Jan. 12, 1943. E. G. F. ARNOTT ET AL 2,308,345

MULTIPLE LAYER IGNITER

Filed April 10, 1941

Fig. 2.

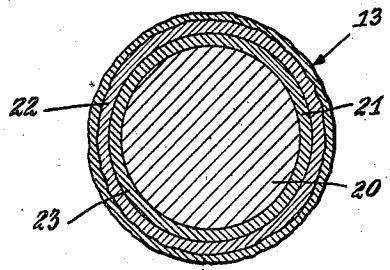


Fig. 1.

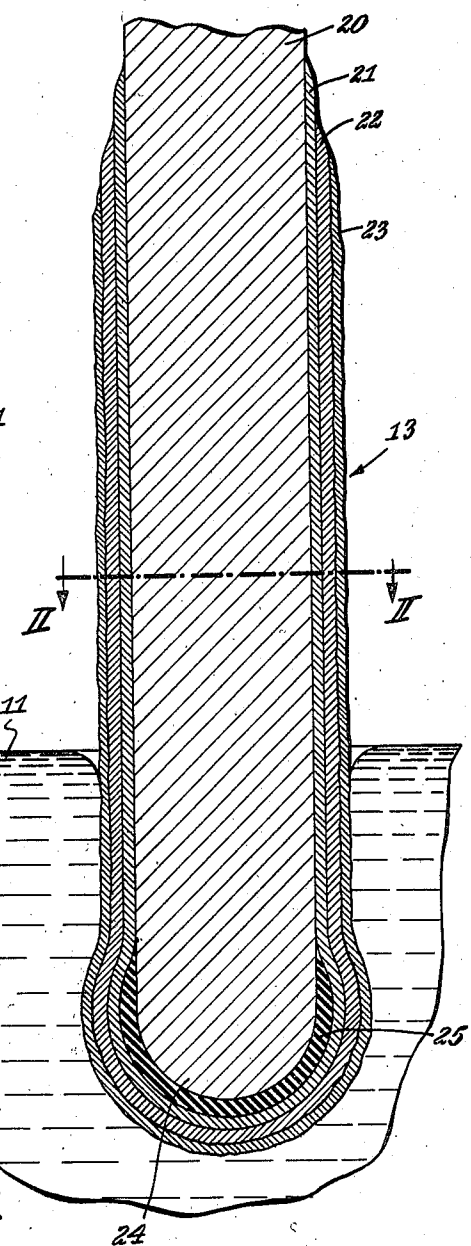


Fig. 3.

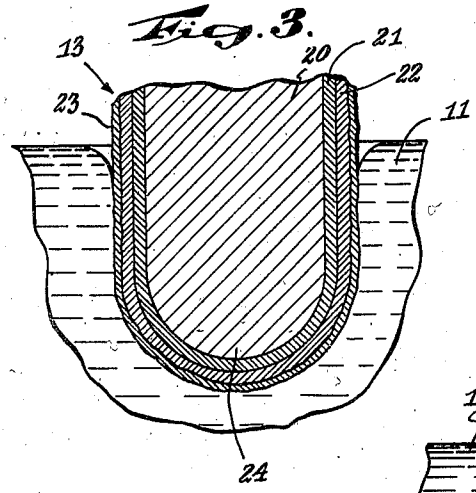


Fig. 4.

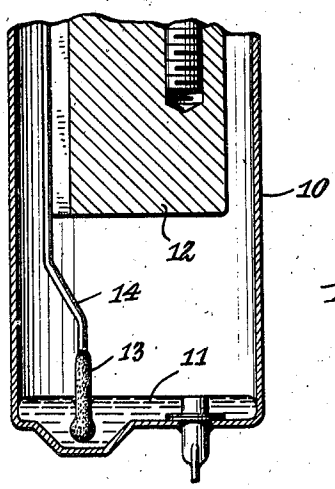
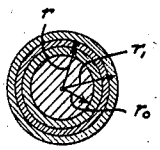


Fig. 5.



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UNITED STATES PATENT OFFICE

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MULTIPLE LAYER IGNITER

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Application April 10, 1941, Serial No. 387,838

13 Claims. (Cl. 250—27.5)

Our invention relates to electrode structure and especially to the starting electrode partially immersed in a mercury pool discharge device.

An object of our invention is to reduce the voltage necessary for starting a mercury pool device.

Another object of our invention is to provide a constant voltage gradient through the starting electrode from the contact with the mercury pool to the metal conductor of the starting electrode.

Another object of our invention is to reduce the current applied to a starting electrode of the mercury pool type of discharge device.

A still further object of our invention is to provide a starting electrode for partial immersion in a mercury pool which electrode will have substantially constant starting voltage characteristic regardless of variation in the depth of immersion in said pool.

