Nov. 3, 1942. J. P. FERGUSON 2,300,882

VACUUM TUBE

Filed Oct. 31, 1941

*Fig. 1.*

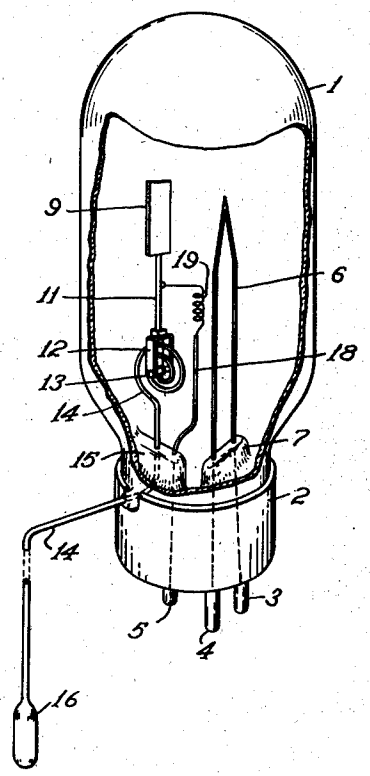



*Fig. 3.*

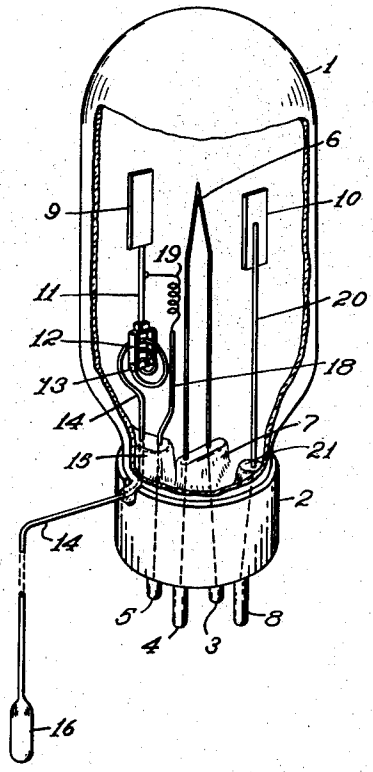



*Fig. 2.*

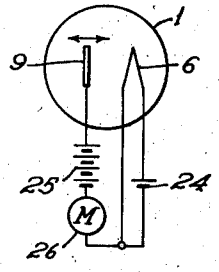
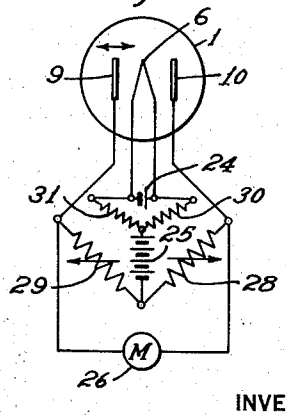



*Fig. 4.*




WITNESSES:

Edward Michaels

T. E. Barthold

INVENTOR

John P. Ferguson.

BY

Hyman Diamond.

ATTORNEY

Patented Nov. 3, 1942 2,300,882

# UNITED STATES PATENT OFFICE

2,300,882

## VACUUM TUBE

John P. Ferguson, Freeport, Tex., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application October 31, 1941, Serial No. 417,349

2 Claims. (Cl. 250—27.5)

This invention relates to electric discharge devices, and more particularly to vacuum tube devices which are adapted to be controlled to translate physical movements and changes of force or pressure into measurable changes of an electric quantity.

In the electronic art, various means have heretofore been used for controlling an electron stream passing between a cathode and an anode electrode. The usual form is to control a charged electrode interposed between the main electrodes providing thereby an additional electrostatic field for accelerating or decelerating the electrons. In certain devices of the prior art, attempts have been made also to initiate control by physical displacement of certain of the electrodes in response to controlling forces. A physical movement of the electrodes in a vacuum tube is difficult to accomplish with satisfactory flexibility, particularly where the movement is to be initiated mechanically or electrically upon conditions existing outside of the tube proper.

A particular feature of this invention is that certain electrodes of a vacuum tube may be displaced with respect to other stationary electrodes with extreme flexibility of movement upon predetermined conditions existing remote from the vacuum tube.

Another feature of the invention is that the mechanical coupling necessary for translating the influence of conditions into mechanical movement of the electrode may be sealed within the exhausted envelope without disturbing the freedom of the control action between the tube and the remote means of control.

An advantage of the invention is that the control action as to the extent of displacement of one electrode with respect to the other may be initiated from any required distance from the tube upon changes of temperature or pressure.

Another advantage of the invention is that small variations of pressure or temperature may be made to cause large displacements of the displaceable electrode in the tube whereby the resultant change of space current may be conveniently indicated by simple conventional electrical indicating devices.

