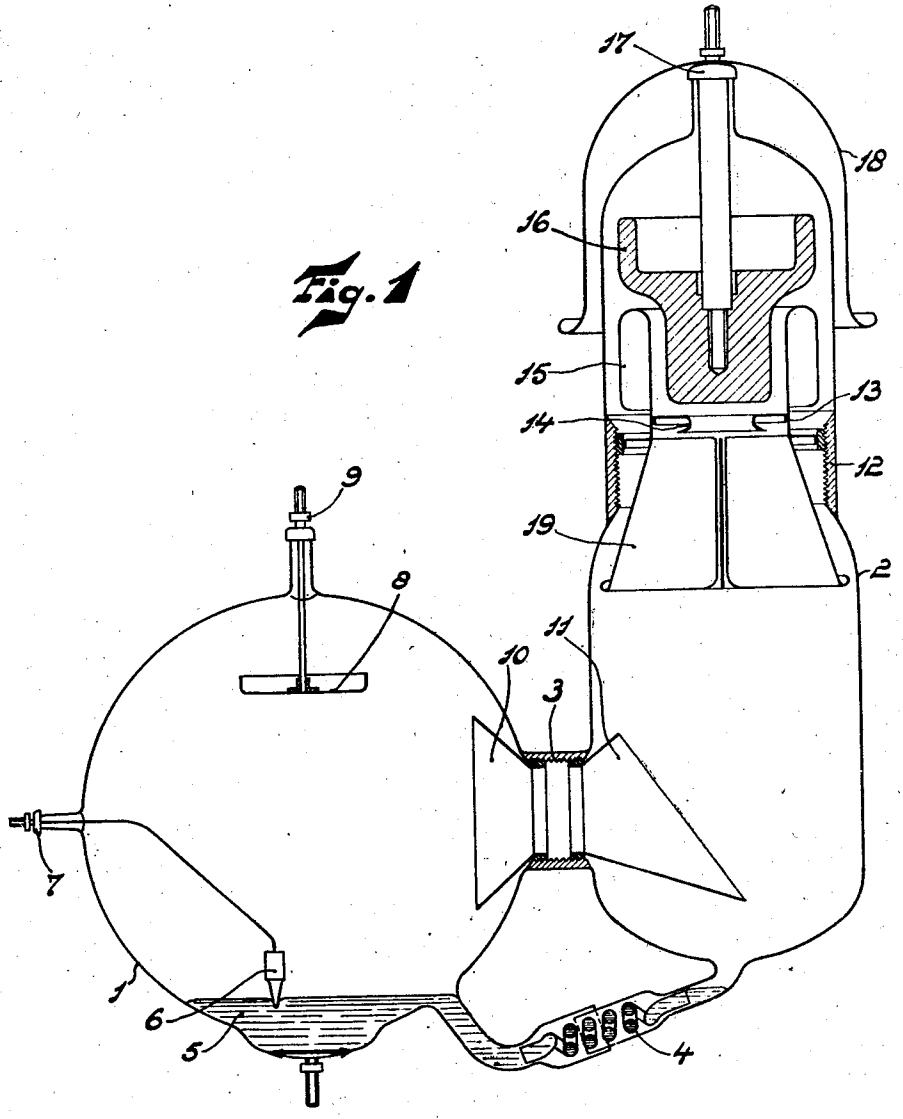
July 13, 1948. J. G. W. MULDER ET AL 2,445,075

DEVICE COMPRISING A MERCURY CATHODE TUBE FOR INTERRUPTING ELECTRIC CURRENTS OF HIGH VOLTAGE

Filed April 17, 1946 3 Sheets-Sheet 1

Fig. 1



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DEVICE COMPRISING A MERCURY CATHODE TUBE FOR INTERRUPTING ELECTRIC CURRENTS OF HIGH VOLTAGE

