Feb. 12, 1929. **H. P. DONLE** 1,701,840

ELECTRON DEVICE

Filed Aug. 5, 1922

Fig. 1.

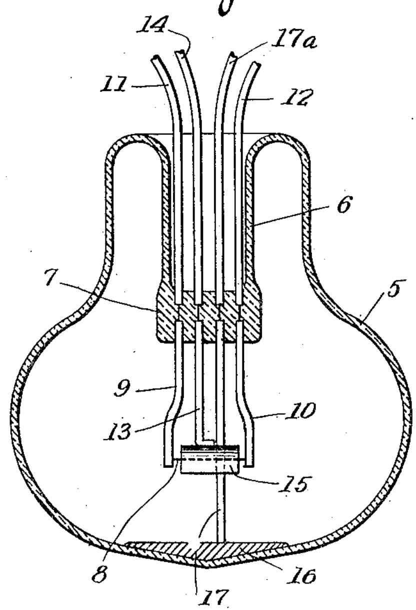


Fig. 2.

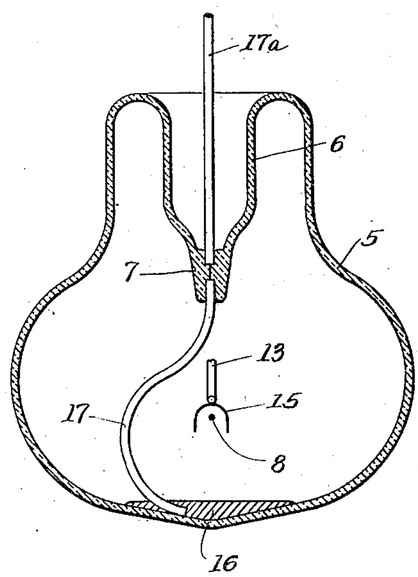
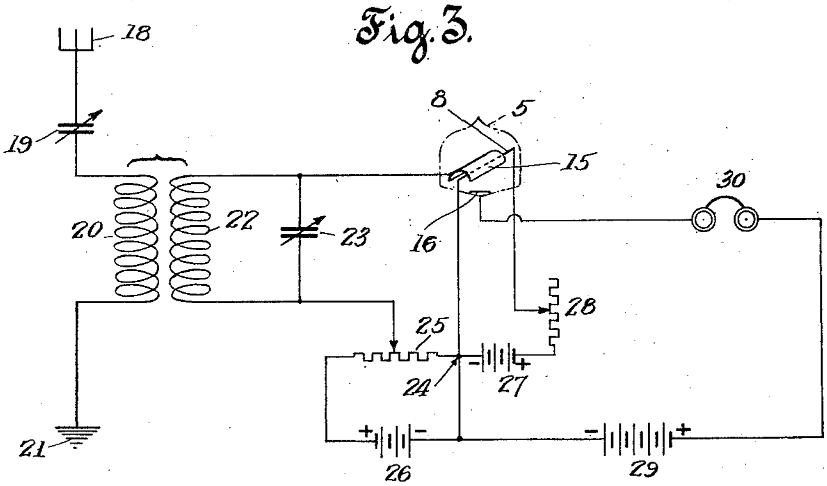


Fig. 3.



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BY

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UNITED STATES PATENT OFFICE.

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ELECTRON DEVICE.

Application filed August 5, 1922. Serial No. 579,828.

My invention relates to electrical signal receiving apparatus, and more particularly to instruments utilized in the reception of intelligence by radio telegraphy or telephony.

The primary object of my invention is to provide a detecting and intensifying system of great delicacy in point of responsiveness to weak signal impulses but of sufficient stability and uniformity of operation to permit even untrained users to secure good results. Further objects are to select or discriminate between radio or other high frequency signals having different frequency characteristics, to produce not merely a loud but a faithful and undistorted signal response to received signal-energy, and to control the action of the entire receiving assembly with a minimum number of adjustments.

I have discovered that by modifying the construction of a three electrode vacuum tube and by utilizing this modified tube with circuit arrangements and adjustments differing from those of the prior art, a substantial and exceedingly useful increase in responsiveness may be secured.

