Aug. 20, 1935. H. EKNAYAN 2,012,239

LUMINOUS TUBE STARTING DEVICE

Filed March 6, 1933 2 Sheets-Sheet 1

FIG. 1.

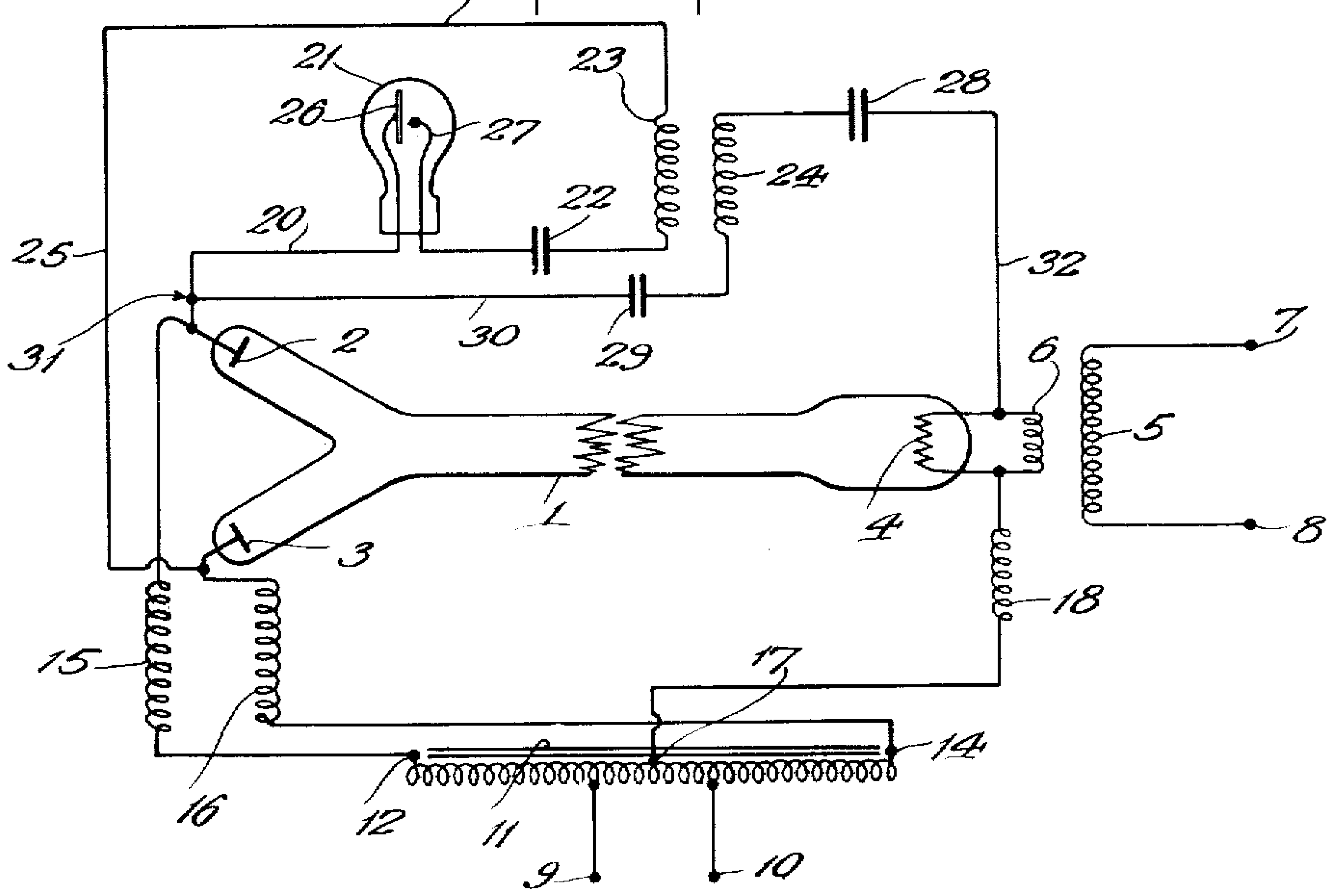

FIG. 2.

