Feb. 27, 1968 AKIHIRO KAWAUCHI ETAL 3,371,246

FLUORESCENT LAMP CIRCUIT WITH A VOLTAGE BOOSTING TRANSFORMER CONVERTIBLE TO A VARIABLE INDUCTANCE FOR CURRENT REGULATION

Filed Feb. 18, 1965 2 Sheets-Sheet 1

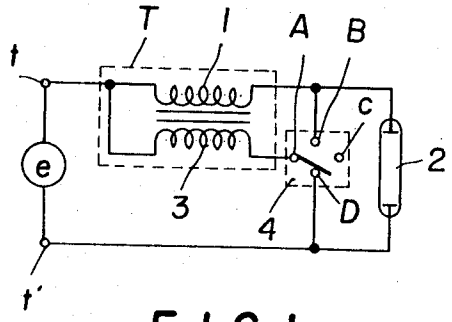


FIG. 1

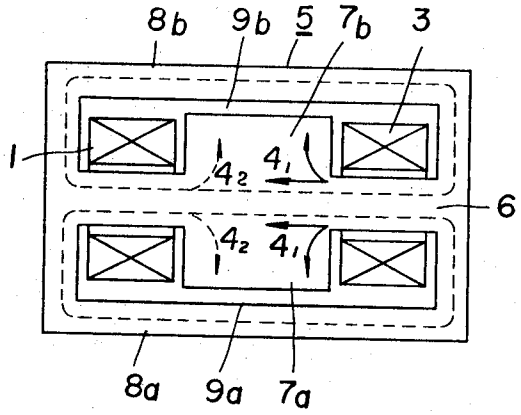


FIG. 2

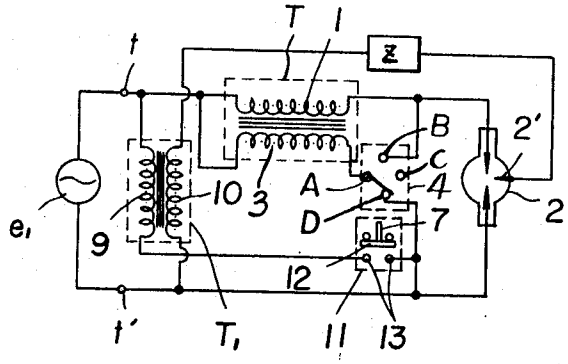


FIG. 3

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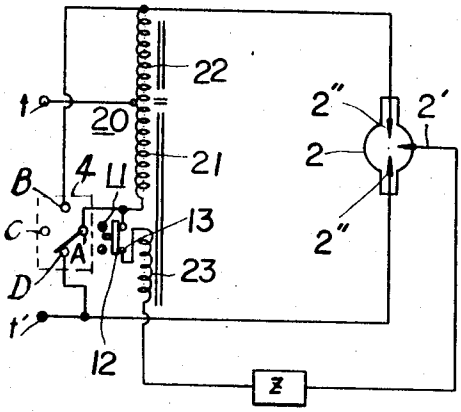


