Aug. 30, 1938. L. TONKS 2,128,861

VAPOR ELECTRIC DISCHARGE DEVICE

Filed July 16, 1936 2 Sheets-Sheet 1

Fig. 1.

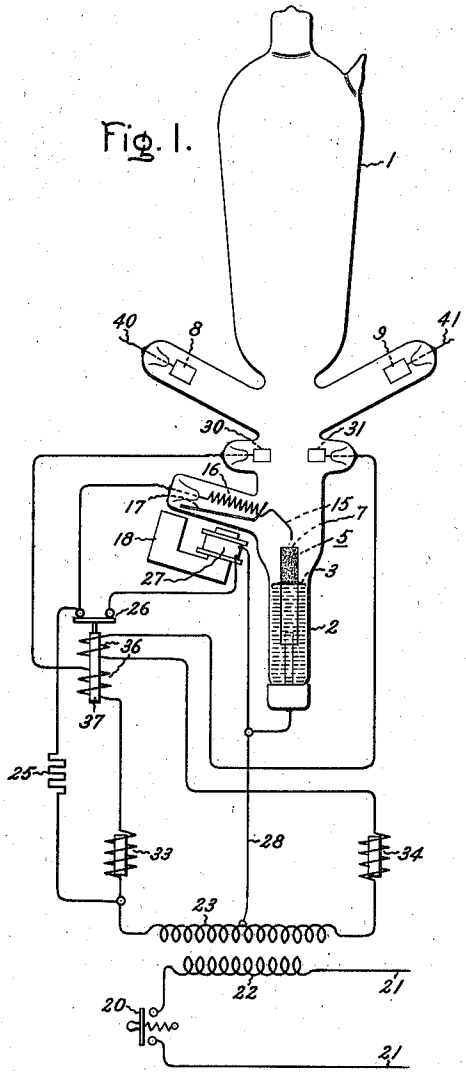


Fig. 4.

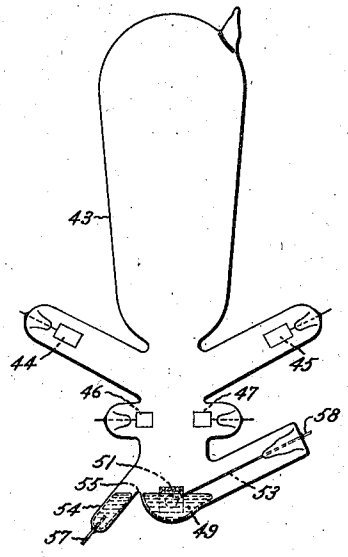


Fig. 2.

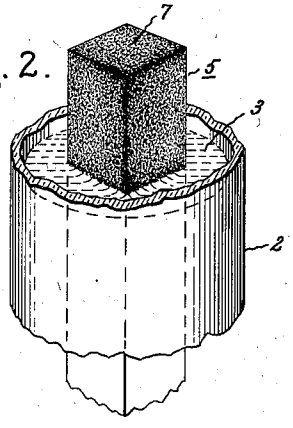


Fig. 3.

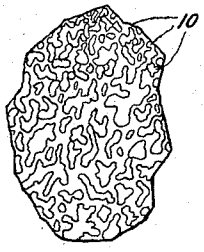
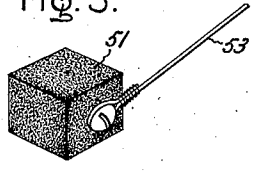


Fig. 5.



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Fig. 6.

