May 17, 1927. 1,629,009

H. C. SNOOK

LOW IMPEDANCE ELECTRIC DISCHARGE DEVICE

Filed Aug. 7, 1920 2 Sheets-Sheet 1

Fig. 1

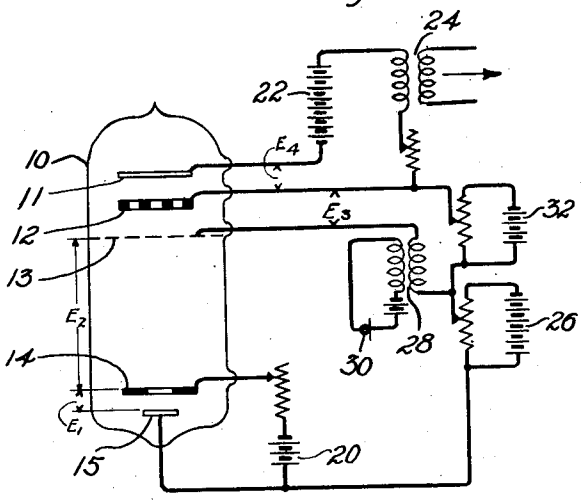


Fig. 2

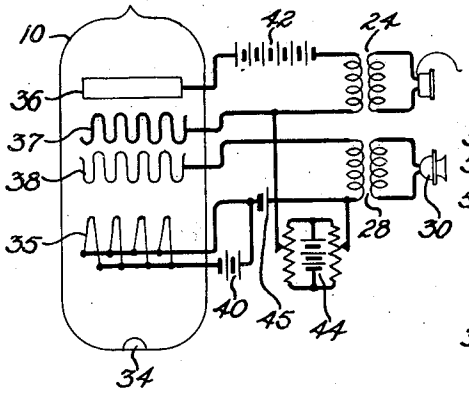


Fig. 3

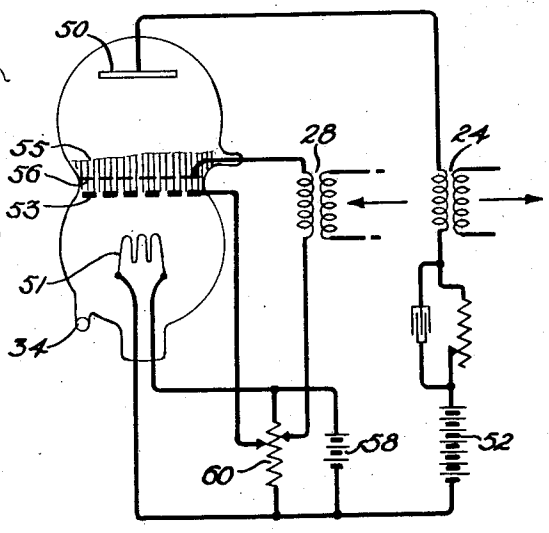


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Fig. 4

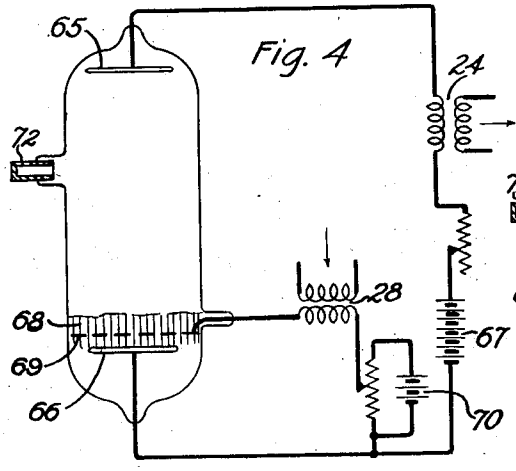



Fig. 5

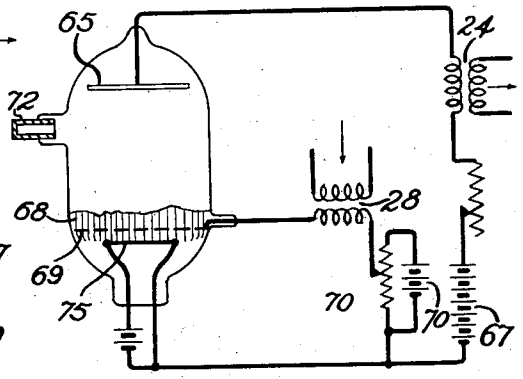



Fig. 6

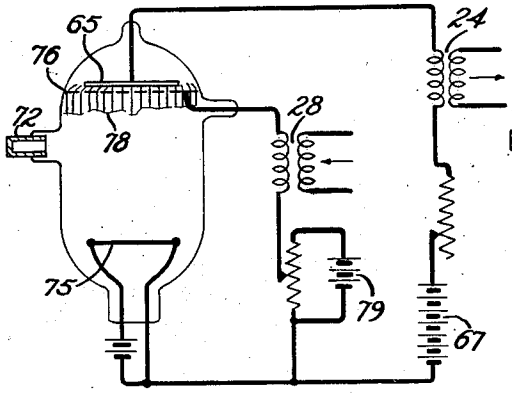
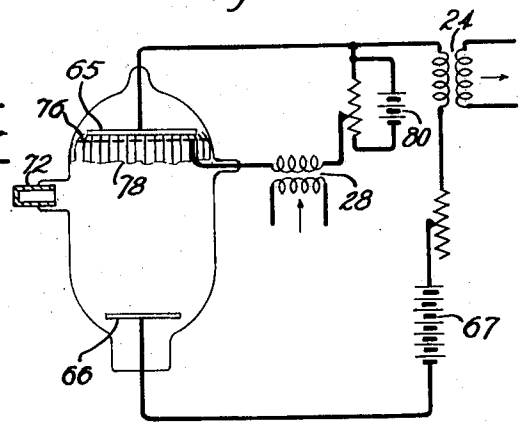



Fig. 7

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Patented May 17, 1927. 1,629,009

# UNITED STATES PATENT OFFICE.

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## LOW-IMPEDANCE ELECTRIC DISCHARGE DEVICE.

Application filed August 7, 1920. Serial No. 401,886.

This invention relates to electric discharge apparatus of a type having relatively low impedance and to a method of operating such apparatus. Discharge devices of this type are adapted to be used as amplifiers of electric impulses, oscillation generators, detectors of high frequency signals, and the like.

Devices making use of this invention are adapted to carry relatively large currents as compared with devices of the so-called pure electron discharge type, for the reason that the discharge or space current is carried both by positive and negative carriers, which are obtained at least in part by the ionization of an attenuated gas or vapor existing between the discharge electrodes.

An object of this invention is to provide a means and a method for controlling the discharge in devices of the above-described type.

A further object of the invention is to provide for the adjustment and operation of discharge devices so that substantially no energy will be consumed in the control or input circuit.

It is known that an ionized gas discharge between electrodes contains bands in which either positive or negative carriers of electricity predominate. In long tubes this characteristic causes the discharge to assume a striated appearance with alternating light and dark spaces. In discharges in which ionization is present to an appreciable extent, it is found that a preponderance of positive carriers is present in the space adjacent the cathode and a preponderance of negative carriers in the space adjacent the anode. In a device of this description there is at any point an electrostatic field or potential which is the resultant of potentials of the various electrodes and of the charges on the particles in the space.

In accordance with this invention a control electrode is placed within the gaseous space for controlling the discharge. In some applications of the invention it is placed in the main discharge, and may be placed in a zone where positive or negative carriers predominate, or of course in a zone where they are present in equal number or in such numbers that their charges neutralize each other in their effects on the electrostatic field. In any case, the potential of the control electrode is preferably normally maintained at a potential equal to the resultant electrostatic field of the space in which it is immersed. It has been found that under these conditions small potential variations applied to the control electrode may modify the discharge so that the variations appear in amplified form in the main discharge circuit, but that no appreciable flow of current in the circuit to which the control electrode is connected will take place. This circuit may be termed the input circuit of the device, and it will be appreciated that it is of considerable advantage thus to maintain the input impedance of the device substantially constant.