FIG. 4

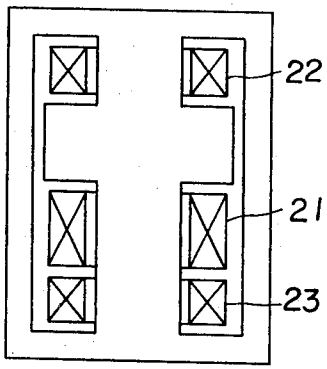


FIG. 5

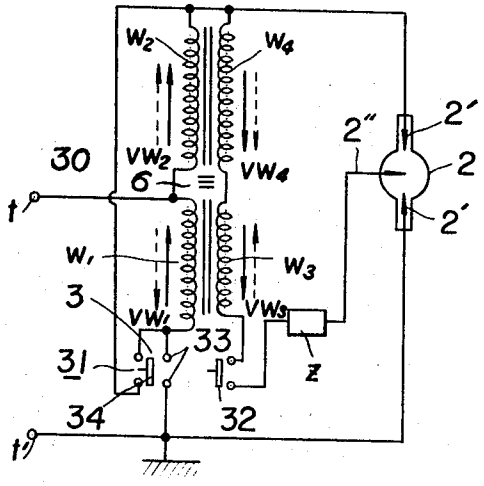


FIG. 6

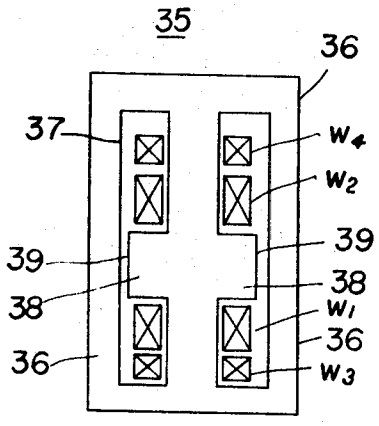


FIG. 7

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FLUORESCENT LAMP CIRCUIT WITH A VOLTAGE BOOSTING TRANSFORMER CONVERTIBLE TO A VARIABLE INDUCTANCE FOR CURRENT REGULATION

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9 Claims. (Cl. 315—262)

ABSTRACT OF THE DISCLOSURE

A starting device for a discharge lamp having a boosting transformer with a primary coil and a secondary coil adapted to be connected in series with the discharge lamp across an electric source. A three position transfer switch is provided which in the first position connects the primary coil across the source, in the second position disconnects the primary coil from the source and in the third position connects the primary coil in parallel with the secondary coil.

This invention relates to a starting device for discharge lamps of the type which requires higher starting voltage than the normal operating voltage.

Discharge lamps such as mercury lamps generally require higher starting voltage than the normal operating voltage which is required to provide steady and continuous operation. Therefore it is necessary to construct the starting device of so discharge lamps such that it can sufficiently boost the source voltage during starting and then to reduce the voltage applied across the discharge lamp to a lower value enough to sustain a stable discharge. As a result conventional starting devices or stabilizers are disadvantageous in that their electrical capacity as well as electric power loss are large and that their physical dimensions are also bulky. Further, as it is necessary to add an additional resistor or reactor in order to vary the brightness of the lamp, difficulties are further increased.

Accordingly it is the principal object of this invention to provide a novel starting device for discharge lamps which can start them rapidly, can maintain discharge during normal operation with lesser power loss, and further, can vary the brightnes of the discharge lamp without increasing electric power loss.

In high voltage discharge lamps having ignition electrodes, such as extra high voltage mercury lamps, for example, in addition to the above mentioned requirements a source of high voltage must be added to supply a high ignition voltage to the ignition electrode, thus increasing the power loss and the physical dimensions of the stabilizer. Further, as the ignition voltage supplied to the ignition electrode is considerably higher than the starting voltage supplied across the main electrodes of the discharge lamp, if such a high ignition voltage were permitted to continuously energize the ignition electrode the wear of the electrodes would become excessive and thus causing failure of the lamp.

A further object of this invention is to provide a novel starting device or stabilizer for a discharge lamp having an ignition electrode which can reduce the size and power loss of the starting device and can reduce wear of electrodes.

A still further object of this invention is to provide a

novel starting device which can reduce the value of the ignition voltage to substantially zero after the starting of the discharge lamp so as to reduce the danger of electric shock as well as undesirable wear and failure of the lamp electrodes.

According to the basic conception of this invention, the stabilizer for use in a discharge lamp provided with a pair of spaced main electrodes comprises a boosting transformer having a primary coil and a secondary coil adapted to be connected in series with the main electrodes across an electric source, and a transfer switch having three operating positions. The transfer switch, when operated to its first operating position serves to connect the primary coil across the source so that the sum of the source voltage and the secondary voltage is applied across the main electrodes to start discharge between them. When the transfer switch is operated to its second or neutral position it will disconnect the primary coil from the source to increase the impedance of the secondary coil thus operating the discharge lamp under reduced brightness condition. When the transfer switch is operated to its third operating position it will connect the primary coil in parallel with the secondary coil thus causing the transformer to act as a reactor or stabilizer with a decreased impedance.