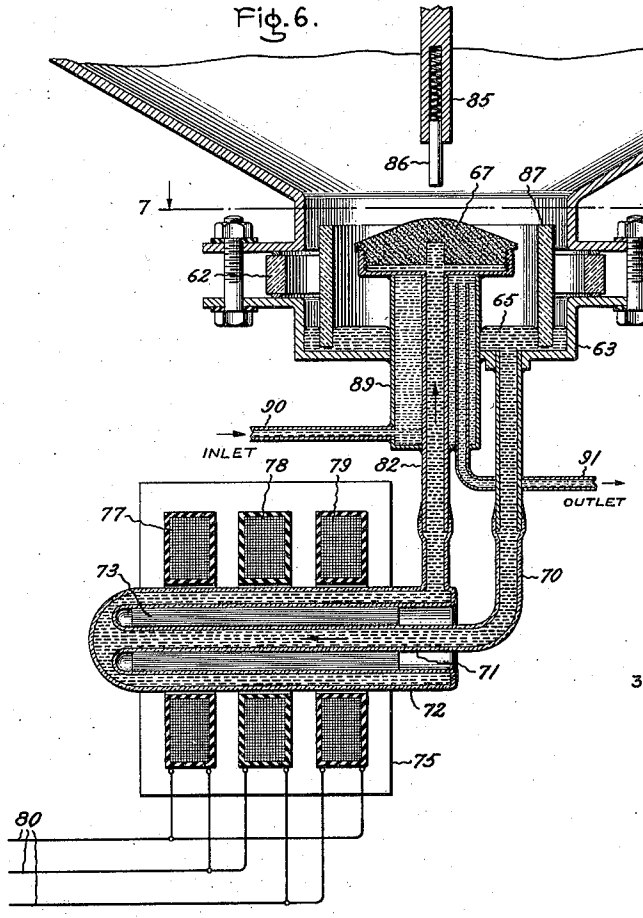


Fig. 8.

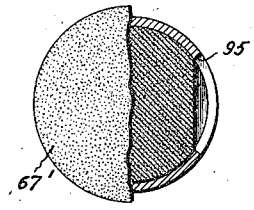


Fig. 9.

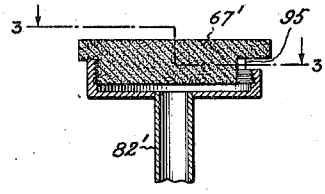


Fig. 7.

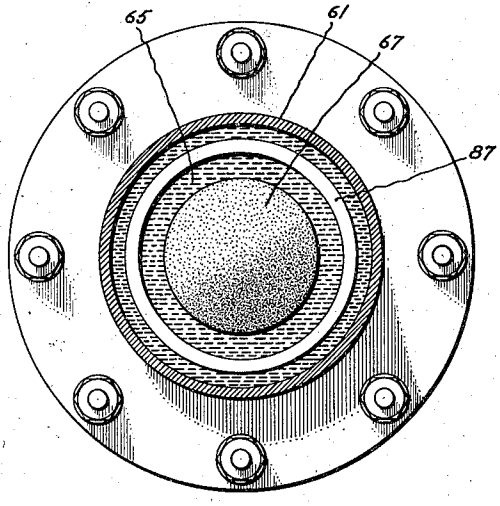
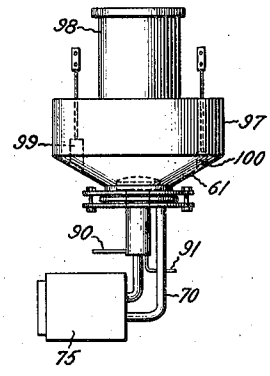


Fig. 10.



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UNITED STATES PATENT OFFICE

2,128,861

VAPOR ELECTRIC DISCHARGE DEVICE

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Application July 16, 1936, Serial No. 90,867

5 Claims. (Cl. 250—27.5)

The present invention relates to vapor electric discharge devices, and more particularly to improvements in means for stabilizing the cathode spot in such devices.

It is desirable in pool-type rectifiers and inverters to prevent the cathode spot from wandering at random over the surface of the pool since the splashing of the pool material and other effects associated with such wandering increase the probability of arc-back and raise the minimum of current required to maintain an arc discharge.