Fig. 1 is a side elevation of one form of vacuum tube which I have found satisfactory,

Fig. 2 is an end elevation of the electrodes of such a tube, and

Fig. 3 is a diagram showing a circuit in which the tube may be effectively used.

My new vacuum tube differs from most evacuated devices heretofore used for somewhat similar purposes in that it contains no interposed or control electrode of the type ordinarily called the grid, that two anodes are used in conjunction with a single incandescent cathode, and that provision is made to supply definitely adjustable amounts of positive ions from the main anode (which, with this in view, may be formed of metallic sodium). I thus produce a vacuum tube detector which shows extraordinary delicacy or sensitiveness to the stimuli of received radio impulses but which, in contrast to prior art tubes depending upon the ionization of included gases at reduced pressures (which phenomenon I do not attempt to utilize), is at all times under complete control. The sensitiveness of my new detector may be as great as, or greater than, that of a prior art detector tube used in a regenerative circuit, yet in my device there are no radio frequency currents fed back from output to input circuits, and indeed the possibility of the flow of such currents in the main anode circuit may be eliminated by the insertion of choke coils without reducing the responsiveness to received signals.

The construction and operation of my device may be more clearly understood by reference to the drawings. In Fig. 1 an evacuated glass envelope 5 provided with a stem 6 and press 7 contains the three electrodes above referred to. The cathode 8 may be of the straight form, for instance of tantalum, tungsten, molybdenum or any of the materials commonly used for incandescent filaments and is supported by the members 9, 10 which are sealed into the press 7 and electrically connected to the terminals 11, 12. The press also carries a third sealed-in supporting member 13 with appropriate electrical terminal 14, to which support is attached the supplementary anode 15, (which may be termed the collector). This electrode is here shown in the form of an inverted and open-ended trough partially surrounding the filamentary cathode 8. Below the cathode and the collector, at 16, and partially filling a depression in the glass envelope 5, is the main anode which may be a layer of metallic sodium. A sealed-in wire 17 and terminal 17^a provide electrical connection with the anode 16. The vessel 5 is preferably exhausted to a high degree by modern pumping means, the gases occluded within or upon the internal glass and metal portions of the tube being driven off by heating, and the sodium being introduced by melting it from a side tube after the tube 5 has been thoroughly cleaned and evacuated. Before using the completed tube as a detector I prefer to heat the sodium sufficiently to vaporize a considerable portion of it, which will condense upon the cooler side-walls of the tube and then, by heating the tube and cooling the anode itself, to recondense the sodium at and immediately adjacent to the anode layer. This process may be repeated several times, and produces a finished tube which will operate uniformly and with great stability.

Fig. 2 shows the inverted trough collector

15, part of its support 13, a section of the filament 8, the anode 16 and wire 17 and the glass container 5, the view being taken at 90° in a horizontal plane from that of Fig. 1 to show the relative arrangement of the three electrodes.

I have made and successfully used tubes such as those shown in Figs. 1 and 2 in which the cathode consisted of about ¾ inches of 0.004 inch diameter molybdenum wire. The collector was of molybdenum, bent from a sheet about ½ inch square with the formed sides approximately parallel. The anode was a layer of pure metallic sodium about ¾ inch in diameter and $\frac{1}{16}$ inch thick, and the distance from anode surface to cathode was about ¼ inch. The peak of the collector was about $\frac{3}{32}$ inch from the cathode. While I do not desire to be limited to the dimensions, materials and arrangements here given, they may serve to explain more fully the construction of one form of my new intensifying detector.

Fig. 3 shows a circuit which I have found satisfactory for operation of my tube so as to take advantage of its increased sensitiveness. In this diagram the antenna 18 is connected through tuning condenser 19 and primary coil 20 to earth 21. Variably coupled to the primary 20 is a secondary coil 22 having its terminals shunted by a tuning condenser 23 so as to form an adjustable resonant circuit. From one armature of this condenser I provide a direct connection to the collector 15 of the intensifying detector tube 5; the other armature of the condenser 23 is connected to the negative terminal of the filament 8, as at the point 24, by way of a potentiometer 25 which is shunted by the collector battery 26 as shown. By adjusting the movable contact of the potentiometer 25 the collector potential with respect to the negative terminal of the filament may be varied from zero to the full positive voltage of battery 26.