Other features and advantages will be apparent from the following description of the invention, pointed out in particularity by the appended claims and taken in connection with the accompanying drawing, in which:

Figure 1 shows in perspective the internal construction of a simple two-element tube in accordance with this invention,

Fig. 2 shows schematically a simple electrical circuit which may be used in connection with the tube of Fig. 1,

Fig. 3 illustrates in perspective the internal construction of a modification of the invention comprising a three-element tube, and

Fig. 4 shows an electrical circuit in connection therewith.

Referring to the drawing, in Fig. 1 the vacuum tube comprises a glass envelope 1, a base 2 terminating in prongs 3, 4 and 5 which connect to the electrodes sealed therein. The cathode 6 shown here is of the filamentary type although other types, such as an indirectly heated cathode, may as well be used. The terminals of the cathode 6 are connected to prongs 3 and 4 and the cathode is supported by means of the seal 7. The anode 9 in the form of a plate is spaced at a certain distance from the cathode 6 and is supported by means of a stem 11 terminating in a forked member 12, the ends of which are connected by means of a pin 13. Bent around the latter is the end of the spiral tube 14 rigidly affixed to the stem 15 through which it protrudes on the side of the base 2. The tube 14 may have any desired length and terminates in a bulb or container 16. The electrical conducting wire 18 to the anode 9 is supported by the stem 15 and is connected to the prong 5 at one end, whereas at the other end it is joined through a flexible connection 19 to the stem 11 of the anode 9.

The spiral tube 14 is a device which has heretofore been used extensively in mechanical gauges for indicating pressure or temperature. It is known as a Bourdon tube consisting of a blind curved tube, oval in section and filled with a suitable fluid. A pressure in the fluid causes anticlastic bending of the tube which results in an expansion of the spiral portion. This expansion produces an angular movement of considerable torque at the end of the spiral tube which can be conveniently utilized as a mechanical force to actuate an indicating instrument or other devices.

It is clearly seen that in accordance with the present invention the force of the Bourdon tube is utilized to produce movement of the anode electrode 9 of the vacuum tube in order to displace this electrode from the cathode 6. The container 16 houses the fluid medium in which the change of pressure is transmitted to the spiral end of the tube. The tube 14 may have any desired length which permits the placement of the container 16 at a remote point from the vacuum tube 1.

The operation of the vacuum tube herein referred to will be described in greater detail after considering the modification shown in Fig. 3. The same reference characters will be employed to indicate identical elements shown in Fig. 1. The tube consists of the glass envelope 1, the base 2 and the prongs 3, 4 and 5 and an additional prong 8. A filamentary cathode 6 is shown terminating in prongs 3 and 4. The con-

struction of the anode 9 is exactly the same as in Fig. 1 having a stem 11, a forked member 12, a pin 13 at the end thereof to which is affixed the spiral end of the Bourdon tube 14. The latter supported by the stem 15 protrudes also on the side of the tube. The electrical contact to the anode 9 is effected by means of a flexible connection 19. The elements so far recited are exactly the same as in the tube shown in Fig. 1. In addition to these there is a second anode electrode 10 within the tube rigidly supported by means of the stem 20 held by the seal 21. The terminal for the anode 10 is brought out in the prong 8.

The constructional features described are intended to show one embodiment of a vacuum tube in which one of the electrodes is supported by means of a sealed-in Bourdon tube movement for physical displacement. It is to be understood that the support of the moving anode or that of the other electrodes may be accomplished in a great number of ways in accordance with modern production methods. Such modifications are not to be considered as being outside of the scope of this invention which resides in the fundamental concept of actuating an electrode of a vacuum tube directly by means of a sealed-in movement of the Bourdon gauge type. The particular physical arrangement and support of the tube elements shown here are merely by way of example to illustrate the operation of the invention.

It is also to be noted that various modifications will be apparent immediately to those skilled in the art. For example, several other electrodes may be included and more than one of those may be supported in the manner shown here to be displaced upon expansion of the coil structure. In this case, one may be arranged to expand in one direction and the other in the other direction thereby obtaining a differential indication with respect to the extent of movement of the respective electrodes.

Referring to the circuit shown in Figs. 2 and 4, the tube elements in the schematic diagram are shown in the conventional manner with the exception that an arrow above the element subjected to physical displacement, indicates that the element is capable of movement. The simple diode in Fig. 2 includes the filamentary cathode 6 and the anode 9. The cathode circuit is completed through the battery 24 and the circuit between the anode 9 and the cathode 6 includes the anode potential source represented by the battery 25 and a current indicating device 26.