One of the objects of the present invention is to provide in connection with a pool-type discharge device means for anchoring the cathode spot to a particular location, which location shall have no tendency to vary in any direction regardless of changes in the level of the cathode pool.

It is a further object of the invention to provide in connection with a spot-stabilizing body means for assuring a continuous supply of cathode material to the active surface of the body.

A further object consists in the provision of a spot anchor of such nature that the minimum of current required to maintain the discharge arc may be reduced to a very low value, while at the same time rapid increases in currest will not cause the cathode spot to be released.

A still further object consists in the provision of a novel substance, suitable for uses such as those outlined above, which substance may be impregnated with mercury and which when once impregnated will retain its wetness and other useful properties for a relatively unlimited period under varying condition of use.

The features of novelty which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, however, together with further objects and advantages thereof will best be understood by reference to the following specification taken in connection with the drawings, in which Fig. 1 shows schematically a discharge device suitably embodying my invention and an associated control circuit therefor; Fig. 2 shows in enlarged detail a spot-anchoring body constructed in accordance with my invention; Fig 3 corresponds to a microscopically enlarged fragmentary section of the body illustrated in Fig. 2; Fig. 4 shows an alternative modification of the invention; Fig. 5 is an enlarged detail view of the spot-anchoring means of Fig. 4; Fig. 6 represents a vertical section of a spot-anchoring device constructed in accordance with the invention in combination with means for positively supplying cathode material thereto; Fig. 7 shows a horizontal section taken on line 7—7 of Fig. 6; Figs. 8 and 9 comprise respectively horizontal and vertical sections of an alternative form of spot-fixing device to be employed in the cathode structure of Fig. 6, and Fig. 10 illustrates schematically a complete discharge device incorporating the cathode structure of Fig. 6.

Referring now particularly to Fig. 1, I have shown a sealed glass envelope comprising an upper bulbous section 1 forming a condensation chamber and a lower portion 2 of somewhat reduced diameter which serves as a reservoir for a quantity 3 of liquid cathode material, such as mercury. Associated with the cathode pool 3, and in this particular case, in direct contact therewith, I provide a spot-stabilizing device or anchor 5 projecting above the surface of the mercury. This anchor comprises a porous body or matrix capable of acting as a wick and may suitably be shaped as shown in Fig. 2. As will be more fully explained in the following, the upper surface 7 of the anchoring body is adapted to co-operate with the main anodes 8 and 9 in conducting an arc discharge through the envelope.

The internal structure of one form of porous anchoring body which I have found particularly advantageous is well illustrated in Fig. 3 which represents a fragmentary section magnified approximately 250 diameters. In use the solid portions 10, which are preferably as small as material which will pass through a 200 mesh sieve, comprise a scaffolding or matrix for a column of mercury which is substantially co-extensive with the body of the wick. Inasmuch as free inter-communication of the mercury in all directions is permitted by the "honeycomb" formation of the wick body, a sufficient capillary effect is realized to raise the mercury (if mercury is the selected cathode material) several centimeters above the pool 3. Accordingly, if the upper surface of the wick is within that distance of the mercury, it will serve as an anchoring point for the discharge arc. The position of the cathode spot being thus made substantially independent of variations in the level of the mercury, the envelope as a whole may be tilted or, under certain conditions, inverted without causing instability of the arc discharge. Furthermore, since the mercury flow through the wick is not confined to definitely spaced channels, the active surface of the wick body or anchor receives a uniformly distributed supply of mercury which

is retained or "immobilized" thereon as an approximately continuous film.

While I consider a porous honeycomb anchoring body having wick-like properties to be broadly novel and not necessarily limited to particular materials, a further important aspect of the invention consists in the application of certain superior substances to this use. I have found that a wick comprising a carburized mass or agglomeration of cohering particles of tantalum, tungsten, or molybdenum presents numerous advantages over wicks composed of such metals as have heretofore been proposed for use in spot-anchoring devices.

