Oct. 15, 1929. J. SLEPIAN 1,731,687

MERCURY ARC TUBE WITH GRID CONTROL

Filed Oct. 15, 1923

Fig.6.

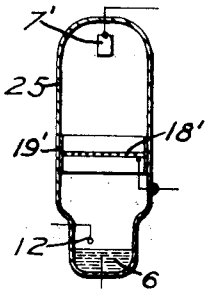


Fig.1.

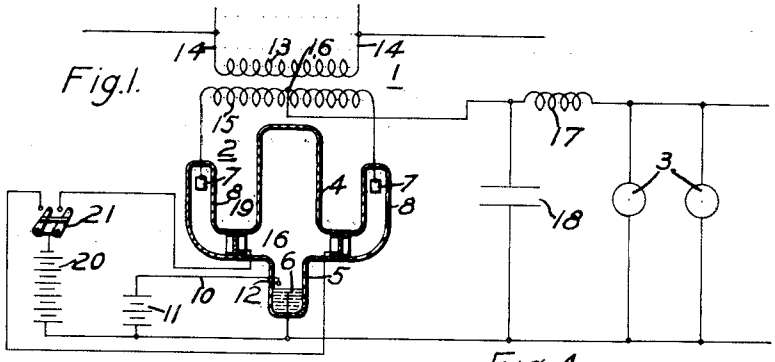


Fig 3

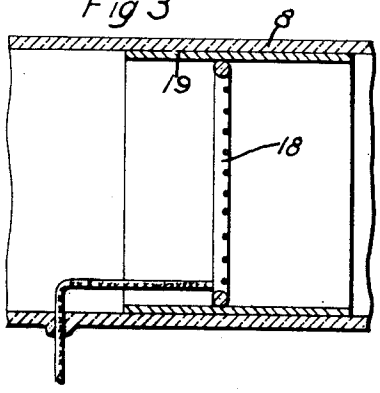


Fig. 4

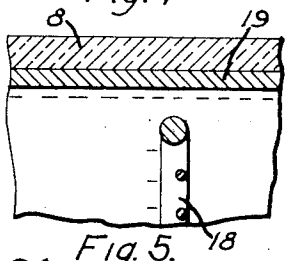


Fig. 5.

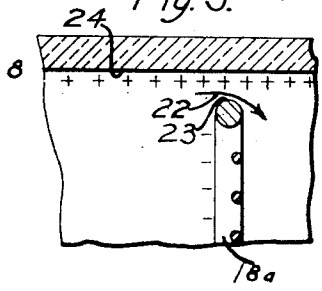


Fig. 2.

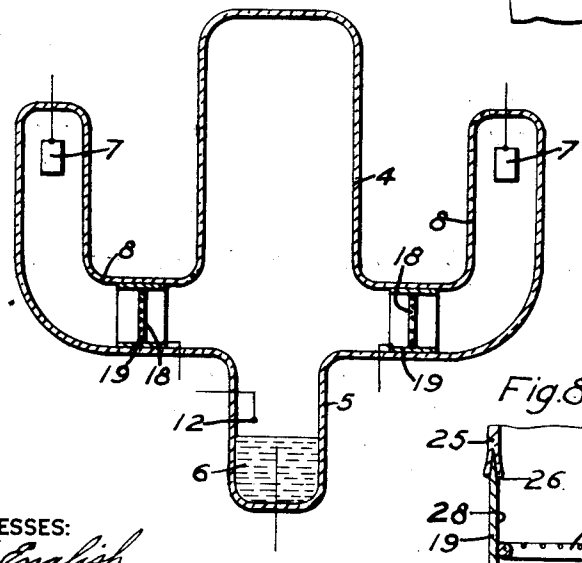


Fig.7

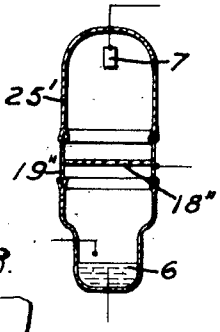
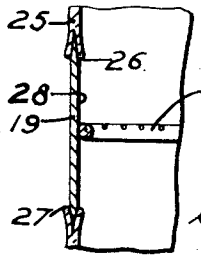


Fig.8.



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UNITED STATES PATENT OFFICE

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MERCURY-ARC TUBE WITH GRID CONTROL

Application filed October 15, 1923. Serial No. 668,555.

My invention relates to mercury arc devices and it has special reference to mercury arc devices utilizing a grid for controlling the current flowing therethrough.

In the practical application of grids for the control of currents flowing in mercury arc devices between a cathode, which is excited to emit a supply of electrons, and an anode, it has been found that an excessively large voltage was necessary to influence materially the flow of current. Very often, the power required for controlling purposes is of the same order as the power of the main working circuit. Accordingly, only slight practical use was made of grid control for mercury arc devices, in spite of the otherwise highly desirable operative characteristics of such devices, such as their capacity to handle large power.