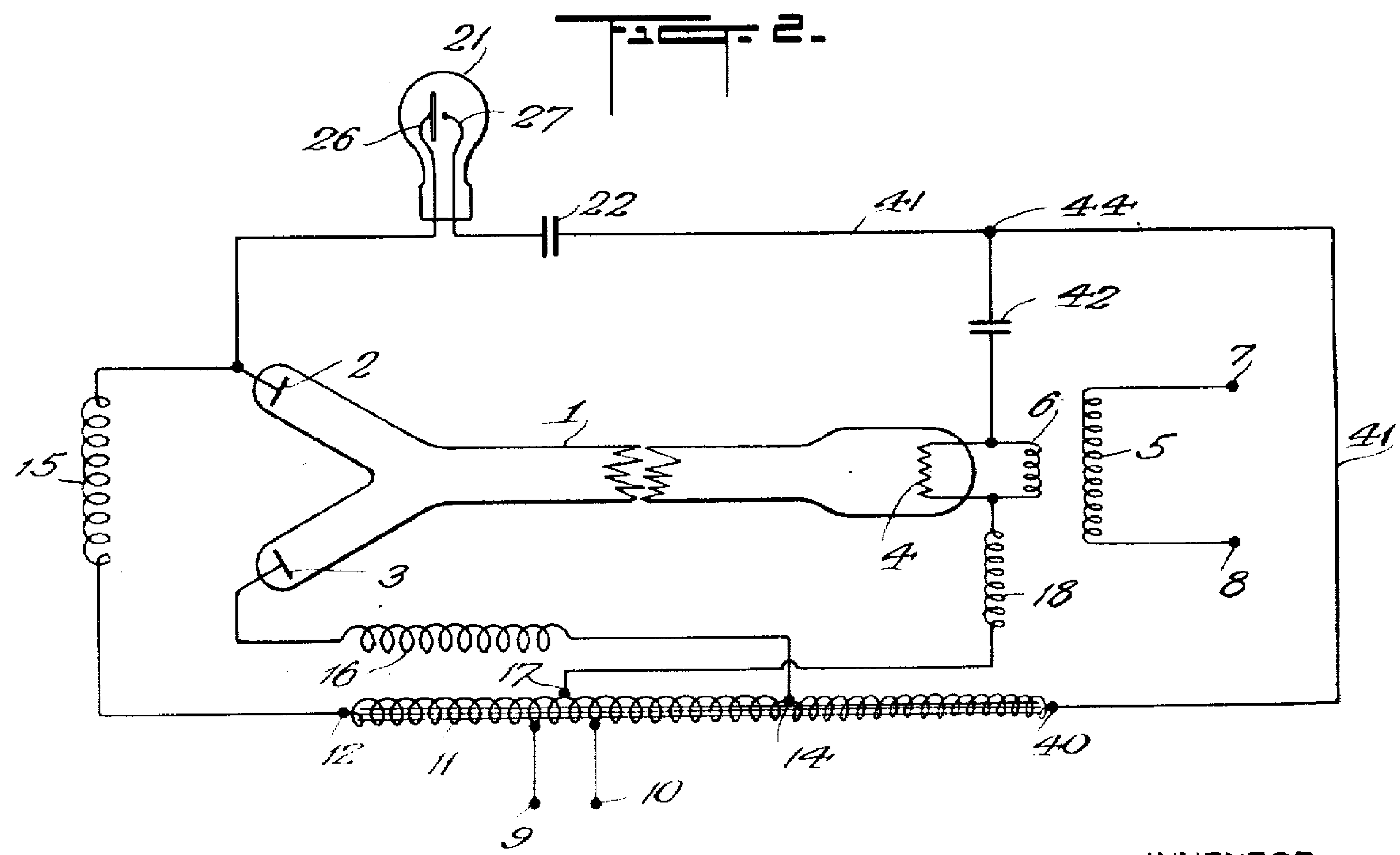

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FIG. 3.