A still further object of our invention is to provide a starting electrode for partial immersion in a mercury pool and which will have little or no variations in starting characteristics due to temperature variations following inactive periods.

Other objects and advantages of the invention will be apparent from the following description and drawing in which:

Figure 1 is an enlarged cross sectional view through a preferred embodiment of our starting electrode partially immersed in a mercury pool cathode.

Figure 2 is a cross section on lines II—II of Figure 1.

Figure 3 is an enlarged cross sectional view illustrating a modification of the structure of Figure 1.

Figure 4 is a view mainly in cross section of our starting electrode installed in a particular type of discharge device.

Figure 5 is a cross sectional view through our starting electrode for purposes of illustrating the various diameters of the coating therein.

Our invention relates to the starting electrode for mercury pool devices and in its specific form, our invention is a substitute for the high resistance make-alive or igniter electrodes now utilized in many types of ignitrons. In Figure 4 is illustrated a particular type of ignitron which is more particularly described in the co-pending application of D. E. Marshall et al. Serial No. 360,890, filed October 12, 1940, for "Offset anode ignitron." The particular ignitron illustrated has a metal casing 10, although a glass casing could also be utilized. In the bottom portion of this metal casing is a mercury pool cathode 11 and above the mercury pool is an anode 12 generally of carbon. The starting electrode 13 is of the form of our invention, but if it were the form of those of the prior art it would be composed of a high resistance material such as boron-carbide having a conical tip partially immersed in the mercury pool. This boron-carbide tip is secured generally to a conductor 14 passing through the insulation in the wall of the casing. The upper portion of the starting electrode to which is secured the conductor metal lead is a slightly extended cylindrical portion. The discharge is started by applying suitable current and voltage to the boron-carbide to create a cathode spot on the mercury pool adjacent the contact with the boron-cathode surface.

Because of the considerable portion of high resistance boron-carbide in the starting electrode from the mercury pool to the contact with a metal lead-in, a high value of current such as 20 or 30 amperes may be required to have a low starting voltage. Types of igniters merely requiring 80 volts pressure with low current are very unusual.

The installation of the starting electrode in one tube may have a greater or shallower depth of immersion from that of another tube and have as a result, a greater or less path of high resistance material from the mercury pool to the metal lead-in conductor. This difference in the length of the high resistance path will cause a difference in starting characteristics in what is otherwise apparently identical tubes. Furthermore, the surface of the mercury in the same tube may be agitated in operation and this agitation will change the starting characteristics because of the various heights of the mercury about the starting electrode. The installation of the prior art starting electrodes has the disadvantage that it should be carefully performed as to the depth of immersion in order to obtain the desired starting characteristic.

With the igniters of the prior art, a considerable variation in required voltage is found between those used continuously and those used in low duty cycle or intermittent operation. The reason for this is that the main body of the igniter which is above the mercury pool forms a large part of the total resistance. This portion of the igniter is subject to large variation in temperature in this type of service. Since the materials used have a high negative temperature coefficient of resistivity the voltage drop across the igniter will be considerably higher for low temperature intermittent operation than for continuous operation where the igniter remains hot.

Our invention overcomes all these disadvantages of the present igniter by utilizing a structure with a substantially constant thickness of high resistance material between the metal conductor and the mercury pool regardless of the variation in the immersion therein. Furthermore, our invention provides a substantial constant voltage gradient from the contact to the mercury pool to the metal conductor. Because of the short and constant length of resistance path through the high resistance material, the voltage requirement is very much less and the period of inactivity does not materially change the operation characteristics.

In Figure 1 we have disclosed a preferred embodiment of our invention which comprises a central metal rod **20** with a layer of two or more high resistance material coatings **21**, **22** and **23** thereon. The second layer has a higher resistivity than the first layer and the third layer has a still higher resistivity than the two layers underneath it. The central rod may be approximately $\frac{1}{16}$ of an inch in diameter and be of tungsten, molybdenum or a metal or alloy having a suitable expansion in comparison with the coating and also having a high melting point. The loyer end **24** of the rod **20** is preferably rounded to avoid any sharp corners. While the first layer may be directly applied to the rod as disclosed in Figure 3 we preferably coat the rounded end or tip with insulating cement **25** as illustrated in Figure 1. This insulating cement has preferably same coefficient of expansion as the central rod and in the case of tungsten we have found the cement sold under the trade designation of "Sauereisen No. 78" to be satisfactory. The purpose of this cement is to reduce the current flow from the end of the rod, which current does not help in the creation of the cathode post.

