Sept. 26, 1950 W. H. TEARE 2,523,789

INITIATING THE ARC IN MERCURY-POOL TUBES

Filed Dec. 30, 1949

Fig. 1.

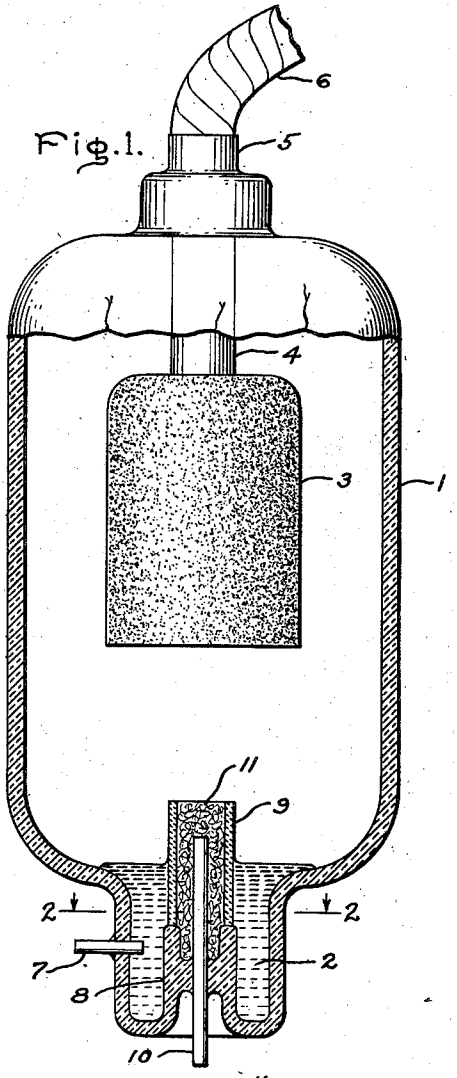


Fig. 2.

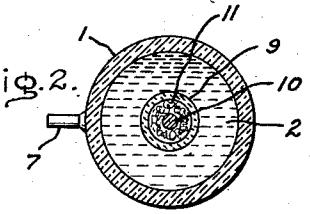


Fig. 3.

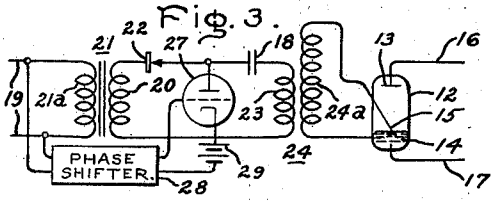
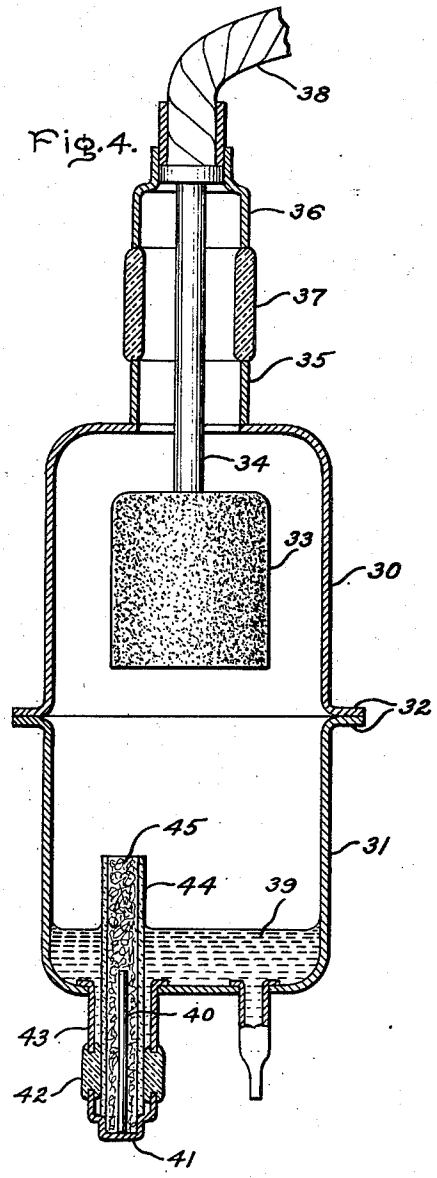


Fig. 4.



