

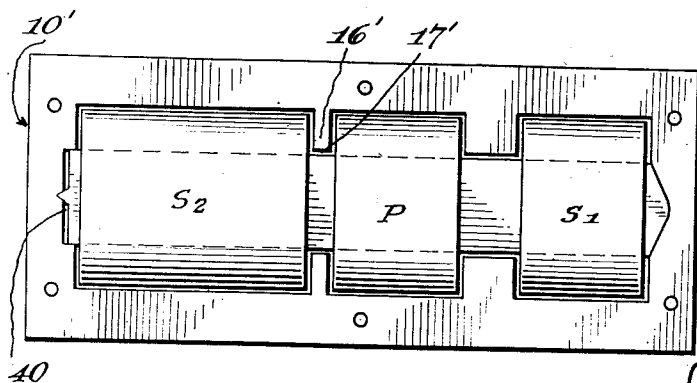
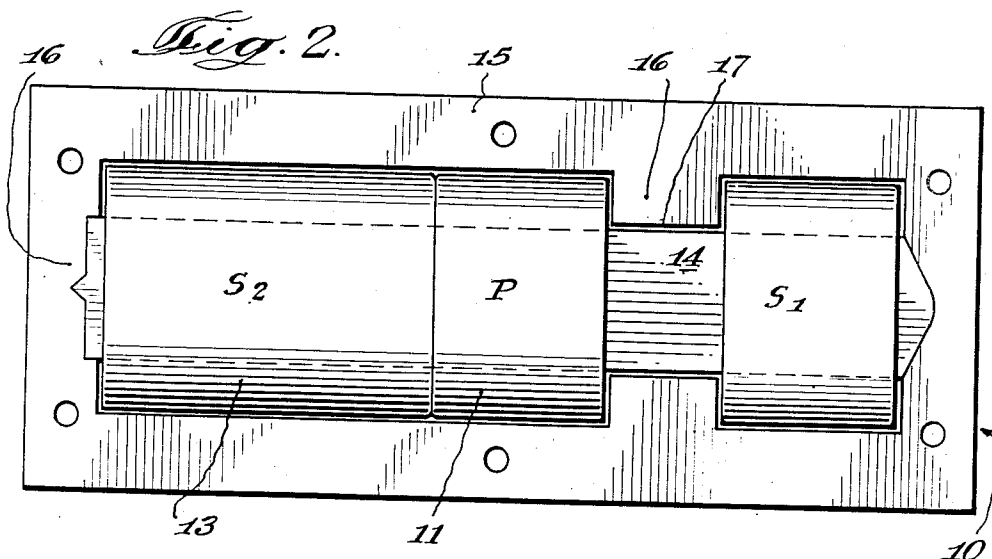
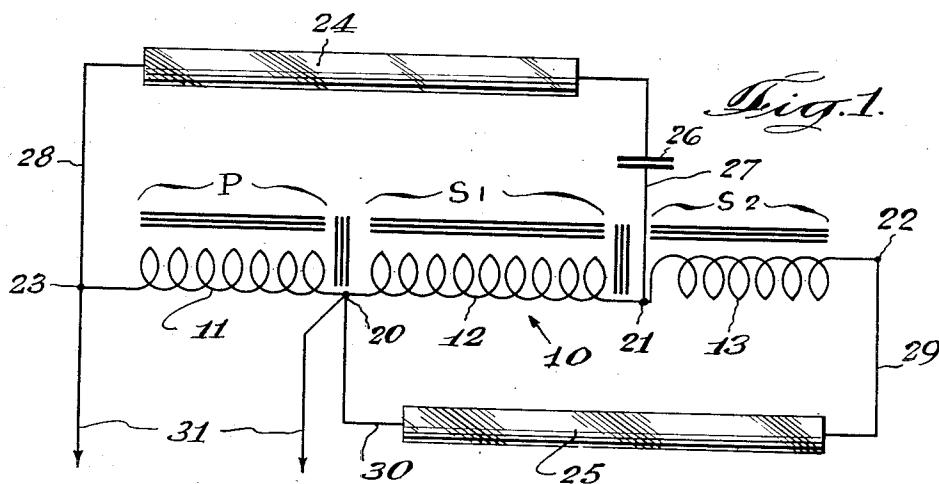
June 26, 1951