For use in discharge lamps of higher voltage rating and provided with an ignition electrode between the main electrodes, a second high voltage transformer is added to energize the ignition electrode and a second switch is added to connect the high voltage output of the second transformer to the ignition electrode. If necessary this second transformer may be combined with the first mentioned transformer and the transfer switch and the second switch may be electrically or mechanically interlocked in such a manner that the transfer switch can deenergize the primary coil of the first mentioned transformer only after the second switch has operated to deenergize the ignition electrode.

In further modification, the transformer is provided with a primary coil, a secondary coil adapted to be connected in series with the main electrodes of a discharge lamp and a pair of serially connected ignition coils adapted to be connected to the ignition electrode. These ignition coils are wound such that the polarities of their induced voltages will be additive when the primary coil is connected across a source whereas substractive when the primary coil is connected in parallel with the secondary coil. In this case, even if the ignition electrode were continuously connected to the ignition coils after the discharge lamp has been started, substantially zero voltage would be supplied to the ignition electrode thus effectively preventing its wear and failure and danger of electric shock.

The features of the invention which are believed to be novel are set forth with particularity in the appended claims. The invention itself, however, as to its organization together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a connection diagram of one embodiment of this invention;

FIG. 2 is a plan view of one example of a magnetic core utilized in this invention;

FIG. 3 shows a connection diagram of a modified embodiment of this invention;

FIG. 4 shows a connection diagram of another embodiment of this invention;

FIG. 5 is a schematic representation of a transformer utilized in the embodiment shown in FIG. 4;

FIG. 6 shows a connection diagram of still another embodiment of this invention; and

FIG. 7 is a schematic representation of a transformer utilized in the embodiment shown in FIG. 6.

Referring now to FIG. 1 of the accompanying drawing which shows the basic form of this invention, a secondary coil 1 of a step-up transformer T and a discharge lamp 2 are connected in series across terminals t and t' of an electric source e. One terminal of a primary coil 3 of the step-up transformer T is connected to the source side terminal of the secondary coil 1 whereas the other terminal of the primary coil is connected to a movable contact A of a transfer switch 4. The transfer switch 4 is also provided with a stationary contact D adapted to connect the primary coil 3 across the source, an idle or neutral contact C which serves to maintain the movable contact in its open state and a third stationary contact B adapted to connect the primary coil 3 in parallel with the secondary coil 1. As shown in FIG. 2 these primary and secondary coils 3 and 1 are wound on a central leg 6 of a laminated magnetic core structure. The central leg 6 has magnetic leakage paths 7*a* and 7*b* on both sides thereof and between the primary and secondary coils. Air gaps 9*a* and 9*b* are provided between the outer ends of said magnetic leakage paths 7*a* and 7*b* respectively and outer legs 8*a* and 8*b* of the magnetic core structure.

The operation of this embodiment is as follows:

At first the movable contact A of the transfer switch 4 is thrown to the first stationary contact D to connect the primary coil 3 across the electric source e. It is to be understood that the polarity of the voltage induced in the secondary coil is in a direction to be added to or boost the source voltage so that a voltage higher than the source voltage will be impressed across the discharge lamp 2 to start it.

The magnitude of the discharge current flowing through the discharge lamp is determined by the leakage impedance of the transformer T, which, in turn, is determined by the leakage flux traversing the air gaps 9*a* and 9*b*. The movable contact A is then switched to the idle or second stationary contact C to deenergize the primary coil 3. Then the magnetic flux 4_1 produced by the primary coil 3 will disappear and only the magnetic flux 4_2 produced by the secondary coil 1 will flow through the outer legs 8*a* and 8*b*, the central leg 6 as well as air gaps 9*a* and 9*b* as indicated by arrows in FIG. 2. As a result the transformer T will act as a reactor of increased impedance to decrease the discharge current as well as brightness of the discharge lamp 2.