Filed April 17, 1946 3 Sheets-Sheet 2

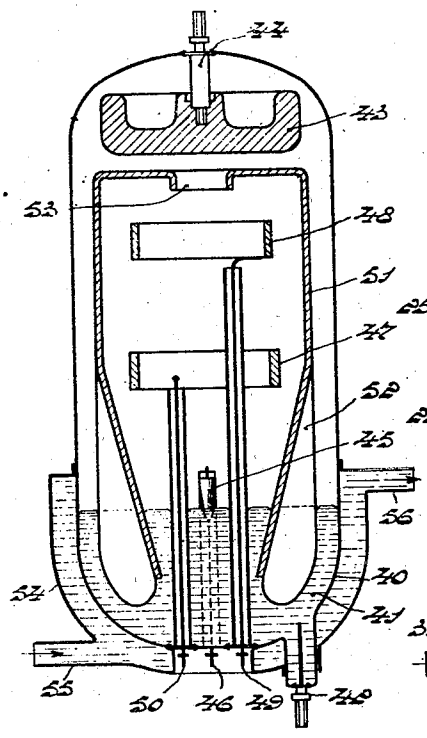


Fig. 3

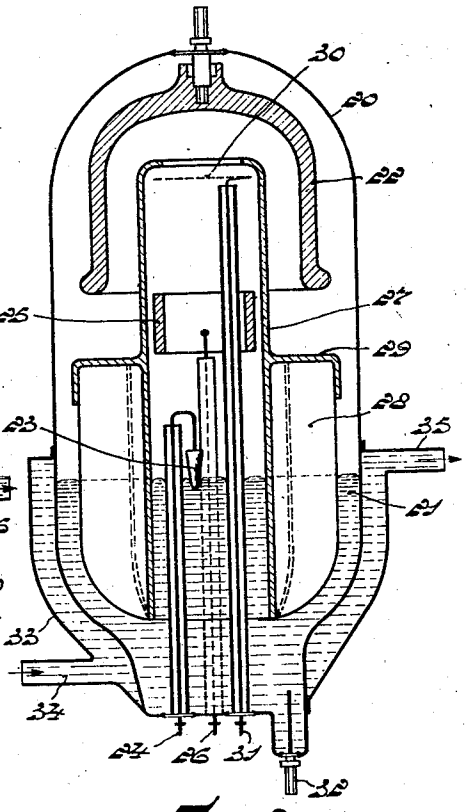


Fig. 2

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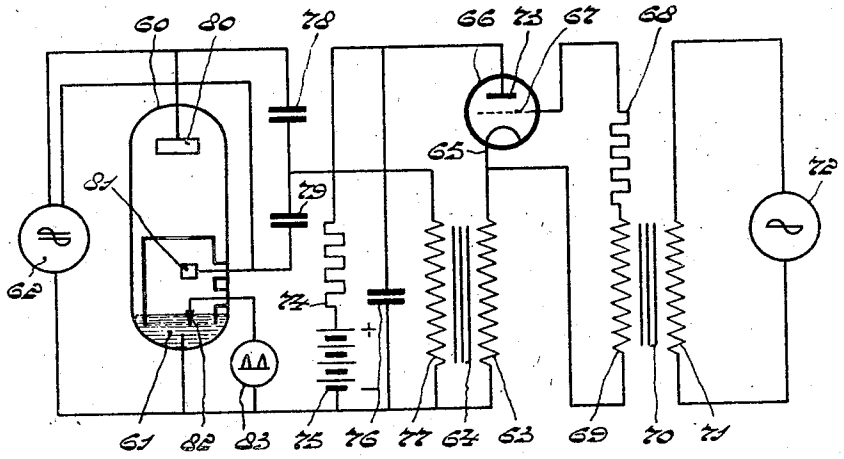