A. E. FEINBERG
APPARATUS FOR STARTING AND OPERATING
GASEOUS DISCHARGE DEVICES

2,558,293

Filed Dec. 29, 1949

2 Sheets-Sheet 1



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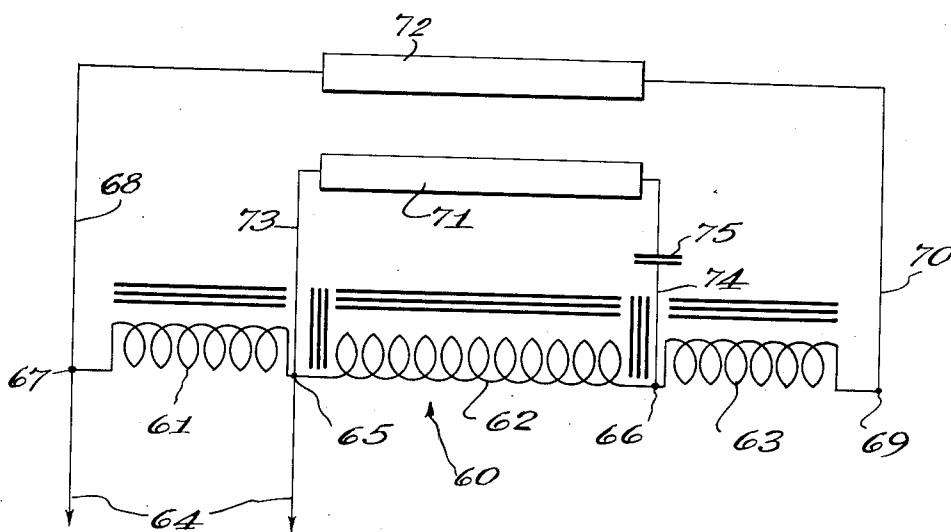


Fig. 4.

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UNITED STATES PATENT OFFICE

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APPARATUS FOR STARTING AND OPERATING GASEOUS DISCHARGE DEVICES

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20 Claims. (Cl. 315—100)

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This invention relates to apparatus for starting and operating gaseous discharge devices, such as fluorescent lamps. It is principally concerned with an electrical circuit for the so-called instant start type of lamp which requires an instantaneously high voltage sufficient to initiate the gaseous discharge in the lamp without the necessity of heating the filaments thereof. Once the discharge has been initiated, it is required of the apparatus that current flow be limited for the reasons well-known and inherent to gaseous discharge devices.

The problem of apparatus to be used in connection with instant start fluorescent lamps becomes more acute when a plurality of lamps is to be started for the simple reason that the ordinary application of a high voltage sufficient to start one lamp instantaneously will cause the voltage to be divided between series connected lamps and the total voltage across either of the lamps will be insufficient to initiate the discharge.

This problem has been attacked by others, notably W. J. Karash, patentee of U. S. Patent No. 2,358,810 in which patent there are shown and described circuits for starting instant start lamps in which it is required that certain inductances and/or transformers be used in order to add the effect of line voltage to the induced voltage of an auto-transformer for starting the first lamp, and then to provide a maximum of reactive impedance across the second lamp.

One of the principal objects of my invention is to provide highly efficient apparatus for initiating the discharge of a plurality of instant start gaseous discharge devices which will be extremely simple and not require expensive circuit elements in addition to an auto-transformer.

In connection with the above object it is pointed out that my new invention utilizes a simple three winding transformer, the general construction of which is similar to that type of transformer used in circuits for starting common heated filament fluorescent lamps. Specifically, no special cores are required, no chokes or inductances need be used in the circuit, and one relatively cheap condenser may be used. The invention lies in the connections of the circuit, the manner of forming and the proportions of the windings, as well as other factors to be pointed out which give rise to the advantages of my invention.

Another object of the invention is to provide apparatus for initiating the discharge of a pair of instant start gaseous discharge devices serially

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and thereafter providing good regulation for the flow of current therethrough.

A further object of the invention is to provide apparatus for initiating the discharge of a pair of gaseous discharge devices in which, following the initiation of such discharge and during the flow of current through both of said devices, the apparatus is constituted in effect a series circuit for said devices.

An object of the invention is to provide a novel arrangement of transformer windings for accomplishing the important functions of my apparatus.

A still further object of the invention is to provide apparatus of the character described which will draw a current from the line having good power factor characteristics.

Other objects will become apparent as the description proceeds in connection with which I have illustrated a preferred embodiment of my invention.

In the drawings:

Fig. 1 is a schematic electrical diagram showing the circuit of my apparatus used to operate two fluorescent lamps.

Fig. 2 is a side elevational view showing the transformer construction capable of being used with my new invention.

Fig. 3 is a view similar to that of Fig. 2, but showing a modified form of my invention.

Fig. 4 is a schematic electrical diagram showing a modified circuit of my apparatus.

Referring to the drawings, the reference character 10 designates generally a transformer which forms an important part of my apparatus. Same is formed of three independently formed windings 11, 12, and 13 comprising a primary P, first secondary S₁ and second secondary S₂ respectively. All of the windings are mounted upon a central winding leg 14 which is pressed into an elongate shell 15, there being a magnetic shunt 16 and an air gap 17 between the windings 11 and 12. The shell 15 and the winding leg 14 are formed of electrical steel laminations in the usual manner thereby providing an iron core for the transformer 10.

The windings are mounted upon the shell 15 in a manner such that the primary 11 is in the center of the shell 15, the second secondary 13 is on the left end of the shell 15 although mounted on the central winding leg 14, and the first secondary 12 is on the right end of the shell 15, separated from the winding 11 by the magnetic shunt 17, and thereby constituting the winding 12 a high leakage reactance. It is obvious that the windings 12 and 13 are both

loosely coupled with the primary 11, but that the first secondary 12 is what may be termed "very loosely" coupled to the primary, when comparing it with the second secondary coupling.

