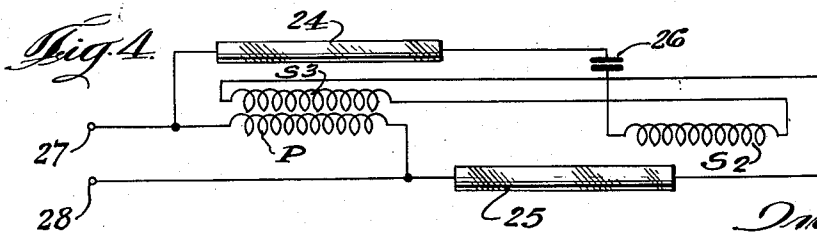
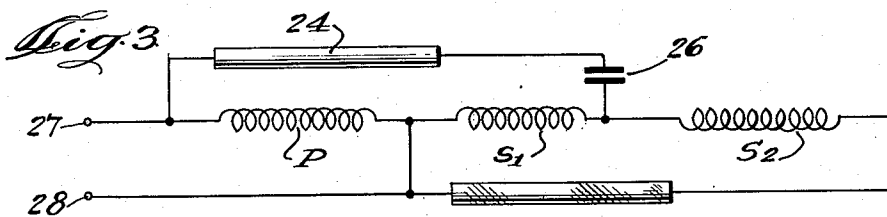
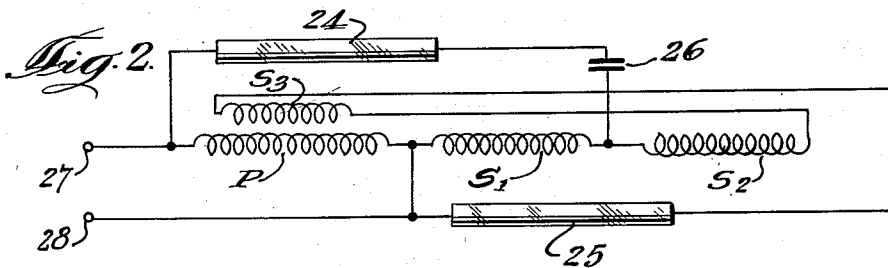
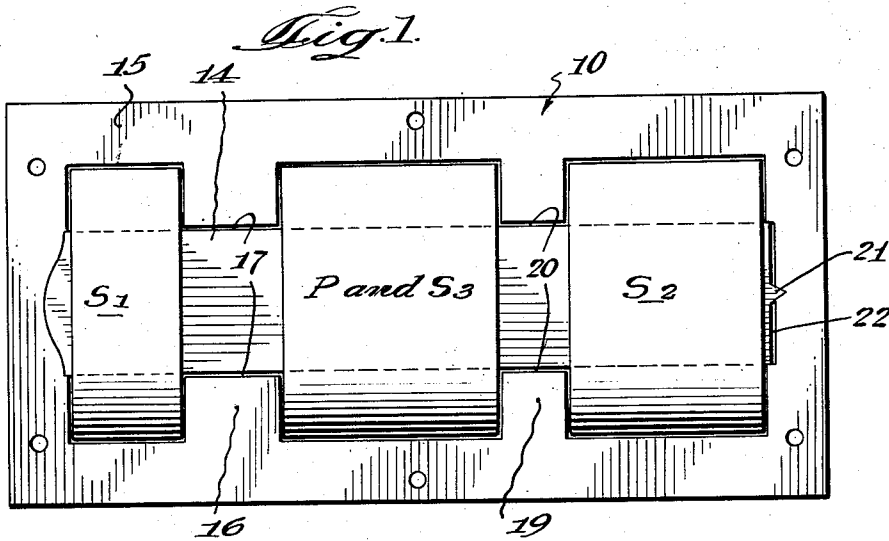


July 6, 1954

A. E. FEINBERG
 APPARATUS FOR IGNITING AND OPERATING
 GASEOUS DISCHARGE DEVICES
 Filed Nov. 17, 1950

2,683,243



Inventor
 Albert E. Feinberg
 By J. Irving Silverman
 Attorney

UNITED STATES PATENT OFFICE

2,683,243

APPARATUS FOR IGNITING AND OPERATING
GASEOUS DISCHARGE DEVICES

Albert E. Feinberg, Chicago, Ill., assignor to Advance Transformer Co., Chicago, Ill., a corporation of Illinois

Application November 17, 1950, Serial No. 196,188

14 Claims. (Cl. 315—138)

1

2

This invention relates generally to apparatus for supplying the ignition voltage for a pair of gaseous discharge devices, and providing operating voltage with suitable regulation for the devices subsequently to the ignition thereof.

The invention is especially intended for use in the type of apparatus described and claimed in my co-pending application Serial No. 135,669 filed December 29, 1949, and entitled "Apparatus for starting and operating gaseous discharge devices," now Patent No. 2,558,293. In that application, I have set forth the description of apparatus for use with the so-called instant start type of gaseous discharge device which requires relatively high voltage to start the same. Such apparatus transforms the voltage obtained from a relatively low voltage source to a relatively high ignition voltage, and, by virtue of the novel arrangement thereof, ignites the devices seriatim, that is to say, one after the other. This function is achieved by means of, among other things, an auxiliary starting secondary S_1 which provides very high leakage reactance due to its very loose coupling with the other windings of the apparatus. The result of this high leakage reactance is to force the operating circuit of the apparatus to become a series circuit in which the greater portion of the current flowing through the discharge devices by-passes the auxiliary starting secondary.

