Aug. 22, 1939. M. A. EDWARDS 2,170,446

ELECTRIC DISCHARGE APPARATUS

Filed March 22, 1938

Fig. 1.

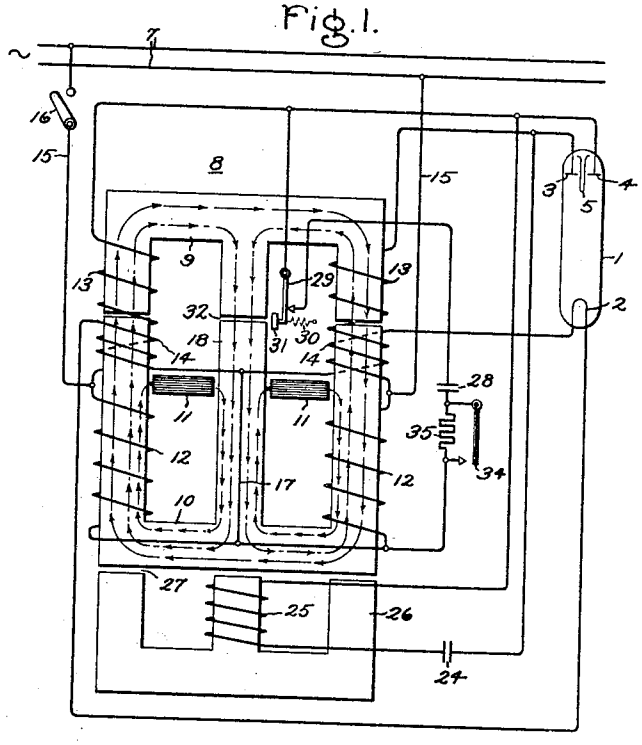


Fig. 2.

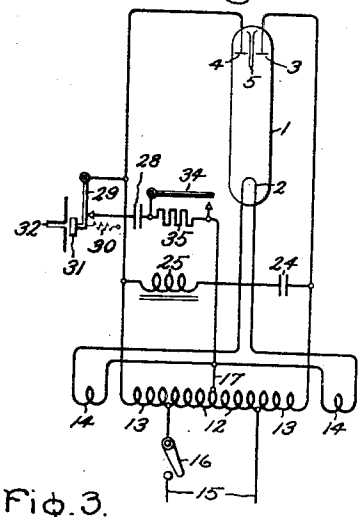


Fig. 4.

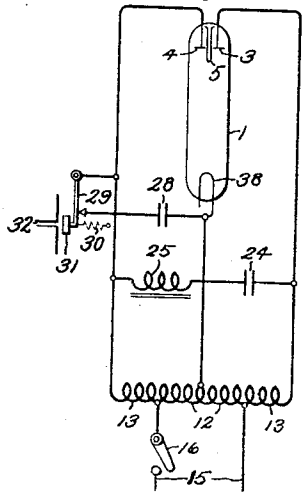
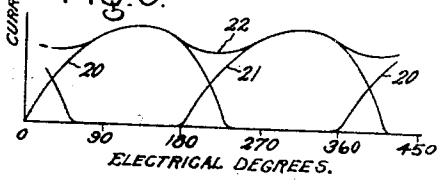


Fig. 3.



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ELECTRIC DISCHARGE APPARATUS

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10 Claims. (Cl. 176—124)

My invention relates to gaseous electric discharge devices and apparatus employed in operating the same from alternating current circuits particularly when the discharge devices are used for the purpose of giving light, namely as lamps, and when their construction is such that they require the application of a higher voltage for starting than for their subsequent operation.

One object of my invention is the provision of improved apparatus for such use which will provide the voltage necessary to cause a discharge in the device to start and after starting has occurred will reduce automatically to the value required for the continued operation of the device thereafter. Another object of my invention is the provision of improved apparatus for such use whereby the amount of flicker incidental to the circuit frequency is reduced to a low, if not imperceptible, value. A further object of my invention is the provision of such apparatus which will operate with high efficiency, will have a starting characteristic which is not injurious to the device, will provide a circuit which has a high degree of stability and one wherein the current supplied to the device is not critical to reasonable variations in the line voltage.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

Referring to the drawing, Fig. 1 is a combined circuit diagram and diagrammatic side elevation of one embodiment of my invention; Fig. 2 is a simplified circuit diagram of the apparatus shown in Fig. 1; Fig. 3 shows curves illustrating the performance of the device and the apparatus, and Fig. 4 is a circuit diagram showing a modification.