Although both coils 12 and 13 have high leakage reactance, it may be advisable under certain operating conditions to place a small magnetic shunt 16' and a gap 17' between coils 11 and 13 to provide additional leakage reactance as shown in transformer 10', Fig. 3.

The windings 11 and 12, namely the primary P and the first secondary S₁ are wound in the same direction to provide additive voltage, while the winding 13 comprising the second secondary S₂ is wound in an opposite direction to provide bucking voltage.

Referring to Fig. 1, note that the windings 11, 12, and 13 are connected in series providing junctures 20 and 21 therebetween, the right hand end of the transformer 10 being designated 22 and comprising the free end of the winding 13 while the left hand end of the transformer being designated 23 and comprising the free end of the winding 11. Note that the windings are not mounted in the order in which they are connected.

There are shown two gaseous discharge devices, comprising a first fluorescent lamp 24 and a second fluorescent lamp 25. My apparatus includes a condenser 26 in a load connecting lead 27 which is connected to the juncture 21. The lamp 24 is arranged in series with the condenser 26, having the load connecting lead 27 from the condenser 26 connected to its right hand side, while the left hand side of the lamp 24 is connected via a load connecting lead 28 to juncture 23. Thus, it will appear that the first lamp 24 is connected across the primary and first secondary of the transformer 10, and in series with the condenser 26. The second fluorescent lamp 25 has its right hand end connected by the lead 29 to the terminal 22, and its left hand end by lead 30 to the juncture 20. Thus it will be obvious that the second lamp is connected across the first and second secondaries. The very loosely coupled secondary 12 is common to the circuits of both lamps 24 and 25. The usual A. C. line 31 is connected across the primary 11 to provide the necessary power.

The first secondary winding 12 has sufficient turns so that it steps up the line voltage of the primary 11 considerably; in some instances almost four times. This voltage E_{s_1} is additive to the line voltage or primary voltage E_p , and since windings 11 and 12 are in series and across lamp 24, they add to provide igniting voltage for the lamp 24. Although the winding 13 is so constituted that it provides an induced voltage E_{s_2} of more than twice E_p , since its voltage is in opposed relationship to P and S₁, the voltage across lamp 25, which is the sum of E_{s_1} and E_{s_2} will be very little prior to any current flow, and certainly less than required to ignite the lamp 25.

The voltage across condenser 26 is negligible prior to ignition of lamp 24, and hence the voltage E_p combined with E_{s_1} appears across lamp 24, lights the lamp, and causes current to commence flowing.

Current now flows in the circuit of lamp 24, and since the inductive reactance of the very loosely coupled secondary S₁ is so great compared to the capacitive reactance of the condenser 26, the current of such circuit is lagging.

The condenser 26 assists in shifting the phase of the voltage in the first secondary 12 by lowering the total reactance of the circuit of lamp 24. Such effect causes a higher flow of current and a consequently greater induced voltage across S₁ which, of course, aids in causing lamp 25 to ignite.

I have found, that the current flow caused by the ignition of the first lamp 24 gives rise to voltage in the winding 12 whose phase is in effect reversed relative to the phase of voltage E_p and hence is additive relative to voltage E_{s_2} of winding 13, the secondary S₂. This voltage is of such magnitude that the combined voltage appearing across lamp 25 is sufficient to ignite the lamp and cause flow of current there-through.

With current flowing through the both lamps, 24 and 25, the high inductive reactance of winding 12 serves to resist flow of current there-through and thus the effective circuit is a series circuit with both lamps 24 and 25 which may be traced as follows: Juncture 23, lead 28, lamp 24, lead 27 and condenser 26, juncture 21, winding 13, terminal 22, lead 29, lamp 25, lead 30, juncture 20. The winding 12 is thus not an effective part of the operating circuit. The condenser 26 and inductive reactance of the apparatus may so neutralize their respective effects that the power factor of current drawn from the line leads 31 using my apparatus is almost unity. It is obvious that the lead 28 and the left hand one of the line leads 31 may constitute a single lead and that the lead 30 and the right hand one of the line leads 31 may also constitute a single lead.

In the event the current drawn from the line is leading, an additional gap 40 may be formed at the end of the winding leg 14 thereby increasing the leakage reactance of the apparatus while incidentally preventing saturation of the core from too greatly distorting the wave shape.

An example of apparatus embodying my invention readily could be constructed for initiating the discharge and providing regulation for a pair of fluorescent lamps known commercially as T-12 lamps having an effective length of 48 inches and being rated at forty watts each. Such apparatus has been successfully produced and operated. The laminations of the shell 15 of the transformer had the dimensions of approximately two and one eighth by five and one quarter inches, and the stack thickness was approximately one inch. The magnetic shunt may be approximately one-half inch wide, and the gap 17 approximately .010 inch. The windows for the windings 11, 12, and 13 may be adjusted in size in accordance with the physical volume of the windings.