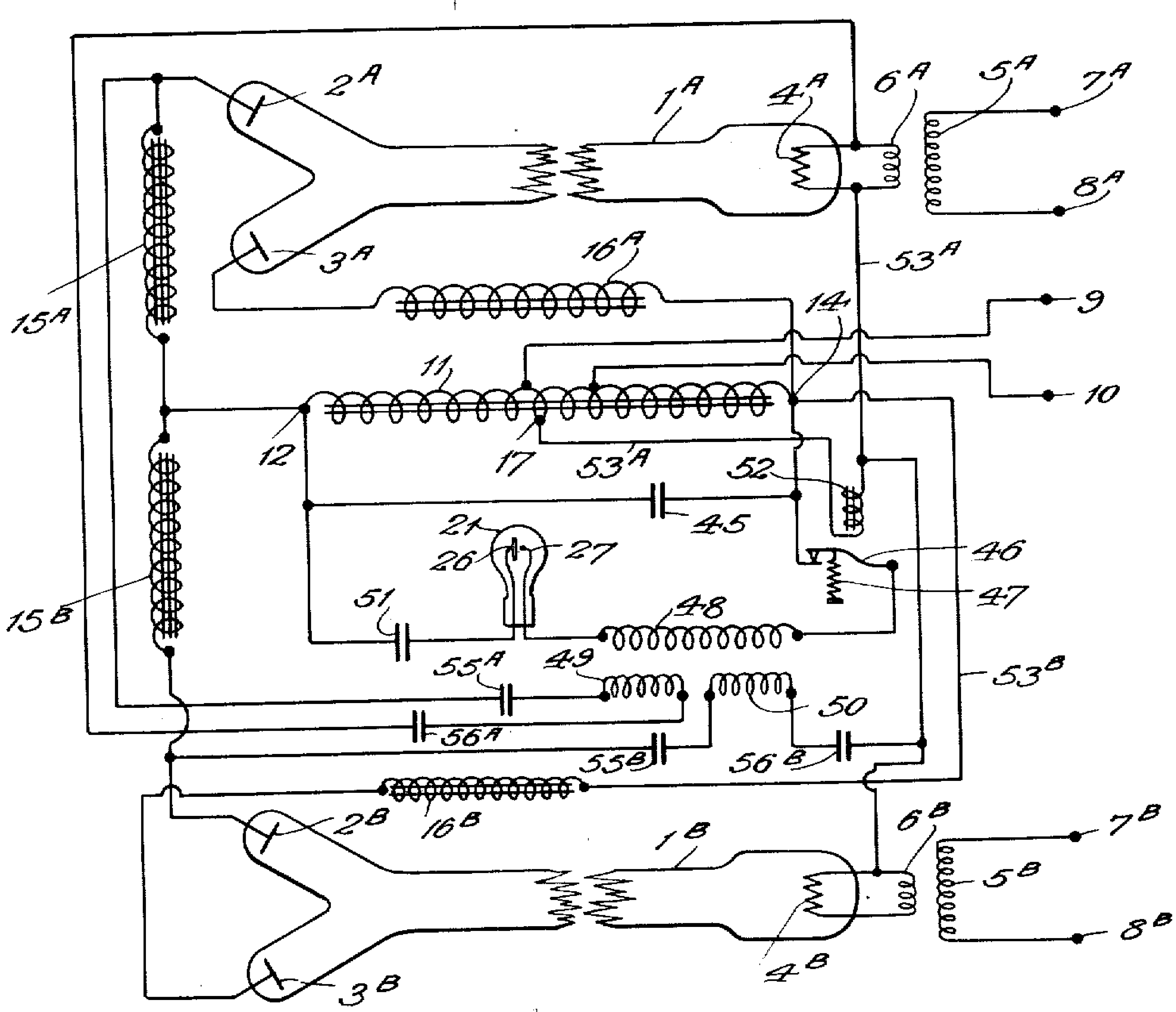
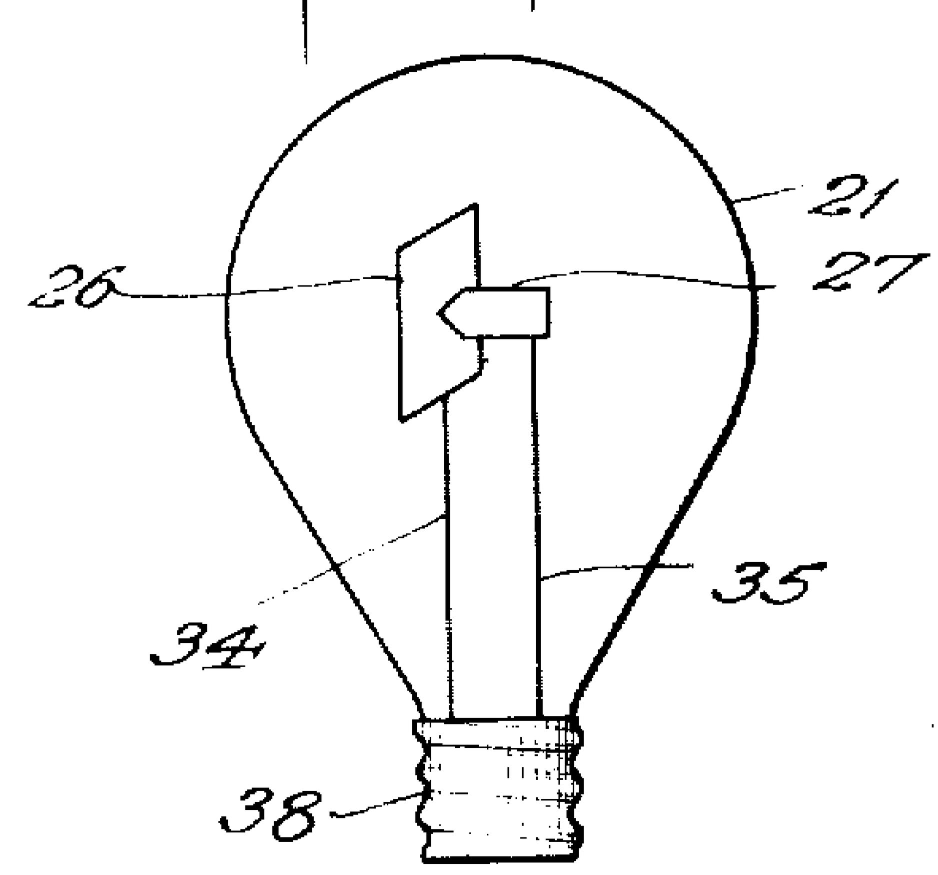