While my invention is applicable to apparatus employing various forms of electric gas discharge devices, it is of particular interest and has been especially developed for use where the devices are employed to give light. A preferred form of such device is a lamp of the positive column type comprising a tubular envelope having electrodes at its ends and containing a gaseous atmosphere such as a few millimeters of a rare gas, for example argon, and a small quantity of a vaporizable metal, such as mercury. Preferably the envelope is coated internally with a suitable fluorescent material in order that the electric discharge, which in itself may be scarcely visible, shall produce the desired high degree of illumination. In the description to follow, therefore, I shall refer to the discharge devices as lamps. It is well known that to start a discharge in such a lamp by the application of a voltage to its electrodes a higher voltage must be employed than that required to maintain the discharge after it has been started.

In Fig. 1, I have shown the electric discharge device or lamp at 1 provided at one end with the thermionic cathode 2 and at the other end with the two similar anodes 3 and 4 preferably separated by the insulating partition 5. If desired, a well known form of separately heated cathode may be employed instead of the directly heated cathode as shown.

Before starting, the lamp has a high resistance and may require a voltage considerably higher than that of the circuit from which it is supplied to start a discharge therein. A lamp, for example, that is adapted to operate on a 110 volt circuit may require the application of approximately 450 volts between its anode and cathode to cause it to start. After it has started however the arc drop may be approximately only 100 volts, but a voltage higher than that is required to maintain the discharge.

The lamp is supplied from the source 7 of single phase alternating current which for example may be a 60 cycle, 110 volt lighting circuit through the unitary structure represented at 8 and comprising a combined high reactance transformer and reactor. The core of the structure comprises two E-shaped members 9 and 10 reversely arranged with respect to each other and with corresponding legs spaced from each other to form magnetic gaps. In the drawing these gaps are shown for simplicity as air gaps but as the apparatus is manufactured they comprise a suitable non-magnetic material against which the two members are clamped. Between the legs of the member 10 are magnetic shunts shown at 11 thereby increasing the flux leakage to provide a higher leakage reactance.

On each of the outer legs of the core structure is a primary winding consisting of the coil 12, a main secondary winding consisting of the coil 13 plus the coil 12 thereby constituting an autotransformer and a separate auxiliary secondary winding comprising the coil 14. The ends of the primary, thus composed of the two coils 12, are connected by the leads 15 and switch 16 with the opposite sides of the source 7. The opposite ends of the main secondary, composed of the two coils 12 and the two coils 13, connect with the two anodes 3 and 4 and the mid-point thereof connects with the cathode 2. The latter connection includes the conductor 17 and the auxil-

iary secondary, made up of the two coils 14, the purpose of which is to supply heating current to the lamp cathodes.

As shown by the drawing the magnetic shunts 11 are arranged adjacent the upper ends of the primary coils and extend between the outer legs of the core structure and the middle leg 18 thereof being spaced from those legs by magnetic gaps which preferably comprise a suitable non-magnetic material. It will be seen that by this arrangement the amount of leakage of the primary flux is greatly increased since the shunts provide a relatively low reluctance leakage path, with the result that the leakage reactance between the primary and the secondary is accordingly increased. The middle leg 18 also provides a return path for the uni-directional component of the flux in each of the two outer legs during the operation of the lamp, such a component being present by reason of the fact that since the lamp acts as a bi-phase rectifier the secondary current is unidirectional. By reason of the middle leg, moreover, I obtain an exceptionally high reactance, hence a low mutual reactance, between the two halves or coils of the secondary winding because of the magnetic shunt effect thereof, whereby they are virtually isolated from each other.

To assist one in the understanding of the several flux paths which the above described structure provides, I have represented the alternating flux at any instant by dash lines and the unidirectional flux by dot and dash lines. In order to cause the magnetization of the core by the primary to have a linear characteristic and also to limit the voltage produced in the secondary by the condition of partial resonance obtained at the time of starting, which condition will be described later, I provide a magnetic gap in each of the outer legs. I also provide a gap in the middle leg 18 so as to prevent saturation therein due to the uni-directional flux through this leg when the lamp is operating.

In the operation of the lamp, an important advantage of the high leakage reactance between the secondary coils together with the high reactance between the primary and the secondary is that it results in obtaining a long commutating angle between the currents supplied to the two anodes and consequently a long conducting time for each anode. Oscillograph records made with apparatus such as disclosed herein show that each anode carries current for approximately 230 degrees so that a large overlap of the anode currents occurs at the beginning and end of each half cycle. With such a large overlap of anode currents the ripple in the total unidirectional or cathode current through the lamp is reduced to a low value and the amount of flicker in the light emitted by the lamp is very small, if not imperceptible. This is illustrated by the curves of Fig. 3. In that figure I have represented at 20 and 21 the wave form of the currents in the anodes 3 and 4 respectively plotted against electrical degrees. This illustrates the large overlap of the anode currents resulting from the above described structure. At 22 I have shown the cathode current which, it will be observed, has but a small amount of ripple therein; this results in the lamp producing light which is substantially without flicker.