The primary winding 11 was formed of 540 turns of number 25 wire; the first secondary winding 12 was formed of 2360 turns of number 35 wire; and the second secondary winding 13 was formed of 1270 turns of number 27 wire. The condenser 26 had a capacity of 2.6 microfarads and a rating of 440 volts maximum voltage. This apparatus operated in a highly satisfactory manner and the lamps 24 and 25 were ignited with such speed that it almost appeared that they ignited simultaneously when the power was turned on.

With a 113 volt 60 cycle A. C. line connected across the primary 11, the voltage E_{s_1} was 405 volts, and the voltage E_{s_2} was 270 volts. E_{s_1} and E_p (the line or primary voltage) are additive

because the windings 11 and 12 are formed in the same wound direction. E_s , on the other hand is a bucking voltage because the winding 13 is formed in the reverse manner. These voltages exist before the lamps 24 and 25 are ignited. Measurements taken across the various windings bear this out in the following manner: The voltage measured from juncture 23 to juncture 21 was found to be 520 volts; the voltage measured from juncture 20 to terminal 22 (across both secondaries 12 and 13) was found to be 150 volts; and the total sum of voltages across the entire transformer 10 taken from juncture 23 to 22 was found to be 270 volts. Since the type of lamp in the circuit requires approximately 450 volts to ignite, obviously the first lamp 24 will ignite since it has almost 520 volts appearing across its terminals, while the second lamp 25 will not ignite because the total voltage across it is only approximately 150 volts. These measurements may be taken by removing the lamps 24 and 25 from the circuit.

Once the lamp 24 has ignited and the gas therein has broken down, current flows through that lamp, said current being limited by the reactance of the circuit including the high leakage reactance of the secondary 12.

With the lamp 24 operating, measurements can be taken of the voltages and currents in the apparatus by not placing the lamp 25 in the circuit, and such measurements are as follows: E_s is now only 210 volts and E_p appears to be 258 volts, while E_p remains at 118 volts; the voltage measured from juncture 23 to juncture 21 is now 162 volts indicating a radical change which I believe is caused by a phase shift having the effect of providing a voltage vector component additive to the voltage across S_2 the second secondary winding 13, and bucking the voltage E_p across the primary P; the voltage across the lamp 25 measured from juncture point 20 to 22 is now 440 volts, or sufficient to ignite the lamp 25; the voltage across the entire transformer 10 from juncture 23 to 22 is 315 volts; the voltage at the terminals of the lamp 24 is 140 volts and that across the condenser 26 is 105 volts; the current in the primary 11 is found to be .8 ampere and the current in the lamp 24 is found to be .120 ampere.

The above measurements are static, that is, made with only the lamp 24 operating and the lamp 25 not in the circuit. This situation will arise if the lamp 25 burns out, and it will be obvious from the values given that the apparatus is operating satisfactorily and may continue to do so, providing an important emergency feature for my apparatus.

It is probable that the initial surge of current occurring with ignition of lamp 24 will produce voltages in the first secondary 12 and the second secondary 13 whose sum will be considerably greater than 440 volts, but in any event, even the sum static voltage is sufficient to ignite lamp 25 when in place.

After lamp 25 has also become ignited, current flows in its circuit, and the condition of voltages and currents in the apparatus as determined by measurements is as follows: The primary voltage E_p is still 118 volts; the voltage across S_1 the first secondary winding 12 is 310 volts; across the second secondary S_2 the voltage is 308 volts; the voltage measured from juncture 23 to juncture 21 is 415 volts; the voltage across the second lamp 25 from juncture 20 to 22 is 107 volts; the voltage measured across the entire

transformer 10 from juncture 23 to 22 is 130 volts; the voltage across the lamp 24 at its terminals is 107 volts; the condenser voltage is 418 volts; the current flowing in each lamp is approximately .435 ampere; and the current in the primary 11 is found to be .580 ampere. With both lamps 24 and 25 operating the current measured in secondary S_1 is only .030 ampere, which demonstrates that the high reactance of the winding 12 has the effect of forcing the entire circuit to act as a series arrangement so that the major flow of current is through the lamps 24 and 25, the winding 13, and the condenser 26. With such a circuit, the reactance occasioned by the presence of the condenser 26 is effective to counterbalance the inductive reactance of the transformer windings, so that there is very good power factor correction and the current drawn from the line 31 can be adjusted practically to be almost in phase with the line voltage.

It should be obvious that for different types of lamps the circuit constants of my apparatus can be adjusted.

In the embodiment of my invention shown in Fig. 4, the connections of the circuit have been somewhat rearranged. The leads 28 and 30 have been interchanged and the windings of the transformer have been varied in accordance with the change. Thus, the transformer 50 corresponds to the transformer 10 of Fig. 1 and is constructed in quite a similar manner. The physical appearance is the same and hence is not shown here.

Electrically, there is a primary winding 61, a first secondary winding 62, and a second secondary winding 63. The winding 62 is reverse wound relative to the other two winding 61 and 63 and of such voltage relationship considering the number of turns relative to the primary winding 61, that there is a voltage developed thereacross that is sufficient to ignite a gaseous discharge device. The windings 61, 62 and 63 are all connected in auto-transformer relationship. Thus, if the voltage required to ignite the gaseous discharge device is of the order of 450 volts, and the line voltage across the primary is 118 volts, then the number of turns of the first secondary 62 is approximately four times the number of turns on the primary 61.