Fig. 4

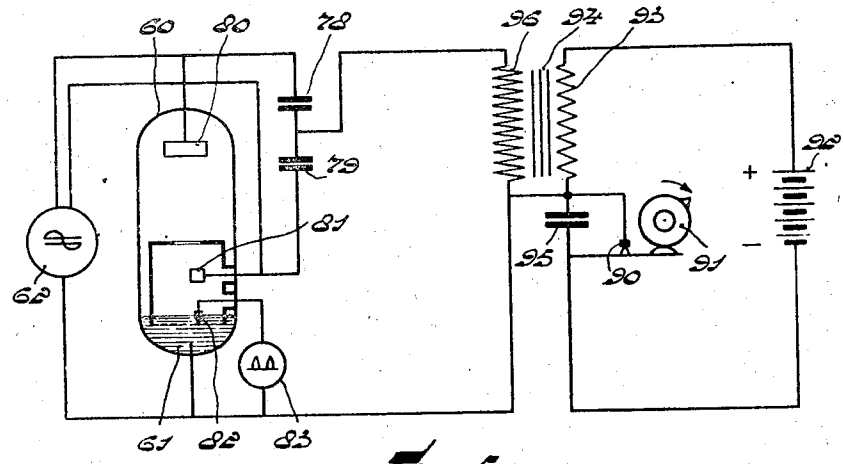


Fig. 5

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2,445,075

DEVICE COMPRISING A MERCURY CATHODE TUBE FOR INTERRUPTING ELECTRIC CURRENTS OF HIGH VOLTAGE

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7 Claims. (Cl. 250—27.5)

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The invention relates to a device for translating electric currents of high voltage, and particularly to apparatus which has incorporated in it a mercury cathode current-converting tube comprising an ignition electrode and an auxiliary anode for producing and maintaining respectively an electron discharge.

With such devices, which are utilized more particularly as direct current-alternating current inverters for high voltage, it is in general very difficult to interrupt the discharge at any time at which this discharge still has a substantial current intensity. More particularly at very high anode voltages it is inconvenient in practice to reduce the anode current to zero even for a short time only or to lower the anode voltage to approximately zero value. Moreover, a particularly great possibility exists for the extinguished discharge to be reignited by the residual ionisation still present prior to the prescribed interruption time.

It is known already, for example, from the French patent specification 844,414 to arrange a set of auxiliary electrodes and an ignition electrode of high resistance inside a screen in such manner that these members communicate with the main discharge chamber and with the main anode arranged therein by means of holes in the edge of the screen at the level of the surface of the mercury. In this case the main discharge is ignited owing to the fact that the cathode spot of the auxiliary discharge, which spot is formed inside the screen, is drawn to the exterior by the anode field or at least is divided and is partly drawn to the exterior. Tubes of this type are not suitable for use at very high voltages since the main anode is exposed without any protection to the liquid and vaporous mercury which is slung from the cathode spot into the main discharge chamber as soon as the cathode spot is drawn to the exterior of the screen.

The invention has for its object to realize with the above described devices for interrupting currents of high voltage such a construction and such an operation that the above-mentioned drawbacks are avoided, more particularly in such manner that the extinction of the discharge takes place with greater reliability and that the main discharge path is kept, even after extinction, as much as possible free of disturbing ionisation.

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According to the invention, for this purpose not only the auxiliary arc, the ignition electrode and the auxiliary anode but also the whole of the operative surface of the cathode are provided within a space chamber which is closed for the major part, the arrangement being such that substantially all the mercury originating from the cathode remains within this chamber while the main discharge and the auxiliary discharge are extinguished by simultaneous voltage impulses of steep wave front on the main and auxiliary anodes, owing to which the cathode spot in the closed space is loosened from the cathode mercury.

In the above described manner the certainty of the extinction of the main discharge is greatly promoted by the fact that the actions of the extinguishing impulse on the main and auxiliary discharges support one another provided that they act simultaneously on these discharges. This is attended with a particularly satisfactory deionisation of the main discharge in consequence of the fact that in all circumstances the cathode spot is screened while in this case it is not necessary to arrange particular extinguishing grids in the discharge path, all the drawbacks inherent to these members, such as a high value of the arc voltage due to the presence of great contractions in the discharge path or the production of appreciable grid currents due to the large operative surface of the grid, being thus avoided.

It is possible to utilize a device according to the invention as a switch for direct currents of high voltage or as an inverter tube, i. e., for converting direct current of high voltage into alternating current. These two applications are particularly important for the solution of the problem of the transfer of energy over a large distance by means of high-voltage direct current. The first-mentioned application makes it possible to construct a switch of high power of particularly small dimensions and, while suppressing the

usually employed extinguishing means, to cause it to function with an extremely small loss of energy. The second application greatly increases the possibility for inverter tubes of being operated in a reliable manner even at very high voltages and a very high power.

It is advisable to utilize for the device according to the invention a current-converting tube which comprises, in addition to the previously mentioned "cathode chamber" and the main anode chamber, which chambers are provided in separate vessels, an intermediate condensation chamber which communicates with the two other chambers through the intermediary of narrow connecting pieces and which prevents mercury particles which originate from the cathode chamber from reaching the main anode along the discharge path, a particularly high blocking capacity in the negative voltage phase of the main anode being thus obtained.

