June 23, 1942. A. VANG 2,287,541

DISCHARGE TUBE

Filed Nov. 7, 1940

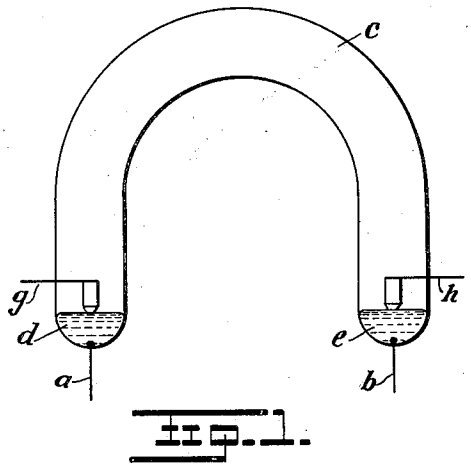


FIG. 1.

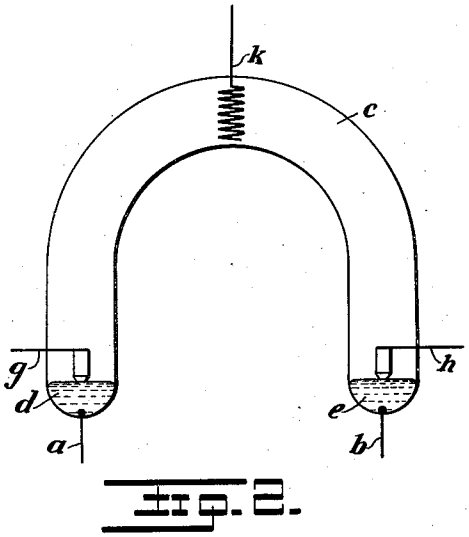


FIG. 2.

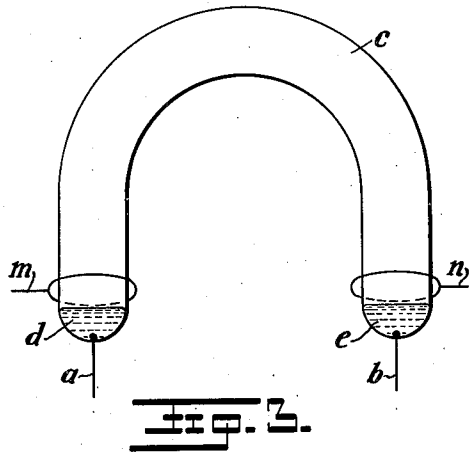


FIG. 3.

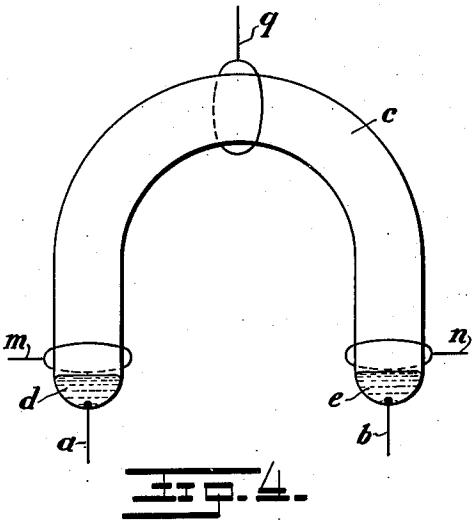


FIG. 4.

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DISCHARGE TUBE

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3 Claims. (Cl. 250—27.5)

This invention relates to new and useful improvements in discharge tubes, and more particularly to electronic switching devices, and it is especially adapted for use in electric circuits carrying a large amount of power, particularly when the electrical current is alternating, and more especially when it is alternating at a high frequency.

One object of the invention is to provide an electronic switch capable of carrying relatively great power, and yet having relatively compact dimensions.

An ancillary object of the invention is to provide an electronic switch which will carry great power at relatively low cost.

Another object of the invention is to provide a switching means for high frequency circuits, which will operate with a minimum of power loss therein.

A further object of the invention is to provide a switching device which will have a minimum rate of deterioration, relative to the amount of power carried.

A still further object of the invention is to provide a switching means for high frequency circuits, which will be capable of precise, dependable and flexible control.

Other objects of the invention will become apparent as the specification proceeds.

In the drawing in which similar letters indicate corresponding parts:

Figure 1 is a schematic representation of one embodiment of the invention, employing igniter electrodes of the conventional type.