The primary winding 61 is connected to an A. C. line 64, and the second secondary 63 has sufficient turns that the sum of voltages across the primary, second secondary and the in-phase component induced in the first secondary 62 after its gaseous discharge device has ignited will be sufficient to ignite a second gaseous discharge device. This shortly will be explained.

All three windings 61, 62 and 63 are connected in series, 61 and 62 being joined at 65, and 62 and 63 being joined at 66. The left hand end or free end of the primary winding 61 is connected at 67 to the lead 68 and the right hand or free end of the second secondary winding 63 is connected at 69 to the lead 70.

Two gaseous discharge devices, such as for example fluorescent lamps 71 and 72 are here shown connected to be ignited and operated by my apparatus. Lamp 71 has its terminals connected to the leads 73 and 74 which extend respectively to junctures 65 and 66. Lamp 72 has its terminals connected to leads 68 and 70 respectively. A condenser 75 is interposed in the lead 74.

The apparatus operates in a manner similar to the apparatus previously described herein. When the line voltage designated V_p (to dis-

tinguish it from the designation E_p previously used) is impressed across the primary winding 61, a voltage V_{s_1} is induced in the first secondary winding 62 sufficient to ignite the lamp 71 and cause current to flow therein. It will be noted that since the winding 62 is wound in an opposite direction to the winding 61, the induced voltage is also opposite in direction. The current now flowing is limited by the impedance of the high leakage reactance winding 62 and the condenser 75. Due to this high leakage reactance of the winding 62 (same being arranged relative to the core and other windings of the transformer 60 in the manner that the winding 12 is arranged relative to the transformer 10), there is a phase shift of the voltage in the winding 62 causing a reverse component of the voltage V_{s_1} to appear across the junctures 65 and 66. The voltage component thus produced when added to the in-phase voltage V_p across the primary winding 61, and V_{s_2} across the second secondary winding 63 provides a voltage across the terminals of the lamp 72 sufficient to ignite the same. Thereafter current flows in effect through the lamps 71 and 72, the condenser 75, and the second secondary winding 63 in series. The reactance of the winding 62 is so high that it is by-passed by the current flowing through the lamps. The condenser 75 serves to increase the current flow through the lamp 71 when same has become ignited by voltage V_{s_1} and acts to correct power factor of the current drawn from the line 64. Other adjustments referred to herein can be made for power factor correction.

A successful example of my apparatus as described above in connection with Fig. 4, has been constructed and operated in connection with a pair of instant start fluorescent lamps. The physical construction of the transformer 60 was substantially the same as that of transformer 10 of the previously mentioned example. The discharge devices 71 and 72 again were T-12, 40 watt, forty eight inch lamps. The primary winding 61 had 575 turns of number 26 wire, the reverse wound first secondary had 2900 turns of number 35 wire, the second secondary had 1420 turns of number 27 wire. With a 118 volt V_p impressed across the primary winding 61, the secondary voltages prior to ignition of the lamps were 450 volts and 275 volts for V_{s_1} and V_{s_2} respectively. V_{s_1} was sufficient to ignite lamp 71, but the combined voltages across the terminals 69 and 67 were insufficient to ignite lamp 72. After ignition of the lamp 71, the voltage across terminals 67 and 69 was of the order of 450 volts and the lamp 72 became ignited. The lamps both operated at a voltage of about 107 volts and with a current of about .425 ampere flowing there-through. The current in the first secondary winding 62 during operation was found to be only .035 ampere since practically all the current of the winding 63, namely .410 ampere was being by-passed through the lamp 72. The condenser 75, for this example, had a capacity of 2.3 microfarads and a rating of 440 volts. The current in the primary winding 61 was found during operation to be .610 ampere.

It will be seen that the lamps of the circuit of Fig. 4 are ignited seriatim, the lamp 71 being first and thereafter being followed by the ignition of the lamp 72. It will also be obvious that the effective circuit after initiation of operation of both lamps is a series circuit which may be traced from one side of the primary winding 61 to the other as follows: juncture 67, lead 68, lamp

72, lead 70, terminal 69, winding 63, juncture 66, lead 74, condenser 75, lamp 71, lead 73, juncture 65.

I should like to emphasize that the nature of current and voltage in circuits involving gaseous discharge devices and the reactive elements is highly complex and the wave forms vary greatly from sinusoidal. It is difficult to theorize concerning the reasons for achieving the results alluded to herein with certainty, and hence I do not desire to be bound by the explanation of theory to which I have attributed such results. The construction may be varied within the scope of my invention and without departing from the teachings thereof and perhaps operating upon explained theory other than set forth. It is therefore desired to be limited only by the structure as set forth in the claims appended hereto and made a part hereof.

