

July 18, 1944.

L. H. LA FORGE, JR

2,354,031

SPACE DISCHARGE TUBE

Filed April 26, 1941

3 Sheets-Sheet 1

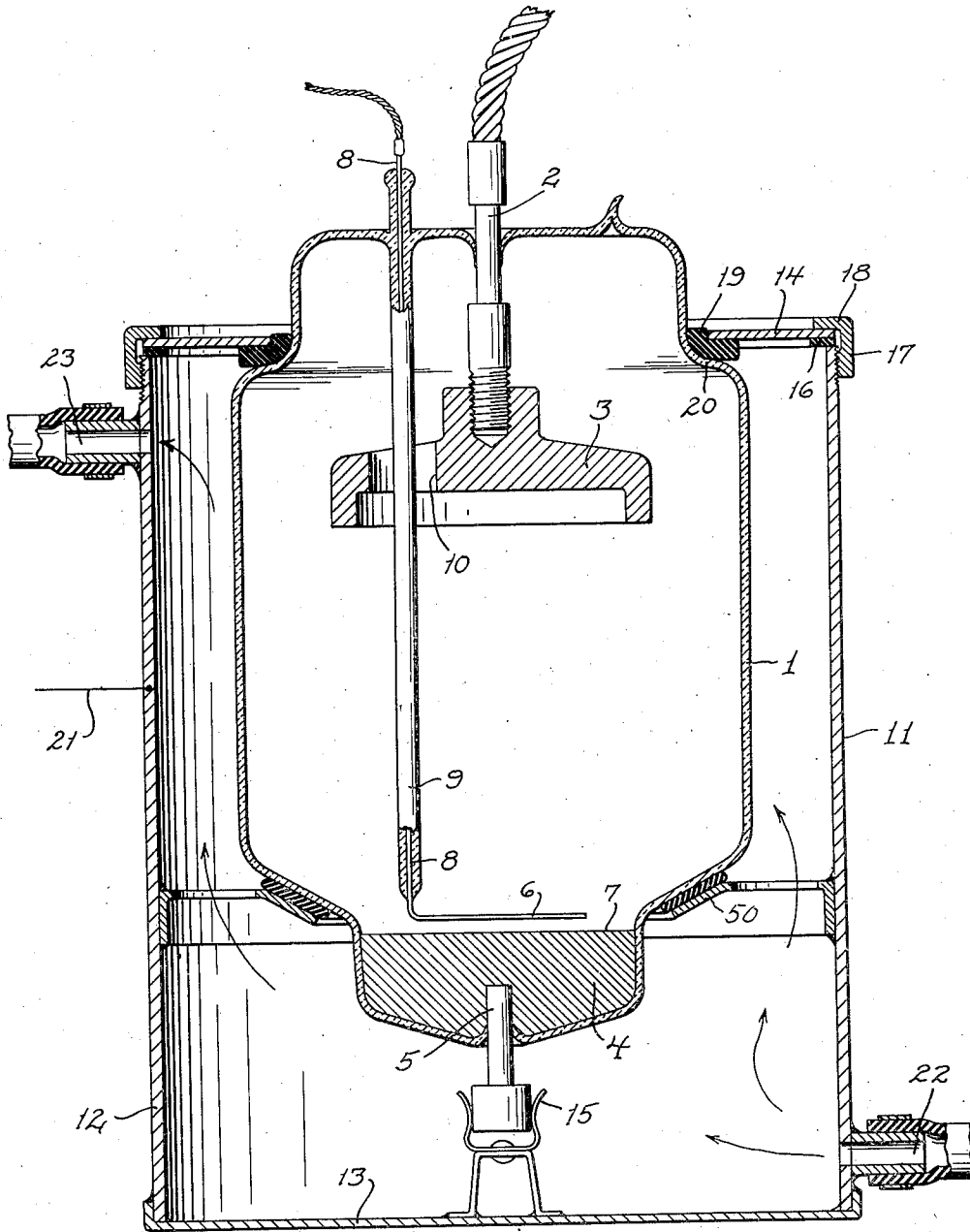


Fig. 1

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3 Sheets-Sheet 2

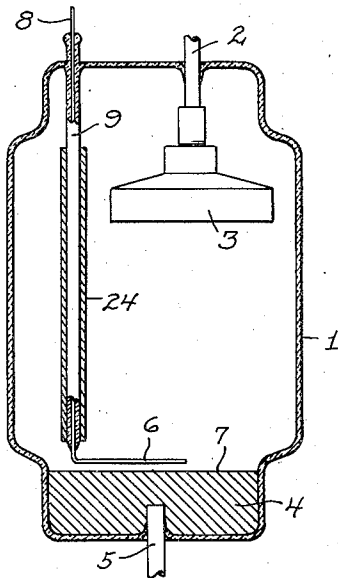


Fig. 2

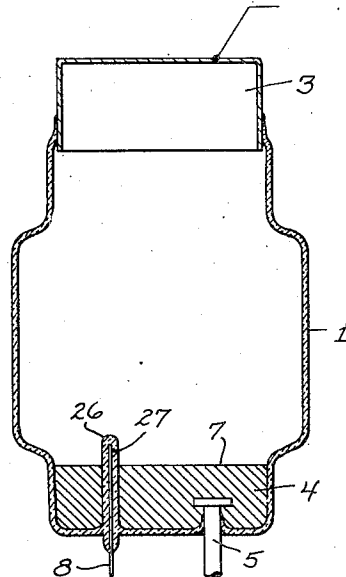


Fig. 3

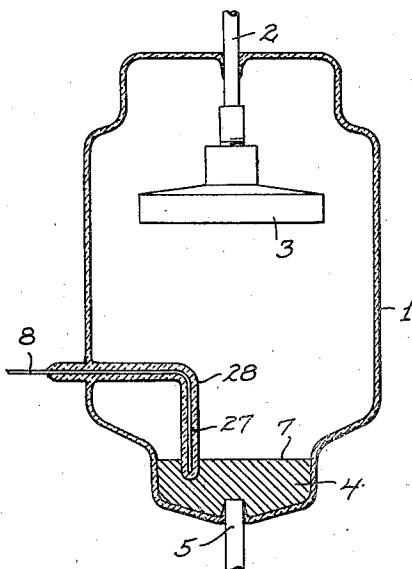


Fig. 4

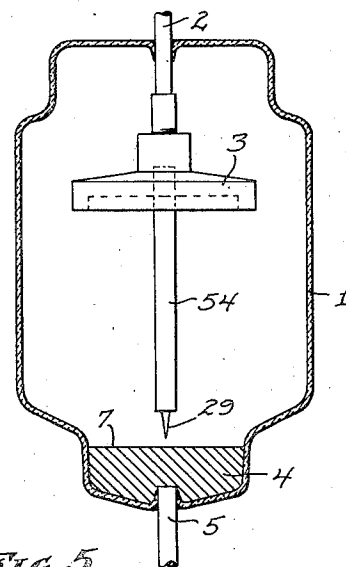


Fig. 5

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3 Sheets-Sheet 3

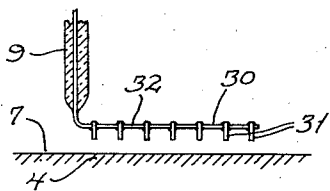


Fig. 6

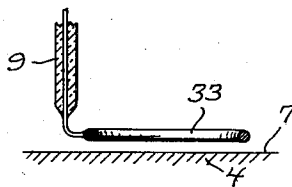


Fig. 7

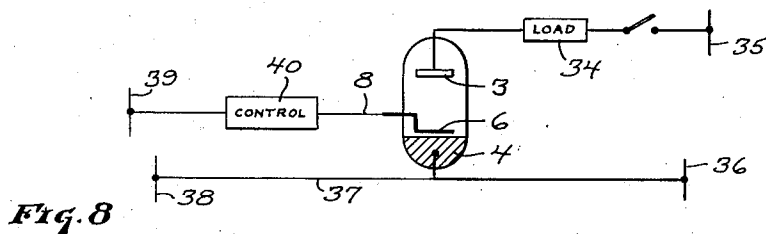


Fig. 8

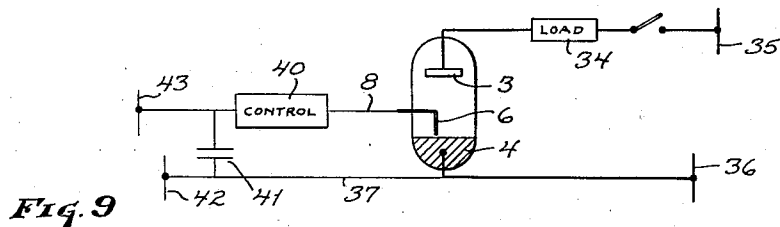


Fig. 9

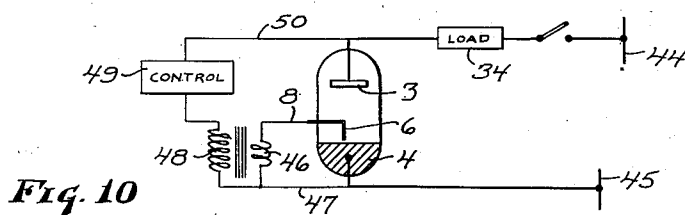


Fig. 10

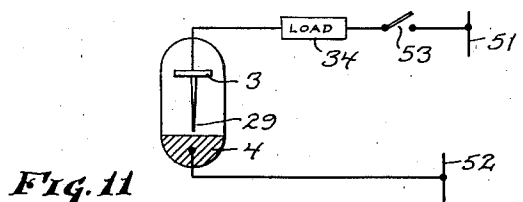


Fig. 11

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UNITED STATES PATENT OFFICE

2,354,031

SPACE DISCHARGE TUBE

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Application April 26, 1941, Serial No. 390,569

7 Claims. (Cl. 250—27.5)

This invention relates to electronic tubes of the space discharge, rectifier class; and relates more particularly to the initiation of the discharge of such tubes.

The invention has particular application to discharge tubes which comprise an anode and a vaporizable self-replenishing cathode, both contained in an envelope. Such tubes are in general well-known and the material commonly employed for the self-replenishing cathode is mercury which has led to the designation of such cathodes as "pool" cathodes.

In the practical use of such tubes, the anode and cathode are connected in a load circuit, and the discharge therebetween, that is to say, the load current flow through the tube between the anode and the cathode, is maintained by the voltage impressed upon them after the flow once starts, but in order to initiate the discharge current, some kind of starting means is provided. Likewise, if the impressed voltage on the tube is discontinued or reverses, the discharge ceases and the starting means must again be utilized to start the tube when current again is wanted in the load circuit.