Figure 2 is a schematic representation of a similar embodiment of the invention, having an internal grid for better control.

Figure 3 is a schematic representation of another embodiment of the invention, employing external electrodes for ignition.

Figure 4 is a schematic representation of a similar embodiment of the invention, having an external grid for better control.

Referring more particularly to the drawing, the lines *a* and *b* represent in all the figures leads from a circuit to be closed by the switching device; the leads being shown connected to the tube. Extending between the leads *a* and *b*, is a closed, partially evacuated chamber *c*, provided with insulating walls, and which may be bent, as shown, to accommodate liquid electrodes. The electrodes, *d* and *e*, are preferably mercury pools, although in some embodiments of the invention they may be of other material. They are electrically connected with the leads *a* and *b*, respectively.

Within the chamber *c* and extending from electrode *d* to electrode *e*, is a rarified gas capable of conducting a current of electricity when ionized, but also capable of strongly resisting the passage of current when deionized. The gas may be derived from the electrode itself, in the case of a mercury electrode, or it may be separately introduced, according to conventional processes now well known in the art.

Referring now to Figure 1, ionization may be started in the gas at will by energizing the igniter electrodes *g* and *h*, which are also well known and need be shown only diagrammatically. If, for example, *a* is negative with respect to *b*, and the gas in the chamber *c* is non-conducting, because it is not ionized, there will be no passage of current between the circuit leads *a* and *b* until the igniter or starting electrode *g* is made positive with respect to *a*, resulting in a current through the igniter electrode which produces heat at the surface of the mercury, initiating ionization in the gas in the tube, whereupon the whole path between *d* and *e* becomes conducting, and a current is permitted to flow in the circuit of which *a* and *b* are leads.

The ionization of the gas is self-supporting so long as the leads *a* and *b* supply sufficient potential difference to pass a current through the tube.

This method of initiating ionization is common practice in tubes intended for rectification, wherein one electrode (the cathode) is a mercury pool, as described, and the other electrode (the anode) is a metal or carbon plate, which resists the passage of current in the opposite direction because the surface of the metal or carbon will not produce ions as readily as the mercury surface. Such tubes may be used as a switching device in alternating current circuits by connecting two of them in opposed parallel relation, so that there will always be a mercury electrode available to initiate ionization, no matter which way the potential may be directed.

My tube, however, is designed primarily for alternating current, and because of its symmetry, which provides a plurality of mercury pools, it is always ready to initiate ionization at either electrode. Thus, for alternating current use it eliminates the necessity of two separate envelopes, and also eliminates the metal or carbon electrodes (anodes), which might cause trouble by disintegrating. Furthermore, the mercury electrodes are capable of carrying a much

greater current than the same area of metal or carbon electrode could carry without permanent damage, and hence one of my tubes can safely operate under a heavier alternating current load than two of the conventional tubes in opposed parallel connection; and from the standpoint of both anode and cathode capacity, my tube has a far greater advantage over thermionic tubes, as the electron emission from any reasonably sized heated filament is very limited.

It is, of course, understood that embodiments of my invention, which may be designed for very great current density, are to be provided with conventional cooling means to prevent overheating of the mercury, and to speed the de-ionization of the tube after the current has stopped.

Figure 2 shows how the state of de-ionization may be assisted and assured between periods of conductivity. Thus a control grid or electrode *k* is placed in the tube in the path of the discharge between the electrodes *d* and *e*. This grid is connected with external timing circuits in such a manner that it will become negative with respect to both of the electrodes *d* and *e* at the end of a conducting cycle, just as the potential between *d* and *e* is approaching zero. It will thus serve to clean up positive ions and to oppose further emission from the recently emitting mercury allowing the surface of the latter to cool and normalize. The grid can then be maintained at a potential always negative with respect to *d* or *e* to insure that there will be no emission from the latter until it is desired to make the tube conducting again, whereupon the negative potential of the grid may be withdrawn and the appropriate igniter electrode activated to initiate ionization in the gas. The timing circuits to accomplish this must of necessity be adapted to the particular service for which the tube may be designed, and will, of course, vary with different installations. They can, however, be readily devised by anyone skilled in the art.