I claim:

1. Apparatus of the character described adapted to ignite and operate a pair of gaseous discharge devices from an A. C. source of relatively low voltage which includes an auto-transformer having a primary, a loosely coupled first secondary having one side connected to one side of said primary and in additive voltage relationship thereto, and a loosely coupled second secondary having one side connected to the second side of said first secondary and in voltage bucking relationship to said primary, means including a capacitive reactor for connecting one of said devices across the primary and the first secondary, means for connecting the second of said devices across the first and second secondaries, and means for connecting said source across said primary.

2. Apparatus of the character described adapted to ignite and operate a pair of gaseous discharge devices from an A. C. source of relatively low voltage which includes a three-winding auto-transformer having a primary, a loosely coupled additively wound first secondary having one end connected with the said primary, a loosely coupled second secondary, the said first secondary having its second end connected therewith, said secondaries being arranged in reverse voltage relationship one to the other, means including a capacitive reactor for connecting one of said devices across and the primary and the first secondary, means for connecting the second of said devices across and the first and second secondaries, and means for connecting said source across the primary, the secondaries having a turn relationship to the primary to cause seriatim ignition of said first and second devices, and the reactance of the first secondary being very high relative to the second secondary whereby after the said devices are both operating the apparatus will form in effect a series circuit connected across the primary, said circuit including the devices, the capacitive reactor, and the second secondary.

3. Apparatus of the character described adapted to ignite and operate a pair of gaseous discharge devices from an A. C. source of relatively low voltage which includes an auto-transformer having a primary, a loosely coupled first secondary having one side connected to one side of said primary and in additive voltage relationship thereto, and a loosely coupled second secondary having one side connected to the second side of said first secondary and in voltage bucking relationship to said primary, means including a capacitive reactor for connecting one of said devices across the primary and the first secondary,

means for connecting the second of said devices across the first and second secondaries, and means for connecting said source across said primary, the first secondary being of higher reactance than the second secondary and being more loosely coupled to the primary than is the second secondary.

4. Apparatus of the character described comprising an auto-transformer for igniting and operating a pair of gaseous discharge devices from a source having a voltage substantially lower than the igniting voltage of either of said devices, and having three windings connected one after the other and comprising respectively, a primary, a first secondary, and a second secondary, leads for extending circuit connections to one of the devices across the primary and first secondary together, leads for extending circuit connections to the second of said devices across the secondaries together, the primary and first secondary having sufficient turns to provide a voltage for igniting the first of said devices when the primary is energized by said source, and the secondaries having sufficient turns to provide a voltage for igniting the second device but being inductively arranged additively to combine their voltages only after ignition of said first device, and means comprising a magnetic shunt establishing a high leakage reactance in said first secondary to prevent substantial passage of current therethrough after ignition of both devices so that the devices and second secondary are connected in an effective series circuit.

5. Apparatus for igniting and operating a pair of gaseous discharge devices from an A. C. source of relatively low voltage which comprises an auto-transformer having a primary, a loosely coupled high leakage reactance first secondary of greater than unity turn relationship to the primary and arranged additively relative thereto, and a second loosely coupled high leakage reactance secondary of greater than unity turn relationship to the primary but arranged bucking relative thereto, a first juncture between the primary and first secondary, and a second juncture between the first and second secondaries whereby said primary, first secondary and second secondary are connected one after the other, said source adapted to be connected across the primary, means for connecting one of said devices from the free end of the primary to the second juncture including a capacitive reactor, and means for connecting the second of said devices from the first juncture to the free end of the second secondary, the resulting voltage relationships being such as to ignite the first device, then the second device, and then to establish a series path for the current through the devices, the second secondary, and the capacitive reactor.

6. Apparatus of the character described for igniting and providing operating regulation for a pair of gaseous discharge devices from a source of alternating current whose voltage is substantially less than the starting voltage of either of the devices, which includes reactive means having a primary winding, first and second secondary windings loosely coupled to the primary and to one another, the coupling of the first secondary winding being substantially looser relative to the other two windings whereby to constitute same a higher leakage reactor, the second secondary winding being arranged in bucking voltage relationship to the other two windings, the windings being connected in series with the first

secondary winding connected between the other two, a capacitive reactor having one side thereof connected to the common juncture of the secondaries, means for connecting the first of said discharge devices between the second side of the capacitive reactor and the free end of the primary winding whereby said first discharge device is in series with the primary, first secondary, and the capacitive reactor, means for connecting the second of said discharge devices across both secondaries, said secondaries having a turn ratio relative to the primary winding to cause ignition of the first of said devices when the primary is connected with the said source followed by ignition of the second of said devices, followed by effective series operation of both devices.

7. Apparatus for igniting a pair of instant start gaseous discharge devices and operating the same with desired regulation from an A. C. source of voltage insufficient to ignite either device comprising an auto-transformer, having a primary adapted to be connected across the source and establishing a voltage equal to the source therein, a first inductively reactive portion of said transformer of high leakage and of relationship relative to the primary for having a voltage induced therein substantially greater than the source voltage whereby the combined voltages will suffice to ignite one of said devices, means for impressing the combined voltages of the primary and the said first reactive portion across said device for igniting same, a second inductively reactive portion of said transformer of high leakage and of relationship relative to the primary for having a voltage induced therein greater than the source voltage, but bucking the same, said first portion producing after ignition of the first device a voltage having a component additive relative to the said bucking voltage whereby the sum of said after ignition voltage and bucking voltage will be sufficient to ignite the second device, and means for impressing the said sum upon the second of said devices to ignite the same.