It is well known that a high reactance transformer produces a low power factor but that the power factor may be improved by the use of a capacitor across the primary or across another winding closely coupled therewith. A capacitor so used, however, is objectionable because of the current harmonics of large magnitude which it draws from the line when lamps of the arc discharge type are being operated by the apparatus and because the high current peaks due to such harmonics are found to be injurious to the electrodes of the lamp if allowed to continue for any appreciable length of time. With apparatus such as that disclosed by this application should a capacitor be connected directly across the secondary for the purpose of improving the power factor it would be objectionable not only for the reasons mentioned above but for the additional reason that it would decrease the angle of commutation thereby off-setting to a certain extent the good effect of the high reactance of the secondary. In the arrangement which I have devised I employ the capacitor 24 across the secondary for improving the power factor and I overcome the objections noted above by connecting in series therewith the reactor or choke coil 25 the reactance of which is materially less than that of the capacitor. The inductive reactance supplied by the reactor is sufficient to dissipate or smooth out the objectional high current peaks originating in the capacitor while the combination of capacitor and reactor is sufficiently capacitatively reactive to effect the desired power factor correction.

The capacitor 24 and the reactor 25 thus bridged across the secondary performs the additional function of raising the voltage applied between the cathode and the anodes of the lamp. This is because the relative amounts of capacitative and inductive reactance in the closed circuit including those members and the leakage reactance between the primary and its secondary is such that a condition of partial resonance exists therein. A condition of actual or complete resonance is not desired, the natural resonance frequency of the circuit being somewhat higher than the supplied frequency. For example, if the supplied frequency is 60 cycles per second the natural resonance frequency of the circuit may be 65 cycles. For stability reasons it is desirable that the operating frequency shall be on the low frequency side of the resonance curve.

The reactor 25 may have any desired core provided it is not the same as the transformer core, in other words, is not in the path of the transformer flux. It may, however, be of a form that constitutes an incomplete magnetic circuit in itself but, for purposes of economy, may be arranged adjacent to a part of the transformer core which part thereby serves to complete its magnetic circuit. Such a core construction is shown by the E-shaped member 26 separated from the transformer core by the magnetic gaps 27.

Inasmuch as the voltage applied between the cathode and either anode, namely the voltage of one-half of the secondary plus that obtained by the above described bridge circuit, is not sufficient to cause a discharge to start in the lamp, I have provided means now to be described for applying a higher voltage between the cathode and one anode to cause the discharge to start. In connection therewith I employ a time delay means whereby the high starting voltage is not applied to the lamp electrodes until the cathode has had time to become heated to the desired degree. For obtaining the higher starting voltage I connect the capacitor 28 across one-half (the left half as shown in Figs. 1 and 2) of the secondary, this capacitor being of such a value that it forms therewith a circuit in partial resonance. The connection of the capacitor in-

cludes the electro-magnetic switch 29 which is biased to closed position by the spring 30 and which has a small armature 31 arranged opposite the gap 32 in the middle leg 18. The capacitor connection also includes the time delay apparatus to insure the heating of the cathode to the desired temperature before the starting voltage is applied. As an example of such apparatus I have shown a well known form comprising a thermal switch having the bi-metallic blade 34 and the resistance heater 35 adjacent thereto and in shunt therewith, the blade being constructed to short circuit the heater when heated thereby.

When the switch 16 is first closed to energize the lamp and the controlling apparatus therefor, a discharge does not immediately start in the lamp since the voltage applied thereto is not sufficient. Heating of the cathode, however, immediately starts. The switch 29 remains in closed position since before the discharge in the lamp starts there is substantially no flux in the middle leg of the transformer and the switch 34 being cool is open. Because of the resistance of the heater 35, the current flow through the capacitor 28 is not sufficient to produce a starting voltage between the cathode and the anode 4 to which the capacitor is connected. However, by the time that the cathode has reached the required temperature the switch 34 will have been bent down by the heat received from its heater so as to short circuit the heater. That being done, the circuit including the capacitor 28 and that half of the secondary to which it is connected immediately comes into partial resonance and the resulting high voltage across the capacitor is applied between the cathode 2 and anode 4. With the starting of a discharge in the lamp between those electrodes, the other anode 3 also comes into action. The uni-directional flux now passing through the middle leg of the core attracts the armature 31 toward the gap 32 and opens the switch 29. It will be seen that the operation of this switch opens the circuit of the capacitor 28 which will be held open as long as the lamp continues in operation. As the switch 34 cools it will open the short circuit around the heater 35 in readiness for a subsequent starting of the lamp.

