

Nov. 25, 1941.

C. P. STOCKER

2,264,055

STARTING CIRCUIT FOR ELECTRIC DISCHARGE DEVICES

Filed April 3, 1939

4 Sheets-Sheet 1

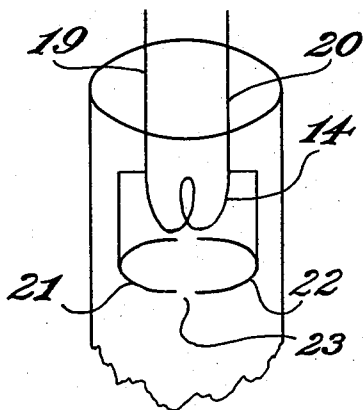


Fig. 1

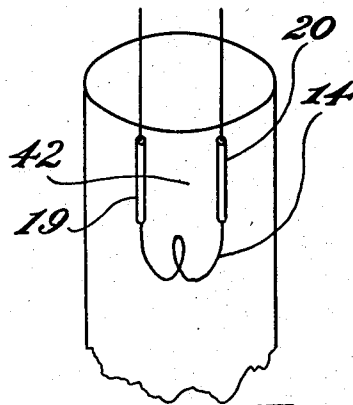


Fig. 2

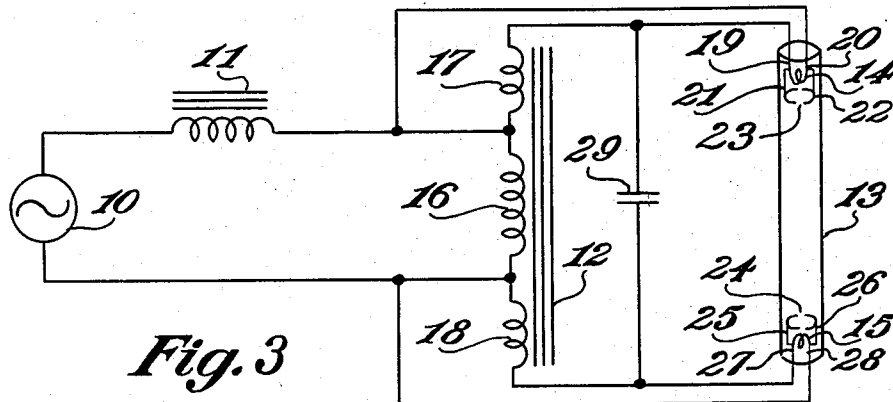


Fig. 3

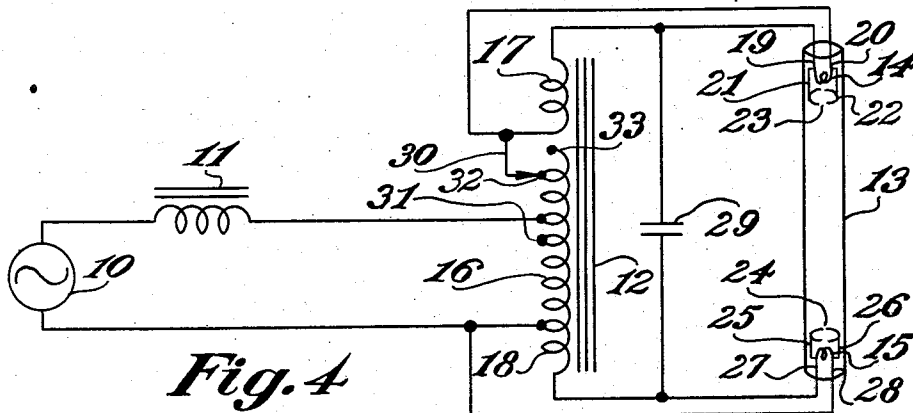


Fig. 4

Closman P. Stocker INVENTOR.

BY

Woodling and Krost
ATTORNEY.