FIG. 4.



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UNITED STATES PATENT OFFICE

2,012,239

LUMINOUS TUBE STARTING DEVICE

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Application March 6, 1933, Serial No. 659,803

2 Claims. (Cl. 176—124)

This invention relates to luminous tubes having a suitable gas and/or vapor filling capable of operation at commercially available potentials of the order of 100–230 volts. According to well known theory the luminosity of such tubes depends upon the splitting up of the atoms or molecular of the gas and/or vapor present in the tube into ions and electrons under the influence of suitable applied electric energy (a process termed ionization) and it is believed that radiation of light is caused either by this splitting up or icnization process or by the recombination of electrons and ions to form or regenerate molecules or atoms. This theory explains the observed phenomenon that a gas or vapor can be made to radiate light when it is subjected to a suitable difference of electric potential applied to electrodes capable of transmitting energy to the said gas or vapor, or both. The ions and electrons of the gas and/or vapor thus activated act as conductors of electricity and the passage of electricity through the gas and/or vapor is known as a discharge.

Expressed in simple terms ions are, according to prevalent theory, atoms from which one or more electrons have been dislodged. An atom contains equally balanced quanta of positive and negative electrical charges, the latter being electrons. Consequently when an electron is dislodged from an atom the latter is no longer a neutral particle in electrical balance, but contains an excess of positive over negative electrical charges. It is therefore positively charged and is known as an ion. The discharge or passage of an electric current through a gas comprises the movement of the positive ions toward the cathode and the electrons; the negative particles toward the anode.

This explains the fact that no discharge will occur until the gas becomes conductive by ionizaticn.

My invention relates to positive column luminous tubes operating at voltages well below 1000 volts and includes tubes which will satisfactorily operate at voltages of the order of magnitude ccmmonly obtained from commercial supply lines, e. g. 90–230 volts.

One of the objects of my invention is the provision of a method and means of ionizing a gas to facilitate the positive column discharge of electrical current thrcugh the gas at low potential.

Once the positive column discharge has been initiated and the tube emits its characteristic light there is no longer need for the application of ionizing energy and such continued application would represent a waste and inefficiency inconsistent with commercial success. The present invention provides a novel means of discontinuing the application of the ionizing means and thereby accomplishing the desired result with a minimum expenditure of energy.

The invention further provides means of accomplishing its objects in an apparatus substantially free from complicated structure.

This invention may be employed in conjunction with the inventions disclosed in my copending application entitled "Luminous tube and circuit", Ser. No. 659,802 and in the copending application of Leo L. Beck entitled "Luminous tube", Ser. No. 659,800 both filed on even date herewith.

Other objects and advantages will appear hereinafter.

In the accompanying drawings are shown certain luminous tubes and circuits therefor embodying my invention. It is intended and will be understood that the invention is illustrated and not limited by these illustrations.

Fig. 1 shows a luminous tube having auxiliary starting means in a circuit the potential of which drops below a predetermined potential as soon as the luminous tube "strikes" or starts to operate, thereby rendering inoperative the starting means after the luminous tube has been put into operation.

Fig. 2 shows a luminous tube having auxiliary starting means in another form of starting circuit.

Fig. 3 shows a tube circuit in which the starting means is in a circuit the potential of which remains above a predetermined potential. The discontinuance of the ionizing means is in this case effected by a switch automatically, as will be more fully hereinafter explained.

Fig. 4 is an enlarged view of the auxiliary tube used to ionize the gas in the principal or luminous tube.