In certain embodiments of the invention, the control electrode is placed in an auxiliary discharge. The arrangement is such that charged particles from the auxiliary discharge may enter the path of the main discharge, and produce ionization therein. The main discharge current may, therefore, be varied by variations in the number of charged particles permitted by the control electrode to enter the main discharge space. The auxiliary discharge may comprise only negatively charged particles, only positively charged particles, or in case the rate of discharge is sufficient to produce ionization, a mixture of both in any desired proportions. If both positive and negative ions are present in the vicinity of the control electrode, its normal potential is maintained, as above described, substantially equal to that of the resultant electrostatic field at that point.

The invention further resides in the details of construction and arrangement described hereinafter, and illustrated in the accompanying drawings in which Figure 1 illustrates diagrammatically a circuit employing the invention, in which an auxiliary discharge principally or wholly of positive carriers, is used for controlling the main discharge; Figure 2 is similar to Figure 1, but employs an auxiliary discharge of negative carriers; Figure 3 illustrates the application of the invention to a discharge device of the type shown in Von Lieben, et al., Reissue Patent No. 13,779, dated July 21, 1914. In Figs. 4, 5, 6 and 7 are shown modifications of the invention in which three-electrode discharge devices are employed.

Referring to the drawings by reference numbers, the tube or container 10, shown in Figure 1, contains a suitable gas or va-

por, such as mercury, helium, hydrogen, nitrogen, argon, neon, carbon dioxide, and the like. Within the tube 10 are suitably mounted a cathode 11, a cooperating anode 12, a control electrode 13, a cathode 14, and an anode 15, the two last mentioned serving to produce the auxiliary discharge, energy for which is supplied by battery 20. The potential $E^1$ between electrodes 14 and 15 is sufficient to ionize the gas therebetween. Cathode 14 is centrally apertured and positive carriers are discharged through the aperture by their own momentum and may, if permitted by the control electrode 13, enter the space between the main electrodes 11 and 12, where they may ionize the gas sufficiently to permit a large current therebetween. Electrodes 11 and 12 are connected externally through a source of current 22, which is preferably so adjusted that the voltage $E^4$ is not quite sufficient to produce a discharge between electrodes 11 and 12 until this space has been further ionized by electric carriers from the auxiliary arc between electrodes 14 and 15. The circuit containing electrodes 11 and 12 may be termed the output circuit of the device and is connected through a transformer 24 to a line or other work circuit for utilizing the transmitted currents. Control electrode 13 is connected to the cathode 14 through a source of potential 26 and to the anode 12 through a source of potential 32. In case the velocity of positive carriers passing from electrode 14 to the space between electrodes 11 and 12 is sufficient to produce ionization in the space containing control electrode 13, so that both positive and negative carriers are present, the potentials $E^2$ and $E^3$ are so adjusted that the potential of electrode 13 is equal to the resultant potential produced by the carriers in the vicinity of the electrode and by the field produced by the other electrodes. Under these conditions, no current will flow in the control electrode or input circuit. If only positive carriers are present in this region no current will flow in the input circuit if the potential of electrode 13, with respect to electrode 14, for example, is maintained as great as or greater positively than the resultant potential in the adjacent space. This circuit is connected to transformer 28 through a source of impulses to be repeated, for example, speech current from a transmitter 30.

Figure 2 is similar to Figure 1, but differs in that an auxiliary discharge consisting principally or wholly of negative carriers is employed. The source of negative carriers is illustrated as a thermionic cathode 35 heated by a source of current 40, and the anode 36, corresponding to anode 12 in Figure 1, is placed farthest away from the cathode 35, the output cathode 37 and a control electrode 38 being intermediate. The batteries 42 and 45 are poled oppositely from the corresponding batteries 22 and 26 in Figure 1. Battery 44, corresponding to battery 32 in Figure 1, is shown provided with a double potentiometer. The potential between cathode 35 and cathode 37 may or may not be made sufficient to produce ionization in the intermediate space. If ionization is present, the potential of electrode 38 is adjusted as above described so that neither positive nor negative current will flow in the input circuit. At 34 is shown a drop of mercury or mercury amalgam which may be employed for maintaining vapor in the tube at the desired pressure.