Inventor:
William H. Teare,
by Merton D Munn
His Attorney

Patented Sept. 26, 1950

2,523,789

UNITED STATES PATENT OFFICE

2,523,789

INITIATING THE ARC IN MERCURY-POOL TUBES

William H. Teare, Ballston Lake, N. Y., assignor to General Electric Company, a corporation of New York

Application December 30, 1949, Serial No. 135,987

10 Claims. (Cl. 250—27.5)

1

The present invention relates to vapor electric discharge devices of the type employing a pool type cathode and particularly to devices of this character having improved discharge initiating characteristics.

For many years initiation of the discharge in mercury arc rectifiers was accomplished by a starting electrode which was immersed in and withdrawn from the pool type cathode. In a variation of this type of starter, mercury from the pool was squirted against the surface of a starting electrode which was spaced a small distance from the cathode surface. In devices of this character, it was customary to maintain a state of ionization within the device after it was once initiated by means of a holding electrode or a holding anode. In another form of pool cathode electric discharge device, a starter electrode is employed in which the starter is continuously immersed in the pool cathode and through which a predetermined minimum current is passed to form a cathode spot and initiate the discharge. A form of this device is described and claimed in Slepian et al. Patent 2,069,283, granted February 2, 1937. The starting electrode, while of relatively high resistance compared with a metallic conductor, is of relatively low resistance as compared with a dielectric and it is generally considered that the starting phenomenon is essentially one of current. While devices of this character have found wide commercial use and have provided dependable and accurate starting of the discharge and satisfactory commercial life, it has been a serious disadvantage, particularly for lower power applications that the electrical energy required to initiate the discharge is large. In circuits where the energy transferred is not large, the energy rating of the control equipment for supplying the arc initiating or firing impulses to the starting electrodes approaches the energy transferred through the main discharge paths of the discharge devices.

Some attempts have also been made to utilize dielectric starters for pool type electric discharge devices in which the starting electrode includes a conductor surrounded by an insulator or dielectric material, such as glass or a ceramic. These starters, in general, have not been satisfactory. They have required a high starting voltage and have had a life too short to be acceptable for commercial application. Many attempts have been made to increase the life and reduce the starting voltage. These attempts have resulted in starters of different compositions and of very thin walled dielectric coverings. None

2

of the attempts have met with appreciable success and a possible explanation for the failure of these previous attempts lies in the requirement of a starting voltage which approaches rather closely the puncture voltage of the dielectric of the starter.

In accordance with important aspects of the present invention, an improved electric discharge device of the pool cathode type is provided with a dielectric starter of the immersion type. The mercury pool of the cathode has a thermionically inactive wetting agent amalgamated therewith to reduce the starting voltage to a point where the starter has satisfactory commercial life. The life is also increased by leaving a portion of the conductor of the starting electrode exposed to the vapor within the discharge device so that immediately upon the establishment of ionization in the region of the starting electrode, the energy of the circuit connected with the starting electrode is discharged in a path which shunts the dielectric starter.

The expression "thermionically inactive" as used in this specification means that the material either has a work function above that possessed by materials usually considered to be effective emitters, such as barium, strontium, calcium or the oxides of these materials or has a sufficiently high vapor pressure (low vaporization point) that it will be evaporated from any parts of the tube on which it may deposit before reaching a temperature at which substantial thermionic emission of electrons occurs. As will be pointed out in more detail, the present invention, in its narrower aspects, contemplates an improved construction of the starting electrode itself and preferred materials for the dielectric of the starting electrode as well as specific wetting agents for the pool cathode which have been found to be particularly advantageous.

It is an object of my invention to provide an improved pool cathode type of electric discharge device having an immersion type of starting electrode which is characterized by acceptable commercial life, accurate starting, relative freedom from arc-backs, and which requires a small amount of energy for initiating the cathode spot and resulting discharge between the principal electrodes.

Further objects and advantages of my invention will become apparent from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims. In the drawing Fig. 1 is an elevational view, partially in section, of an

electric discharge device embodying my invention; Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1; Fig. 3 illustrates a type of energizing circuit for the starting electrode of a discharge device embodying my invention; and Fig. 4 is an elevational view in section of a modified discharge device embodying my invention.

Referring now to Figs. 1 and 2 of the drawing, I have shown my invention embodied in an electric discharge device including a glass envelope 1, a body of conducting liquid 2, preferably mercury which provides a cathode at one end of the device and an anode 3 supported from the other end of the envelope by a suitable supporting conductor 4 joined to a terminal 5 which is hermetically sealed to the envelope and which provides a connection for an anode conductor 6. As illustrated, the anode is a body of graphite, although it will be understood that a suitable metal, such as nickel, may be employed, if desired. An external terminal and lead-in conductor for the cathode is provided by conductor 7 sealed through the body of the envelope below the level of the pool type cathode.