Referring now to Fig. 1, the tube 1 contains a rare gas with or without a substance capable of vaporizing by the heat generated upon discharge of current through the gas, e. g. mercury. Discharge occurs during operation of the tube alternately from each of the anodes 2 and 3 to the cathode 4 which is a thermionic activated cathode operating at a high thermo-emissive temperature. Cathode 4 is heated by current from a transformer having a primary coil 5 and secondary coil 6, the former being supplied with current from terminals 7 and 8 of a 110 volt A. C. supply. Current to operate the tube 1 is supplied from terminals 9 and 10 of a 110 or 220 volt alternating supply circuit. This voltage is stepped up to 440 volts (or any other desired voltage) by autotransformer 11 from the terminals 12 and 14 of which alternating current is supplied to anodes 2 and 3 through limiting resistances or ballasts 15 and 16 respectively. From the cathode 4 there is a connection to the midpoint 17 of the autotransformer through choke coil 18. Tube 1 is therefore a rectifying or double anode tube. The open circuit potential from each of the anodes 2 and 3 to the midpoint 17 of the autotransformer may be about 220 volts.

In connection with tube 1, I provide a starting circuit shunted across the anodes 2 and 3. Tracing this circuit, it comprises the wire 20, the tube 21, the 0.1 microfarad condenser 22, the primary 23 of a radio frequency transformer (having secondary coil 24) and wire 25. The tube 21 (shown in greater detail in Fig. 4) contains electrodes 26 and 27 in series and will be described hereinafter in greater detail. Secondary coil 24 is in series with anode 2, as shown, and cathode 4 through condensers 28 and 29, each having a capacity of 0.001 to 0.002 mircrofarad. Tracing the circuit containing secondary coil 24, it comprises coil 24, condenser 29, wire 30 (connected to wire 20 at the point 31), the column of gas in the tube 1, the cathode 4, wire 32 and condenser 28.

The purpose of the tube 21 is to assist in generating a high frequency oscillation or discharge between the anode 2 and cathode 4 to ionize the gas filling in tube 1 and render it conductive; and tube 21 is so constructed that this high frequency discharge ceases as soon as the principal or positive column luminous discharge takes place between cathode 4 and anodes 2 and 3 respectively.

Furthermore I have found that by controlling the pressure and nature of the gas in the tube 21 and other variables as hereinafter shown I can control not only the potential at which discharge occurs through the tube 21 but also the frequency of that discharge in a high frequency circuit. For example by having electrodes 26 and 27 spaced about 0.125 inch apart in tube 21 in which the filling is argon at a pressure of 30 to 60 millimeters, the minimum breakdown voltage of the gas filling is about 350 to 400 volts, and the frequency of the discharge created in the primary circuit comprising tube 21 and secondary circuit comprising coil 24 is of the order of 10,000 to 20,000 cycles per second. Frequency of this order of magnitude is effective as an ionizing medium. I take advantage of the minimum breakdown voltage of the tube 21 in a manner which will appear from the following description of the operation of the tube.

First cathode 4 is brought to an emissive temperature by applying heating current from transformer 5—6. Then a potential of about 440 volts is applied across the anodes 2 and 3 from terminals 12 and 14 of the autotransformer 11. The potential difference in the shunt circuit comprising tube 21 is therefore about 440 and discharge of the spark type occurs between electrodes 26 and 27 setting up a high frequency oscillation. A similar high frequency oscillation is then induced in the circuit containing coil 24, anode 2 and cathode 4, and the column of gas in the tube and the latter becomes ionized. Thereupon a positive column arc discharge occurs between cathode 4 and anodes 2 and 3 respectively. Thereupon the voltage between anodes 2 and 3 falls spontaneously from about 440 to about 340 volts due to the existence of the positive column discharge in tube 1. Consequently the voltage in the shunt across anodes 2 and 3 likewise falls to the same value and tube 21 becomes inoperative as a high frequency oscillator. Due to the peculiar nature of tube 21 it requires from about 350 to 440 volts to operate as a high frequency oscillator. Below 350 volts tube 21 may "go out", i. e. cease to operate at all or operate as a glow lamp, but in either case it ceases below about 350 volts to generate high frequency oscillations. The positive column discharge in the tube 1 continues. Tube 21 therefore functions as an automatic switch or valve controlling the application of high frequency ionizing discharge to tube 1.

I will now proceed to describe the structure and principles of tube 21 in greater detail, reference being had for this purpose to Fig. 4.

