

Nov. 16, 1943.

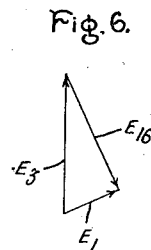
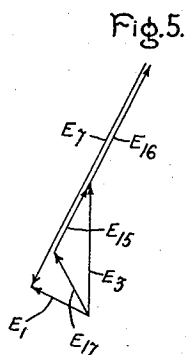
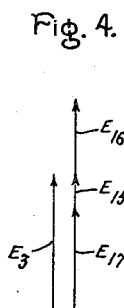
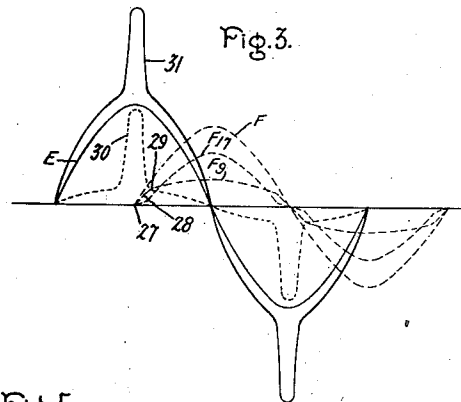
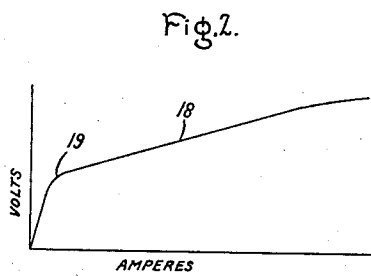
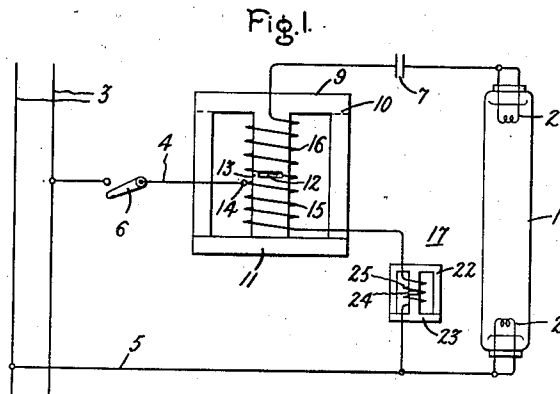
H. W. LORD

2,334,567

APPARATUS FOR STARTING AND CONTROLLING DISCHARGE DEVICES

Filed Jan. 22, 1942

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 7.

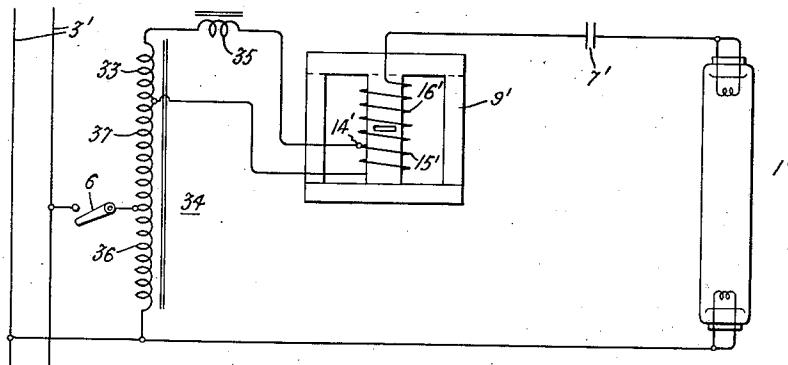
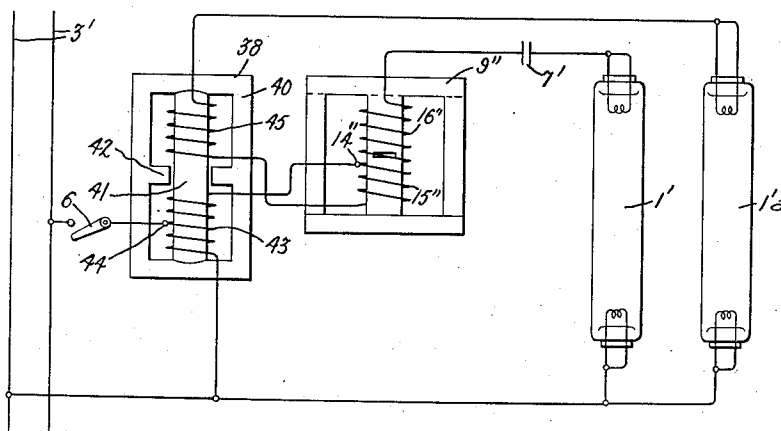