In high frequency circuits the value of my invention is particularly evident, for conventional tubes are liable to "flash back" or conduct in the wrong direction if reverse potential appears before the gas is completely de-ionized. The "flash back" causes the anode to disintegrate, and may damage the tube irreparably. Since the de-ionization time of conventional tubes is about 1000 micro-seconds, they are limited to a frequency of about 1000 cycles per second for efficient operation. My tube, however, is not subject to damage by high frequency currents, because either electrode can serve as cathode. Furthermore, the fact that the gas is not de-ionized before reverse potential appears is made use of to increase the efficiency of conduction at high frequency, as it eliminates the necessity for separately ionizing the cathodes before each pulse. This characteristic makes my tube ideally suited to such operations as for example, the discharging of a condenser in a high-frequency circuit, where it is desired to have the tube remain conducting for the duration of the discharge, after being once started.

Figures 3 and 4 show how external control or starting electrodes can be substituted for the aforementioned internally disposed control or starting electrodes. The loops *m* and *n* replace the conventional type igniter electrodes *g* and *h*. To initiate ionization of gas within the chamber *c* it is only necessary to send a sharp pulse of potential into the loop *m* or *n* above the prospective cathode, similar to the pulse which may be obtained from a conventional make-and-break induction coil.

The resulting sharp pulsations of the electrostatic field within the chamber *c* result in sufficient ionization of the gas to initiate conduction through the whole tube.

The grid *k* of Figure 2 can also be replaced by an external control grid or electrode *q*, shown in Figure 4, provided compensating changes are made in the grid-control circuit to supply *q* with an appropriately more negative operating potential.

It is obvious that many changes may be made in the form, construction and arrangement of the several parts, as shown, within the scope of the appended claims, without departing from the spirit of the invention, and I do not, therefore, wish to limit myself to the exact construction and arrangement shown and described herein.

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

1. A discharge tube of the character described, comprising in combination, an envelope of insulating material formed into the shape of an inverted U; a mercury electrode in each end of said inverted U-shaped envelope; means whereby said mercury electrodes may be connected to an outside circuit; an ignition electrode located outside said envelope near each of said mercury electrodes, and a control grid located outside said envelope half way between said mercury electrodes.

2. A discharge tube of the character described, comprising in combination, an envelope of insulating material formed into the shape of an inverted U; a mercury electrode in each end of said inverted U-shaped envelope; means whereby said mercury electrodes may be connected to an outside circuit; a rarified gas filling the envelope between the said mercury electrodes; an ignition electrode located outside said envelope near each of said mercury electrodes and a control grid located outside said envelope, half way between said mercury electrodes.

3. A discharge tube of the character described, comprising in combination, an envelope of insulating material, a plurality of spaced mercury electrodes in said envelope, said electrodes being adapted to be electrically connected in an external circuit, and a starting electrode disposed outside said envelope and adjacent each of said mercury electrodes.

4. A discharge tube of the character described, comprising in combination, an envelope of insulating material formed in substantially inverted U shape, a mercury electrode in each end of siad inverted U-shaped envelope, said electrodes being adapted to be electrically connected in an external circuit, and a starting electrode disposed outside said envelope and adjacent each of said mercury electrodes.

5. A discharge tube of the character described, comprising in combination, an envelope of insulating material, a plurality of spaced mercury electrodes in said envelope, said electrodes being adapted to be electrically connected in an external circuit, a starting electrode disposed outside said envelope and adjacent each of said mercury electrodes, and a control electrode disposed externally of said envelope and intermediate said mercury electrodes.

6. A discharge tube of the character described, comprising in combination, an envelope of insulating material formed in substantially inverted U shape, a mercury electrode in each end of

said inverted U-shaped envelope, said electrodes being adapted to be electrically connected in an external circuit, a starting electrode disposed outside said envelope and adjacent each of said mercury electrodes, and a control electrode disposed externally of said envelope and intermediate said mercury electrodes.

7. A discharge tube of the character described, comprising in combination, an envelope of insulating material, a plurality of spaced mercury electrodes in said envelope, said electrodes being adapted to be electrically connected in an external circuit, a starting electrode disposed outside said envelope and adjacent each of said mercury electrodes, and a control electrode disposed intermediate said mercury electrodes.

8. A discharge tube of the character described, comprising in combination, an envelope of insulating material formed in substantially inverted U shape, a mercury electrode in each end of said inverted U-shaped envelope, said electrodes being adapted to be electrically connected in an external circuit, a starting electrode disposed outside said envelope and adjacent each of said mercury electrodes, and a control electrode disposed intermediate said mercury electrodes.

ALFRED VANG.