It is true of many materials which have heretofore been suggested for this use that while they may be initially capable of being wet by mercury, this capacity tends to diminish appreciably after more or less prolonged exposure to an arc discharge. Furthermore, certain materials which are otherwise suitable are found to disintegrate and to contaminate the mercury surface and the interior of the discharge device after a short period of use. On the other hand, the materials which I have mentioned above (porous carburized tantalum, molybdenum or tungsten) are substantially free of these difficulties.

Among the specific materials which I have named, I consider carburized molybdenum to be a preferred embodiment. I have repeatedly used wicks embodying this material in half-wave rectifying devices without observing any substantial loss of wetness or mechanical deterioration after many hundred hours' operation. Furthermore, I have found that in discharge devices utilizing such wicks, an arc may be maintained with a current as low as three-tenths of an ampere, thus making possible the use of pool tubes in circuits heretofore regarded as of too low power for their successful employment.

One procedure which I have found suitable for the production of satisfactory carburized wicks comprises the following:—A quantity of powdered molybdenum of a fineness sufficient to permit it to pass through a 200 mesh screen is pressed at about three and one-half tons per square inch and the compressed body is partially sintered in a vacuum or inert atmosphere at a temperature of at least 1400° C. and, preferably, at 1500° C. for about two hours. The sintered mass, which has a structure substantially corresponding to that shown in Fig. 3, is then carburized at a temperature of at least 1250° C. and, preferably, at about 1500° C. for about one hour, carburization being acomplished by placing the wick material in a graphite tube and then firing in a hydrogen atmosphere at the temperature indicated. While I do not at present consider the extent of carburization to be a critical factor in the production of successful wicks, particular samples which I have tested show a gain in weight of from 5 to 6 per cent after submission to the carburization step above described.

Measurements which I have made on completed wicks show a porosity of from about 40 to about 69 per cent, this being the percentage of void space occurring in a given body of the material. Prior to use, the porous spaces are saturated with mercury, for example, by plunging the wick into a mercury pool while hot, this immersion being accomplished in vacuum or in an inert atmosphere. Such a procedure serves to wet the metal surfaces throughout the body of the wick with mercury, thus impregnating the wick and preparing it for installation in a discharge envelope. It should be pointed out in this connection, however, that a mercury-impregnated wick-like article having the properties described above is capable of uses other than as a spot-anchoring means. For example, such an article may be used in cleaning or filtering mercury, the power or capacity of the interior surfaces of the wick to be wet by mercury facilitating the ready flow of mercury through the structure.

The mode of use of this novel type of spot-anchoring device may best be understood by again referring to the disclosure of Fig. 1. Here I have shown in cooperative relation with the wick **5** a starting electrode **15** which is resiliently supported by a spring **16** so as to permit it to be moved up and down with respect to the surface of the wick. Downward motion of the electrode is accomplished by an iron armature **17** when acted upon by an electromagnet **18** arranged outside the envelope.

In connection with the particular circuit illustrated the discharge may be initiated by closing the switch **20**, thus establishing a connection from a source of alternating supply **21** to the transformer primary **22**. This connection will cause a pulse of current to be transmitted from the transformer secondary **23** through a resistor **25**, a normally closed contactor **26**, a magnet coil **27** and thence through the conductor **28** back to the transformer winding. The resultant energization of the magnet **18** draws down the armature **17** and brings the electrode **15** into contact with the upper surface of the anchor body, thus effectively short circuiting the coil **27** and causing the electrode **15** to be again released. The ionization produced by the ensuing arc causes a discharge to occur between the surface of the anchoring body and that one of the two holding anodes **30** and **31** which at the moment is at a sufficient positive potential with respect to the pool **3**. These anodes are kept at a difference of potential with respect to the cathode by voltage derived from the respective halves of the transformer secondary **23** and are enabled to maintain ionization from one cycle to the next by means of inductances **33** and **34** included in their respective circuits. Accordingly, a holding arc which strikes alternately on the two holding anodes is continuously maintained, and the device is at all instants in readiness to carry current between the cathode and the main anodes **8** and **9**. These latter electrodes may be energized by connection to suitable circuits which are not illustrated but which include the lead-in conductors **40** and **41**.