Fig. 8.



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UNITED STATES PATENT OFFICE

2,334,567

APPARATUS FOR STARTING AND CONTROLLING DISCHARGE DEVICES

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Application January 22, 1942, Serial No. 427,788

11 Claims. (Cl. 315-244)

My invention relates to apparatus for starting and controlling electric discharge devices employed on alternating current circuits. Although my invention is applicable to the starting and controlling of discharge devices of various forms, it has been particularly devised to be used with fluorescent lamps now coming into extensive use. Such lamps comprise a transparent tubular envelope containing mercury vapor at low pressure and having the inner surface of its side walls coated with a suitable phosphor which, under the influence of an electric discharge through the mercury vapor, produces fluorescence. The lamp electrodes which are mounted in the ends of the envelope are filamentary in the form and are coated with a suitable electron emitting material. Such a lamp requires for its starting the application of a voltage impulse considerably higher than the voltage necessary to keep the lamp in operation after it has been started. Inasmuch as the voltage required to start such a lamp is materially less if the lamp electrodes are heated prior to the application of the starting voltage, and since less injury is done to the lamp if its electrodes are preheated, it has become common practice to heat the electrodes to the point of electron emission prior to the application of the starting voltage.

To avoid the delay incident to the preheating of the electrodes instant starting of such lamps has been effected by applying thereto a voltage sufficient to make them break down immediately even with cold electrodes. For that purpose use has been made of a high reactance step-up transformer designed to give the necessary high starting voltage but such apparatus has had the objection of being electrically inefficient and of being cumbersome, since it has poor material utilization, and accordingly is expensive to manufacture.

One object of my invention, therefore, is to provide improved apparatus for producing a starting impulse for an electric discharge device the electrodes of which are not or need not be preheated with which apparatus the above noted objections may be avoided. Another object is the provision of apparatus for that purpose, the total internal power losses of which are low at starting and during the normal operation of the device and also are low if the device cannot be started or if it is removed from the circuit.

In accordance with my invention, briefly, I have provided apparatus which when connected between a discharge device and a source of al-

ternating current supply will produce a voltage peak and will superpose it on the voltage wave supplied to the device by the source, the maximum value of the voltage impulse thus produced being sufficient to cause the device to start without electrode preheating. After the device has started the apparatus functions in part as the ballast impedance for the device.

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

Referring to the drawings, Fig. 1 is a circuit diagram illustrating a simple form of my invention; Fig. 2 shows the volt-ampere characteristic of the transformer-reactor forming a part thereof; Fig. 3 is a diagram showing the voltage and flux curves with the apparatus illustrated by Fig. 1 at starting; Figs. 4 and 5 are vector diagrams showing the various voltage values in the apparatus illustrated by Fig. 1 respectively before and after the discharge device starts; Fig. 6 is a vector diagram similar to that of Fig. 5 but with the capacitor of Fig. 1 omitted; and Figs. 7 and 8 are circuit diagrams illustrating modifications of my invention.