When the tube is used in an alternating current load circuit and the impressed voltage therefore passes through zero value, the tube, because of its inherent rectifying property, stops passing discharge current at the zero value of the half cycle during which current flows, and must be started again and repeatedly for each half-cycle in which the polarity is in the direction to maintain discharge. When a succession of half cycles of current is wanted in the load circuit, a timing apparatus is utilized to actuate the starting means on successive half cycles synchronized with the alternations of the impressed voltage. It follows that, particularly in alternating current practice, the starting means for the tube must be considered in conjunction with the timing means.

Various starting means and devices have been proposed for such tubes.

In one well-known type, the cathode is a pool of mercury; and a starting element in the form of a high resistance pencil is mounted in the envelope and has its end projected into or passing upwardly through the mercury pool; and to start the discharge, the pencil is energized by electric current conducted through the wall of the tube. This type of starter requires large amperage in the pencil to effect starting, and when, as is frequently the case in practice, it is desirable to employ a timer of the electronic tube type, the very small electronic timing current

which such timers provide, must first be amplified by an amplification apparatus with attendant expense and complication.

In another type of starter, an electrode is provided which is normally spaced from the surface of a mercury pool and, by means of a mechanism, is moved to contact with the pool and then withdrawn to draw an arc at the surface of the pool; or the mercury pool is made in two separate parts and by mechanical movement of the tube the two parts of the pool are made to contact with each other and then separated to cause an arc to be drawn therebetween. These starters have the disadvantage of the mechanical features necessary to draw the arc, and do not lend themselves readily to timed starting.

Starters have also been proposed comprising a starting electrode mounted in the tube above the surface of a mercury pool and starting is effected by impressing upon the pool and the electrode, voltage sufficient to cause a spark discharge therebetween, and to produce an electron emissive "hot spot" on the mercury, this type of starter having however the disadvantage that to effect starting the impressed voltage must be very high, so high in fact that it weakens and breaks down the insulating property of the envelope wall through which the high potential energy to the starting electrode must be conducted, as well as the disadvantage that such high potential must be developed by the timer when timing is wanted.

All such starters, and others which have been proposed, depend upon the theoretical conception that, in order to initiate the discharge, electrons must be emitted from the surface of the pool in sufficient number and velocity to effect ionization of vapor or gas in the envelope, which ionization rapidly multiplies and accelerates until the tube "breaks down" into a full discharge.

Mercury is in some respects an ideal material for the cathode of such tubes because after the discharge has started it readily vaporizes and provides the ionizable medium in which the discharge is maintained, and because it readily condenses again and flows back to the pool to constantly replenish it; but the use of mercury as the cathode introduces disadvantages and difficulties in the initiation of the discharge both in the starting means and in the timer therefor, such as those mentioned above.