Current for heating the filament cathode 8 is supplied form the cathode battery 27 and controlled by the serially connected variable resistance 28. The main anode circuit runs from the common negative point 24 through the anode battery 29, which may have a variable potential, and the telephones 30 to the anode 16. Obviously the telephones may have substituted for them any other translating or coupling device, e. g., a relay, a loudspeaker or the primary of a transformer leading into an amplifying system.

In setting up the circuit of Fig. 3 I use coils and condensers of sizes appropriate to the antenna dimensions and the wave frequencies to be received, so as to bring the resonant adjustments of the two radio frequency circuits well within the ranges of the tuning condensers 19 and 23. For battery 27 I prefer to use three storage cells with a total voltage of about 6, since the filamentary cathode may require approximately one ampere of current to raise it to the requisite temperature for sufficient electron emission. The rheostat 28 may conveniently have a resistance of about four ohms. The collector battery 26 may have a potential of about three volts; for this circuit it is entirely feasable to use 2 or 3 dry cells, since the potentiometer 25 may be of as much as 600 ohms resistance and the battery current is therefore only about 10 milli-amperes. The collector current, under best operating conditions, is between 500 and 1000 microamperes with most of the tubes that I have used. I find that in some tubes the anode circuit battery 29 may conveniently have an electromotive force of from twenty to forty volts; here again dry cells are satisfactory, since the current flow in the anode circuit is normally less than 1000 microamperes and frequently not over half that.

To operate my receiver I establish the circuit as shown in Fig. 3, heat the filament to normal brilliancy and (while listening in the telephones) tune the primary and secondary circuits to approximate resonance with the frequency of the waves I desire to receive. Having thus obtained signals, I proceed to intensify these by adjusting the collector potential and the filament current to their optimum absolute and relative values, as judged by increased strength of the received signals. Occasionally it is found desirable to readjust the radio frequency circuits to a small extent during this process, but I make no attempt to secure or magnify radio frequency currents in the anode circuit by tuning, the provision of by-pass condensers or otherwise. In receiving radio telephone signals on my intensifying detector one is struck by their loudness and clarity and, in contrast to their reception on regenerative or other oscillating anode-circuit devices, the absence of distortion which would be caused by either internal self-oscillations or too great persistance of vibration in the tuned receiving circuits.

Although for general information I have described in detail one form of device and circuit embodying my invention, it is not necessary to use this specific arrangement in order to secure its benefits. Many modifications of structure and connections will at once occur to those skilled in the art; for instance, the device of Fig. 1 may be utilized quite effectively in capacity-coupled or in auto transformer radio circuits such as are common in radio reception.

One need not even use exactly the form of tube shown in Fig. 1; for instance, the anode material may be contained in an insulating or conducting cup instead of lying directly upon the glass wall of the tube. I have secured excellent results from tubes such as that shown in Fig. 1 of my United States Patent #1,291,441 by utilizing the control electrode as a collector and supplying a positive electromotive force therefor as in the present specification. The form shown in Fig. 2 of that patent is of course inoperative as the collector device of my present invention, since its control electrode is insulated from the electron stream and thus, though satisfactory as an interposed or grid controlling element, is incapable of passing the collector current requisite here. In using such an external-anode tube as that of my Patent 1,291,441 the sodium or other material which is apparently necessary to cooperate in the newly discovered phenomenon of intensification is provided by electrolysis of the glass wall through the action of the main anode current.

The trough-like design of collector 15 is convenient but not essential; I have secured good results by using two electrically connected plates, one on either side of the cathode and parallel thereto, placed edgewise with respect to the main anode.