Finally, when the movable contact A of the transfer switch 4 is thrown to the third stationary contact B, the primary and secondary coils 3 and 1 will be connected in parallel. At this time, the magnetic flux 4_1 produced by the primary coil 3 will flow in the direction to oppose the magnetic flux 4_2 produced by the secondary coil 1, but as there are leakage flux paths between these coils, the fluxes will flow through the leakage flux path as determined by the lengths of the air gaps to decrease the impedance of the transformer to fully energize the discharge lamp. Further the primary and secondary coils will share the lamp current between them in proportion to their turn ratio, thus acting as a choke coil.

Thus, it will be seen that by switching the movable contact A of the transfer switch 4 between stationary contacts C and B, the brightness of the discharge lamp can be readily varied. Further by utilizing the primary coil 3 as a boosting coil at the time of starting and then as a brightness controlling coil after starting, all coils are utilized effectively during starting as well as normal operation of the discharge lamp, thus decreasing energy loss and the physical dimensions of the stabilizer.

In the embodiment thus far described, when the movable contact A is thrown to the stationary contact C to open the primary coil 3 the reluctance of the magnetic core when viewed from the secondary side will be greatly lowered, thus increasing the impedance of the transformer too much. However, this problem can be avoided by providing a suitable air gap in the common magnetic flux path. Alternatively, an auxiliary coil may be wound upon the common flux path which is arranged to be energized when the movable contact is thrown to the stationary contact C whereby to cancel the secondary magnetic flux. Further, the magnetic core may be made as a shell type or a core type.

In the modification shown in FIG. 3, a discharge lamp 2 having a starting or an ignition electrode 2′ is connected in series with the secondary coil 1 of the transformer T across an AC source e_1. The transfer switch 4 is modified to a push button type having a movable contact A operable between two pairs of stationary contacts D and B. A high voltage transformer T′ is added to impress a high ignition voltage to the ignition electrode 2′. The primary coil 9 of this transformer is connectable across the source when a movable contact 12 of a second push button type switch 11 is thrown to the stationary contacts 13 while the secondary coil 10 is connected to the ignition electrode 2′ via a current limiting high impedance Z. If desired it is possible to construct the switch 11 such that it will disconnect the high voltage transformer T′ from the source a short time later than the disconnection of the primary coil 3 of the transformer T.

The operation of the modified embodiment is as follows: To start the discharge lamp 2, both switches 4 and 11 are depressed at the same time to energize primary coils 3 and 9 to apply the boosted high voltage across the main electrodes 2″ and 2″ concurrent with the application of high ignition voltage across the ignition electrode 2′ and the lower main electrode 2″. Thus, an electric discharge will be initiated at first between these ignition and main electrodes which will induce the discharge between main electrodes 2″.

Immediately after starting the discharge lamp 2, the push button switch 11 is released to disconnect the primary coil 9 of the high voltage transformer T′. It is preferable to interlock two switches 4 and 11 so that the movable contact A of the switch 4 will engage its stationary contacts B shortly after the opening of the contacts 13 of the switch 11. This arrangement assures steady discharge under relatively low supply voltage since the discharge is transferred between main electrodes 2″ only after they have been sufficiently heated up enough to emit electrons. For extra high pressure mercury lamps this starting time may be of the order of 2 to three seconds. On the other hand, the first switch 4 can be closed for a period enough to insure sufficient preheating of the main electrodes the second switch 11 may be interlocked with the first switch. Insufficient preheating often results in extinguishment of discharge.

Like the transfer switch 4 of FIG. 1, after starting of the discharge lamp 2 the movable contact A may be held for a moment in the neutral position (corresponding to the idle contact C of FIG. 1) or thrown to bridge the stationary contacts B. Again in the neutral position the secondary coil 1 alone will be included in circuit with the discharge lamp to act as a high impedance choke coil. However when the stationary contacts B are bridged, the primary and secondary coils will be connected in parallel to reduce the impedance thus fully energizing the discharge lamp. Any well known suitable electrical or mechanical interlocking device may be utilized to operate the switches 4 and 11 concurrently or with a time delay.