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C. P. STOCKER

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4 Sheets-Sheet 2

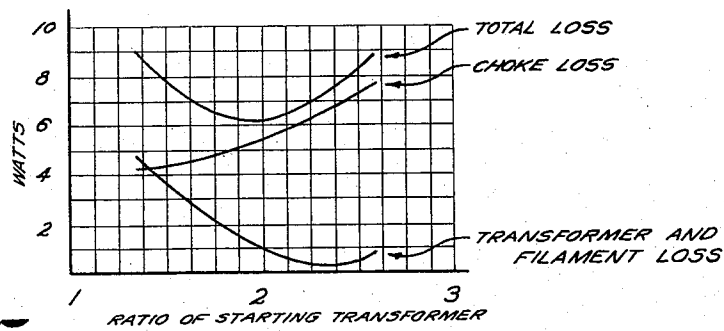


Fig. 5

Fig. 6

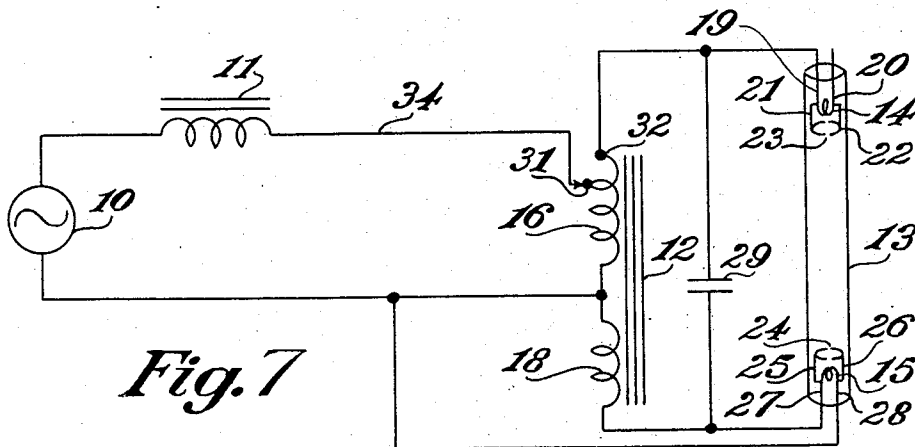
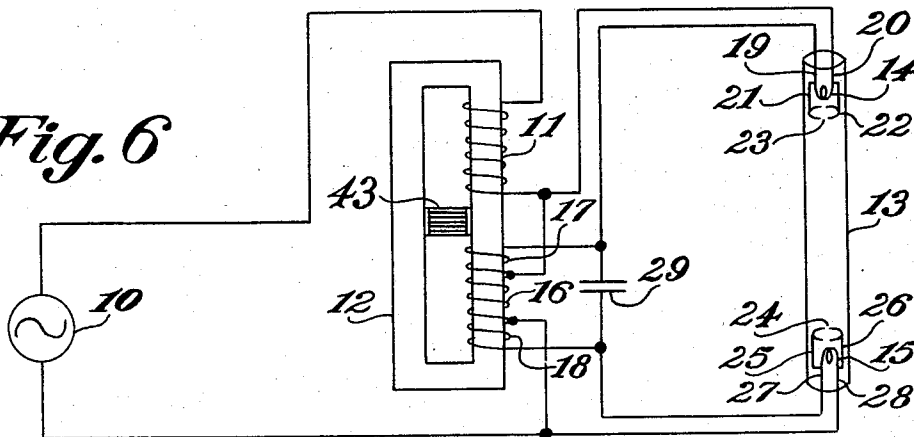


Fig. 7

Closman P. Stocker INVENTOR.

BY Broodling and Krost ATTORNEY.

Nov. 25, 1941.

C. P. STOCKER

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STARTING CIRCUIT FOR ELECTRIC DISCHARGE DEVICES

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4 Sheets-Sheet 3

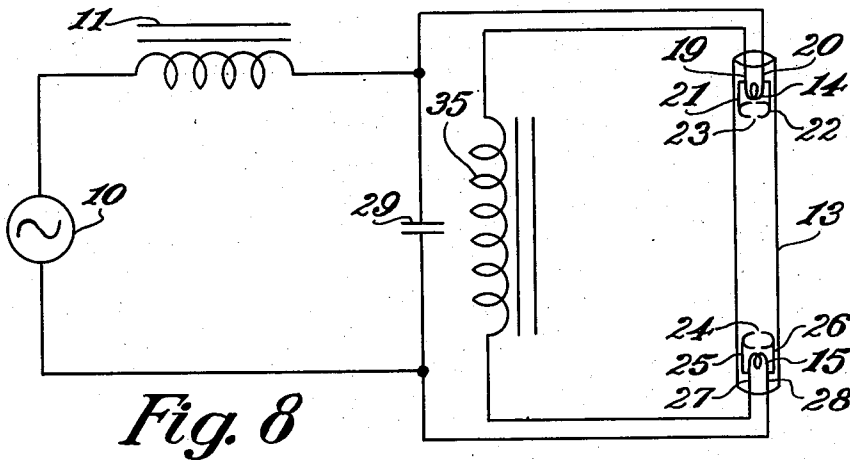


Fig. 8

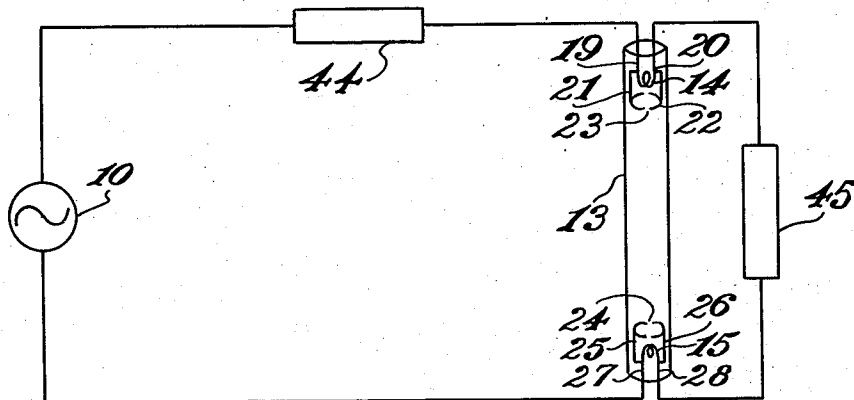


Fig. 9

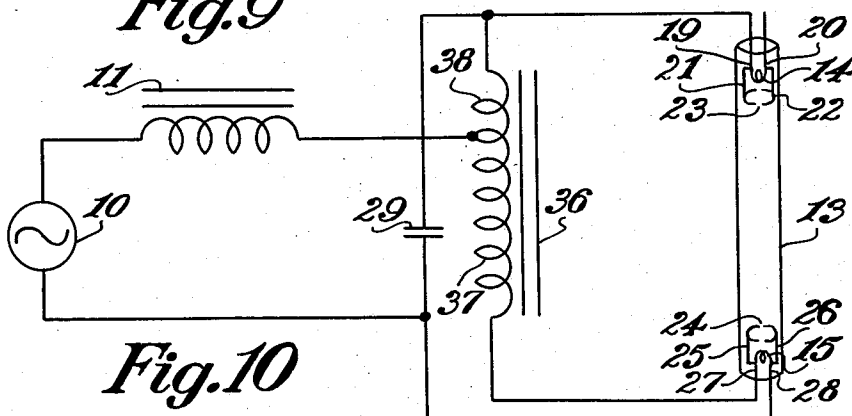


Fig. 10

Closman P. Stocker INVENTOR.

BY *Shoodling and Krost*
ATTORNEY.