The inner layer we preferably form of equal parts of boron-carbide powder of 320 mesh and silicon carbide of 500 mesh mixed with a few percents of silicon powder. Our preferred composition is 10 grams of boron-carbide, 10 grams of silicon carbide and ½ gram of silicon. This powder is mixed with a binder and preferably with approximately 10½ cubic centimeters of a binder consisting of nitro-cellulose mixed with a solvent such as amyl-acetate or diethyl-carbonate. The rod **20** is immersed in this mixture to the desired depth and withdrawn at a rate depending upon the thickness of the coating desired. Our rod **20** which has an outside diameter of .097 inch we withdraw slowly from the mixture in 5 to 45 seconds and have a coating formed thereon of .002 inch to .005 inch in thickness. We prefer to withdraw the rod in 15 seconds and produce a coated rod of a diameter of .104 inch. The coating may be thickened by withdrawing the rod in a shorter period or may be made thinner by a still slower withdrawal. The dipping may be repeated if necessary.

This first coating may be dried naturally in air or it may be fired in hydrogen at 1100° C., for ten minutes such as described in Patent 2,235,504 pp. 2, lines 45 to 55, issued to R. Rennie, March 18, 1941.

In order to increase the resistivity of the second coating **22** we preferably increase the percentage of silicon carbide therein. Our preferred coating is that of 5 grams of boron-carbide to 15 grams of silicon-carbide with ½ gram of silicon mixed in the solution previously described. The rod is inserted and then withdrawn gradually in 15 to 30 seconds to provide a second coat thereon. Further layers may be added if desired in order to gradually increase the resisitivity of the layer from the inner metal conductor to the surface thereof. In our preferred embodiment, however, we do not immediately dry or heat the second coating but while the coating is still moist we roll the rod in approximately 180 mesh silicon carbide to form a hard rough crystalline layer **23**, over the outside surface of the coated rod. A rough surface reduces the total current. Boron-carbide may be used instead of silicon carbide. The complete rod is then preferably fired again in hydrogen for ten minutes at 1100° C. and after being cleaned with a soft brush is fired in air up to 960° C. and cooled rapidly.

A metal rod coated with a single thin layer of high resistance material will usually fail when used as an igniter. This failure is due to a puncture through the coating caused by the high voltage gradient near the surface of the metal. The high gradient is caused by the fact that, due to the cylindrical shape, the current density in the coat is high at the inner surface. If this gradient anywhere exceeds the dielectric strength of the material, a puncture will occur. In our igniter the voltage gradient near the surface of the metal is reduced below the dielectric strength of the material. The theoretical explanation of this result with reference to the diameter in Figure 5 is as follows:

Suppose the successive layers to be very thin and composed of materials which increase in resistivity as the distance from the metal rod increases, so that the resistivity ρ at any point in the coating a distance r from the center of the rod is given by ar where a is a constant determined by the total resistance and the outside diameter of the igniter. Then the resistance dR of a thin shell of thickness dr at a distance from the center of the rod will be

$$dR=\frac{\rho dr}{2\pi r}=\frac{ardr}{2\pi r}=\frac{a}{2\pi}dr$$

and the total resistance of the igniter will be

$$R=\frac{a}{2\pi}\int_{r_0}^{r_1}dr=\frac{a}{2\pi}(r_1-r_0)$$

where r_0 is the diameter of the metal rod and r_1 the outside diameter of the igniter.

Then since the voltage $V=IR$ for a given current I, $dV=IdR$, and:

$$dV=\frac{Ia}{2\pi}dr$$

from above.

The voltage gradient

$$\frac{dV}{dr}=\frac{Ia}{2\pi}=\text{a constant}$$

Therefore, since the voltage gradient is a constant through the coating, the dielectric strength of the igniter will be a maximum for the given total resistance required if the dielectric strength of each layer is the same. If the known dielectric strength of each layer increases as the resistivity increases, then the maximum total dielectric strength will be obtained by making the resistivity increase faster than the first power of the radius or mathematically $\rho=ar^n$ where $n>1$.

In place of the three layers previously described, any number of very thin coats may be applied to the rod to provide a covering gradually increasing in resistivity from the inner surface to the outer surface in contact with the mercury. We have taught that this can be accomplished by utilizing an equal percentage of

silicon carbide and boron-carbide with a few percent of silicon to act as a binder in the first layer and then increase the silicon carbide in the second layer and then a still further increase in the silicon carbide percentage to make the outer layer all silicon carbide. The percentage of silicon carbide could be made still less in the inner coat and then gradually increase in percentage to the outer coat. Other materials, such as boron-nitride, might be used in combination and especially the combination of materials listed in the co-pending application of R. Rennie, Serial No. 284,574, filed July 15, 1939, for "Ignitron starters."

We prefer to limit the various layers to a thickness of a few mils (or thousandths of an inch) and preferably from 2 to 5 mils as previously described.