Each of the holding anode circuits includes a coil **36** associated with a magnetic armature **37** connected to the contactor **26**. Thus, the initiation of either of the holding arcs causes the contactor to open, thus de-energizing the magnet coil **27** and permitting the electrode **15** to be retained in its retracted position.

In Fig. 4, I have shown an alternative embodiment of the invention comprising a sealed envelope **43** enclosing main anodes **44** and **45** and auxiliary anodes **46** and **47** adapted to be energized as indicated in connection with Fig. 1. In this case, the cathode comprises a mercury pool **49** and a spot anchor **51** of the material above described held in permanent contact with the mercury, the form of the spot anchor **51** being shown in greater detail in Fig. 5. A suitable potential difference is impressed between the mercury in the offset arm **54** and that in the pool **49** through the leads **57** and **58**. In this case, the

discharge is initiated by tilting the envelope 43 to cause a portion of the mercury contained in the offset arm 54 to contact the main mercury body 49. Upon thereafter restoring the envelope to its upright position, the interruption of the mercury at the point indicated at 55 will cause a holding arc to be established. Thereafter, a holding arc is continuously maintained and the tube is in readiness to pass current from its main anodes as has already been described in connection with Fig. 1.

In Figs. 6 to 10 I have shown a modified application of the invention in connection with a discharge device of the class conventionally referred to as "tank rectifiers". A particular feature of this modification comprises incorporation of means for positively supplying mercury to the active surface of the cathode spot-fixing body. Referring especially to Fig. 6, I have shown the lower portion of a tank 61, for example of metal, enclosing a vapor electric discharge device. Supported from the bottom of the tank and separated therefrom by suitable insulating means such as the insulating ring 62 shown in the drawing, I provide a metal cup 63 adapted to serve as a reservoir for a quantity of mercury 65 contained therein. Above the mercury reservoir and supported in a manner hereinafter to be more fully explained, I provide a cathode-spot-fixing means comprising a rigid body 67 suitably of the form shown. This body is of a permeable construction and is preferably constituted of a porous wick-like material, such as is described in the foregoing.

In accordance with my invention, I further provide means for circulating mercury from the supply contained in the reservoir 63 into contact with the wick body 67. This means is shown in the present instance as comprising a conduit 70 having a continuous portion thereof leading to an electromagnetic pumping device. The pumping device illustrated consists in part of a central duct 71, of non-magnetic material, surrounded by a hollow annular shell 72 with which it is in communication, and from which it is separated by a magnetic iron core 73 suitably consisting of parallel iron wires. Surrounding the annular shell 72 is positioned a second magnetic core 75 provided with a plurality of spaced coils 77, 78, and 79, respectively. These coils are adapted to be supplied with power from the various phases of a polyphase alternating current source (not shown) to which connection is made by means of the conductors 80 connected in the proper sequence with respect to phase.

With the connections illustrated the currents in the various coils will be such as to produce a constantly fluctuating magnetic field in the iron core 73 and through the mercury. The direction of this field is such as to induce transverse currents in the mercury and by reaction of these currents with the magnetic flux to produce an electro-dynamic force tending to circulate the mercury in the direction indicated by the arrows. Sufficient excitation should be employed to force the mercury through the duct 82 into contact with the wick-like body 67. The pressure thus developed taken in connection with the capillary effect of the wick structure causes the mercury to penetrate to the upper exposed surface of the wick whence it may return to reservoir 63.