Nov. 25, 1941.

C. P. STOCKER

2,264,055

STARTING CIRCUIT FOR ELECTRIC DISCHARGE DEVICES

Filed April 3, 1939

4 Sheets-Sheet 4

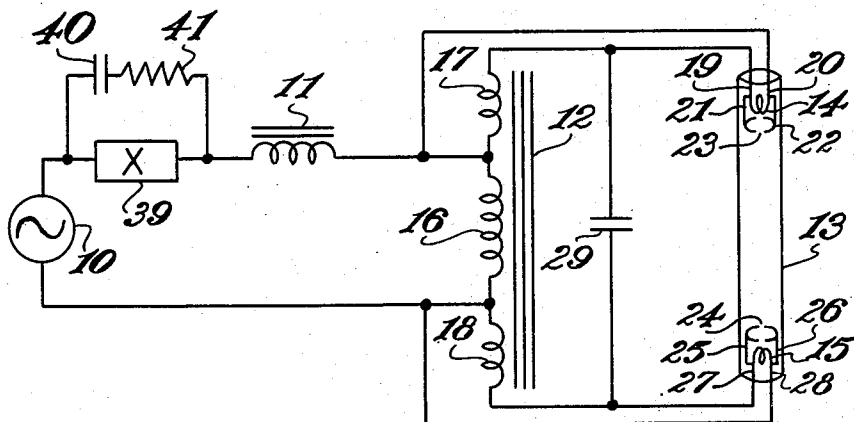


Fig. 11

Closman P. Stocker INVENTOR.

BY

Shoedling and Kroat
ATTORNEY.

UNITED STATES PATENT OFFICE

2,264,055

STARTING CIRCUIT FOR ELECTRIC DISCHARGE DEVICES

Closman P. Stocker, Lorain, Ohio, assignor, by direct and mesne assignments, to General Electric Company, a corporation of New York

Application April 3, 1939, Serial No. 265,645

3 Claims. (Cl. 176—124)

My invention relates to electric discharge devices generally, and more particularly to methods and apparatus for starting and operating such devices from a suitable source of electric current. In particular my invention starts and operates electric discharge devices from either alternating current or direct current without moving parts. Preference is given to my invention as related to methods and apparatus for use on alternating current circuits because of the lower losses and greater use of this form of electric energy.

One of the objects of my invention is to provide an exceedingly simple circuit for automatically starting and operating electric discharge devices without the use of moving parts.

An object of my invention is to produce auxiliary discharges at the main electrodes of the discharge lamp to increase the ease with which the lamp ignites.

Another object of my invention is to heat the filaments of a discharge lamp sufficiently to maintain an auxiliary discharge at each filament before igniting the discharge lamp and to maintain sufficient voltage between the two auxiliary discharge paths to ignite the gaseous discharge lamp.

Another object of my invention is to start electric discharge lamps equipped with filaments in the following sequence:

- a. Heat filaments.
- b. Cause auxiliary discharge.
- c. Maintain potential difference between main electrodes, sufficient to ignite electric discharge lamp.
- d. Limit current in main discharge path to decrease filament heating.
- e. Extinguish auxiliary arc discharge upon ignition of electric discharge lamp.
- f. Maintain reduced current flow through filaments during normal operation of electric discharge lamp.

Another object of my invention is to use a leakage type transformer in combination with an electric discharge lamp equipped with filaments to produce the above mentioned sequence of operation.

Another object of my invention is to cause substantially instantaneous starting of electric discharge lamps having filaments.

Another object of my invention is to provide a starting and operating arrangement in which the losses during operation are exceptionally low.

Another object of my invention is to provide

a starting mechanism which increases the life of the discharge tube.

Another object of my invention is to maintain a reduced current flow through the filaments of a low voltage electric discharge lamp during normal operation of the lamp.

Another object of my invention is to utilize the combination of filament heating and an auxiliary arc discharge during the starting condition of the lamp and to extinguish the auxiliary arc, and to maintain a reduced current flow through the filament during the time the lamp is in normal operation.

Another object of my invention is to prevent cooling of filaments in an electrical discharge lamp when operating the lamp in flasher service.

Another object of my invention is to provide a method of flashing electric discharge devices and maintain substantially normal lamp life in flasher service.

My invention is particularly adapted to starting and operating low voltage gaseous electric discharge lamps containing a rare or monatomic gas such as argon or neon, or certain metallic vapors, such as sodium, mercury, or any other gas or vapor etc., or any combination of gases and metallic vapors which require the use of a current limiting impedance in series with the lamp.

According to my invention I provide a series current limiting impedance which cooperates with an untuned current shunting means, connected across the discharge tube or lamp, to establish and maintain a lamp starting condition until the gaseous discharge lamp ignites. Upon ignition the untuned current shunting means assumes a lower voltage during the normal operation of the lamp because of the increased current flow through the current limiting impedance. In the working of my invention the untuned current shunting means may comprise a transformer, a saturable inductance or a non-linear resistance. In general I refer to these untuned circuit shunting means as a non-linear impedance element or specifically to the type of unit used. The current limiting impedance will be referred to as a linear inductance or a linear resistance or a linear impedance.

A typical starting arrangement of the prior art may comprise a relay arranged to connect the filaments in series and then disconnect the series filament circuit to allow the discharge to take place. This and other arrangements are described in the article entitled "Low voltage fluorescent lamp" by G. E. Inman and R. N.

Thayer in *Electrical Engineering*, June, 1938, page 245.

Other methods have been proposed in which a vibrating reed is used to strike a piezo-electric crystal, and thereby generates sufficient voltage to start the discharge device similar to the starting arrangement described in U. S. Patent 2,123,056 to Eugene Lemmers.