In certain cases it may, however, be advantageous to make no use of a separate condensation chamber and to construct the discharge tube in such manner that the operative surface of the cathode and the electrodes for producing and entertaining the auxiliary discharge are enclosed by a screen of a material of satisfactory thermal conductivity, said screen, or at least part thereof, being immersed in the cathode mercury, which is preferably provided with a cooling device. It is advantageous to select in this case a construction such that the heat developed in the discharge substantially delivered to the surroundings through the intermediary of the screen and the cathode mercury. It is frequently possible to withdraw in this way so much heat from the discharge path that the complication of a separate condensation chamber can be avoided.

According to a particularly advantageous embodiment of the inventive idea use is made of a current-converting tube wherein the operative surface of the cathode and the electrodes for producing and entertaining the auxiliary discharge are surrounded by a substantially cylindrical screen which is partly immersed in the cathode mercury and which, if desired, may be provided in its uppermost aperture which acts as a passage for the main discharge, with controlling members whilst the bell-shaped main anode surrounds the upper portion of this screen, the arrangement being such that nowhere within the tube between the anode and these parts are available uninterrupted paths of electrostatic lines of force which are longer than approximately half the length of the free paths of the electrons at the operating pressure of the tube. In this way substantially the whole of the discharge path is enclosed by a screen of satisfactory thermal transmission, whilst a construction of particularly small dimensions and of high blocking capacity in the non-conducting phase is obtained.

According to another form of construction of a current converting tube for a device according to the invention, the screen inside of which are present the operative cathode surface and the electrodes for producing and entertaining the auxiliary discharge, is arranged coaxially in the cylindrical discharge vessel of the tube at a small radial distance therefrom whilst the anode is arranged in a similar manner in the extension of this screen and the upper passage aperture of the screen is covered, with a small intervening space, by the anode front which is perpendicular to the axis of the tube. Thus the screen is substantially not covered by the anode in the radial direction, which favours the dissipation of heat from the screen to a high extent.

The invention will be explained more fully with reference to a few examples of tubes and wiring diagrams according to the invention which are diagrammatically shown in the drawings.

Figs. 1, 2 and 3 represent diagrammatically and in section constructions of tubes for devices according to the invention.

Figs. 4 and 5 represent wiring diagrams of extinguishing devices according to the invention.

Fig. 1 represents a current-converting tube whose discharge vessel consists of two parts 1 and 2 which are connected to one another through the intermediary of a metal connecting tube 3 hermetically sealed thereto and of a helically wound glass tube 4. The part 1 contains a mercury cathode 5 which is in contact with an ignition electrode 6 of semi-conductive material which is led to the exterior at 7. In the upper half of 1 is arranged an auxiliary anode 8 which entertains the auxiliary arc as soon as the ignition is brought about by the electrode 6. As the ignition electrode may also be utilized a capacitative electrode, for example a thin-walled ball of quartz which is partly immersed in the mercury and which is internally provided with a conductive coating which is led to the exterior so as to be screened. In the upper half of the part 2, which is divided in two at approximately half its height by a ring 12 of chrome-iron, is arranged a main anode 16 which is hermetically led to the exterior at 17. On either side of the metal connecting tube 3 are provided funnel-shaped pieces 10 and 11 for guiding the main discharge between the cathode 5 and the anode 16 and for protecting the sealing-in zones of the tube 3. Moreover, a positive or negative voltage may be applied to the aggregate 3—10—11 in order to facilitate the ignition of the arc or to increase the blocking capacity in the non-conducting phase. Inside the annular wall portion 12 is arranged a body 13 whose lower end has the shape of a funnel and which serves, as does the previously described body 10—3—11, to guide the discharge towards the main anode 16 and to protect the seals of the ring 12. The body 13 terminates at its upper end in a hollow profiled rim 15 and is internally provided with a diaphragm 14 and with radial faces 19. Only the central portion of the anode front is left free by the rim 15 and the diaphragm 14 which prevent for the rest the formation of uninterrupted paths of lines of force which are longer than half the length of the free paths of the electrons, which paths otherwise might be formed between the anode surface and adjacent conducting parts of other potential, the blocking capacity of the tube being thus greatly enhanced. The anode terminal 17 has secured to it a bell-shaped screen 18 which prevents undesirable concentration of electrostatic lines of force on the backside of the anode.