8. Apparatus for igniting a pair of gaseous discharge devices and operating the same from a low voltage A. C. source which comprises a transformer having three windings comprising a primary, first secondary and second secondary, the secondaries being in reverse voltage relationship one to the other, lead means for forming a series circuit for one of said devices across two windings, lead means for forming a series circuit for the other of said devices across two windings, the first of said secondaries being common to each circuit and having relatively high inductive reactance whereby to impede flow of current therethrough after ignition of both devices and forcing the current to flow in series through the devices and the second secondary.

9. Apparatus of the character described adapted to ignite and operate a pair of gaseous discharge devices from an A. C. source of relatively low voltage which includes an auto-transformer having a primary, a first secondary and a second secondary, both secondaries being loosely coupled to the primary, the first secondary being connected between a terminal of the primary and a terminal of the second secondary, the first secondary being arranged in bucking voltage relationship to the primary while the second secondary is arranged in additive voltage relationship to the primary, leads having a capacitive reactor for connecting one of said devices across the first secondary, leads for connecting the sec-

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ond of said devices across all three of said windings, and line leads for connecting the source across the primary, the secondaries having a turn relationship to the primary whereby the first of said devices will be ignited when power is applied to the primary by said source causing a flow of current through said first secondary which in turn will produce a component of voltage in said first secondary in phase with the voltages of the primary and second secondary such that sum of voltages across the three windings after ignition of said first device is sufficient to ignite the second of said devices, the said first secondary having a relatively high leakage reactance greatly to limit the flow of operating current there-through whereby after ignition the said devices will operate as though in effect they are connected in series with only the second secondary and the primary.

10. In apparatus of the character described for igniting and thereafter regulating the operation of a pair of gaseous discharge devices from a source of A. C. voltage substantially less than the igniting voltage of either device, a multiple winding auto-transformer having a primary and two secondaries, the two secondaries being arranged in voltage bucking relationship one to the other with reference to a circuit containing both secondaries, means including a capacitive reactor for connecting one of said devices across a part of the said auto-transformer including at least the first secondary and excluding the second secondary, means for connecting the second of said devices across windings of said transformer including at least both of said secondaries, said windings and primary having a turn relationship to produce upon energization of said primary a voltage across the first device sufficient to ignite the same, but across the second device insufficient to ignite the same, said first secondary having a high leakage reactance whereby after ignition of said first device there will be a phase shift in the voltage thereof providing a component additive to the second secondary whereby to increase the voltage across said second device to a value sufficient to ignite the same.

11. Apparatus for igniting a pair of gaseous discharge devices and operating same from a low voltage source of alternating current, which comprises a transformer having an iron core, three windings mounted upon the core and comprising a primary, a first secondary, and a second secondary, means for connecting said devices in two separate series circuits across two parts of said transformer, one part including at least said first secondary and excluding said second secondary, and the second part including at least both secondaries, whereby the said first secondary is common to each of said circuits formed, said secondaries being arranged in voltage bucking relationship one to the other on said core with said first secondary physically spaced from the other two windings to provide very loose coupling and high leakage reactance therein during operation, whereby current flow will be impeded there-through during operation forcing flow of current substantially to by-pass the same to provide an effective series circuit through said devices and the said second secondary.

12. Apparatus of the character described comprising an auto-transformer for igniting and operating a pair of gaseous discharge devices from a source having a voltage substantially lower than the igniting voltage of either of said devices, and having three windings inductively

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arranged one relative to the other and comprising a primary, a first secondary, and a second secondary, means for connecting one of said devices in a circuit across the primary and first secondary together, means for connecting the second of said devices in a circuit across the secondaries together, the secondaries being arranged with their open circuit voltages opposing one another in said mentioned circuit, the primary and first secondary having sufficient turns to provide a voltage for igniting the first of said devices when the primary is energized by said source, and the secondaries having sufficient turns to provide a voltage for igniting the second device but being inductively arranged additively to combine their voltages only after ignition of said first device, and means comprising a magnetic shunt establishing a high leakage reactance in said first secondary to prevent substantial passage of current therethrough after ignition of both devices so that the devices and second secondary are connected in an effective series circuit.