My invention improves upon the prior art by automatically starting electric discharge lamps without moving parts and without the use of exceptionally high starting voltages. At the same time, low losses are maintained in the starting unit.

While I have described my invention with reference to electric discharge lamps containing one or more filaments similar to the typical commercial 15 and 20-watt fluorescent low voltage lamps, operated on 110 volts alternating current, it is to be understood that my invention is not to be limited to these or any other specific type of gaseous or vapor lamp.

Other objects and features of my invention, the novel features of which are particularly pointed out in the claims appended hereto, may be more readily and more fully understood from the following description when read with reference to the accompanying drawings, in which like parts of my invention are designated by like reference characters and in which:

Figure 1 shows an enlarged view of one of the main electrodes in the low voltage gaseous discharge lamp, and shows in detail, the electrodes for furnishing the auxiliary discharge as related to the filament.

Figure 2 shows an enlarged view of a main electrode in which the auxiliary discharge is adapted to take place between the lead in wires to the filament.

Figure 3 shows my invention using a transformer and an inductance as applied to a low-voltage gaseous discharge lamp for operation on alternating current.

Figure 4 shows a modification of my invention as shown in Figure 3 as one possible method of arriving at an optimum operating condition for my invention when used in conjunction with a discharge lamp.

Figure 5 shows how the total losses and the losses of the individual units may vary with the ratio of the exciting winding to the total winding on the starting transformer. The total losses include the energy required to maintain the filaments at a reduced heat as well as the losses in the individual units when the discharge lamp is in operation.

Figure 6 shows my invention as applied to an auto-type leakage reactance transformer.

Figure 7 is a modification of my invention as shown in Figure 1 in which the electric discharge lamp is started with one electrode cold.

Figure 8 shows another embodiment of my invention in which a substantially linear inductance is used as a current limiting impedance and in which a saturable inductance is connected in series with the filaments of the electric discharge lamp and in parallel with the lamp.

In Figure 9 I show a generalized starting circuit in which the series impedance may be any suitable linear impedance and where the untuned current shunting means may be any suitable non-linear impedance. By using a linear resistance for the current limiting impedance and a suitable non-linear resistance connected in series with the filaments and in parallel with the discharge lamp,

my invention becomes a universal starting device capable of operating upon either alternating current or direct current without moving parts.

Figure 10 shows my invention using the saturable transformer modified to start the electric discharge lamp with one electrode cold.

In Figure 11 my invention is shown adapted to be used for flashing an electric discharge lamp. In this circuit the filament heating and auxiliary arc discharges are used to obtain prompt ignition and during the time the lamp is lighted the filaments are maintained at a reduced heat and auxiliary arcs extinguished.

Electric discharge lamp starters of the prior art have in general, one disadvantage and that is starting or ignition of the lamp is erratic. By this I mean that these starters fail, in many cases, to cause ignition of the lamp on the first impulse. Such lamp starters may make as many as three or four attempts before ignition occurs. In a typical starter which is commercially available, the ignition of the lamp is controlled by a thermal element. With this type of starter an elapsed time of several minutes may be necessary for the thermal element to cool between starts. Another disadvantage of starters of the prior art is that should the electric discharge lamp deteriorate after a long and useful life, so that the main arc discharge conducts less than normal rated current, the starter may fail to remain in an operated position, in which case the starter operates and releases. In some tests which I conducted and in which the lamp current decreased to a value below normal, I found that the starters were destroyed because of welding of the starting contacts. This occurs when the lamp starter attempts to start a lamp which will not remain ignited but which does not have burned-out filaments. Another disadvantage of the present commercially available starters is that they are delicate and the adjustment easily destroyed if dropped or mistreated. Since the commercially available starters are delicate and the adjustment easily destroyed they may require frequent maintenance and accurate adjustments which are costly and bothersome.

With my invention, I overcome these difficulties. A lamp starter made in accordance with my invention is rugged and able to withstand shocks and jars without harmful effects. In normal operation, my lamp starter causes substantially instantaneous ignition in the lamp and does not depend upon thermal elements or moving parts to perform this operation. Because of these characteristics, a lamp starter made in accordance with my invention may be used for flasher service because of its prompt and positive action in causing electric discharge lamps to ignite. Also, my invention can be made physically small so as to be easily mounted in a molding such as may be associated with the electric discharge lamp and lastly, the starting mechanism is fool-proof and self-protecting in case of lamp deterioration or failure.

In typical low voltage discharge lamp starting units, commercially available today, a high transient starting voltage is applied across the main electrodes of the lamp as a starting condition. With this type of starter the inductance is connected in series with the discharge lamp and a source of alternating current. By interrupting the flow of current through the inductance without disconnecting the inductance from the lamp it is possible to obtain a high transient voltage due to the rapid decay of flux in the inductance.

The current interrupting device may comprise contacts which connect the two filaments of the low voltage electric discharge lamp in series, without any impedance between the filaments. This method causes the filaments to heat but does not impress a voltage for igniting the lamp simultaneously with the filament heating. After the predetermined time the circuit is interrupted. The interruption causes the series inductance to impress a high transient voltage upon the lamp as previously explained. It should be noted that in this type of starter a potential sufficient to ignite the lamp is not impressed upon the lamp until the circuit heating the filaments is broken. Tests show, that depending upon the temperature of the lamp and filament at the time the circuit is interrupted, that voltages as high as 300 volts R. M. S. values are impressed upon the tube to cause ignition with this type of starter.

Experiments indicate that the high voltage applied to the lamp for starting, tends to rapidly deteriorate the coated filaments of the lamp. It is believed that the coating on the filaments of the lamp rapidly disappears from the filament because the filament is bombarded and the coating knocked off by high speed gas molecules.