In Fig. 1 the electric discharge device 1 is represented as a fluorescent lamp which, for example, may be a 40 watt lamp having a length of 48 inches and a diameter of $1\frac{1}{2}$ inches such lamps being in common use at the present time. It has a tubular glass envelope containing mercury vapor at low pressure and a small quantity of neon or argon gas. The electrodes 2 are filamentary in form being wound in close coils and constructed of a refractory metal wire such as tungsten coated with a suitable electron emitting material such as barium oxide or strontium oxide. Since the electrodes are not provided with means for raising their temperature to the point of electron emission prior to the application of the starting voltage to the device as is commonly done, they are preferably constructed to have a very small mass whereby when a voltage impulse of sufficient value is applied to the device to make it break down without prior heating of the electrodes, the electrodes or portions thereof at least have their temperature raised so quickly that little loss of the electron emitting material and a very slight blackening of the adjacent ends of the envelope, if any, occurs. The two ends of each electrode are shown connected together in order that the operating current may be supplied to the electrode at both ends

thereof. However, if desired the current may be supplied to the electrode from one end only.

The device, which may have a voltage drop thereacross of 110 volts when running is connected to be energized from the source of alternating current supply 3 which may be a 60 cycle, 230 volt lightning circuit through the connections 4 and 5 which include the switch 6 and the capacitor 7. For producing the above mentioned voltage peak to effect the starting of the device and to control the device after it has been started, I employ apparatus including a reactor-transformer having a core provided with a short air gap and with a narrow portion or portions which readily saturate. Such a reactor-transformer as represented at 9, may comprise a three-legged laminated core structure built up of E-shaped laminations 10 and bar laminations 11, adjacent laminations being reversed to break the joints in the usual and well known manner. The middle leg of each E lamination has the narrow transverse aperture 12 punched therein whose length is somewhat less than the width of the leg whereby the core bridges 13 which readily saturate are left at the ends of the apertures. The apertures are centrally positioned in the middle legs so that when assembled to form the finished core they all align. Thus the middle leg of the core has an air gap therein bridged by two narrow core portions which saturate and desaturate twice with each cycle of the applied voltage. A reactor or transformer having such a core is commonly spoken of as having a bridged-gap. The ratio of the total cross sectional area of the two air gap bridging portions of the core leg may be approximately 15% of the total cross sectional area of the leg. The length of the air gap may be made so that with the device taking normal current the voltage across the transformer is such that although saturation does occur in the bridges 13 saturation of the entire core does not occur to any appreciable extent.

The transformer winding is shown for convenience as a single winding on the middle leg, the winding having the tap 14 whereby the transformer functions as an auto-transformer of which the part 15, whose voltage may be 140 volts is the primary, and the part 16, whose voltage may be 180 volts, is the secondary. During the normal operation of the discharge device the secondary and the capacitor 7 constitute the ballast for the device, the reactance of the capacitor predominating. The secondary 16 is shown included in the connection 4 between the switch 6 and the capacitor 7 and the primary 15 is shown connected through the reactor 17, whose voltage may be 120 volts, between the switch 6 and the connection 5. For greater economy in the use of copper one may prefer to make the parts 15 and 16 as separate windings using wire of different sizes, each winding also extending the entire length of the middle leg. The transformer 9 has a non-linear volt-ampere characteristic of the form shown at 18 in Fig. 2 where the bend 19 marks the point at which saturation occurs in the bridges 13.

The reactor 17, which is a linear reactor, may comprise a three-legged laminated core structure built up of the E-shaped laminations 22 and T-shaped laminations 23, adjacent laminations being reversed to break the joints in the usual manner. In the middle leg is the air gap 24 and surrounding that leg is the winding 25 whose voltage may be 120 volts.