The operation of the tube is as follows: after a cathode spot has been formed by means of the electrode 6, an auxiliary discharge is produced between the mercury cathode 5 and the auxiliary anode 8, owing to which the cathode spot is maintained so that as the case may be with the aid of suitable potentials applied to the electrodes 3 and 13, a main discharge may be formed on the anode 16. The cathode spot always remains in this case inside the vessel 1 while mercury passing through 3 in the form of vapour is condensed in the lower portion of the vessel 2 and

can flow back through the glass tube 4 to the mercury cathode 5. As soon as, in accordance with the invention, voltage impulses with a steep wave-front are applied simultaneously to the auxiliary anode 8 and the main anode 16, the cathode spot at the surface of the cathode 5 disappears due to the fact that the anode voltages of the main and auxiliary discharges approximate for a short time to the zero value or attain this value. Owing to the construction of the tube no ionization occurs during the blocking phase in the part 2 of the discharge vessel whilst mercury originating from the cathode compartment is condensed in the lower portion of 2 and cannot reach the main anode 16. In consequence thereof the tube functions in a very reliable manner even at unidirectional voltages of 20,000 volts. A tube of the above-mentioned dimensions, is suitable for a current intensity of 6 amp. R. M. S. whilst in the case of larger dimensions it is very well possible to extinguish tens of amperes.

Fig. 2 shows a diagrammatical section of a current converting tube comprising a discharge vessel 20 of glass which contains a mercury cathode 21 and a main anode 22. In the mercury cathode is provided a semi-conductive ignition electrode 23 which is led out of the tube at the lower end thereof at 24. Above the ignition electrode is arranged an annular auxiliary anode 25 which is likewise taken out of the tube at the lower end at 26. With this construction of the tube no use is made of a separate condensation chamber but for the transmission of the heat of condensation and of the heat due to energy losses use is made of a cylindrical screen 27 the lower end of which is immersed in the mercury and which surrounds the operative surface of the cathode, the ignition electrode and the auxiliary anode. This screen consists of a material of satisfactory thermal conductivity and is provided with a plurality of radial faces 28 which have large surfaces of contact with the cathode mercury and which assist in the transmission of heat from the screen 27 to the mercury 21 by which the heat is delivered through the wall of the vessel 20 to the exterior, if desired with the aid of an artificial cooling device. The upper portion of the screen 27 is surrounded by the bell-shaped anode 22; the relative position of this anode, of the cylindrical portion of the screen 27 and of the flat portion thereof which is bent down at its outer edge is such that within the tube between the anode 22 and other members whose potentials are different from that of the latter anode uninterrupted paths of lines of force of more than approximately half the length of the free paths of the electrons are avoided at the operating pressure of the tube. Inside the screen and at the upper end thereof is arranged a grid-shaped member 30 with the aid of which, by applying a positive voltage thereto, the ignition of the main discharge or, by applying a negative voltage, the extinction or the continuance thereof can be promoted. At the lower end of the tube the grid 30 is led to the exterior at 31 and the cathode 21 at 32. The lower portion of the tube is surrounded by a cooling jacket 33 which is provided with an inlet tube 34 and an outlet tube 35 and through which may circulate any desired gaseous or liquid cooling medium.

The method of operation of the above-described tube corresponds to that of the tube according to Fig. 1. With respect to the latter it offers, however, the advantage of smaller dimensions or of reduced susceptibility of damage. Neither in