To overcome this I employ in conjunction with the heated filament, an auxiliary discharge for producing ionization in the lamp. Referring to Figure 1, I show an enlarged view of a main electrode comprising auxiliary electrodes 21 and 22 shunted by a filament 14 as used in my invention. I have found that the starting voltage can be materially reduced if an auxiliary arc is maintained between the auxiliary electrodes 21 and 22 during the time a potential is impressed across the lamp. It will be noted from the table below that a potential only slightly higher than the potential used for normal lamp operation will cause ignition when an auxiliary arc discharge is used. Below is a table taken from actual data on a typical 20-watt low voltage fluorescent electric discharge lamp showing ignition voltage as applied across the lamp as compared with filament and auxiliary discharge current at the starting electrodes.

Filament and auxiliary discharge current	R. M. S. voltage applied across lamp sufficient to cause ignition
0 } No current through auxiliary arc	320-345 60-cycles A. C.
.1 } discharge path.	320-345 60-cycles A. C.
.2 }	264 60-cycles A. C.
.3 }	237 60-cycles A. C.
.35 }	230 60-cycles A. C.
.41 (auxiliary discharge across one filament)	188 60-cycles A. C.
.5 (auxiliary discharge across both filaments)	148 60-cycles A. C.
.55 (auxiliary discharge across both filaments)	130 60-cycles A. C.
.6 (auxiliary discharge across both filaments)	125 60-cycles A. C.
.7 (auxiliary discharge across both filaments) saturating value.	70-80 60-cycles A. C.
.8 (auxiliary discharge across both filaments) saturating value.	70-80 60-cycles A. C.

It will be noted that in this particular case, the auxiliary discharge did not occur across both filaments until approximately .5 ampere was flowing to the filament. At this time it was necessary to apply between 130 and 148 volts across the tube to cause ignition. Under this condition the auxiliary arc carried very little current. The table shows that as the current into the filament and auxiliary discharge was increased to .7 or .8 ampere, the ignition voltage was reduced to between 70 and 80 volts. In this connection several things should be pointed out.

Normal operating voltage across this particular tube was 65 volts. Thus it can be seen that as soon as the auxiliary arc has reached a stable value, the ignition voltage of the lamp is approximately the operating voltage.

In experiments, it is curious to note that with a series impedance, the filament shunted by the auxiliary arc maintains a substantially constant voltage across the filament terminals within wide variations of current. While I have not shown in the table, values beyond .8 ampere, I have gradually increased the current into the filament and auxiliary discharge to 8 amperes which is ten times the maximum current value shown in the chart. With 8 amperes through the filament and auxiliary arc, the voltage across the terminals was still substantially constant. It is believed that under this condition, the filament receives practically a constant amount of current and all excess current is passed through the auxiliary arc stream. Thus the auxiliary discharge path protects the filaments by maintaining a substantially constant voltage across the filament. At the same time ionization of the gas by the auxiliary discharges conditions the lamp for ready ignition at low voltage. However, once a saturating value of ionization is reached, no noticeable improvement in starting results from increased current flow through the auxiliary arc stream. By "saturating value" referred to in the table, I mean that the voltage drop across the filament and the auxiliary electrodes becomes substantially constant after the auxiliary arc is established. It is to be clearly understood that the saturating value referred to in connection with this table does not pertain to the saturation of any of the inductance elements or transformer referred to later in this specification.

With this in mind, it can be easily seen that it is possible to start the low voltage electric discharge lamp upon ignition voltages which may be approximately as low as normal operating voltage of the lamp.

Referring to Figure 1, filament 14 is adapted to be heated from an external source, by means of lead-in wires 19 and 20. Auxiliary electrodes 21 and 22 are connected directly to lead-in wires 19 and 20 respectively. The auxiliary arc is passed through gap 23 between electrodes 21 and 22. The combination of filament 14 and auxiliary electrodes 21 and 22 form one main electrode in the type of low voltage electric discharge tube herein considered.

It is not always necessary to provide the auxiliary electrodes 21 and 22. In Figure 2, lead-in wires 19 and 20 serve as auxiliary electrodes as well as lead-in wires. In this case, the auxiliary discharge occurs through gap 42. Filament 14 together with lead-in wires 19 and 20 constitute one main electrode.

In Figure 3, I show my invention as applied to a two filament or double filament electric discharge lamp in which the lamp is adapted to start with an auxiliary discharge shunting each filament. Electric discharge lamp 13 is provided with filaments 14 and 15 and auxiliary electrodes 21 and 22, and 25 and 26. To obtain the desired action in igniting and operating electric discharge lamp 13, I provide a transformer 12 which cooperates with current limiting impedance 11 to automatically, and without moving parts, carry forward the essential steps of this invention. Transformer 12 has a main winding or exciting winding 16 and filament or starting windings 17 and 18 which are connected directly to filaments

14 and 15 respectively. When so connected transformer 12 is in parallel circuit relation with lamp 13. Windings 17 and 18 are so proportioned with respect to the filaments 14 and 15 and auxiliary discharge gaps 23 and 24, that upon being connected to power supply 10, through choke 11, the filaments are heated to their rated value and auxiliary discharges are produced through discharge gaps 23 and 24. Windings 17 and 18 are also proportioned with winding 16 so as to supply voltage across discharge tube 13, that is between the main electrodes sufficient to ignite the tube. In actual practice I have found that if the starting voltage applied to the main electrodes, before ignition but during the time the filaments are being heated and the auxiliary discharges are occurring, is made at least twice the operating voltage of lamp 13, that this is suitable for taking care of fluctuations in commercial supply voltage. It should be pointed out that this starting voltage can be increased or decreased if it is desired, by changing the connection to the taps on winding 16 of transformer 12 as will be explained in connection with Figure 4. When ignition occurs in lamp 13, an additional current flows through inductance 11 and reduces the voltage on transformer 12 and consequently upon the filaments 14 and 15. This reduction in voltage is sufficient to extinguish the auxiliary arcs through gaps 23 and 24, but maintains a reduced current flow through filaments 14 and 15. With the filaments maintained at a reduced heat the loss in the filaments is reduced.