The principal object of my invention is to provide an improved grid-controlled mercury arc tube wherein the action of the grid is positive and dependable, and the power required for the control of the current flow is a minimum.

I have found that the apparent inoperativeness of the grid heretofore employed in such devices and the dis-proportionately small effect of the grid on the current flow may be radically improved by a small but, in itself, fundamental change in the construction of the tube. To this end, I provide, in a mercury arc device of the above character, and along the path of the current between the mercury cathode and the anode, a passageway having, in effect, walls of conducting material. A grid, which may have any of the familiar forms known in the construction of electron tubes, spans the conducting walls of the passageway. The grid and the conducting passageway are conductively connected and are preferably maintained at the same potential in accordance with the desired control of the current through the tube.

Essentially, my invention aims to eliminate a zone which is usually found between the grid and the walls of the vessel which is not subjected to the controlling influence of the grid and which thus permits conducting particles such as electrons to slip past the grid without coming into the region of the positive controlling action of the same.

With the foregoing and other objects in view, my invention consists in the constructions and details of arrangement described and claimed hereinafter and illustrated in the accompanying drawing, wherein

Figure 1 is a diagrammatic view of a mercury arc tube employed for the rectification of an alternating current and for the supply of the same to a direct-current load;

Fig. 2 is an enlarged sectional view of the rectifier shown in Fig. 1;

Fig. 3 is a sectional view of a portion of the rectifier shown in Figs. 1 and 2, illustrating the construction of the portions of the tube adjacent the grid;

Fig. 4 is an enlarged sectional view of a portion of the tube adjacent to the grid, explaining the operation of the improved grid construction;

Fig. 5 is an enlarged sectional view of a portion of a tube with the grid arranged in accordance with the prior-art practice without the employment of my improved construction and illustrating the harmful action which I have succeeded in overcoming;

Fig. 6 is a diagrammatic view of a single-anode rectifier equipped with a grid according to my invention;

Fig. 7 is a diagrammatic sectional view of a modified tube which embodies the broad principles of my invention; and

Fig. 8 is a sectional detail view of a portion of the tube shown in Fig 7.

In the system of Fig. 1, a transformer 1 supplies current through a double-wave rectifier 2 to a direct-current load 3. The rectifier 2, which may be also used as a switch for cutting off the power of the supply from the load, is shown in an enlarged view in Fig. 2 and comprises a substantially tubular glass envelope or vessel 4 having a lower portion 5 arranged as a container for mercury 6, serving as a cathode, and two anodes 7 which are mounted in two side arms 8 respectively of the envelope. An exciting circuit 10 comprises a source of current 11 connected between the cathode 6 and an auxiliary electrode 12 mounted within the vessel 4 adjacent to

the surface of the mercury 6 and serves to maintain an arc upon the surface of the mercury electrode 6 for the emission of electrons during the operation of the rectifier.

The supply transformer 1 has a primary winding 13 which is connected to an alternating current supply line 14 and a secondary winding 15 which is connected between the two anodes 7 of the rectifier. The direct-current load 3 is connected between the middle point 16 of the secondary transformer winding 15 and the cathode 6 of the rectifier in a familiar manner. The circuit leading to the load 3 may contain a serially connected inductance device 17, and a shunt connected condenser 18 for smoothing out the fluctuations of the current caused by the pulsations of the supply.

I provide, furthermore, an arrangement for controlling the flow of current through the mercury arc by means of which I may stop the supply of the direct current to the load 3. To this end, as shown in detail in Fig. 3, a grid 18 is spanned between the walls of the tubular portions 8 of the vessel leading to the anode 7, the portions of the walls adjacent the grid 18 being covered with a conducting layer or deposit 19, of iron for instance, which is in conductive connection with the grid 18.

The conductive deposit or coating 19, which constitutes a conducting cylinder, and the grid 18 mounted therewithin are so arranged that all the current-conducting particles moving between the cathode 6 and the anodes 7 pass either through the openings of the grids or between the metallic walls 19 of the cylinder and the border portion of the grid. The advantages and the effect of the above-described grid construction will be explained hereinafter.

A control source of electromotive force 20 may be connected, by means of a switch 21, between the cathode 6 and the individual grids 18 respectively for applying a negative charge to the grids and stopping the flow of current between the cathode 6 and the anodes 7.