the construction according to Fig. 3 is made use of a separate condensation vessel. The cylindrical discharge vessel 40 contains cathode mercury 41 with a supply conductor 42, a main anode 43 with a supply wire 44, a semi-conductive ignition electrode 45 with a supply wire 46 which is led to the exterior in an insulated manner at the lower end of the tube and two auxiliary anodes 47 and 48 with supply wires 50 and 49 which are led to the exterior at the lower end. The cathode chamber is surrounded in this case by a screen 51 provided with radial cooling vanes 52, said screen being immersed in the cathode mercury in a similar manner to that shown in Fig. 2. The lower portion of the screen 51 has a frusto-conical, the upper portion, however, a cylindrical shape, the latter portion being at a very short distance from the wall of the vessel 40 so that here again a satisfactory transmission of heat to the exterior is possible. The top of the screen is flat and at a very small distance therefrom and parallel thereto is located the front face of the anode 43 which is cylindrical on the outside and which is likewise arranged within the discharge vessel at a very small distance therefrom, owing to which also in this case uninterrupted paths of lines of force of excessive length are avoided. The auxiliary anodes 47 and 48 arranged in succession promote the reliability of the ignition of the main discharge through the aperture 53 on the anode 43. Owing to the use of a plurality of auxiliary anodes we are at liberty to take the screen 51 of such height that no mercury originating from the cathode spot can pass at all through the aperture 53 but that it deposits previously on the wall of the screen 51 and flows back to the cathode 41. For the purpose of cooling the latter the lower tube portion is surrounded by a cooling jacket 54 provided with tubes 55 and 56 for the supply and the discharge respectively of a gaseous or liquid cooling medium.

Fig. 4 represents diagrammatically an extinguishing device comprising a current-converting tube wth a mercury cathode which may form part of a direct current-alternating current inverter tube according to the invention. The cathode 61 of the tube 60 is connected on the one hand, to an inverter circuit-arrangement diagrammatically denoted by 62 and on the other hand via the primary winding 63 of a transformer 64 to the incandescent cathode 65 of a relay tube 66. The grid 67 of this tube has connected to it, through the intermediary of a resistance 68, the secondary winding 69 of a peak voltage transformer 70 whose primary winding 71 is connected to an alternating current supply 72. The anode 73 of the relay tube 66 is connected through the intermediary of the series connection of a resistance 74 and a source of unidirectional voltage 75 and, parallel thereto, via a condenser 76 to that terminal of the primary winding 63 which is remote from the incandescent cathode 65, said terminal of the primary winding being also connected to the mercury cathode 61 of the current-converting tube. With every positive impulse on the grid 67 the condenser 76 is abruptly discharged via the discharge path of the relay tube so that in the secondary winding 77 of the transformer 64 are set up voltage impulses of steep wave-front which are supplied through condensers 78 and 79 to the main anode 80 and the auxiliary anode 81 of the current converting tube, the latter electrode having a uni-directional voltage applied to it in the D. C.-A. C. inverter system. The said impulses

are produced at the frequency of the controlling alternating current mains, for example 50 cycles, and thus the anodes 80 and 81 acquire, at least for a short time, a negative or a low positive or zero potential with respect to the cathode and this during a period of time which is sufficiently long to cause the suppression of the cathode spot and therefore of the current in the current converting tube 60, for example during 10^{-5} seconds. It is highly important that the impulses should be supplied to the anodes 80 and 81 exactly simultaneously since otherwise the reliability of the extinction of the discharge is greatly reduced. The main and auxiliary discharges of the tube 60 are periodically produced by the ignition electrode 82 which is supplied by a source of peak voltage 83 in synchronism with the source of current 72. The periodic simultaneous extinction of main and auxiliary anode currents is synchronously brought about each time by means of the above-described circuit-arrangement according to the invention.

Fig. 5 represents one form of construction of the extinguishing device, wherein the extinction frequency is obtained by mechanical agency by means of an interrupter contact 90 which is driven by a cam 91 provided on a spindle having a suitable speed of revolution. Similar parts of the diagram are denoted by the same numerals as in the case of Fig. 4. The interrupter contact 90 periodically closes and interrupts the current from a battery 92, which current flows through the primary winding 93 of a coil 94. The point of interruption is bridged by a condenser 95. By means of this arrangement, which corresponds to a usually employed ignition device for explosion engines, voltages impulses of steep wave front are delivered to the terminals of the secondary winding 96 of the coil, said impulses being supplied in the manner of Fig. 4 through the condensers 78 and 79 to the anodes 80 and 81 of the mercury cathode tube 60. This arrangement is also suitable for a switching device for the interruption of uni-directional current of high voltage, provided that the interrupter contact 90, instead of being periodically actuated by the rotating cam, is actuated only once in each switching-off operation, for example, by means of a push-button, in which event the cathode 61 and the anode 80 act as terminals of the direct-current switch.