The numeral 21 designates the tube generally as well as the envelope, which may be made of any suitable or preferred material. The electrode 26 may be a plate or disk of aluminum separated about 0.125 inch from the pointed end of electrode 27, likewise made of aluminum. The latter as shown is a slug of metal with a pointed end directed at the electrode 26. Electrode 26 is mounted on stem 34 and electrode 27 is mounted on stem 35, the stems being connected to the screw base 33 in known manner. By having in tube 21 a filling of argon at a pressure of 30 to 60 millimeters with the electrodes 0.125 inch apart, the minimum potential at which the tube 21 operates as a high frequency oscillator is about 350 volts. I can vary this critical voltage by varying the nature and/or pressure of the gas and the distance between the electrodes. Increasing the pressure and/or the distance between the electrodes increases the critical voltage and, conversely, decreasing the pressure and/or decreasing the distance between the electrodes, decreases the critical voltage. Selecting and using gases having potential gradients higher than argon (e. g. neon, helium, nitrogen) increases the critical voltage and gases having potential gradients lower than argon (e. g. krypton and xenon) lowers the critical voltage. I may therefore, with this knowledge, build a tube having any desired critical or minimum operating voltage for generating high frequency oscillations and thus adapt my tube 21 to the exigencies of any particular circuit. In tube 1 the open circuit voltage between cathode 4 and respective anodes 2 and 3 may be about 220 volts. The open circuit voltage between anodes 2 and 3 is therefore about 440. This voltage drops to about 340 when the positive column discharge occurs between cathode 4 and anodes 2 and 3. In this particular case, I therefore adjust the critical voltage of tube 21 in the manner indicated at 350 volts. If the voltage existing between anodes 2 and 3 during operation of tube 1 were necessarily greater (as for example by reason of an elongation of tube 1) let us say for example 510 volts, then I would in accordance with the teachings herein contained construct tube 21 to have a critical voltage of about 520 volts. By critical or minimum operating voltage I mean the voltage below which tube 21 becomes inoperative.

Fig. 2 differs from Fig. 1 in part, in that the tube 21 is shunted across one of the anodes and the thermionic cathode instead of across the anodes.

Referring to Fig. 2, the current for supplying positive column discharge between cathode 4 and anodes 2 and 3 respectively is supplied in a manner similar to that shown in connection with Fig. 1, like numerals being used to designate like parts in so far as possible. Tube 21 has a breakdown potential of about 440 volts and a minimum operating or critical potential of about 350 volts and becomes inoperative as a high frequency oscillator below 350 volts. I therefore arrange tube 21 in a circuit which, prior to the initiation of a positive column discharge through tube 1, has a potential above 350 volts. To get the necessary voltage to render tube 21 operative I provide an extension 40 of autotransformer 11. I then arrange two parallel circuits. One of these includes extension 40, wire 41, 0.05 microfarad condenser 42, coil 6 and choke coil 18. The other circuit in parallel with the first named circuit includes 0.05 microfarad condenser 22, tube 21, anode 2, the gas column in tube 1, and cathode 4. The potential difference between the points 44 and midpoint 17 is, in each of these parallel circuits, necessarily the same according to the laws of shunt circuits. Owing to the fact that the voltage necessary to cause an initial positive column discharge through tube 1 is greater than the operating voltage, the potential difference between points 44 and 17 is greater before the positive column discharge occurs than afterward. Before it occurs, the potential difference is, owing to extra winding 40, enough to break down tube 21 and start it operating, i. e. above 350 volts, e. g. from 380 to 440. This causes a high frequency oscillation in the tubes 21 and 1, ionizes the gas filling and renders it conductive. As soon however as, owing to this ionization and conductivity, a positive column discharge occurs through tube 1, the potential fall through tube 1 decreases so that the potential difference between points 44 and 17 falls below 350. Thereupon tube 21 ceases to operate to produce high frequency oscillations.

The details of operating a tube such as shown in Fig. 2 are as follows:

First thermionic cathode 4 is brought to an emissive temperature by alternating current supplied from terminals 7 and 8 through transformer 5—6. Then current is supplied to autotransformer 11 from terminals 9 and 10. This sets up high frequency oscillations in tube 21 and tube 1 and the gas in the latter is ionized. Immediately thereupon a positive column discharge occurs from terminals 12 and 14, ballasts 15 and 16, through tube 1, choke coil 18 and back to midpoint 17 of autotransformer 11 and the potential drop through tube 1 decreases to about two thirds of its open circuit or starting voltage which may be for example about 220 volts. Thereupon the voltage between points 44 and 17 likewise decreases below 350 volts, tube 21 ceases to be operative and high frequency oscillation stops. The positive column discharge in tube 1 however continues.

Whereas Figs. 1 and 2 illustrate forms of my invention according to which the tube 15 is in a circuit where the potential spontaneously drops below the critical operating potential of said tube, Fig. 3 illustrates a case where the tube, e. g. tube 15, that generates the high frequency oscillations is in a circuit where the potential does not drop sufficiently low to render the said tube thereby inoperative, and in order to discontinue the generation of high frequency current, means, as for example a switch, must be employed for this purpose.