When the switch 6 is closed to energize the de-

vice and the control apparatus therefor, the sinusoidal voltage wave applied to the device through the secondary 16 (it being assumed that the wave form of the source 3 is sinusoidal in form or approximately so) is insufficient of itself to cause the device to break down. Current does flow, however, through the shunt circuit comprising the primary 15 of the transformer 9 and the reactor 17 by which means a voltage peak is superposed on the voltage wave applied to the device from the source. The operation of the apparatus by which this result is produced may better be understood by reference to Fig. 3. Here the curve E represents the sine wave of voltage impressed from the source of supply on the device before break down; the dash line F represents the total flux in the core of the transformer 9 and in the core of the reactor 17; the dash line F₉ represents the flux in the core of the transformer alone; and the dash line F₁₇ represents the flux in the core of the reactor alone. From these curves it will be seen how the total flux F which varies substantially like a sine wave distributes itself between the cores of the transformer and the reactor and changes its distribution as the wave advances. Starting from the zero point 27 of the total flux wave F corresponding to the point of maximum value of the voltage wave the flux in the core of the transformer, curve F₉, first rises rapidly as shown by the part 28, then as saturation occurs in the bridges 13 of the core of the transformer the curve bends as indicated by 29, after which the rate of flux increase becomes relatively slight until the total flux F reaches its maximum value, after which it varies in the reverse manner to that just described, as clearly shown by the curve F₉. The flux in the reactor, curve F₁₇, on the other hand first increases slowly from the point 27, then, as the flux in the transformer passes the point of saturation, it increases rapidly, the sum of ordinates of the curves F₉ and F₁₇ being at all times equal to the ordinate of the curve F for the same abscissa. Since the flux in the core of the transformer undergoes a rapid change while passing through zero, as shown by the part 28 of the curve F₉, a voltage impulse is generated in the secondary 16. This impulse is represented by the dotted curve 30. As this impulse comes at the same or substantially the same time as the crest of the voltage wave applied to the discharge device from the source of supply and since it is of the same polarity as that wave, it produces the superposed voltage peak as shown at 31. The maximum value of the applied voltage wave plus the voltage of the peak superposed thereon gives a total value amply sufficient to start the discharge device without any preheating of its electrodes.

After the device has started the secondary functions together with the capacitor 7 as ballast for the device and inasmuch as the reactance of the capacitor predominates the device thereafter operates with a leading current, the angle of lead being dependent upon the relative amounts of capacitance and inductance of the ballast.

With the apparatus which I have devised and have described above I am able to obtain an important operating economy. The reactor 17 and the primary 15 being permanently connected in series across the source of supply unfortunately give rise to a certain amount of energy loss while the device is in operation but because of a particular cooperation of parts, the loss due to the shunt circuit so formed is materially reduced under normal operating conditions. As was

pointed out above, the current taken by the discharge device when the capacitor 7 is used is leading and the current taken by the device passes through the secondary. Now, it is well known that, in a circuit comprising an inductive reactive member supplied by a source of voltage, if the current is made to lead the applied voltage a voltage will be produced in that member which is additive to that voltage. Applying this principle to the circuit shown by Fig. 1, because of the leading current produced by the capacitor a voltage is produced in the secondary 16 which adds to the applied voltage and since 15 and 16 have the same core a voltage is induced in the primary 15 which opposes the voltage applied thereto by the source through the reactor 17. The effect of this opposing voltage in the primary obviously is to reduce the energy losses in the members 9 and 17.

Referring to Fig. 4 which is a vector diagram of the sine wave voltages in the apparatus shown by Fig. 1 at starting, E_s represents the voltage of the source, E_{15} and E_{16} represent the voltages respectively of the primary and the secondary of the transformer 9, and E_{17} represents the voltage of the reactor 17, the sum of the voltages E_{15} , E_{16} and E_{17} being the peak voltage applied to the discharge device at starting. During the operation of the discharge device the voltages are shown by the vector diagram comprising Fig. 5 where E_s , E_{15} , E_{16} and E_{17} represent the voltages of the same parts mentioned above, E_7 represents the voltage of the capacitor and E_1 represents the voltage across the discharge device.

The same apparatus with the omission of the capacitor 7 may be used for the case where the discharge device is to be operated on a lagging current, that is, where the ballast for the device is inductive rather than capacitive. In that case, however, I do not obtain the economy of operation which I do when employing a capacitor, as in Fig. 1 to make the circuit of the discharge device preponderantly capacitive. With the capacitor omitted the vector diagram of the various voltages with the discharge device operating would be as represented by Fig. 6 where E_1 , E_3 and E_{16} represent the voltage of the same parts as in Fig. 5.