I will now explain the deficiencies of the grid construction utilized heretofore and the advantages secured by my construction. The high conductivity of mercury arc devices employing an arc playing on the surface of the mercury electrode is based on the fact that the negative electrons which are emitted from the arc upon the mercury surface move, under the influence of the electrostatic field induced by the potential applied to the main electrodes in the direction from the cathode to the anode, and in their travel they collide with the molecules of mercury vapor which fill the vessel, splitting the same into positive ions and negative electrons. The positive ions and the electrons thus obtained start, in turn, to travel along the path between the cathode and the anode, new collisions take place, more carriers of electricity are obtained and the abundance of carriers of electricity so obtained produces the high conductivity of such tubes, but constitutes also, on the other hand, the main source for the difficulties in the application of a successful grid control to such devices.

It has been found that a negatively-charged grid of ordinary construction, if placed between the cathode and the anode of such a device, has almost no effect on the flow of current therein, if the current flow through the tube was initiated before the application of the negative potential to the grid. This is so, probably, by reason of the fact that the negative charge of the grid is automatically neutralized and taken care of, by the abundant supply of positive ions in the tube.

If the current is, however, made to go out by some means for a short time interval, a negative charge on the grid may prevent the current from again starting to flow. For instance, a negative charge applied to a grid will prevent the current from starting to flow after the interval of no current flow during the reversed half cycle of alternating current.

This action of the grid may be explained as follows.

A negative charge existing upon a grid prior to the initiation of a current flow repels the negative electrons emitted from the cathode, preventing their passage past the grid; furthermore, if the potential upon the grid be sufficiently high, the velocity of the electrons will not reach a value sufficient to produce large numbers of positive ions by collision with the molecules of vapor in the space between the cathode and the grid. Such positive ions as are formed will be attracted by the negative charge upon the grid and neutralized therein. It is thus possible to prevent the initiation of current flow in a mercury rectifier tube by the application of a sufficiently high negative potential to a grid, although the cathode is maintained in an electron-emitting state and a proper potential, which would ordinarily cause a flow of current, is applied between the cathode and the anode.

In spite of the above, theoretically feasible and apparently true explanation of the operation of a grid, small success has been obtained in the use of grids for the control of mercury arc devices. I explain these difficulties in the practical operation of prior grid-controlled mercury arc devices as follows: During the period of current-conduction, the heavy positive ions filling the entire space of the vessel diffuse partially towards the walls thereof and accumulate also on the insulating walls in the neighborhood of the grid. With an ordinary grid extending across the path of the electrons there will exist a space, be it even very small, between the grid and the adjacent insulating wall of the vessel in which the effect of the negative charge upon the grid will

be entirely neutralized by the positive charge on the adjacent walls, thus affording to the electrons a passageway through which they may slip past the grid into the part of the vessel between the grid and the anode.

The phenomenon of current conduction past grids of ordinary construction is illustrated in Fig. 5 showing an enlarged view of the portion of the tublular vessel arm 8 and the grid 18*a*. With the ordinary construction, there will be one or more spaces 22 between the boundary 23 of the grid and the adjacent wall portion 24, said spaces being possibly small but nevertheless sufficiently large for an electron to slip through in the above described manner, the crosses and dashes indicating the positive charge accumulated upon the walls of the vessel and the negative charge applied to the grid, respectively.

A negative electron which slips thus into the space between the grid 18 and the anode 7 moves thereupon under the full influence of the applied potential, collides with the molecules of the vapor filling the vessel, generates new electrons and ions and in a small fraction of time the tube becomes fully conductive in spite of the negative charge applied to the grid.

My invention contemplates the prevention of the passage of electrons through neutral zones in the neighborhood of the grid and to this end the grid is mounted within a portion of the tube having the inner walls thereof covered with a layer 19 of conducting material such as iron or nickel, as shown in Figs. 1 and 2. The grid 18 is pressed into the tubular conducting layer 19 of the vessel and makes contact with the conducting walls thereof at one or more points.

The conditions prevailing upon the application of a negative charge to the grid, arranged according to the improved construction, are shown in Fig. 4. With the improved arrangement, the walls surrounding the grid are charged to the same potential as the grid, and exercise, upon the electrons tending to move occasionally towards the anode, a repelling action in the same manner as the grid. By my improved arrangement of the grid, I positively prevent the neutralization of the negative charge which is applied to the grid and I also increase the effectiveness of the grid action as such.

To illustrate the effectiveness of a grid constructed according to my invention, the following results of tests, made with a tube having first an ordinary grid arrangement and then an improved grid arrangement, may be compared. The cathode of a mercury arc tube was excited by means of an auxiliary arc and a negative potential of 150 volts was applied to the grid with respect to the cathode. Under those conditions a potential of 42 volts applied to the anode was sufficient to start a current through the tube, whereas with zero voltage applied to the grid it required 17 volts on the anode to start a current.