Even the temperature of operation is not especially critical; the intensifying effects may be secured with the tube sufficiently warm to liquefy the sodium anode 16, although the sensitiveness is equally high at lower temperatures. The cooler condition is obviously to be preferred, for with the anode in solid form the tube may be operated in any position.

Sodium is a particularly desirable metal for tubes utilizing this signal intensifying effect, but I do not desire to be limited to main anodes formed of this metal, since I have secured excellent operation from tubes having anodes of potassium, and from alloys of these (e. g., sodium and potassium in equal proportions). From my experience with these intensifying tubes it appears that there should be present a controlled quantity of sodium or equivalent ions and that these ions should be formed at the anode and not by collision between electrons from the cathode and molecules of sodium or similar vapor at points remote from the anode. Both sodium and potassium are metals of the so-called alkali group and have highly electro-positive characteristics. Although it is not intended that the tube shall be operated at a temperature such that the anode metal is wholly vaporized, nevertheless it appears that there is a surface action more or less dependent upon the fact that the metal is readily volatilized. It should be understood, therefore, that the terms alkali metal and highly electro-positive metal, as used in the claims, are intended to cover metals having the aforesaid characteristics.

I prefer to operate the tubes at a relatively low temperature so as to reduce the vapor pressure of the anode material to such a degree that the chance of forming ions by electron collision with vapor molecules in the evacuated space is minimized. By such use of low vapor densities I am able to maintain around the cathode and within the collector a space charge of electrons emitted from the cathode, and to control the density of such space charge by adjustment of (for example) the temperature of the cathode and the potential of the anode.

Although I have shown the telephones or other indicating instrument associated directly with the main anode circuit, I do not wish to be limited to such connection for it is an interesting and novel feature of my receiver that equally intensified signals may be obtained by connecting the telephones serially in the collector circuit. Under these conditions the positive terminal of battery 29 may be connected directly to the main anode 16 and its negative terminal directly to the common point 24; the anode circuit thus acts as an intensifying circuit only, the output function (which is combined with intensifying in the arrangement of Fig. 3) being transferred to the collector circuit. The constantly flowing currents in both the anode and the collector circuits are normally reduced upon the arrival of signals, the amount of such reduction being substantially the same in both circuits and reproducing the signal variations or envelopes.

The phenomena which underlie the operation of my new device are quite obscure and complicated, although its desirable effects are easily obtained and controlled in the manner I have described. Without desiring to be limited by any statement of theory, I may say that the arrangement acts as though the collector circuits possessed an inherent and controllable conduction time lag of adjustable period, which may be due to a certain variability of time required for the production of a certain degree of ionization of the sodium or other anode material and which permits cumulative effects of successive radio frequency signal impulses without destroying the proportionality of audible response.

For convenience in mounting I prefer to carry the four terminals 11, 12, 14 and 17^a to the contacts of a standard four-prong lamp base such as is commonly used with three-electrode vacuum tubes. It is feasible to invert the tube when the anode is run at the preferred relatively low temperature range and hence is solid; to guard against the effects of accidental overheating which might melt the main anode the tube may be operated in the position shown by Figs. 1 and 2 or the lamp base may be mounted below the main anode, (which is in this instance carried by a depression in or cup attached to the top of the stem), the filament and collector supporting wires running downward through the press and stem but the anode, cathode and collector being maintained in substantially the same relative positions shown in the drawings. Other variations of structure and adaptations of the principles and novel features of the invention herein disclosed will occur to those familiar with the use of vacuum tubes in high frequency signaling.

I claim:

1. A vacuum tube comprising an envelope having a reentrant portion, a press member joined to the apex of said portion, two electrodes only mounted in said press member, a third electrode of an alkali metal mounted within said envelope and in spaced relation to said electrodes, and leads for said two electrodes and said third electrode supported in said press member.

2. A vacuum tube comprising an envelope having a reentrant portion, a press member joined to the apex of said portion, a two terminal cathode carried by said press, an anode of an alkali metal in spaced relation to said press, a curved electrode mounted on the side of the cathode which is more remote from the anode, and leads for said cathode, anode and electrode carried by said press member.

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