With a device according to the invention it is possible to interrupt uni-directional currents by means of the above-described tubes and circuit arrangements in a reliable manner at voltages of the order of magnitude of 20,000 volts and with current intensities of the order of magnitude of from 10 to 100 amperes.

What we claim is:

1. A high voltage mercury-arc tube comprising a cathode chamber, a liquid cathode, an ignition electrode and a keep-alive electrode for maintaining a gaseous atmosphere in said cathode chamber, an anode chamber spaced from and interconnected to said cathode chamber, an anode in said anode chamber, and an electrical conducting member adjacent said anode, the shortest distance between said anode and said adjacent electrical conducting member being less than one half the mean free path of the electrons in the atmosphere within the tube.

2. A high voltage mercury-arc tube comprising a cathode chamber, a liquid cathode, an ignition electrode and a keep-alive electrode for maintaining a gaseous atmosphere in said cathode chamber, an anode chamber spaced from and interconnected by means of a constricted passageway to said cathode chamber, an anode in said anode chamber, and an electrical conducting member adjacent said anode, the electrical distance between said anode and said electrical conducting member being less than one half the mean free path of the electrons in the atmosphere within the tube.

3. A high voltage mercury-arc tube comprising a cathode chamber, a liquid cathode, an ignition electrode and a keep-alive electrode for maintaining a gaseous atmosphere in said chamber, an anode chamber spaced from and interconnected by means of a constricted passageway to said cathode chamber, an anode in said anode chamber, and a shield member of good thermal conductivity arranged between said anode and said cathode, the shortest distance between said anode and said shield member being less than one half the mean free path of the electrons within the atmosphere within the tube.

4. A high voltage mercury-arc tube comprising a cathode chamber, a liquid cathode, an ignition electrode and a keep-alive electrode for maintaining a gaseous atmosphere in said cathode chamber, an anode chamber spaced from and interconnected by means of a constricted passageway to said cathode chamber, an anode in said anode chamber, a shield member enclosing said ignition and said keep-alive electrodes, said shield member being of good thermal conductivity and partly immersed in said liquid cathode, the shortest distance between said anode and said shield member being less than one half the mean free path of the electrons within the atmosphere within the tube, and fluid heat exchanging means to cool said cathode chamber.

5. A high voltage mercury-arc tube comprising a cathode chamber, a liquid cathode, an ignition electrode and a keep-alive electrode for maintaining a gaseous atmosphere in said cathode chamber, an anode chamber, a constricted passageway interconnecting said cathode chamber to said anode chamber, shield members having good thermal conductivity connected to the ends of said passageway to aid condensation of the gas of said atmosphere, means to return condensation from said anode chamber to said cathode chamber, an anode in said anode chamber, and an anode shield member arranged between said anode and said cathode, the shortest path between said anode and said anode shield member being less than one half the mean free path of the electrons in the atmosphere within the tube.

6. A high voltage mercury-arc tube comprising an envelope, a liquid cathode, an ignition electrode, a keep-alive electrode for maintaining a gaseous atmosphere, a screen member and an anode in said envelope, a shield member enclosing said ignition electrode and said keep-alive electrode, said shield member being interposed between said anode and said cathode, being partly immersed in said liquid cathode and arranged to divide the interior of said envelope into a cathode chamber and an anode chamber, said shield member having an aperture beyond said screen member and adjacent said anode, the shortest distance between said anode and said shield member being less than one half the mean free path of the electrons in the atmosphere within the tube, and fluid heat exchanging means applied to said envelope in the region of said cathode.

7. A high voltage mercury-arc tube comprising

an envelope, a liquid cathode, an ignition electrode, a plurality of keep-alive electrodes successively arranged for maintaining a gaseous atmosphere and an anode in said envelope, a shield member enclosing said ignition electrode and said keep-alive electrodes, said shield member being interposed between said anode and said cathode, being partly immersed in said liquid cathode and arranged to divide the interior of said envelope into a cathode chamber and an anode chamber,

the shortest distance between said anode and said shield member being less than one half the mean free path of the electrons in the atmosphere within the tube, and fluid heat exchanging means applied to said envelope in the region of said cathode.

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