In the modified form of my invention illustrated by the circuit diagram comprising Fig. 4, the apparatus is substantially the same as that shown by Figs. 1 and 2 except that the lamp is provided with the non-thermionic cathode 38: hence, no secondary coils are needed for cathode heating and the cathode connects directly with the mid-point of the secondary. Moreover, since the cathode is not initially heated, it is unnecessary to provide any means for delaying the application of the starting voltage. The operation of the apparatus represented by Fig. 4 otherwise is like that already described above in connection with Figs. 1 and 2.

I have chosen the particular embodiment described above as illustrative of my invention and it will be apparent that various other modifications may be made without departing from the spirit and scope of my invention which modifications I am to cover by the appended claims.

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

1. In combination, an electric discharge device having a cathode and a plurality of anodes, a transformer having spaced points of its secondary connected each with one of said anodes and an intermediate point thereof connected with said cathode, means for applying a starting voltage between said cathode and one of said anodes, said transformer being constructed to provide a path for the uni-directional flux resulting from the operation of said device, and means responsive to said flux for rendering said starting means inoperative.

2. In combination, an electric discharge device having a cathode and a plurality of anodes, a transformer having the ends of its secondary connected each with one of said anodes and having an intermediate point thereof connected with said cathode, means connected between one end of said secondary and said intermediate point for producing a starting voltage for said device, said transformer being constructed to provide an alternating flux path and a uni-directional flux path, and means responsive to the flux in the latter path for rendering said means inoperative.

3. In combination, an electric discharge device having a cathode and a plurality of anodes, a transformer having the ends of its secondary connected each with one of said anodes and having an intermediate point thereof connected with said cathode, a capacitor connected between one end of said secondary and said intermediate point for producing a starting voltage for said device, said transformer being constructed to provide an alternating flux path and a uni-directional flux path, and means responsive to the flux in the latter path for opening said capacitor connection.

4. In combination, an electric discharge device having a cathode and a plurality of anodes, a transformer having a core structure comprising three legs, a secondary winding on two of said legs, the ends of the winding being connected each with one of said anodes and an intermediate point thereof being connected with said cathode, means for applying a starting voltage to said device, and means responsive to the flux in the third leg of said core structure for controlling said means.

5. In combination, an electric discharge lamp having a cathode at one end and a plurality of anodes at the other end, a transformer core having two outer legs and an intermediate leg traversed by an air gap, primary and secondary coils on each of said outer legs, the secondary coils being connected each with said cathode and with one of said anodes, a capacitor connected across one of said secondary coils to provide a starting voltage for said lamp, a switch in circuit with said capacitor and means responsive to the flux in said air gap for controlling said switch.

6. In combination, an electric discharge device having a cathode and a plurality of anodes, a high leakage reactance transformer having spaced points of its secondary connected with said anodes and an intermediate point thereof connected with said cathode, a capacitor connected to improve the power factor and means associated therewith for preventing the effect of said capacitor of diminishing the overlap of the anode currents.

7. In combination, an electric discharge device having a cathode and a plurality of anodes, a transformer having spaced points of its secondary connected with said anodes and an intermediate point thereof connected with said cathode, said transformer having means providing a high leakage reactance between the parts of said secondary divided by said intermediate point and a capacitor and a reactor connected in series in a normally closed circuit across said

secondary, said reactor being arranged out of the path of flux of the transformer.

8. In combination, an electric discharge device having a cathode and a plurality of anodes, a transformer having spaced points of its secondary connected with said anodes and an intermediate point thereof connected with said cathode, a capacitative connection comprising a capacitor and a reactor across said secondary and forming therewith a normally closed circuit whose resonance frequency is higher than the applied frequency, said reactor being arranged to operate independently of the flux of said transformer.

9. In apparatus for controlling electric discharge devices, a transformer comprising a core having a central leg and two outer legs all connected together at their ends, each of said outer legs having thereon a coil forming a part of the primary winding and a coil at the side of said coil and forming therewith a part of the secondary winding and a magnetic shunt between said central leg and each of said outer legs arranged at points intermediate said coils.

10. In apparatus for controlling electric discharge devices, a transformer comprising a core including a plurality of E-shaped members arranged with their legs toward each other, a magnetic shunt arranged between the center leg of one member and each of the outer legs thereof, a coil on each outer leg of said one member between one of said shunts and the yoke portion of the member, and coils on the outer legs of said members between said shunts and the yoke portion of the other of said members.

MARTIN A. EDWARDS.