Furthermore, when a mercury pool is employed for the cathode, the starting of the discharge is, in general, unreliable and variable; that is to say, when the starter is actuated, starting does not always occur, and the starter must be actuated

again or repeatedly to effect starting; or the actual starting delays for a measurable time period after the starting energy is applied; and such irregularity can be overcome only by increasing the quantity of starting energy; and such irregular starting prohibits the use of such tubes in those fields of application in which very accurate timing of the discharge is wanted, and in which electronic timing is desirable but rendered too expensive and complicated by the necessity of amplifying the starting energy. Typical of such fields is that of electric welding in which the duration of the welding current is wanted for exactly a pre-selected number of half cycles of current and in which the value of the current is to be controlled by controlling the exact instant in each half cycle at which the discharge current begins to flow.

It has been ascertained that mercury cannot be made to give off electrons from its surface sufficient to ionize an ionizable gas or vapor in contact with the surface, except under the impulsion of a relatively great quantity of electrical energy, that is to say, mercury has a relatively high "electron affinity"; and it is believed that it is this property of mercury which renders starting of the discharge irregular as mentioned, except when a relatively great quantity of energy is utilized, because with a mercury pool cathode tube, it has been demonstrated that starting of the discharge is caused by the emission of electrons from the pool surface of sufficient velocity and quantity to ionize the vapor near the pool surface, as will be referred to hereinafter.

I have discovered, however, that if a suitable material which has the property of emitting electrons under the impulsion of a relatively small quantity of energy be incorporated in or dissolved in the mercury to make of it an alloy or amalgam, the quantity of energy required to cause the emission of electrons therefrom is less than can be accounted for by the emission characteristics of the components of the alloy; and that if such an alloy be used as the cathode of a discharge tube, the discharge of the tube can be started by the application of a quantity of energy less than the minimum required to effect ionization of the gas or vapor in the tube envelope by the emission of electrons from the alloy, and that starting may therefore be effected by a quantity of starting energy so small that unamplified electronic timing current is ample for the purpose; and that a striking improvement is made in the reliability of starting of the tube and in the accuracy of the timing of the starting.

I have found that such an alloy which for practical reasons adapts itself to use as the cathode of a discharge tube, is made by dissolving pure barium metal in mercury, although other metals may be used as will be referred to.

It is among the objects of the present invention:

To provide generally an improved electronic tube of the space discharge type;

To provide a space discharge tube having an improved self-replenishing cathode;

To provide a space discharge tube having improved starting characteristics;

To provide an improved self-replenishing cathode for space discharge tubes;

To provide an improved starter for space discharge tubes of the self-replenishing type;

To provide a space discharge tube having associated therewith improved means for cooling the same.

Other objects will be apparent to those skilled in the art to which my invention appertains.

My invention is fully disclosed in the following description taken in connection with the accompanying drawings in which,

Fig. 1 is a longitudinal sectional view of a tube embodying my invention in one form and showing means for cooling the same by the flow thereover of a cooling medium such as water or oil;

Figs. 2, 3, 4, and 5 are views illustrating modifications of the tube proper of Fig. 1, showing particularly modifications of a starter electrode and the disposition of the same shown in Fig. 1;

Figs. 6 and 7 are views showing other modifications of the starter electrode;

Figs. 8, 9, 10, and 11 are diagrammatic views illustrating examples of starting circuits for the tubes of the other figures which I may employ.

This invention may be embodied in various forms of tubes a few of which have been illustrated and will now be briefly described.

Referring to Fig. 1 I have shown at 1 the envelope of the tube which may as usual in such tubes be made of glass. An anode conductor 2 is sealed through the upper end of the tube and supports in the tube an anode 3. In a lower portion of the tube is the cathode 4. A cathode conductor 5 is sealed through the wall of the tube and contacts with the cathode. A starter electrode 6, spaced a few millimeters from the surface 7 of the cathode, is connected to a lead in wire 8 sealed in a glass tube 9 which in turn is sealed through the upper wall of the tube. In this particular form, the tube 9 passes through a perforation 10 in the anode.

The tube of Fig. 1 is arranged to be cooled by liquid such as water and to this end is enclosed in an upwardly open, cup form jacket, shown generally at 11. The jacket 11 is preferably formed from metal and comprises a side wall 12 and a bottom wall 13, which may be integral, and a cover wall 14. On the inner side of the bottom wall 13 is a metal receptacle or spring clip 15 into which the lower end of the anode connector 5 may be inserted when the tube as a whole is inserted downwardly into the jacket 11. The cover 14 is placed upon the upper end of the wall 12 and sealed thereon by a gasket or other seal 16, the cover 14 being secured in place and a pressure seal effected by an internally threaded nut element 17, threaded on the upper end of the wall 12 and having a flange 18 overlapping the cover 14. The upper end portion of the tube may project outwardly through a perforation 19 in the cover 14 and a gasket 19 may be placed between the cover 14 and a shoulder 20 on the envelope 1 to seal the jacket 11 at this point and to support the tube in upright position. The tube is supported by a bracket 50 connected to the wall of the jacket.