The boosting transformer T and the high voltage transformer T′ may be combined into a single transformer. Thus, in FIG. 4 a transformer 20 having a primary coil 21, a boosting secondary coil 22 and a tertially coil 23 is used with two push button switches 4 and 11 connected in the same manner as in FIG. 3 except that the switch 11 is connected to directly open and close the circuit to the ignition electrode 2′. The relative position between the primary coil 22, the secondary coil 21 and the tertially coil 23 is shown by FIG. 5.

In the embodiments shown in FIGS. 3 to 5 the discharge lamp can be started rapidly by applying a high ignition voltage to the ignition electrode and a high starting voltage across main electrodes, and after the main electrodes have been heated to operating temperatures the primary and secondary coils of the boosting transformer are connected in parallel to continue steady operation of the dischtrge lamp under considerably lower voltage than the starting voltage. Moreover, the time interval of applying a high ignition voltage to the ignition electrode can be reduced when compared to conventional starting devices so that it is possible to reduce wear and damage of lamp electrodes. The current limiting impedance Z may be eliminated if sufficiently large leakage path were provided between the primary and secondary coils of the high voltage transformer T'.

FIG. 6 shows a connection diagram of another embodiment of this invention which can produce higher ignition voltage than the modification shown in FIG. 4. In FIG. 6 an auto-transformer 30 is provided with a primary coil w_1, a secondary or boosting coil w_2 and a pair of ignition coils w_3 and w_4 of equal number of turns. When a transfer switch 31 is operated to bridge its stationary contact 33, the primary coil w_1 is connected across the input terminals t and t' to induce a secondary or boosting voltage in the secondary coil w_2 so that the sum of the source voltage and the boosting voltage is applied across the main electrodes 2' of the discharge lamp. Concurrently with the operation of the switch 31, the switch 32 is also operated to connect the serially connected ignition coils w_3 and w_4 to the ignition electrode 2'' of a discharge lamp 2 via a high impedance Z. While it is preferable to interlock the switches 31 and 32, they may be operated independently.

FIG. 7 represents a schematic diagram of the auto-transformer 30 to show the relation between various coils w_1 to w_4 inclusive and a laminated magnetic core 35. As the primary coils w_1 and w_2 are connected in series or parallel it is necessary to prevent interference between these coils, especially when they are connected in parallel. The magnetic core 35 shown is of the shell type having two outer legs 36 and a central leg 37 provided with lateral leakage paths 38 which are facing to the inner side surfaces of the outer legs 36 with air gaps 39 interposed between them. As shown, the primary coil w_1 and one of the ignition coil w_3 are wound about the center leg 37 beneath the leakage paths 38 while the secondary coil w_2 and the other ignition coil w_4 are wound above the leakage paths. It is to be understood that the ignition coils w_3 and w_3 are so wound that the polarities of their induced voltages ar additive when the primary and secondary coils w_1 and w_2 are connected in series, or the transfer switch 31 is operated to bridge contacts 32, and are substractive when the primary and secondary coils are connected in parallel or the transfer switch 31 is operated to bridge its contacts 34. Thus, when the switches 31 and 32 are operated to their right hand positions, the sum of the primary and secondary voltages ($V_{w1}+V_{w2}$) will be applied across the main electrodes 2'—2' whereas the sum of voltages of all coils ($V_{w1}+V_{w2}+V_{w3}+V_{w4}$) will be applied across the ignition electrode 2'' and the lower main electrode 2' to start the discharge lamp 2'. As a result sufficiently high ignition voltage and starting voltage are applied to rapidly start the discharge lamp. The starting time for ultra high voltage mercury lamps may be 2 to 3 seconds.