In Figure 3, anode 50 and thermionic cathode 51 are connected through a source of current 52, and an intermediate screen 53 is provided at a constricted portion of the tube. Source 52 is so adjusted that an ionized discharge takes place and due to the presence of the screen 53 a positive space charge is present on the side of the screen toward the anode 50. The boundary of this space in which positive carriers predominate is indicated in the drawing at 55. The control electrode 56 is placed in this space and is adjustably connected to the resistance 60 which is traversed by current from battery 58. The circuit is so adjusted that the potential of electrode 56 is equal to the resultant potential of the space adjacent thereto. Electrodes 53 and 56 are shown as having potentials corresponding to potentials intermediate the ends of cathode 51. It is obvious, however, that the potentiometer 60 may be so arranged as to give either or both of these electrodes a potential more positive than any part of the cathode. With the arrangement of Figure 3 the amplification of small incoming impulses is obtained by controlling a positive space charge in the path of the main discharge between electrodes 50 and 51.

Figures 4, 5, 6 and 7 show further modifications of the idea of controlling a discharge by an electrode immersed in a space charge of positive or negative value. In Figure 4 the anode 65 and cathode 66 are connected through a source of potential 67 sufficient to ionize the gas. Cathode 66 may be coated with barium oxide or strontium oxide, or the like, to increase its activity in emitting electrons when bombarded by the discharge. Control electrode 69 is immersed in the positive space charge 68 adjacent the cathode. A device such as a palladium tube 72 may be provided for controlling the gas pressure in the device. Figure 5 is similar to Figure 4, except that a thermionic cathode 75 is substituted for the cathode 66. In both Figures 4 and 5 the potential of electrode 69, which is derived from source 70, is at such a positive value with respect to the cathode, that substan-

tially no current will normally flow in the input circuit.

Figure 6 differs from Figure 5 in that the control electrode 76 is placed in the negative space charge 78 adjacent the anode 65. Since the negative space charge is less extensive than the positive space charge at the cathode, the electrodes 65 and 76 are placed nearer together. The potential of electrode 76 is made equal to the resultant potential produced by the negative space charge and the positive field, the resultant potential usually being positive with respect to the cathode as indicated in the drawing.

In Figure 7 the input circuit is connected between control electrode 76 and anode 65. A source of potential 80 having its negative pole connected to electrode 76 is required to give this electrode a potential corresponding to that obtained from battery 79 in Figure 6.

While various modifications of arrangements employing the invention have been shown, it is to be understood that the invention is not limited to the exact arrangements shown but is entitled to a range of equivalents within the scope of the appended claim.

What is claimed is:

In combination, an electric discharge device comprising a gas filled container, a plurality of main discharge electrodes and a plurality of auxiliary discharge electrodes therein, a source of current connected between said main discharge electrodes, means for adjusting the potential of the current from said source to a point insufficient to produce ionization between said main electrodes, a second source of current connected between said auxiliary electrodes for producing a discharge therebetween and a flow of positive carriers between said main electrodes to cause ionization therebetween, a control electrode located between said auxiliary electrodes and said main electrodes to control the degree of said ionization, a third source of current connected between said control electrode and one of said main electrodes, a fourth source of current connected between said control electrode and one of said auxiliary electrodes, and means for adjusting current from said third and said fourth sources so that the potential of said control electrode is substantially equal to the resultant of the potentials produced by the carriers in the vicinity of said control electrode and by the field produced by said other electrodes.

In witness whereof, I hereunto subscribe my name this 4th day of August A. D., 1920.

HOMER C. SNOOK.