The envelope is provided at the central portion of the lower end thereof with a re-entrant portion 8 to which is sealed a sleeve of insulating material 9. The sleeve extends a substantial distance above the body of the cathode and surrounds a second lead-in conductor 10 which is sealed through the envelope centrally within the sleeve 9. In the illustrated embodiment, the space between the conductor 10 and the wall of the sleeve 9 is filled with a suitable conductor and I have found that a metallic wool, such as a body of steel wool 11 may be packed in this space to provide for the application of voltage between the inner and outer walls of the insulated cylinder 9 in response to an application of a voltage between the conductors 7 and 10. While in the broader aspects of my invention the sleeve 9 may be of any suitable dielectric material including the glasses and ceramics the advantages of my invention are more fully obtained if the sleeve is formed of a suitable ceramic material such as aluminum zirconium oxide or zirconium silicate.

While in the preferred embodiment illustrated, the dielectric covering for the conductor of the starting electrode is formed as a separate sleeve, it will be understood that in the broader aspects of my invention the covering may be applied directly as a coating on the conductor of the starting electrode.

As illustrated in the drawing, the cathode liquid which in the preferred embodiment is mercury wets the insulating sleeve 9 and does not wet the glass wall of the envelope. This amount of wetting, while not critical, has been found to be particularly advantageous in reducing the magnitude of the voltage required to be impressed across the wall of the sleeve 9 to initiate the cathode spot. The amount of wetting agent which must be added to the mercury pool to produce this wetting depends upon the character of the outer surface of the sleeve 9 and its composition as well as on the wetting agent or the combination of wetting agents employed. It will be readily appreciated that where the envelope and the dielectric coating of the starting electrode are the same material, that the mercury will necessarily wet both the envelope wall and the coating of the starting electrode. A large number of wetting agents may be used and I have found suitable such materials as magnesium, nickel, lead, aluminum, copper, silver, gold, tin, indium, zirconium, tantalum, and titanium. I have also found that mixtures of the wetting agents are more effective to produce the desired wetting action. The test results obtained with a number of different ceramic compositions were particularly good where one of the wetting materials is magnesium. If one part in 500,000 to one part in a million of magnesium is added to the mercury cathode and a similar quantity of one of the other agents, such as nickel, sufficient wetting of the dielectric or insulating sleeve results to produce the desired reduction in starting voltage when the dielectric of the sleeve is one of the ceramics, such as the oxide or silicate of zirconium or the oxide of aluminum. With other ceramics or with glasses different amounts of the wetting agents may be required.

The dimensions of the insulating sleeve of the starting electrode are not critical and in general I have employed a sleeve of larger diameter than those commonly used in immersion types of starting electrodes of the prior art. In one successful tube embodying my invention, the sleeve is approximately $\frac{5}{16}$'' in diameter and has a wall thickness of 20 to 30 mils, other starters having a wall thickness of 10 to 60 mils have been used successfully. If the wall thickness is greater, a higher voltage is required and as the thickness is reduced, the possibility of puncturing the dielectric coating by the voltage gradient impressed on the sleeve during starting increases.

As a result of the use of a wetting agent it has been possible to reduce the applied voltage required between the conductor of the starting electrode and the cathode pool to initiate a cathode spot on a particular tube from the order of 5000 to 6000 volts to a value as low as 500 to 1000 volts. It may be that the success of discharge devices embodying the present invention as compared to the prior art devices results to a considerable degree from this reduction in the starting voltage to a value substantially below the puncture voltage of the material employed in the sleeve. In order to further reduce the stress imposed on the sleeve 9 during the starting operation, the conductor 10 of the starting electrode is electrically exposed to the interior of the discharge device above the level of the liquid cathode so that as soon as ionization occurs as a result of the formation of a cathode spot, a low impedance path shunting the sleeve of the starter is established and the energy of the circuit connected with the starting electrode is dissipated through this shunt circuit. The operation of the starting electrode will become more apparent by a consideration of the circuit illustrated in Fig. 3.