Considering Fig. 3, the high frequency circuit comprises the 4 mocrofarad condenser 45, the switch 46 (closed by spring 47 until an arc discharge occurs through tubes 1A and 1B), the primary coil 48 of a radio frequency transformer (having secondary coils 49 and 50), tube 21 having electrodes 26 and 27, and the 0.1 microfarad condenser 51. When, as will be seen, an arc discharge occurs through tubes 1A and 1B, the solenoid 52 becomes energized and opens switch 46 thereby opening the high frequency circuit and discontinuing the application of ionizing or starting energy to the tubes 1A and 1B.

I will now describe the other parts of the circuit shown in Fig. 3.

Autotransformer 11 receives current from the 110 or 220 volt supply terminals 9 and 10 and steps up the voltage to about 440 or other desired voltage depending on the potential fall through tubes 1A and 1B as determined by the dimensions of these tubes, nature of gas filling, etc. From terminals 12 and 14 of autotransformer 11 current is applied to anodes 2A and 3A of tube 1A (containing a rare gas with or without mercury) through current limiting means 15A and 16A respectively. From cathode 4A current is led back to midpoint 17 of autotransformer 11 through solenoid 52 and wire 53A. Cathode 4A is coated with an activated thermionic substance and is arranged to be heated to an emissive temperature by current from the filamentary transformer having primary coil 5A and secondary coil 6A.

From terminals 12 and 14 of autotransformer 11 current is likewise applied to anodes 2B and 3B of tube 1B (containing a rare gas with or without mercury) through current limiting means 15B and 16B respectively; and from cathode 4B current is led back to midpoint 17 of transformer 11, through wire 53B, solenoid 52, and wire 53A. Thus it will be seen that solenoid 52 becomes energized whenever arc-discharge current passes through tubes 1A and 1B, thereby opening switch 46. Cathode 4B is coated, like cathode 4A, with a thermionic substance and is heated by current from a filamentary transformer having a primary coil 5B and secondary coil 6B.

Secondary coil 49 is in series with anode 2A and cathode 4A, as shown, of tube 1A through the two 0.002 microfarad condensers 55A and 56A; the secondary coil 50 is in series with anode 2B and cathode 4B through the two 0.002 microfarad condensers 55B and 56B.

The operation of tubes 1A and 1B and circuits thereof will now be described.

First cathodes 4A and 4B are brought to an emissive temperature by applying current to the respective transformers 5A—6A and 5B—6B. Thereafter, from supply terminals 9 and 10, a potential of about 440 volts is applied from terminals 12 and 14 of auto-transformer 11 to the high frequency tuned circuit comprising condenser 45, condenser 51, tube 21 (containing electrodes 26 and 27) and coil 48. The tube 21 contains argon at a pressure of 30 to 60 mm. and at this range of pressure the frequency of the oscillation circuit of tube 21 is controlled so that it is of the order of 10,000 to 60,000 cycles per second. Frequency of this order of magnitude is particularly effective as an ionizing agent. The high frequency discharge is simultaneously applied to both tubes 1A and 1B through the radio frequency transformer 48—49—50 and thereupon an arc discharge immediately occurs in each tube which discharge energizes solenoid 52 which in turn opens the high frequency circuit and keeps it open during continuance of the arc discharge. The arc discharge occurs in tube

1A from anodes 2A and 3A to cathode 4A connected to the midpoint 17 of transformer 11 and in like manner in tube 1B.

It will be noted that tubes 1A and 1B are connected in parallel to the same transformer 11. If one of these tubes "lighted" or "struck" prior to the other, the tube "striking" first would consume all the current and the other tube would be inoperative. It is therefore essential that in a case like the one illustrated in Fig. 3 both tubes be ionized at the same instant. This is accomplished by the radio frequency transformer having two secondary coils 49 and 50 energized from the common primary coil 48.

Considering again the tube 21, it will be noted that the specific form of preferred tube contains a gas (preferably a rare gas) at a relatively high pressure e. g. argon at a pressure of 30 to 60 millimeters as compared to the relatively low pressure of the gas in the luminous tubes. This pressure is preferably the one that corresponds to the minimum potential gradient for a given gas and a tube of given diameter and may be about 2 mm. for neon in a tube having an internal diameter of 27 mm. In the tube 21 the discharge is of the spark discharge or concentrated arc type while in the luminous tubes the discharge is of the diffuse or positive column type. Furthermore by having one of the electrodes, as 27, drawn down to a point directed at the plane surface of the other electrode the discharge is further concentrated. The object of designing and equipping tube 21 as herein disclosed is to render it particularly adapted to create high frequency oscillations of a character capable of efficiently ionizing the gas in the luminous or diffuse discharge tube.