In Fig. 4, a dual anode tube of the type shown in Fig. 3 is schematically represented in which, as the arrow indicates, the anode 9 is the movable one, whereas the anode 10 is of the conventional fixed type. The energizing current for the filamentary cathode 6 is supplied by the battery 24 and a divided circuit is utilized for energizing both of the anodes 9 and 10. This is accomplished by connecting a bridge circuit in the form of resistors 28 and 29 in series between anodes 9 and 10 and resistors 30 and 31 in series between terminals of the cathode 6, the junction point of both resistors being connected to opposite terminals of the anode supply source represented by the battery 25. A potential indicating device 26 is connected between the terminals of resistors 28 and 29 to which the anodes 10 and 9 are connected, respectively.

Considering the operation of the circuits, in Fig. 2 the meter 26 being in series with the anode supply source will indicate the space current between the cathode 6 and the anode 9. In an electron discharge device in which no gas ionization takes place, the discharge current passing through a given space when the cathode is at a sufficiently high temperature will vary directly as the 1½ power of the impressed voltage. This relation is expressed by the space charge equation

$$I = aV^{1\frac{1}{2}}/d^2$$

where

I is the current through the tube measured in amperes per square centimeter of cathode surface,

$a$ is a constant depending on the area and configuration of the electrodes,

V is the voltage impressed between the electrodes, and

$d$ is the distance in centimeters between electrodes.

From this equation it will be seen that the current through the tube varies directly as the area of the electrodes and the impressed voltage, and inversely as the square of the distance between the electrodes. Now if the electrodes are stationary, the current will remain unchanged as long as all the other constants remain the same. A movement of one of the electrodes, that is, the anode 9, for example, will cause a variation of the current inversely with the square of the distance between the anode 9 and the cathode 6. As stated before, the movement is effected by the particular support shown in Figs. 1 and 3, and the resultant current variations will indicate the extent of pressure changes which cause the anti-clastic expansion of the Bourdon tube. In an experimental structure a Bourdon tube of the following dimensions was used:

The steel tubing from which the spiral was formed was 16 inches long and ⅛ inch in diameter. The liquid container was approximately 1½ inches long and ⅜ inch in diameter. The length of the tubing between container and the spiral portion was about 3 inches. The angular displacement of the anode obtained by the Bourdon tube of the above dimensions was approximately 1 degree for 1° C. change in temperature.

The vacuum tube used had the following average dimensions: the anode area was 6 square centimeters and was placed one-half centimeter distance from the cathode. With 100 volts potential difference between cathode and anode supplied by the battery, approximately 56 milliamperes static plate anode current was obtained. The change in current for various distances obtained by the movement of the anode in the direction away from the cathode was as follows:

| Distance between anode and cathode in centimeters | Current in milliamperes |
|---|---|
| .5 | 56 |
| .6 | 39 |
| .7 | 28 |
| .8 | 21.5 |
| .9 | 17 |
| 1 | 14 |

From this it is seen that the tube is very sensitive to small temperature changes to which the fluid container is exposed.

In the circuit shown in Fig. 2, battery voltages applied to the filament or the anode must be held constant in order to restrict any current change to that caused by the movement of the anode. To obviate the necessity of maintaining poten-

tials at a critical value, the circuit shown in Fig. 4 utilizing the dual anode type of tube may be used to advantage. A bridge circuit is provided wherein the internal resistance between the cathode and each anode forms two arms of the bridge and the other two arms are made up by the resistances **28** and **29**. These resistances may be varied for balancing the bridge circuit. To assure further balance, the filament terminal of the source represented by the battery **25** is connected effectively to the midpoint of the filament by means of two resistors **30** and **31** of equal value connected to the terminals of the filament. Assuming no motion of the anode **9**, the voltage across one diagonal of the bridge indicated by the meter **26** is balanced to zero by adjustments of the resistive arms and under this condition any change in the voltage of either the filament supply battery **24** or the anode supply battery **25** will result in equal changes as to current flow between the anodes and the cathode. In this manner no difference of potential will appear across the diagonal of the balanced bridge. When physical displacement of one anode takes place, the balance is disturbed and the voltage appearing across the bridge will be of a magnitude proportionate to the disbalance that is in proportion to the movement of the anode.

As stated before, the physical displacement of the anode is effected by a fluid medium whereby the actuating device for the displacement may be rigidly held within the exhausted tube envelope yet it can be extended to considerable distances from the tube. It is particularly intended for measuring temperatures at remote points. It can also be used for indicating pressures or various physical phenomenon which will react on the fluid within the container.

I claim as my invention:

1. A thermionic device comprising a vacuum tube structure having a cathode and an anode electrode, means supporting said anode electrode displaceably with respect to said cathode comprising a pressure responsive element in the form of a coiled fluid filled Bourdon tube, one end of which supports said anode and the other terminating outside of said tube in a container for said fluid.

2. A thermionic device in accordance with claim 1 in which a second anode electrode is rigidly supported within said tube structure.

JOHN P. FERGUSON.