As the temperature of the main electrodes is increased to a sufficient high temperature to provide ample electron emission, the lamp voltage is decreased so that it is now possible to open the switch 32 to deenergize the ignition electrode and at the same sime or at a time slightly later than this the transfer switch 31 is thrown to its contacts 34 to connect the primary and secondary coils in parallel. As mentioned hereinabove, the transformer 30 then acts as a stabilizing choke coil. At this time as the induced voltages V_{w3} and V_{w4} cancel each other the voltage across the switch 32 is zero or substantially zero. By this reason even when the switch 32 is maintained closed during the operation of the lamp, the voltage impressed upon the ignition electrode will be substantially zero so that it is able to prevent wear of electrodes and danger of electric shocks. Again any suitable electrical or mechanical interlocking device may be used to operate the switches 31 and 32 in the manner as described above.

In the conventional starting devices for high voltage mercury lamps a primary coil and an ignition coil are wound on the same magnetic core so that a high voltage of about several hundred volts is normally induced in the ignition coil even after the mercury lamp has been started. Consequently, it is necessary not only to eliminate the danger of electric shock but also to employ a switch 32 having substantial insulating ability. These troubles can be obviated according to this invention since the induced voltages V_{w3} and V_{w4} cancel each other after starting the discharge lamp.

While certain particular examples of starting devices have been described for the purpose of illustration and description, it is to be understood that various changes can be made therein without departing from the spirit and scope of the invention, whereby it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A starting device for a discharge lamp comprising a boosting transformer having a primary coil and a secondary coil adapted to be connected in series with said discharge lamp across an electric source and a transfer switch having three operating positions, said switch when operated to a first operating position serving to connect said primary coil across said source, when operated to a second operating position serving to disconnect said primary coil from said source and when operated to a third operating position serving to connect said primary coil in parallel with said secondary coil.

2. The starting device according to claim 1 wherein said transformer is equipped with a leakage path for magnetic flux between said primary coil and said secondary coil.

3. The starting device according to claim 1 wherein said discharge lamp is provided with a pair of spaced main electrodes and an ignition electrode interposed between said main electrodes, and a second high voltage transformer is provided, said transformer having a primary coil and a secondary coil adapted to be connected to said ignition electrode and a second switch is provided operable to connect said primary winding across said source.

4. The starting device according to claim 1 wherein said discharge lamp is provided with a pair of spaced main electrodes and an ignition electrode between said main electrodes, said transformer is further provided with a high voltage tertially winding and a second switch is provided to connect said high voltage winding to said ignition electrode.

5. The starting device according to claim 3 wherein said transfer switch and said second switch are electrically or mechanically interlocked such that said transfer switch is operable to its second or third operating position from its first operating position only after said second switch has operated to deenergize said ignition electrode.

6. The starting device for a discharge lamp comprising a boosting auto-transformer having a magnetic core including a primary core portion and a secondary core portion, a primary coil wound on said primary core portion, a secondary coil wound on said secondary core portion and a pair of serially connected ignition coils, one of said ignition coils is wound on said primary core portion and another of said ignition coils is wound on said secondary coil portion, a discharge lamp having a pair of spaced main electrodes connected in series with said secondary coil across an AC source and an ignition electrode

connected with said ignition coils, a transfer switch having at least two operating positions, said switch when operated to a first operating position serving to connect said primary coil across said source and when operated to second operating position serving to connect said primary coil in parallel with said secondary coil.

7. The starting device according to claim 6 wherein said pair of ignition coils are so wound that the polarities of their induced voltages are additive when said primary coil is connected across said source whereas the substractive when said primary coil is connected in parallel with said secondary winding.

8. The starting device according to claim 6 wherein a second switch is provided to connect said ignition coils and said ignition electrode, and said transfer switch and said second switch are interlocked such that said second switch can be operated to deenergize said ignition electrode only after said transfer switch has been operated to

connect said primary coil in parallel with said secondary coil.

9. The starting device according to claim 7 wherein said transformer including said magnetic core having a magnetic leakage path disposed between said primary core portion and said secondary core portion.

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