As is well understood by those skilled in the art, the initiation of the conduction in a discharge device employing an immersion type of starting electrode is effected by supplying a voltage or current impulse between the conductor of the starting electrode and the cathode pool of sufficient current or voltage to establish a cathode spot. In Fig. 3, I have illustrated schematically a circuit suitable for use with discharge devices embodying my invention. The discharge device is illustrated schematically as including an envelope 12, an anode 13, a pool type cathode 14 and a starting electrode 15 which is constructed in accordance with the invention as described in connection with Fig. 1. As will be readily understood, the anode and cathode 13 and 14 are connected to conductors 16 and 17 respectively which will be connected to a source of voltage and a suitable utilization circuit. The

starting electrode is connected to be energized from a suitable impulse producing or firing circuit. As illustrated, a capacitor 18 is connected to be charged from an alternating current supply circuit through a circuit including the secondary winding 20 of a transformer 21, a rectifier 22, and the primary winding 23 of an output transformer 24. The primary winding 21a of the transformer 21 is connected with the supply circuit 19 and the secondary winding 24a of transformer 24 is connected between the starting electrode 15 and cathode 14 of the discharge device 12. The transformer may to advantage be of the air or powdered iron core type similar to those utilized for producing high voltage pulses of short duration in radar systems and may have a step-up ratio in the order of 1 to 10 to produce a high voltage output. The production of this voltage impulse results from the discharge of the capacitor 18 through the winding 23 and the discharge path of an electric discharge device 27 connected to complete the discharge circuit of the capacitor 18 through the winding 23. The discharge of the device 27 is synchronized with the voltage of the alternating current circuit 19 which in the normal application of the tube 12 will also be the supply voltage of the anode-cathode circuit of the tube. This synchronization is accomplished by a phase shifting circuit designated by the numeral 28 energized from the circuit 19 and having its output connected between the grid and cathode of the device 27. A suitable negative biasing means, such as a battery 29 is also connected in circuit with the control member and in combination with the variable phase voltage output of the phase shifter determines the instance at which an impulse is supplied to the electrode 15.

As stated earlier in the specification, it is a serious disadvantage in the application of discharge devices employing immersion ignition of the type described in Slepian Patent 2,069,283 that the energy required for initiating the cathode spot is large. In devices embodying my invention, the spot may be initiated by the application of approximately 1/10 of a watt averaged over a cycle. The rate of supplying energy may be in the order of 1 kilowatt but the time interval is only a fraction of a microsecond. The physical size of the firing circuit required is in the order of 1/20 or less of the physical size of the circuit required for firing a comparable discharge device of the type described in the Slepian et al. patent.

The firing circuit described above is preferably designed to produce a maximum voltage substantially above the voltage required to initiate the cathode spot and in order to relieve the dielectric sleeve of the starter from this voltage stress at the earliest possible moment the upper end of the sleeve is left open electrically so that as soon as ionization within the envelope appears a low impedance discharge path for the capacitor 18 is established. As will be readily appreciated by those skilled in the art, the ionization present in the discharge device as soon as the cathode spot is formed essentially short circuits the secondary winding of the transformer 24a through an ionized path from the exposed portion of the metallic material 11 to the cathode pool and thereby establishes a low impedance discharge path for the capacitor 18 through the primary winding 23 of the transformer 24. With the discharge tube of my invention it has been found that it is unnecessary to provide a shunt or series unilaterally conducting device in circuit with the starting electrode. As is well understood, these devices are employed with starting electrodes of the type disclosed in Slepian et al. Patent 2,069,283.

In Fig. 4, I have shown my invention applied to a metal envelope discharge device which is otherwise generally similar to that described in connection with Fig. 1. In Fig. 4 the envelope of the device includes a pair of cup-shaped metal elements 30 and 31 provided at their open ends with outwardly extending flanges 32 which are placed in contact and bonded together, as by welding, to form the envelope. The anode 33 is supported from the envelope in insulated relation with respect thereto by a lead-in conductor 34 and a seal construction including metal cylinders 35 and 36 which are sealed to a glass cylinder 37 and bonded at opposite ends to the conductor 34 and the cup-shaped element 30 of the envelope. A suitable anode conductor 38 is connected to the lead-in conductor 34. The cathode 39 is provided by a body of mercury in the lower end of the envelope which is provided with a wetting agent or agents in the same manner as described in connection with Fig. 1. The starting electrode assembly is generally similar but is supported from the envelope in a different manner. The lead-in conductor 40 for the starting electrode is bonded to a metal cap 41 which is sealed to the envelope means of a glass cylinder 42 and a metal sleeve 43. The insulating sleeve 44 of the starting electrode surrounds the conductor 40 and rests on a shoulder of the cap 41. The sleeve 44 is preferably bonded to the glass cylinder 42 and the interior of the sleeve 44 is filled with conducting material 45 to apply the starting voltage to the interior of the sleeve 44.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. An electric discharge device comprising an envelope, an anode within the envelope, a mercury pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode having a portion immersed in the cathode and a portion extending above the surface of the cathode, said electrode including a conductor extending below the surface of said pool and completely insulated from contact with said pool by an outer surface of refractory electrically insulating material, and a thermionically inactive wetting agent in said mercury pool for controlling the starting characteristic of said starting electrode.