In an installation of a plurality of electric discharge devices or lamps where the devices are divided between circuits of two different types one lagging and the other leading current for the purpose of reducing the stroboscopic effect and for maintaining a high power factor of the total energy supplied, I may employ the apparatus which I have devised and disclosed herein for starting and operating such devices on either lagging or leading circuits. If the circuit is to be lagging the ballast will be inductive as by omitting the capacitor 7; if it is to be leading the ballast will be capacitive by retaining the capacitor.

The modified form of my invention, shown by Fig. 7, is adapted to be supplied from a source 3' of alternating current at a lower voltage than that employed with the circuit shown by Fig. 1, namely at 118 volts. The discharge device 1' in this case may be a 40 watt lamp having a length of 48 inches and a diameter of 1½ inches as before. The capacitor 7' has substantially the same capacitance as the capacitor 7. Transformer 9' is similar to the transformer 9 of Fig. 1 except that the primary 15' thereof has fewer turns, the voltage of which may be 35 volts. The voltage of the secondary 16' may be 145 volts. 75

The primary 15' is supplied from the secondary winding 33 of the auto-transformer 34, the voltage of which winding may be 60 volts, through the separate linear reactor 35 whose voltage may be 30 volts. The winding 36, the primary, of the transformer is connected across the source of supply 3' and between that winding and the winding 33 is another secondary winding 37, the voltage of which and of the winding 36 may each be 118 volts. The discharge device 1' is connected to be supplied from the auto-transformer 34 through the transformer 9'.

The operation of the modified form of my invention shown by Fig. 7 is in its essential features similar to that of the form shown by Fig. 1. Because of the fact that the source of supply of this form has a lower voltage than the source of the other form the step-up transformer 34 is used so that the discharge device will be supplied with the proper voltage both for starting and operating it. In this form the voltage applied to the primary 15' for the production of the voltage peak is supplied through the small separate reactor 35 from the winding 33 of the auto-transformer.

Instead of supplying the primary of the transformer 9' from the winding 33 through a separate reactor as in Fig. 7, I may provide a second electric discharge device, similar to the device 1', connected to be operated simultaneously therewith from the same source of supply but on a lagging current circuit and supply the primary with the current taken by said second device. Such an arrangement is illustrated by the modification shown by Fig. 8 where the two electric discharge devices 1' and 1'a, the one on a leading current circuit and the other on a lagging current circuit are supplied from the same source 3' which may be a 118 volt 60 cycle lighting circuit through the step-up transformer 38. This transformer has a high reactance secondary in addition to a closely coupled secondary and may have a construction like that illustrated including a forced core structure. As shown, the transformer core is built up of similar rectangular laminations 40 and bar laminations 41, the latter having convex ends adapted to make a snug fit between concave portions of the rectangular laminations when forced into position. The rectangular laminations have the inwardly projecting ears 42, the ends of which are slightly spaced from that part of the core formed by the bar laminations, which ears constitute magnetic shunts. Below these shunts, as shown on the drawing, is the winding 43, whose voltage may be 236 volts, having the tap 44. That part of the winding below the tap, namely the primary, is connected through the switch 6 with the source 3' which may be a 118 volt, 60 cycle lighting circuit. The lower end of the winding 43 connects with the electrodes at the corresponding ends of the two discharge devices and the upper end of the winding connects with the tap 14'' on the transformer 9'' which is similar to 9 in Fig. 1. Above the magnetic shunts is the additional secondary winding 45, whose voltage may be 215 volts, which by reason of the core structure shown has high reactance. The lower end of this winding, as shown, connects with the lower end of the primary 15'' of the transformer 9'' and the upper end connects with the electrode at the opposite end of the device 1'a. As in Fig. 1 the upper end of the secondary 16'' connects through the capacitor 7' with the electrode at the opposite end of the device 1'.