The starter electrode lead wire 8 and the anode connector 2 are by this construction accessible externally of the jacket 11, and connection to the cathode may be made directly to the jacket 11, for example by a wire shown diagrammatically at 21.

A conduit nipple 22 communicates with the interior of the jacket 11 at a lower portion thereof, and a nipple 23 communicates with the jacket interior at an upper portion, and conduits connected to these nipples may conduct cooling liquid such as water or oil through the jacket to conduct heat away from the envelope 1 for well-known purposes, the liquid preferably flowing in at the nipple 22 and out at the nipple 23.

By bringing the starter lead-in wire 8 and the anode conductor 2 out of the upper end of the tube, and by causing the upper end of the tube to project out of the cooling liquid, all necessity of insulating the wire and conductor from the liquid is obviated; and also the upper end of the tube, not being directly cooled by the cooling liquid, operates at a temperature at which mercury vapor from the pool will not condense thereon and tend to short circuit the anode conductor and starter lead-in wire; nor run down over the glass tube 9 and short circuit the starting electrode to the pool and prematurely or accidentally start the tube, or interfere with accurate starting as will become apparent.

The cathode 4 is, in this particular embodiment, a mixture or amalgam or alloy of mercury and barium. The improved operating characteristics to be more fully described will be present with cathodes of various ratios of mercury and barium and with the proportion of barium as small as .005% by weight, but I prefer to employ about .1% of barium. And I have found that the characteristics of the tube can better be predetermined if the barium when incorporated in the mercury is in uncontaminated pure metal form, and to this end I prefer to take precautions in the process of mixing the two components, and to this end I prefer to proceed as follows.

I first put into the cathode portion of the envelope the preselected quantity of metallic barium in a pure unoxidized uncontaminated condition, and then I sealedly connect the envelope to an exhaust pump, and by means of the pump and the known processes of baking and bombarding, I produce in the envelope a hard vacuum.

I then boil mercury connected to the exhausting system and distill over into the tube the quantity of mercury selected, condensing the same into a pool at the cathode end of the tube. The barium metal at this time floats on the surface of the mercury. I then impress upon the anode 3 and cathode 4 electric potential; and I impress a suitable potential between the starting electrode 6 and the cathode 4 to be referred to and thereby start discharge through the tube between the anode and cathode. The discharge heats or boils the mercury and the barium dissolves or amalgamates with the mercury. The exhaust pump is preferably again operated to draw off any oxide or hydroxide of barium which may be present or produced by the boiling of the alloy.

As an alternative mode of introducing the alloy into the tube, mercury and barium may be mixed and heated or boiled, externally of the tube, and distilled over into it.

The tube may be sealed off from the exhaust at a pressure in the envelope such as is commonly employed for pool discharge tubes; or an ionizable gas such as argon may be introduced into the tube at a suitable pressure if desired, but inasmuch as the mercury and barium of the cathode vaporize into the envelope in operation, other gas or vapor is not usually necessary.

The anode 3 may be of usual material for such anodes but is preferably of course one which does not amalgamate with mercury vapor.

The starting electrode 6 in the form of Fig. 1 is a bare wire in that portion projecting out of the sealing tube 9, and it may be of any suitable material such as graphited iron, tungsten, platinum, etc. providing that it does not amalgamate with the mercury. The tube when in operation and filled with mercury vapor, condenses the

vapor on the walls of the envelope, and vapor likewise condenses on the sealing tube 9, and since potential is imposed upon the starter electrode 6 and the cathode 4, there would be a tendency for such potential to be short-circuited through a layer of condensed mercury on the tube 9 and the envelope wall, and it is for this reason that the tube 9 is disposed in close proximity to the anode 3. The anode 3 in operation becomes hot and heats the tube 9 preventing the condensation of vapor thereon in portions thereof adjacent the anode. Obviously the tube 9 could be disposed adjacent to the periphery of the anode 3 instead of passing through it, to the same end, as shown in the modification of Fig. 2.

On the other hand, if, with the arrangement of Fig. 2 the tube 9 is not kept hot enough by the anode 3 to prevent the condensation of mercury and barium thereon, the tube 9 may have thereon a layer or sleeve 24 of material which will not become wetted by the mercury vapor, or which will prevent the glass tube from condensing mercury thereon, one such material being commercial "Alsimag."