According to my invention I use as shown in Figs. 1, 2 and 3, in combination with a luminous positive column tube of the glow-discharge or diffuse arc discharge type containing a rare gas at low pressure of the order of less than 10 millimeters, a high frequency circuit to supply ionizing energy to said luminous tube, said high frequency circuit comprising a spark-discharge or oscillator tube containing electrodes spaced apart in a gas at a pressure relatively high with respect to the pressure of the gas in the luminous tube. These electrodes may be in closely disposed spaced relation and by having the gas in the spark discharge tube at high pressure, and also, preferably, by having one of said electrodes pointed I get a discharge of the spark or concentrated arc type. These electrodes are connected in parallel with electrodes spaced apart in the luminous tube. In series with the spark-discharge tube I also prefer to insert a capacitance e. g. a condenser. Thus I provide a shunt circuit, one of the branches of the shunt containing the spark discharge or oscillator tube, the other branch containing electrodes in the luminous tube. Thus, in Fig. 1, the branch of the shunt containing the spark discharge tube comprises the wire 20, the electrodes 26 and 27 in tube 21, condenser 22, coil 23 and wire 25; and the other branch of the shunt comprises the electrodes 2 and 3 in tube 1. In Fig. 2, one branch of the shunt contains the wire 41, condenser 22, electrodes 26 and 27 in tube 21, anode 2 and cathode 4. The other branch comprises condenser 42, both branches starting at point 44 and ending at point 17.

In Fig. 3, one branch comprises ballast 15A, anodes 2A and 3A and ballast 16A; the other branch comprises condenser 51, tube 21 containing electrodes 26 and 27, coil 48 and switch 46.

In the form of the invention illustrated by Figs. 1 and 2, the potential in both branches of the shunt is dependent on the potential fall between the electrodes in the luminous tube; and in the form of my luminous tubes exemplified by tube 1 in Figs. 1 and 2 they are characterized by the fact that the potential required to create an initial discharge is greater than the potential fall in the luminous tube after discharge has occurred. Consequently the potential fall in the branch of the shunt containing my spark discharge tube is likewise decreased subsequent to the initiation of discharge in the luminous tube. I take advantage of this property and in the form of the invention described and shown in connection with Figs. 1 and 2, I construct my spark discharge tube so that it will operate (to provide high frequency oscillations) at the potential obtaining before discharge in the luminous tube, but will not operate (to produce high frequency oscillations) after discharge in the luminous tube. This I accomplish, as hereinafter described, by constructing my spark discharge tube so that it has a minimum or critical operating voltage.

According to my invention therefore I use in combination with a luminous tube of the low pressure diffuse-arc or positive column discharge type having a negative resistance characteristic (and characterized further by the fact that the potential necessary to create an initial discharge is greater than the potential during operation thereof) a means to ionize the gaseous filling to facilitate said initial discharge. This ionizing means comprises a gas-filled spark discharge or oscillator tube having a predetermined minimum or critical operating voltage. The spark discharge tube is arranged in circuit with electrodes in the luminous tube to create high frequency oscillations through the oscillator tube and luminous tube upon the application to said oscillator or spark discharge tube of a potential greater than its critical potential. The circuit referred to in which the oscillator and luminous tube are arranged has a potential which varies with variations in the potential fall in the luminous tube, this potential fall being greater than the critical voltage of the spark discharge tube prior to initiation of a positive column discharge in the luminous tube and less than said critical voltage subsequent to the initiation of said discharge in the luminous tube whereby the spark discharge tube becomes self-extinguished or inoperative as soon as a luminous discharge occurs in the luminous tube.

Having disclosed the principles of the invention and certain specific embodiments of those principles, I intend to claim the invention as broadly as permitted by the state of the art.

What I claim is:

1. In combination with a positive column luminous tube having a gaseous filling, ionizing means to facilitate the creation of an initial discharge through said tube, said ionizing means comprising the branches of a shunt circuit, one branch containing a capacity and the other branch containing an auxiliary gas discharge tube, said shunt circuit also containing circuit opening and closing means and the primary coil of a high frequency transformer the secondary coil of which is connected in series with electrodes spaced apart in said positive column tube, means to apply potential to said shunt circuit to generate high frequency oscillations therein,

means to keep said shunt circuit closed until positive column current is discharged through said luminous tube and means actuated by the current discharged through the luminous tube to open said shunt circuit.

2. In combination with a positive column luminous discharge tube, a high frequency circuit to supply ionizing energy to said luminous tube comprising a spark discharge tube containing electrodes closely disposed in a gas at high pressure and having an operating potential higher than the starting potential of said luminous tube, means to supply the spark discharge tube with operative potential and shunt connections from the electrodes of the spark discharge tube to electrodes of the luminous tube spaced apart a distance such that the potential drop between said electrodes during operation of the luminous tube is less than the potential required to operate the spark discharge tube.

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