In the operation of this form of my invention

when the supply switch is closed the lagging current circuit device 1'a immediately starts. The leading current circuit device 1', however, does not start until after the other device has started for the voltage applied to it by the transformer 38 through the secondary 16'' and the capacitor 7' is insufficient. After the device 1'a has started the transformer 9'' functions as a step-up peaking transformer, in the same manner as the transformer 9 in Fig. 1, the voltage induced in the part 16'' thereof being effective to add to the voltage of the transformer 38, the total resultant peak voltage being sufficient to cause the device 1' to start. It will be understood that the transformers 38 and 9'' are so constructed and related to each other that the two devices after being started are supplied each with current of the desired amount.

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

1. In combination, a source of alternating current supply, an electric discharge device, ballasting means for said device including an inductive member, means connecting said device and said ballasting means with said source to be supplied therefrom, and means energized from said source and inductively related to said member for inducing a peaked voltage in the inductive member, said peaked voltage being superposed on the voltage wave of the source.

2. In combination, a source of alternating current supply, an electric discharge device, ballasting means for said device including an inductive member, means connecting said device and said ballasting means with said source to be supplied therefrom, and means including a core provided with a part constructed to saturate for inducing in said member a peaked voltage wave, said voltage wave being superposed on the voltage wave of the source.

3. In combination, a source of alternating current supply, an electric discharge device, ballasting means for said device including an inductive member, means connecting said device and said inductive member in a series circuit across said source to be supplied therefrom, means including a second inductive member energized from said source, and a core structure common to said inductive members having a short air gap bridged by a narrow portion constructed to saturate.

4. In combination, a source of alternating current supply, an electric discharge device connected to be supplied from said source, means operative to ballast said device and means cooperating with said ballasting means for superposing a voltage peak on the voltage wave supplied to the device from said source.

5. In combination, a source of alternating current supply, a circuit connected across said source comprising a reactor and the primary of a transformer having a core including a short air gap bridged by a part constructed to saturate at the voltage of the source, an electric discharge device, and means connecting said device and the

secondary of said transformer in series to be supplied from said source.

6. In combination, a source of alternating current supply, a circuit connected across said source comprising a reactor and the primary of a transformer having a core including a short air gap bridged by a part constructed to saturate at the voltage of the source, an electric discharge device, a capacitor, and means connecting said device, the secondary of said transformer and said capacitor in series to be supplied from said source, the capacitance of said capacitor being such that said series circuit reactance is capacitive.

7. In combination, a source of alternating current supply, a discharge device, connections for energizing said device from said source, a transformer connected to be energized from said source, the core of said transformer having a short air gap and a saturating portion arranged in parallel, said transformer having a winding part included in one of said connections.

8. In combination, a source of alternating current supply, a discharge device, a transformer having a parallel arranged short air gap and saturating part in its flux path, means including a winding part on said transformer for connecting said device to be energized from said source and means including a separate reactor for connecting said transformer to be energized from said source.

9. In combination, a source of alternating current supply, a discharge device, a transformer having a parallel arranged short air gap and saturating part in its flux path, means including a winding part on said transformer and a capacitor for connecting said device to be energized from said source, the net reactance of said winding part and said capacitor being capacitive, and means including a reactor having a linear volt-ampere characteristic for connecting the primary of said transformer across said source.

10. In combination, a source of alternating current supply, a discharge device, an auto-transformer having a bridged-gap core, means including a capacitor and the secondary of said transformer for connecting said device across said source, the reactance of said capacitor being greater than the reactance of said secondary, and means including a reactor having an air-gap in its core for connecting the primary of said transformer across said source.

11. In combination, a source of alternating current supply, a plurality of electric discharge devices connected to be energized from said source, the voltage normally applied to one of said devices being insufficient to cause it to start, means for raising the voltage of said source to cause the other of said devices to start, means responsive to the starting of said other device for producing peaked voltage wave, and means for superposing said peaked voltage on the voltage normally applied to said one device to cause it to start.

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