Again, as shown in Fig. 3, the starting electrode 25 may be entirely enclosed in a glass tube 26, extending upwardly through and to a point above the surface 7 of the cathode; or as in the modification of Fig. 4 the starting electrode 27 may be entirely enclosed in a tube 28, and the wire 8 may be led into the side wall of the envelope and the end of the tube 28 with the electrode 27 therein may be projected into the pool cathode 4.

As a further modification, the form of Fig. 5 may be employed in which the starting electrode 29 is electrically connected to and depends from the anode 3.

In Fig. 6 is shown a starting electrode 20 similar to the electrode 6 of Fig. 1 but provided with a plurality of depending points or teeth 31 the lower ends of which are spaced from the surface 7 of the pool 4, and these may conveniently be provided by spot welding vertically disposed short pieces of wire to a horizontal support 32; and in Fig. 7 is shown a starting electrode 33 in the form of a loop.

To start the main discharge through the tube, potential, to be more particularly referred to, is impressed between the starting electrode and the alloy pool, and this may be done by any suitable circuit arrangement, those illustrated diagrammatically in Figs. 8, 9, and 10 being suitable for any of the electrode arrangements of Figs. 1, 2, 3, 4, 6, and 7, and the circuit of Fig. 11 being particularly directed to the electrode form of Fig. 5.

Referring to Fig. 8, the anode 3 and cathode 4 are connected in series with a load 34 and connected to supply mains 35 and 36. The circuit for the starter 6 comprises a wire 37 connected to the cathode 4 from a supply main 38, and a wire 8 connected to the other supply main 39 through a "control" 40, which control may be any suitable means for closing the circuit at the time or instant at which it is desired to start the discharge.

The supply mains 35—36 and 38—39 may be energized with alternating or direct current.

In Fig. 9 an arrangement similar to that of Fig. 8 is provided except that a condenser 41 is provided which, prior to the time of starting, is charged from mains 42 and 43, and the "control" apparatus at the time of starting closes the circuit to the electrode 6 to discharge the condenser thereto.

The circuit of Fig. 10 is more suitable to an alternating current system. Alternating current mains 44 and 45 supply the main tube voltage. The starting electrode 6 is connected to the secondary 46 of a transformer the other side of the secondary being connected by wire 47 to the cathode 4. The primary 48 of the transformer is connected to the wire 47 and to a control 49 and thence by wire 50 to the anode 3. By means of the transformer, the line potential is transformed to that suitable for the starting electrode 6, and by means of the control 49 the electrode 6 may be energized or have potential impressed thereon at the desired instant in the half wave of the alternating voltage impressed upon the anode and cathode; and accordingly the control 49 may be any known form of electronic or other accurate timer.

In Fig. 11 in which the tube would be used to rectify current in a load 34 from alternating current mains 51 and 52, the tube will start whenever the line switch 53 is closed, the main line potential on the anode 3 and cathode 4 being impressed between the starting electrode 29 and the cathode 4, and in this connection, with reference to Fig. 5, the main body 54 of the starting electrode connected to the anode 3 is preferably made of high resistance material to prevent any substantial current from flowing therethrough.

Coming now to the improved characteristics of the tube as compared with prior tubes, a number of important features have been observed which will now be considered.

With a mercury and barium alloy pool as described, and with the starting electrode spaced a few millimeters, such for example as three millimeters, from the surface of the mercury, instantaneous starting will invariably occur when a potential as low as 30 to 100 volts is impressed upon the starting electrode and the pool. As compared with this, using a pool of pure mercury and with all other conditions identical, the tube will not start even with an impressed voltage as high as 30,000 volts.

Again, the quantity of energy required to start the tube with the mercury and barium pool is so small as to be immeasurable in a practical sense. If, experimentally, the voltage impressed upon the starting electrode and cathode be gradually raised from zero, while a potential of say 110 volts is impressed upon the anode and cathode, and if an ammeter calibrated to measure tenths of micro-amperes be connected in series with the starting electrode, then when the starting voltage has been raised to the point at which the tube main discharge starts, which as stated may be a starting electrode voltage of 30 to 100 volts, the current in the starting circuit will be so small as to give no indication on the meter and is therefore less than $\frac{1}{10}$ micro-ampere.

Now the conventional theoretical concept of the initiation of discharge through a tube of this type, is predicated upon the hypothesis that electrons are emitted from the cathode in sufficient quantity and velocity to ionize the vapor adjacent the surface of the pool, but experimental evidence points to the conclusion that starting of this tube is not effected by ionization produced by electrons flowing between the starting electrode and the pool surface, but is effected by the development of a field action therebetween, and not involving the flow of electrons across the field; because the minimum voltage per centimeter in the gap between the electrode and the pool surface which will start the discharge is

less, and the flow of electrons (if any) is less, than has been found by prior authoritative researchers to be necessary to produce electrons capable of ionization.