With the same kind of tube, but provided with an improved grid arrangement, it was sufficient to apply to the grid a negative potential of 6 volts only to prevent a current through the tube with the anode maintained at a positive potential of 220 volts. The latter figures do not, in any way, indicate the limit of the possible performance of such tubes and are given only in order to illustrate the effectiveness of the new grid arrangement.

It was the small change in the grid construction which turned a mercury arc tube, that was heretofore incapable of economical and rational control by a grid, into an instrument whose operation may be controlled by a small energy applied to the grid circuit.

In Fig. 6 is shown a mercury arc tube, having a mercury cathode 6 and a single anode 7′ mounted in a tubular glass vessel 25. A grid 18′ is provided in the tube and is constructed in accordance with the principles set forth hereinabove and comprising a tubular metallic passageway 19′ formed by any convenient method, by spraying of a layer of iron for instance, or inserting an iron cylinder fitting into the tube, and a grid 18′ supported by the metallic walls of the passageway and in conducting connection therewith. I have found that the operation of the tube may be very effectively controlled by a small voltage which is applied to the grid in the same manner as the double anode tube described in Figs. 1 and 2.

In Fig. 7 is shown a modification of my invention wherein the metallic cylinder 19″ surrounding the grid 18″ forms a part of the walls of the glass vessel 25′ and is joined thereto by means of gas-tight welds. The particular construction of the metallic cylinder and of the metal-to-glass welds are not a part of my present invention and are described and claimed in the copending applications of C. Kirwer Serial No. 665,487 and D. Ulrey Serial No. 665,407, and D. Ulrey and C. Kirwer Serial No. 665,414, all filed on September 28, 1923 and assigned to the Westinghouse Electric & Manufacturing Company.

The construction shown in Fig. 7 is illustrated in detail in Fig. 8. The metal cylinder 19″ is made of copper and has two end portions provided with knife-like edges 26 and 27 to which the adjoining glass portions are welded. A grid 13″ is mounted between the walls of the cylinder, the latter being coated with a mercury-resistant material 27 such as nickel, in order to protect the copper from the detrimental action of the mercury.

The grid constructions shown and described hereinabove may be made in any of the familiar forms known in the construction of grid-controlled vacuum devices and any of these forms may be used in connection with

my invention, which aims to prevent a neutralization of the negative or controlling charge upon the grid by an accumulated, uncontrolled charge on portions of the vessel in the neighborhood of the grid, and it is my desire that any means which intend to produce the same effect shall be regarded as covered by the appended claims. Likewise, I wish that the forms of my invention illustrated and described hereinabove shall be considered as illustrative of the mode in which the same may be practically applied and I desire, therefore, that the appended claims shall cover all such modifications as come within the true scope and spirit of my invention.

I claim as my invention:

1. A gaseous electric device comprising a vessel, two main electrodes in said vessel, a gaseous medium for conducting current between said electrodes, the conducting path between said electrodes including a passageway having conducting walls, a grid disposed in said passageway, means sealed through the tube wall for controlling the electric potential of said grid and the electric potential of said conducting walls.

2. A mercury arc device comprising an evacuated glass vessel, a mercury cathode in said vessel, an anode in spaced relation to said mercury cathode, a portion of said glass vessel constituting a tubular passageway for a flow of current, a coat of metal on the walls constituting said passageway, and a grid spanning said passageway between the metallically coated walls thereof and means sealed through the tube walls for providing a conductive connection to said coat of metal.

3. A space current device comprising a vessel of insulating material, a cathode and an anode mounted in said vessel, a gaseous medium for conducting current between said cathode and said anode, and a grid spanning the entire cross-sectional area of said vessel in spaced relation to both said cathode and said anode, said grid including a cylindrical conducting portion extending peripherally around the grid and for short distances toward said anode and said cathode and substantially in contact with every portion of the inner walls of said vessel surrounding said grid.

4. A mercury-arc device comprising an evacuated glass vessel, a mercury cathode in said vessel, an anode in spaced relation to said mercury cathode, a portion of said glass vessel constituting a tubular passageway for a flow of current, a reticulated grid extending over substantially the entire cross-section of said tubular passageway, a tubular layer of conducting material substantially in contact with the inner surface of said tubular passageway and extending longitudinally along said passageway in both directions from said grid, and adapted to be conductively connected to the negative terminal of a source of unidirectional potential.

5. A gaseous electric device comprising a vessel, a cathode and an anode mounted in said vessel, a gaseous medium for conducting current between said cathode and said anode, the conducting path between said cathode and said anode including a passageway to be highly ionized, a tubular wall of conducting material entirely surrounding said passageway, a reticulated grid extending over substantially the entire cross-section of said passageway, and adapted to be conductively connected to the negative terminal of a source of unidirectional potential.

In testimony whereof, I have hereunto subscribed my name this 9th day of October, 1923.

JOSEPH SLEPIAN.