An examination of Figure 1 and 3 will disclose that there is a constant thickness of high resistance material between the metal rod 20 and the contact with the mercury whether the electrode is raised or lowered in the mercury. The starting voltage required will not be changed because there is no change in length of resistance path with immersion as is true with the prior art igniters. The path of the current through the high resistance material is completely under the surface of the mercury and will be maintained at the temperature of the mercury pool by conduction and, as a result, will not have large temperature fluctuations.

If a prior art igniter has not been used for some time, the current would have to traverse a large portion of the cool high resistance material above the surface of the mercury and then this cooled high resistance material will become warm with the heat of operation and change its resistivity.

Igniters have been made in accordance with our invention which require a maximum peak voltage of 80 volts and a maximum peak current of 15 amperes. When started cold, these igniters only require 95 volts maximum peak and less than 15 amperes. The method of assembling our igniters by dipping them into the solutions and firing them is obviously extremely economical in comparison with the expensive method of forming the prior art igniters. Our igniters also require extremely low voltage and relatively low current in comparison with the prior art igniters. The voltage required is practically independent of the temperature and also independent of the immersion depth. The method of assembly provides a uniformity between igniters that is impossible with those of the prior art.

Although we have shown and described specific embodiments of our invention we do not desire to be limited thereto as various other modifications of the same may be made without departing from the spirit and scope of the appended claims.

We claim:

1. A starting electrode comprising a conductor comparatively free of resistance and a plurality of layers of high resistance materials on said conductor next an end portion thereof adapted to be inserted in a pool cathode, said coating providing substantially uniform resistance therethrough to said conductor from any part of the outer surface of said coating.

2. A starting electrode comprising a conductor comparatively free of resistance and a plurality of layers of high resistance materials on said conductor of different resistivity and next an end portion thereof adapted to be inserted in a pool cathode, said coating providing substantially uniform resistance therethrough to said conductor from any part of the outer surface of said coating.

3. A starting electrode comprising a conductor comparatively free of resistance and a plurality of layers of substantially constant thickness on the active portion of said starting electrode, said coating providing substantially uniform resistance therethrough to said conductor from any part of the outer surface of said coating.

4. A discharge device comprising an anode, a mercury pool cathode and a starting electrode partially immersed therein, said starting electrode comprising a conductor comparatively free of resistance and a plurality of layers of high resistance materials on the portion of said conductor immersed in the mercury, said coating providing substantially uniform resistance therethrough to said conductor from any part of the outer surface of said coating.

5. A discharge device comprising an anode, a mercury pool cathode and a starting electrode partially immersed therein, said starting electrode comprising a conductor comparatively free of resistance and a plurality of layers of high resistance materials on the portion of said conductor immersed in the mercury, said layers being of different resistivity, said coating providing substantially uniform resistance therethrough to said conductor from any part of the outer surface of said coating.

6. A discharge device comprising an anode, a mercury pool cathode and a starting electrode partially immersed therein, said starting electrode comprising a conductor and a plurality of layers of high resistance materials on the portion of said conductor immersed in the mercury, said layers forming a coating of substantially constant thickness on said conductor just above and below the surface of the mercury.

7. A discharge device comprising an anode, a mercury pool cathode and a starting electrode partially immersed therein, said starting electrode comprising a conductor and a plurality of layers of high resistance materials on the portion of said conductor immersed in the mercury, said layers increasing in resistivity from said conductor to the surface in contact with the mercury.

8. A discharge device comprising an anode, a mercury pool cathode and a starting electrode partially immersed therein, said starting electrode comprising a conductor and a plurality of layers of high resistance materials on the portion of said conductor immersed in the mercury, said layers increasing in resistivity from said conductor to the surface in contact with the mercury, and forming a coating of substantially constant thickness on said conductor just above and below the surface of the mercury.

9. A starting electrode comprising a conductor and a plurality of layers of high resistance materials on said conductor next an end portion thereof adapted to be inserted in a pool cathode, the outer layer being of higher resistivity than the inner layer.

10. A starting electrode comprising a conductor and a plurality of layers of high resistance materials on said conductor next an end portion thereof adapted to be inserted in a pool cathode, the resistivity of the outer layer being greater than that of the layer beneath it.

11. A starting electrode comprising a conductor and a plurality of layers of high resistance materials including silicon carbide on said conductor next an end portion thereof adapted to be inserted in a pool cathode.

12. A starting electrode comprising a conductor and a plurality of layers of high resistance materials including silicon carbide on said conductor next an end portion thereof adapted to be inserted in a pool cathode the percentage of silicon carbide increasing from the amount in the inner layer to the amount in the outer layer.

13. A starting electrode comprising a metal rod, a first layer of boron-carbide and silicon carbide on said rod, a second layer of boron-carbide and silicon carbide of higher resistivity on said first layer and an outer layer of silicon carbide on said first and second layers.

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