13. A lamp ballast for operating two discharge devices comprising a primary, a first secondary, a second secondary, a pair of terminal leads for extending connections to a discharge device, the terminal leads and the secondaries being so connected that when a load is across the terminal leads it forms a loop with the two secondaries and the voltages of said secondaries in opposition to one another in said loop prior to the flow of current through the secondaries whereby at that time the voltage across the terminal leads is substantially the difference between the voltages across the two secondaries, another terminal lead extending from the loop for connection in a circuit leading to another discharge device, the loop circuit being connected in circuit with the primary at a point on the loop such that only the first of the two secondaries lies between that point and the other terminal lead and that first secondary being in step-up auto transformer relationship to the primary, a magnetic structure coupling the primary with the two secondaries, the secondaries being more closely coupled to the primary than to one another, said first secondary taking a lagging current upon starting of current flow therethrough whereby after current commences to flow therethrough the direction of the voltage across the first secondary is substantially reversed with respect to the voltage induced in the other secondary and the voltage across said first terminal leads becomes substantially the sum of the voltages across the two secondaries, said first secondary being of substantially higher reactance than that of the other secondary whereby in operation of the ballast said first terminal leads in series with the second secondary are shunted by the higher reactance secondary, and the circuit which includes the first terminal leads in series with the secondary and shunted by the higher reactance secondary is in series with said other terminal lead.

14. A lamp ballast for operating two discharge devices comprising a primary, a first secondary, a second secondary, a pair of terminal leads for extending connections to a discharge device, the terminal leads and the secondaries being so connected that when a load is across the terminal leads it forms a loop with the two secondaries and the voltages of said secondaries in opposition to one another in said loop prior to the flow of current through the secondaries

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whereby at that time the voltage across the terminal leads is substantially the difference between the voltages across the two secondaries, another terminal lead extending from the loop for connection in a circuit leading to another discharge device and including the primary, the loop circuit being connected in circuit with the primary at a point on the loop such that only the first of the two secondaries lies between that point and the other terminal lead and that first secondary being in step-up auto transformer relationship to the primary, a magnetic structure coupling the primary with the two secondaries, the secondaries being more closely coupled to the primary than to one another, said first secondary taking a lagging current upon starting of current flow therethrough whereby after current commences to flow therethrough the direction of the voltage across first secondary is substantially reversed with respect to the voltage induced in the other secondary and the voltage across said first terminal leads becomes substantially the sum of the voltages across the two secondaries, said first secondary being of substantially higher reactance than that of the other secondary whereby in operation of the ballast said first terminal leads in series with the second secondary are shunted by the higher reactance secondary, and the circuit which includes the first terminal leads in series with the secondary and shunted by the higher reactance secondary is in series with said other terminal lead, and a condenser in series with said first secondary and of a capacity reactance less than the inductive reactance of the first secondary.

15. A lamp ballast for operating two discharge devices comprising a primary, a first secondary, a second secondary, a pair of terminal leads for extending connections to a discharge tube, the terminal leads and the secondaries being so connected that when a load is across the terminal leads it forms a loop with the two secondaries and the voltages of said secondaries in opposition to one another in said loop prior to the flow of current through the secondaries whereby at that time the voltage across the terminal leads is substantially the difference between the voltages across the two secondaries, another terminal lead extending from the loop for connection in a circuit leading to another discharge device, the loop circuit being connected to the primary at a point on the loop such that only the first of the two secondaries lies between that point and the other terminal lead and that first secondary being in step-up auto transformer relationship to the primary, a magnetic structure coupling the primary with the two secondaries, said structure including a rectangular shell and a central winding leg between the transverse ends of the shell, the secondaries being at the ends of the central leg and the primary being between the secondaries so that the secondaries are more closely coupled to the primary than to one another, magnetic shunts bridging a major portion of the space from the central leg to the shell on opposite sides of the primary to provide high leakage reactance for the secondaries, said first secondary taking a lagging current upon starting of current passing therethrough whereby after current commences to flow therethrough the direction of its voltage

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across the first secondary is substantially reversed with respect to the voltage induced in the other secondary and the voltage across said first terminal leads becomes substantially the sum of the voltages across the two secondaries, said first secondary being of substantially higher reactance than that of the other secondary whereby in operation of the ballast said first terminal leads in series with the second secondary are shunted by the higher reactance secondary, and the circuit which includes the first terminal leads in series with the secondary and shunted by the higher reactance secondary is in series with said other terminal lead, and means for preventing saturation of the central core leg adjacent the second secondary comprising a bridged air gap between the adjacent end of the core leg and the shell.

16. Apparatus for igniting a pair of discharge devices and operating same from a low voltage source of alternating current, which comprises a transformer having a primary, a first secondary, and a second secondary, leads for connecting to a discharge device, said leads being in a series circuit including the primary and only the first one of the two secondaries, leads for connecting another discharge device in a loop which includes both secondaries with their open circuit voltages in opposition in said loop and which excludes the primary, the first secondary being more closely coupled with the primary than it is with the second secondary and having a relatively high inductive reactance whereby to impede flow of current therethrough after ignition of the devices, and thereby forcing the current to flow in series through said devices and the second secondary.

17. A structure as defined in claim 11 in which said first part comprises said first secondary winding and excludes the primary winding.

18. A structure as defined in claim 11 in which said second part comprises all three of said windings.

19. A structure as defined in claim 11 in which said first part comprises said first secondary winding and excludes the primary winding, and said second part comprises all three windings.

20. A structure as defined in claim 11 in which said first part comprises said first secondary winding and excludes the primary winding, and said second part comprises all three windings, and said means for connecting the device including said first secondary winding includes a condenser.

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