During the starting condition, the filament and auxiliary discharge arc act as a load upon transformer 12. Under this condition the impedance of transformer 12 is almost entirely resistive while the impedance of current limiting inductance 11 is inductive reactance. Due to this quadrature relation between the voltages of inductance 11 and transformer 12, a larger voltage is obtained across each element than would be the case if the voltages were in phase. This is an advantage because it is possible to reduce the ratio of the exciting winding to the total winding on transformer 12 and thus obtain lower total losses.

Capacitor 29 is used for reducing radio interference caused by the operation of the discharge lamp and is not used to tune any of the circuit elements. I therefore consider my lamp starting and operating device as an untuned circuit.

I have explained the operation of my invention as using the auxiliary arc discharge for starting and because of its many advantages I prefer this method of operation. However, I should point out that my invention as shown in Figure 3 may be designed to satisfactorily start and operate electric discharge lamps without producing the auxiliary arc discharge providing losses are not considered important.

Applying my invention as shown in Figure 3, I have found that this method of starting does not cause the starting filaments to deteriorate rapidly. In comparative tests made with typical commercial starters similar to those previously mentioned, I have found that the electric discharge lamps do not tend to blacken even after prolonged starting tests when operated in accordance with my invention. Using a commercially available starting arrangement for a test, I flashed an electric discharge lamp at intervals of once per minute, with 54 seconds on and 6 seconds off, it was noted that blackening tended to occur at the end of 3 days. On this same duty 75

cycle using my invention to cause an auxiliary arc discharge as described above, blackening did not occur until approximately 6 weeks after the start of the test. In this test the lamps were operated continuously until they failed. Also, my invention seems to prolong the life of the lamp. This may be due to the use of the auxiliary arc and the low starting voltages combined with the continuously heated filament at a reduced temperature.

In another series of comparative tests made to ascertain the number of possible starts that might be obtained from a given lamp, my experiments show that in general, using my invention, approximately the full life of the lamp is obtained and therefore, the number of starts depends upon the duty cycle. With commercially available starters impressing a high voltage across the lamp for starting, the life of the lamp seems to be definitely limited by the number of starts. Using commercially available starters, my tests indicate that 30,000 to 40,000 starts causes lamp failure even though the actual burning time of the lamp may be relatively short. As a comparison using my invention on slow flashing, I have obtained normal life of the lamp after having flashed the lamp 70,000 times. On rapid flashing I have obtained good lamp life with over 2,000,000 flashes. In the rapid flashing tests, the lamp was flashed once per second, one-half second on, and one-half second off.

Figure 4 shows my invention applied to an electric discharge lamp in which transformer 12 contains taps 31, 32 and 33. By moving lead 30 from tap 32 to tap 31 a lower starting will be applied to lamp 13. However, by shifting lead 30 from tap 32 to tap 33 a higher starting voltage will be impressed upon lamp 13. I prefer to design filament windings 17 and 18 so as to maintain a given auxiliary arc discharge during the starting period. By adjusting lead 30 to the proper tap on transformer 12 it is possible to arrive at an adjustment which will give minimum loss in the starting unit during normal operation of the lamp. Since the total loss during the operation of the lamp will depend upon the losses in filaments 14 and 15 and the losses in transformer 12 and inductance 11, it is necessary to design the starting unit for a given size discharge lamp where a maximum efficiency is to be obtained.

Figure 5 shows a typical set of loss curves taken upon the various units of my invention as shown and described in connection with Figures 3 and 4. Figure 5 shows the losses of the series choke or inductance and the losses in the filaments and transformer plotted against the ratio of the starting winding 16 compared to the total winding used for impressing a starting voltage across lamp 13. It will be seen that the total loss in this particular instance was a minimum when the voltage impressed upon lamp 13 was slightly less than twice the voltage across winding 16. It should be noted that the total loss shown by the curve in Figure 5 is represented by a V curve and hence has a very definite minimum loss. There may be other ways of arriving at this same design but the method described in connection with Figure 4 has been found satisfactory in a number of cases.

Referring to Figure 6 a starting unit made in accordance with my invention is shown in the form of a leakage reactance type of transformer. In this embodiment of my invention, series inductance 11 and transformer 12 are incorporat-

ed on the same core but are separated by a magnetic shunt 43. In carrying out my invention in this form I preferred to utilize auto-type transformer connections in order to reduce losses to a minimum. In using this construction the operation and starting cycle is substantially the same as described in connection with Figure 3.

In Figure 7, I show how my invention may be applied to operate an electric discharge lamp utilizing only one filament and one auxiliary discharge for starting purposes. One main electrode remaining cold during the starting process. The starting cycle of the circuit shown in Figure 7 is similar in all respects to the starting cycle described in connection with Figure 3 with the exception that only one electrode is utilized to produce ionization for starting purposes. It should be pointed out that in starting an electric discharge lamp with one electrode cold it is necessary to impress a higher voltage upon the discharge lamp to cause ignition. To do this I prefer to have lead 34 connected to tap 31 as shown in Figure 7 and thus obtain the increased potential necessary for causing ignition of lamp 13.

In Figure 8, I show another modification of my lamp starting invention. In this modification I replace transformer 12 by a saturable or non-linear inductance 35. In the working of this embodiment of my invention I prefer to have filaments 14 and 15 in electric discharge lamp 13 capable of lighting to full brilliancy on current values substantially below the current value upon which lamp 13 normally operates. Also, I prefer to utilize auxiliary discharge gaps 23 and 24 to promote starting.