In this way, I am able to obtain what is in effect a rigid cathode having the electron emissive properties of a mercury pool. It will be apparent that considerable variations in the position of the tank 1 may be permitted without having an appreciable effect on the operation of the cathode. Furthermore, the precise location of the spot-fixing body 67 is not critical. It might, for example, be mounted on the lateral wall of the tank rather than in the base of the tank as shown.

It will be understood that in initiating a discharge from my improved cathode structure, some means such as the starting electrode 85 (shown partly broken away) may be employed. This electrode may be lowered by suitable means (not shown) until its tip 86 comes in contact with the upper surface of the body 67. Upon thereafter retracting the electrode a transient arc may be established of sufficient duration to ionize the mercury and to permit a main discharge to take place. To protect the gasketed joint between the ring 62 and the tank 61 from the destructive effects of the arc, I may provide an annular cylinder 87 of a material such as quartz which is capable of resisting the effects of the arc. The cathode structure itself may be cooled by means of a water jacket 89 having inlet and outlet ducts 90, 91, respectively, for circulating a cooling fluid therethrough.

In Figs. 8 and 9, I have illustrated an alternative modification of the spot-fixing body. In this case a portion of the wick 67′ is cut away as indicated at 95 to permit more or less free flow of the mercury forced up through the duct 82′. In this case I rely on the capillary effect of the porous body to assure a continuous supply of mercury at the upper and active surface thereof. Otherwise, the mode of operation is similar to that already described.

In Fig. 10, I have shown a complete discharge device in which the invention may be suitably incorporated. In this figure parts corresponding to those already described are identically numbered. It will be seen that in addition to the cathode structure already set forth, the tank comprises a lateral wall 97 and a superimposed condensing chamber 98. Supported within the tank and above the cathode are provided a main anode 99 and a holding anode 100, respectively.

In the foregoing, I have referred to mercury as an exemplary cathode material. It should be understood, however, that other liquid metals, for example, gallium, or sodium or cadmium, when in the liquid phase, may alternatively be employed.

Furthermore, while I have shown particular structural embodiments of my invention, it will be understood that many modifications may be made by those skilled in the art without departing from the invention, and I aim by the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

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

1. An electrical device comprising an anode, a mercury pool spaced therefrom, and a cathode-spot-fixing element in contact with said mercury, said element comprising a rigid porous body constituted of carburized partially sintered particles of a metal of the group consisting of tantalum, tungsten, and molybdenum and having a discharge-receiving surface appreciably above the normal level of the mercury pool.

2. An electrical discharge device comprising an anode, a cathode including a pool of liquid mercury and a wick-like body of honey-comb structure in contact with the pool and having a discharge receiving surface appreciably above the normal level of the pool, said body comprising

carburized cohering particles of molybdenum acting by capillarity to maintain a thin film of mercury on said discharge-receiving surface during the operation of the device.

3. In an electrical discharge device, a reservoir of liquid cathode material, a solid body having a discharge-receiving surface adapted to retain a thin film of cathode material thereon during the use of the device, said body being constituted of a porous wick-like substance capable of being wet by the cathode material so as to facilitate capillary conduction of cathode material through the body, and means for pumping cathode material from said reservoir into contact with a surface of said body other than said discharge-receiving surface, thereby to effect a continual supply of liquid cathode material to said discharge-receiving surface through the pores of the body.

4. An electrical discharge device comprising an anode, a mercury reservoir, a solid body having an exposed surface which functions in cooperation with the anode to support a discharge through the device, said body being constituted of a porous wick-like substance capable of being wet by mercury so as to facilitate capillary conduction of mercury through the body, and means for pumping liquid mercury from the reservoir through the pores of the body to the said exposed surface thereof.

5. In an electrical discharge device, a mercury reservoir, a solid body having a discharge-receiving surface adapted to retain a thin film of liquid mercury thereon, said body being constituted of a honeycomb structure of cohering particles of carburized molybdenum, and means for pumping liquid mercury from said reservoir through the pores of the body to said discharge-receiving surface.

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