Robert A. Millikan and others have found that the minimum voltage per centimeter at a material surface which will cause electrons to be emitted is 10^8 ; whereas in the present tube with a working gap at the starter of 3 millimeters and a starting potential at the gap of 30 volts as described the volts per centimeter is only 10^2 , which is not enough to produce electron flow.

Leonard B. Loeb has found that the minimum electron flow out of a material surface which will ionize a gas or vapor is approximately 1 micro-ampere; whereas in the present tube, when starting occurs on a rising electrode potential, no electron flow is detectable on a $\frac{1}{10}$ micro-ampere meter.

It follows that with the present tube, the minimum starting voltage per centimeter of gap is so low that the flow of electrons is precluded, and that starting is effected not by ionization produced by the starter; and that the starting voltage could be raised considerably above the minimum value before any ionizing flow of electrons would occur.

As further and practical evidence that the tube embodying my invention effects starting of the main discharge by a phenomenon or principle different from that of effecting initial ionization by electron flow in the space between the starting electrode and the pool surface, starting of the tube can readily be effected with the modification forms of Figs. 3 and 4 with the starting electrode enclosed in a glass tube and when the glass walls of the tubes 26 and 28 of Figs. 3 and 4 have a thickness of $\frac{1}{4}$ " at which thickness the low starting voltage used is too small to cause a flow of electrons through the glass wall sufficient to ionize vapor in the tube.

And again, I have found experimentally that the tube discharge can be started by the influence of a spark coil of the small commercial size used for leakage testing, sometimes known as a Tesla coil, operating at a distance of two feet from the tube, and without any electrical connection with the starting electrode or pool.

While as shown, the present tube using a pool of mercury and barium as described has minimum starting quantitative conditions which preclude the possibility that starting is effected by ionization by the starter, there is experimental evidence to show that a like tube having a pure mercury pool does start by a starter effected ionization. As stated above the present tube with a pure mercury pool requires an impressed voltage of greater than 30,000 volts to start it. This, for a 3 millimeter starting gap is greater than the 10^8 volt per centimeter which Millikan found produced electron flow, and consequently considerable electron emission is present at the time of starting.

It has been determined by other researchers that the electron affinity of mercury may be taken at 1.79 volts, and that of barium at .1 volt approximately (different for different authorities). A comparison between the minimum starting voltage of the tube using a pool of pure mercury, and the same tube with a pool of mercury and barium, with a low percentage of barium such as .1%, shows such an enormous reduction of the minimum starting voltage for the alloy pool, that it cannot be accounted for by any comparative quantitative application of the electron affinity theory which involves ionizing emission of electrons.

And conversely, the enormously greater energy required to start with the pool of pure mercury, leads inevitably to the conclusion that the pure mercury pool starts by ionization produced by the starter. The starting phenomena for the two pools, as the experimental evidence and physical data show, are different, and the principles of starting are different in consequence, the pure mercury pool starting by starter-effected ionization, and the alloy pool without ionization.

I have mentioned above the advantage of low starting voltage. Other advantages may be mentioned. For a discharge tube of given dimensions and impressed anode and cathode potential, the voltage drop through the tube with a pure mercury pool will be approximately eight volts whereas with a mercury and barium alloy pool the voltage drop is only five to six volts; and starting is instantaneous, that is to say, there is no substantial lag between the instant of impressing the starting potential on the starting electrode, and the instant at which the main discharge starts; and starting is invariable, that is to say, it never fails; and starting occurs alike in different cases whether the discharge current flowing upon starting is large or whether it is exceedingly small; and the discharge never dies out or ceases if the discharge current is reduced by changing the external load resistance, or by reducing the impressed anode to cathode potential, through an operative range.

The exceedingly small quantity of energy required to start the discharge is evidently due to the presence of barium in the mercury pool but the proportion of barium is not critical. In general the greater the proportion of barium the lower the minimum starting voltage on the starting electrode; and the optimum proportion of barium would probably be the maximum proportion at which vaporization, condensation, and continuous replenishment of the cathode would continue to occur; but since with a small proportion of barium such as .1%, the minimum starting voltage is so low, no practical gain is attained by employing a greater proportion of barium.

I have found that the above-described advantages may be more completely developed in the tube of my invention when the polarity of the potential on the starting electrode is positive with respect to the cathode, when the anode is positive with respect to the cathode.

