual sealed-in conductors, the cathode conductors being numbered 3 and 4, the input conductor 24 and the anode conductor 23. For the sake of simplicity no base has been shown for the device. This device may

be used as a radio detector or as an amplifier, with the usual circuit connections for three electrode devices. For example, in Fig. 5 a typical receiving circuit has been shown connected to receive signals from the antenna 27. The secondary of the antenna transformer 28 is connected by the conductor 29 to the plate circuit 23 of the device and by the conductor 24 to the grid electrode 30. The plate circuit contains a source of current 31 and a telephone receiver 32. A tuning condenser 33 is provided as usual. When the device is to be used as a detector a grid condenser 34, and a grid leak 35 also may be provided.

The device shown in Fig. 2 closely resembles the device of Fig. 1. The anode and grid plates in this case are bent substantially at right angles at one edge to give them greater rigidity and to permit them to be more readily welded or otherwise attached to the holders. As shown in this figure two sets of binding rings, or holders, are applied to each set of electrodes. The anode plates are welded to the rings 36, 37 and the grid plates to the rings 38, 39. The cathode 40 in this modification consists of a spiral stretched out to the desired length. By the use of a spiral a greater length of wire may be introduced for a given length of electrodes, thus minimizing the cooling effect of the leads which is especially important because of the low cathode temperatures used.

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

1. An electric discharge device comprising a container, an electron-emitting cathode having a generally rectilinear extension, and a plurality of cooperating electrodes each of which consists of groups of members having a maximum surface extension in a radial direction with respect to said cathode, each of the respective members of one group being located respectively between members of the other group, and one of said groups being in closer electrostatic relationship to said cathode than the other group.

2. An electric discharge device comprising a container, a cathode therein having a generally rectilinear extension, an anode and an input electrode, said anode and input electrode each comprising a plurality of substantially flat members mounted radially about said cathode, the members constituting the input electrode being in interleaved relation with said anode members and being closer to said cathode than said anode members.

3. An electric discharge device comprising a container, a rectilinear filamentary cathode consisting of refractory material, an anode and an electrostatic input electrode, said anode and input electrode each comprising a plurality of flat plates, means supporting said plates substantially radially with respect to said cathode, the plates constituting one of

said electrodes being interleaved with the plates constituting the other electrode and the plates constituting the input electrode being closer to the cathode than the plates constituting the anode.

4. An electric discharge device comprising a container, an electron-emitting cathode having a generally rectilinear extension, a plurality of cooperating electrodes in said containers each of which consists of plate-shaped members mounted radially with respect to said cathode, the plate members of one electrode being mounted in interleaved relation with the plate members of the cooperating electrode, each plate being substantially in the plane which includes said electron emitting cathode.

5. An electric discharge device comprising a filamentary cathode having a mainly linear extension, a grid electrode comprising plates mounted radially about said cathode, each of said plates being respectively located in a plane which includes the cathode, and an anode electrode also comprising plates spaced in interleaved relation to said grid plates.

6. An electric discharge device comprising a cathode, an anode and a grid, said cathode having a generally rectilinear extension, said anode and grid each comprising a group of substantially flat members mounted radially about the cathode and in overlapping relation with one another.

7. An electric discharge device comprising a cathode, an anode and a grid, said cathode having a generally rectilinear extension, said anode and grid each comprising a group of substantially flat members mounted radially about the cathode, each of the members being located respectively in a plane which includes the cathode.

8. An electric discharge device comprising a cathode, an anode and a grid, said cathode having a generally rectilinear extension, said anode and grid each comprising a group of substantially flat plates mounted radially about the cathode and in overlapping relation with one another, each of the plates of one group being located respectively between plates of the other group and each plate being located respectively in a plane which includes the cathode.

9. An electric discharge device including a cathode, an anode and a grid, the anode and grid comprising substantially flat members radially disposed with respect to the cathode, the grid members being closer to the cathode than the plate members whereby the cathode may be shielded from positive ion bombardment.

10. An electric discharge device including a cathode, an anode and a grid, the anode and grid comprising substantially flat members angularly disposed with respect to one another, the grid members being closer to the

70

75

80

85

90

95

100

105

110

115

120

125

130

cathode than the plate members whereby the cathode may be shielded from positive ion bombardment.

11. An electric discharge device including
5 a cathode, a anode and a grid, the cathode having a mainly linear extension and the anode and grid comprising substantially flat members angularly disposed with respect to one another, the cathode being located sub-
10 stantially at the apex of the angle formed by the anode and grid members and the grid and anode being unequally spaced from the cathode.

12. A thermionic valve comprising an an-
15 ode element and modulating elements mounted on opposite sides of the anode element, and in spaced relation therewith, and an electron emitting element located in the plane of the anode element and equi-distant from
20 the modulating elements.

13. A thermionic valve comprising an elec-
tron emitting element, a series of flat anode
plates, and a series of flat modulating plates,
25 said anode plates and modulating plates being alternately mounted in intersecting planes common to the electron emitting element.

14. A thermionic valve comprising an elec-
tron emitting element, and two substantially
30 flat spaced plates located substantially parallel with the stream of emitted electrons, and formed therebetween a passageway for the electronic emission, said electron emitting
element being located in a plane bisecting said
35 intermediate passageway.

15. An electron discharge device compris-
ing a container having mounted therewithin
an electron emission element, and in the plane
of and edgewise to said element, a cooperat-
40 ing anode element comprising a plurality of plates, and a control element.

16. An electric discharge device compris-
ing a source of positive ions, an electron emit-
ting cathode, an anode adapted to be posi-
45 tively charged and an input electrode adapted to be charged negatively with respect to the anode, said anode and input electrode including members which lie substantially in
planes subtending an acute angle at the
50 cathode whereby the positive ions formed in the region between the anode and input electrode are attracted toward the input electrode and away from the cathode.

In witness whereof, we have hereunto
55 set our hands this 30th day of September, 1924.

IRVING LANGMUIR.
KENNETH H. KINGDON.

CERTIFICATE OF CORRECTION.

5

Patent No. 1,892,244.

December 27, 1932.

IRVING LANGMUIR, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 75, claim 4, for "containers" read "container"; page 4, line 5, claim 11, for "a" second occurrence read "an"; and line 32, claim 14, for "formed" read "forming"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of February, A. D. 1933.

(Seal)

M. J. Moore,
Acting Commissioner of Patents.