2. An electric discharge device comprising an envelope, an anode within the envelope, a mercury pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode having a portion immersed in the cathode and a portion extending above the surface of the cathode, said electrode including an outer surface of refractory electrically insulating material and an internal conductor exposed to the interior of said envelope only above the surface of said cathode, and a thermionically inactive wetting agent in said mercury pool for con-

trolling the starting characteristic of said starting electrode.

3. An electric discharge device comprising an envelope, an anode within the envelope, a mercury pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode having a portion immersed in the cathode and a portion extending above the surface of the cathode, said electrode including an outer surface of ceramic material and an internal conductor extending below the surface of said pool and completely insulated from contact with said pool by said ceramic material, and a thermionically inactive wetting agent in said mercury pool for controlling the starting characteristic of said starting electrode.

4. An electric discharge device comprising an envelope, a conducting liquid pool cathode within said envelope, an anode within said envelope in spaced and insulated relation with respect to said cathode, a starting electrode assembly comprising a conductor sealed through said envelope below the surface of said cathode and extending into said cathode, a sleeve of refractory insulating material surrounding said conductor and completely separating said lead-in conductor from direct contact with said pool, said sleeve having an opening above the surface of said cathode to expose said conductor electrically to ionization within said envelope to provide a low impedance path in shunt relation to said sleeve upon establishment of ionization within said envelope.

5. An electric discharge device comprising an envelope, an anode within the envelope, a pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode including a conductor sealed through said envelope below the surface of said cathode and a sleeve of ceramic material surrounding said conductor and separating said conductor from contact with said cathode, said sleeve being open at its upper end and providing communication between said conductor and the interior of said envelope above the surface of said cathode.

6. An electric discharge device comprising an envelope, an anode within the envelope, a liquid pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode including a conductor sealed through said envelope below the surface of said cathode and a sleeve of refractory electrically insulating material surrounding said conductor and separating said conductor from contact with said cathode, said sleeve being substantially larger in diameter than said conductor and open at its upper end for communication with the interior of said envelope above the surface of said cathode and a body of conducting material in the space between said conductor and said sleeve.

7. An electric discharge device comprising an envelope, an anode with the envelope, a mercury

pool cathode within the envelope in spaced and insulated relation with respect to the anode, a starting electrode having a portion immersed in the cathode and a portion extending above the surface of the cathode, said electrode including an outer surface of refractory insulating material and an internal conductor exposed to the interior of said envelope above the surface of said cathode, a wetting agent in said mercury pool comprising a mixture of magnesium and nickel for controlling the starting characteristic of said starting electrode.

8. An electric discharge device comprising an envelope, an anode within the envelope, a mercury pool cathode within the envelope in spaced and insulated relation with respect to the anode, a starting electrode having a portion immersed in the cathode and a portion extending above the surface of the cathode, said electrode including an outer surface of refractory insulating material and an internal conductor exposed to the interior of said envelope above the surface of said cathode, a wetting agent in said mercury pool including a small quantity of magnesium for controlling the starting characteristic of said starting electrode.

9. An electric discharge device comprising an envelope, an anode within the envelope, a liquid pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode including a conductor sealed through said envelope below the surface of said cathode and a sleeve of refractory electrically insulating material surrounding said conductor and separating said conductor from contact with said cathode, said sleeve being substantially larger in diameter than said conductor and having an opening communicating with the interior of said envelope above the surface of said cathode and a body of conducting wool-like material within said sleeve and electrically connecting said conductor with the inner surface of said sleeve.

10. An electric discharge device comprising an envelope, an anode within the envelope, a mercury pool cathode within the envelope in spaced and insulated relation with respect to said anode, a starting electrode having a portion immersed in the cathode and a portion extending above the surface of the cathode, said electrode including a conductor extending below the surface of said pool and separated from electrical contact therewith by a body of refractory electrically insulating material, and a thermionically inactive wetting agent in said mercury pool for controlling the starting characteristics of said starting electrode selected from the group of wetting agents consisting of magnesium, nickel, lead, aluminum, copper, silver, gold, tin indium, zirconium, tantalum, titanium and mixtures thereof.

WILLIAM H. TEARE.

No references cited.