As before, I establish and maintain a starting condition which is automatically changed to an operating condition when lamp 13 ignites. Filaments 14 and 15 of lamp 13 are designed to operate at rated brilliancy upon a fraction of the current normally taken by the lamp after ignition. While the filament and auxiliary electrode construction in the lamp may be of any suitable design, when operated by my invention as shown in Figures 8 and 9, I prefer to utilize filaments and auxiliary electrodes made to operate as shown, described and claimed in my copending application for U. S. Letters Patent Serial No. 266,971, filed April 10, 1939. Referring to Figure 8, saturable inductance 35 is connected in series with filaments 14 and 15 and is connected in parallel circuit relation with lamp 13. Substantially linear inductance 11 is connected between this combination and the source of alternating current. Under the starting condition, inductance 35 saturates and its impedance is lowered so that sufficient current flows through filaments 14 and 15 to cause them to operate at their rated brilliancy. Under this condition, I prefer to have auxiliary discharges take place through gaps 23 and 24. Since the starting condition takes only a fraction of the current taken by lamp 13 in normal operation, it is possible to impress sufficient voltage across lamp 13 to permit ignition as soon as lamp 13 is conditioned for starting.

When lamp 13 ignites, the main discharge occurs between the main electrodes. It is to be understood that a main electrode may comprise a filament and auxiliary discharge electrodes as described in connection with the detailed drawings in Figures 1 and 2. The main discharge will take place between any two main electrodes and the discharge may localize upon any one part

of a main electrode or any combination of parts in the main electrode. This can be more readily understood by referring again to detailed Figures 1 and 2. When lamp 13 ignites the voltage across lamp 13 is reduced from its starting voltage to the normal operating voltage of the lamp. The reduction in voltage across the lamp and also across saturable or non-linear inductance 35 reduces the flux density in the magnetic core of inductance 35 so that it is no longer saturated. Under this condition, the impedance of inductance 35 increases greatly thereby reducing the current flow through filaments 14 and 15, extinguishing auxiliary arcs through gaps 23 and 24 and reducing the loss due to the starting mechanism to a minimum. Under the normal operating condition, a small amount of current is still permitted to pass through filaments 14 and 15. As soon as lamp 13 ignites, the lamp is operated at the proper current values by current limiting impedance 11.

While I show capacitor 29 in circuit relation with the current limiting impedance 11 and non-linear impedance 35, it should be pointed out that this capacitor is used only for suppressing radio interference caused by discharge lamp 13 and is not used for tuning purposes in my invention. It is to be clearly understood that the various elements used in my invention form an untuned circuit.

Although it is necessary to have an electric discharge lamp with properly designed filaments to permit working of my invention as shown in Figure 8, a distinct advantage is gained thereby because inductance 11 and saturable inductance 35 may be made considerably smaller than the corresponding pieces used in my invention as shown in Figure 3.

Also, due to the tremendous change in the impedance of inductance 35, I am able to greatly reduce the losses of the starting unit.

The embodiment of my invention shown in Figure 9 may be classed as a universal circuit for starting and operating low voltage electric discharge lamps. I refer to it as a universal circuit because if current limiting impedance 44 is a substantially linear resistance and impedance element 45 is a suitable non-linear resistance a correctly designed electric discharge lamp may be operated from either alternating current or direct current. This is accomplished without the use of moving parts. Whenever the lamp starting and operating circuit shown in Figure 9 is to be operated from direct current or where it is desirable that the circuit operate as a universal starting and operating circuit, I prefer to use a non-inductive resistance for impedance 44 and a non-linear resistance for impedance 45. However, where lamp 13 is to be operated upon alternating current impedance 44 may be any suitable linear impedance and impedance 45 may be any suitable nonlinear impedance. Where only alternating current operation is desired the starting and operating circuit shown in Figure 8 is preferred.

Impedance 45 as used in my universal lamp starting and operating circuit may have characteristics similar to the material shown and described in U. S. Letters Patent 1,822,742, issued to K. D. McEachron, September 8, 1931, which material is similar to that known under the trade name of "Thyrrite." In some cases it may be desirable to utilize the non-linear properties of cuprous oxide rectifiers connected to act as a non-linear resistance and to pass alternating current in both directions.

In Figure 9, current shunting means represented by non-linear impedance 45 is arranged to have a lower resistance during the starting condition of lamp 13 than during the operating condition of lamp 13. Current limiting means represented by linear impedance 44 is designed to permit during starting substantially full voltage from source 10 to be applied to the lamp. Similar to the action of the circuit described in connection with Figure 8, I prefer to have the filaments 14 and 15 in lamp 13 designed to operate at rated brilliancy upon a fraction of the current used by lamp in normal operation. With lamp 13, designed to have a main discharge current larger than the current through the filaments, I am able to proportion linear impedance 44 and non-linear impedance 45 so that substantially the full voltage of source 10 is applied across lamp 13. Since the starting voltage is higher than the operating voltage of lamp 13, non-linear impedance 45 will have its impedance substantially reduced, which permits sufficient current to flow through filaments 14 and 15. During the starting condition sufficient voltage must be impressed across lamp 13 to cause lamp ignition which is the same as causing the lamp to light.

During the starting condition I prefer to have the auxiliary arc discharge maintained to provide ready ignition at the voltage available across the main discharge electrodes of lamp 13. As soon as lamp 13 ignites the lamp assumes a lower voltage, due to the increased current flow through current limiting impedance 44, when the main discharge occurs.

As previously explained, this decrease in voltage across lamp 13 causes non-linear impedance 45, which acts as an untuned current shunting means across the lamp, to increase its impedance and thereby reduce filament heating. Under this condition the auxiliary arc discharges which may be maintained during the starting condition are extinguished during the normal operation of the lamp.