I have mentioned that it is desirable to provide the mercury barium pool in pure state, uncontaminated by oxide, and this is because, as I have found, if oxide be present it tends to accumulate on the surface of the pool and raises the minimum starting potential, but even more important, renders the starting unreliable.

It is well known that barium has the property of emitting electrons when heated, and I am aware that it has been proposed to mix barium with the mercury pool of a discharge tube, to increase the flow of electrons emitted from the pool by the heat of the discharge after the discharge has been started; and I am aware that it has been proposed, theoretically, to emit electrons from a pool of mercury by the strain of an electrostatic field if of sufficiently great intensity. But so far as I am aware it has not heretofore been proposed to start the discharge flow between the anode and cathode of a pool type discharge tube, by any field action on the pool of the tube (with or without a component of barium therein), by a field strength below the value at which the pool emits ionizing electrons.

In the foregoing I have described barium as the

preferred metal to mix or dissolve with the mercury to make the alloy pool, and I have chosen this metal because it can so readily be made to dissolve in mercury in pure state; but I contemplate the use of other metals for example calcium, sodium, strontium, etc. And while for practical and economical purposes I prefer to employ any alloy cathode pool of mercury and one of such elements, I contemplate the employment of mercury and more than one of such elements.

I am not certain as to all of the metals which will, when alloyed with mercury, produce the low potential field action above described; and it would be almost a physical impossibility to experimentally determine all of them and all of their suitable combinations of one, two, or more, with mercury. Some of them I have mentioned. Therefore I here define them as "activating metals" for the purposes described above in detail for barium.

I claim:

1. A space discharge tube comprising an envelope containing an anode and a mercury pool cathode arranged to be subjected to potential, a starter comprising a starter electrode having a portion spaced from the pool surface, and means for causing a discharge between the anode and the pool cathode to start at a minimum potential impressed across the electrode and pool which is less than sufficient to effect emission of ionizing electrons from the pool said means comprising barium metal dissolved in the mercury.

2. A space discharge tube comprising an envelope containing an anode and a mercury pool cathode arranged to be subjected to potential, a starter comprising a starter electrode having a portion spaced from the pool surface, and means for causing a discharge between the anode and the pool cathode to start at a minimum potential impressed across the electrode and pool which is less than sufficient to effect emission of ionizing electrons from the pool said means comprising an activating metal dissolved in the mercury.

3. A space discharge tube comprising an envelope containing vapor at reduced pressure and an anode and a pool cathode arranged to be subjected to potential, a starting electrode having a portion spaced from the pool surface, the pool comprising mercury and one or more activating metals dissolved therein which cause starting of a discharge between the anode and the pool cathode to occur when potential is impressed across the starter portion and the pool less than sufficient to cause emission of ionizing electrons from the pool surface.

4. A space discharge tube comprising an envelope containing an anode and a mercury pool cathode arranged to be subjected to discharge producing potential; starting means comprising a starter electrode having a portion spaced from the pool surface whereby potential impressed upon the electrode and pool will cause a discharge to start between the anode and the pool cathode; and means for reducing the impressed potential necessary to effect the starting of the discharge, and for causing the discharge to start at less than electron-emissive temperature of the pool, comprising barium metal dissolved in the mercury.

5. A space discharge tube comprising an envelope containing an anode and a mercury pool cathode arranged to be subjected to discharge producing potential; starting means comprising a starter electrode having a portion spaced from

the pool surface whereby potential impressed upon the electrode and pool will cause a discharge to start between the anode and the pool cathode; and means for reducing the impressed potential necessary to effect the starting of the discharge, and for causing the discharge to start at less than electron-emissive temperature of the pool, comprising an activating metal dissolved in the mercury.

6. A space discharge tube comprising an envelope containing vapor at reduced pressure, and an anode and a pool cathode arranged to be subjected to discharge-producing potential; a starting electrode having a portion so disposed relative to the pool surface that potential impressed upon the electrode and pool will cause a discharge to start between the anode and the pool cathode; and means to reduce the impressed

potential necessary to start the discharge, comprising pool material consisting of an alloy of mercury and barium.

7. A space discharge tube comprising an envelope containing vapor at reduced pressure, and an anode and a pool cathode arranged to be subjected to discharge-producing potential; a starting electrode having a portion so disposed relative to the pool surface that potential impressed upon the electrode and pool will cause a discharge to start between the anode and the pool cathode; and means to reduce the impressed potential necessary to start the discharge, and to cause the discharge to start at less than electron-emissive temperature of the pool comprising pool material consisting of an alloy of mercury and an activating metal.

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