In the working of my invention as shown and described in connection with Figures 8 and 9, I prefer to have the main electrodes of lamp 13 constructed so that the main discharge occurs on some part of the main electrode which prevents damage to the fragile filaments. Since the main discharge current is greater than the filament current in this embodiment of my invention it is desirable to have the filaments relieved from carrying the greater part of the main discharge. While any suitable construction of the main discharge electrodes may be used, I prefer to use an electric discharge lamp similar to those shown and described in my copending U. S. Patent application Serial No. 266,971, filed April 10, 1939.

Figure 10 shows a modification of my invention which uses in combination with substantially linear inductance 11, a saturable autotransformer designated as 36. This particular modification of my invention differs from my previous disclosures in that the filament is lighted in series with inductance 11 and winding 37 of transformer 36. As described in connection with Figure 8, I prefer to have filament 15 designed so that it will operate at proper brilliancy upon a fraction of the current used by lamp 13 in normal operation. Under the starting condition, transformer 36 is designed to work at saturation so that the impedance of winding 37 will be low enough to permit rated current

to flow through filament 15. Inductance 11 is approximately linear and is used to limit the current when lamp 13 ignites. Under the starting condition, current flows through winding 37 and filament 15 and causes transformer 36 to impress an increased voltage across lamp 13. At the same time, ionization caused by the heating of filament 15 and discharge through auxiliary gap 24 conditions lamp 13 for ignition. When ignition occurs, the voltage across lamp 13 is reduced. This reduction in voltage across lamp 13 at ignition is sufficient to permit transformer 36 to establish an unsaturated condition. This consequently increases the impedance of winding 37 and permits a reduced current flow through filament 15 and extinguishes auxiliary arc discharge through gap 24.

In Figure 11, I show the preferred arrangement of my invention when used in flashing an electric discharge lamp. Fundamentally, my invention shown in Figure 11 is the same as my invention shown in Figure 3. However, in Figure 11 circuit interrupting device 39 has been added in series with my lamp starting invention. I have found in the operation of my invention that if capacitor 40 in series with resistance 41 is used to shunt interrupter 39, it is possible by correctly proportioning condenser 40 and resistance 41 to maintain a heated condition in filaments 14 and 15 without the accompanying auxiliary discharge in gaps 23 and 24 during the off period of interrupter 39. Tests indicate that additional lamp life may be expected if filaments 14 and 15 are permitted to operate at a predetermined but lowered heat level during the off period of interrupter 39. This is accomplished by current from source 10 flowing through capacitor 40 and resistance 41, during the off period of interrupter 39. It therefore seems desirable to make this modification where long lamp life is desired in flasher operation of electric discharge lamps.

In order to simplify and clarify the description of my invention, I have omitted mentioning capacitor 29 with reference to each figure. Capacitor 29 is used to shunt the tube or lamp 13 in order to minimize radio interference set up by the main gaseous discharge during normal operation. The value of this capacitor is not critical as it is not used for tuning purposes. A satisfactory capacitor size has been found to be between .005 and .05 mfd. for use with 15 and 20 watt fluorescent low voltage discharge lamps.

In my description I have tried to point out clearly that there are two different conditions applied to the tube or lamp—a starting condition and an operating condition—and that the starting condition permits lamp ignition at low voltages and that the ignition of the lamp automatically causes the starting condition to be changed to the operating condition.

In the following claims I refer to linear inductance or substantially linear inductance and by this I mean an inductance having a magnetic core, which core is operated below saturation.

Also in the following claims I refer to electric discharge lamps having one or more filaments, or having at least one filament sealed therein or having two filaments or as having double filaments. By this I mean a gaseous discharge lamp or device having filaments sealed in similar to those shown in the drawings. While I have shown these lamps to have one shape, I do not wish to be limited by shape of the lamp or by

the disposition of the various elements located within the lamp so long as the operation is similar to that described in this specification.

In Figure 9, source 10 is shown as an alternator, but since this embodiment of my invention may be made to operate upon either alternating current or direct current it is to be understood that in this particular case source 10 may be any suitable source of electrical energy.

Although I have described my invention with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and scope of the invention as hereinafter claimed.

I claim as my invention:

1. A circuit for starting and operating a low voltage electric discharge lamp from a source of alternating current in which the operating voltage across said lamp is less than the voltage of the supply source, comprising in combination, a linear inductance, a non-linear inductance, an electric discharge lamp having two filaments sealed therein, said non-linear inductance being connected in series with the two filaments and in parallel with said discharge lamp to form a continuous circuit, and means for connecting said linear inductance in series with said continuous circuit and with said source of alternating current, said non-linear inductance being saturated during the starting condition of the lamp and non-saturated during the operating condition.

2. In combination, a linear inductance, a non-linear inductance, an electric discharge lamp having two filaments sealed therein, said non-linear inductance being connected in parallel with the electric discharge lamp and in series with the two filaments to form a continuous circuit, and means for connecting said linear inductance in series with said continuous circuit and with said source of alternating current, said linear inductance, non-linear inductance and discharge lamp cooperating to establish a starting condition which includes heating said filaments and saturating the non-linear inductance to cause ignition of the electric discharge lamp, the ignition of said lamp causing the impedance of said non-linear inductance to increase and change the lamp starting condition to a lamp operating condition.

3. An alternating current device for connecting an electric discharge lamp having filaments sealed therein with a source of alternating current comprising a linear inductance, a saturable inductance and a capacitor, said saturable inductance being connected in parallel with the lamp and in series with the filaments, said linear inductance being connected in series with a source of alternating current and with said lamp filaments, said saturable inductance being adapted to be saturated before ignition of the lamp and unsaturated after ignition occurs in the lamp, and means for connecting said capacitor in parallel with said lamp.

CLOSMAN P. STOCKER.