Such apparatus is especially suitable for use as ballasts for fluorescent lamps, which are negative resistance devices of the gaseous discharge type. The apparatus is embodied in a transformer having three windings mounted upon a common unitary iron core, said windings consisting of a primary P, the loosely coupled first secondary S_1 , and a second secondary S_2 , with the windings connected serially in the order named, and the secondaries S_1 and S_2 connected in voltage bucking relationship. Means, comprising electrical leads enable the low voltage line to be connected across the primary P, while other means including a condenser enable one of the lamps to be connected across the combined primary P and the first secondary S_1 . The second lamp is arranged to be connected across the combined secondaries. Thus, in the preferred embodiment the first, or auxiliary starting secondary is common to both lamp circuits.

When power is applied to the primary P, the combined voltages of the primary and first secondary are sufficient to ignite the first lamp, and thereafter the flow of current through the lamp, condenser and the first secondary produce a voltage component in the first secondary,

due to its high leakage reactance, which is of reverse phase and combines with the voltage of the second secondary S_2 to provide sufficient igniting voltage for the second lamp. Following ignition of both lamps, current flows through the lamps in series with the condenser, the primary P, and the second secondary S_2 , with only a nominal current flowing in the first secondary S_1 .

My invention consists of an improvement of the apparatus of said copending application, and the principal object is to provide an improvement making the said apparatus cheaper, quieter, lighter in weight, and in providing a better wave shape for the operating current, increasing thereby the lighting efficiency thereof when same is used as a ballast for fluorescent lamps. Such improvement comprises modifications of the apparatus to enable same more efficiently to operate in connection with certain type of lamps, such as for example the 96 inch T-12 lamp which ignites at 625 volts and operates at 195 volts.

This type of discharge device requires a high starting voltage. The line voltage being of the order of 118 volts, note that a transformation of more than five to one is required. The construction of a transformer in accordance with the teachings of the said co-pending application indicates the use of an end non-magnetic gap adjacent the second secondary S_2 . The number of turns of wire which would be required on S_2 to assure the provision of this high ignition voltage would produce an abnormal magnetomotive force in the core thereat. To counteract this effect and maintain good wave shape, it is required to increase the size of the gap, but this produces a magnetizing current of excess value which may be more than enough to correct power factor for a ballast with leading lamps. This over-correction may result in overheating due to a high primary current. In addition, the added reluctance in the magnetic circuit increases the leakage of flux to the canister in which the ballast is contained, and flow of flux in such canister gives rise to noise, vibration, and excessive heating.

The construction above described would normally have a large component of magnetomotive force of the leading current through S_2 (by reason of the series connected condenser) in phase with the magneto-motive force of the primary magnetizing current. This might give rise to saturation in the iron core in the immediate vicinity of S_2 were it not for the existence of the end non-magnetic gap which draws a lagging magnetizing current to prevent saturation. This

construction is taught in Berger Patent No. 2,461,957 dated February 15, 1949, Transformer. As explained above, the use of a large end gap with high magneto-motive forces in S_2 does not adequately solve the problem. Another object of the invention therefore is to solve this problem in a novel manner, whereby the voltage requirements of S_2 and hence the number of turns necessary is decreased.

In a circuit such as discussed above, I have found that the open circuit voltage induced in the second secondary S_2 must have a definite relationship to the operating voltage of either lamp in order to provide the necessary regulation. This relationship is generally described by the ratio of open circuit voltage of the primary P plus the induced open circuit voltage of S_2 to the operating lamp voltage. This ratio must be at least 2.5:1 to 3:1 according to the desired degree of regulation, with the higher ratios providing better regulation. In order to meet this high ratio requirement the difficulty of too great a magneto-motive force again arises. In my invention herein described I have been able to achieve the advantages referred to herein by decreasing substantially the voltage requirements of S_2 but at the same time without in any manner disturbing the regulation ratio described hereinabove. Accordingly, another object of the invention is concerned with the achievement of these ends in the manner described.

My invention consists in materially lowering the voltage requirements of the second secondary by the addition of a third secondary winding, mounted on the same magnetic core in closely coupled relationship with the primary P , but in voltage additive relationship relative to the second secondary S_2 .

I have hereinafter set forth a preferred embodiment of my apparatus as required by statute, and have described the circuit thereof in detail, but merely for illustrative purposes. Further, I have explained the theory of operation in accordance with my understanding thereof, but only by way of further clarification and not limitation. I have illustrated the invention in the conventional manner in drawings which, for the sake of completeness, include figures representing and repeating disclosures made in the co-pending application referred to.

Fig. 1 is a side elevational view of a transformer embodying my new invention.

Fig. 2 is a schematic electrical diagram showing the circuit of my apparatus used in connection with two fluorescent lamps.

Fig. 3 is a diagram similar to that of Fig. 2 but showing the circuit of my co-pending application herein referred to, additional features having been incorporated therein and combined therewith as set forth hereinafter.

Fig. 4 is a view similar to that of Fig. 2, except that one of the windings, namely S_1 , has been omitted.

Referring now to the drawings, the reference character 10 designates generally an iron core transformer which has three independently formed windings consisting of a primary P , a first secondary S_1 (sometimes referred to as the auxiliary starting winding or secondary), and a second secondary S_2 . A third secondary, namely S_3 , is closely coupled with the primary P , and may be wound on top of P , as will be explained hereinafter. All of the windings are mounted upon a central winding leg 14 which is pressed into the elongate rectangular shell 15, there being

a magnetic shunt 16 and air gap 17 between the windings S_1 and the combined windings P and S_3 , and another shunt 19 and air gaps 20 between the winding S_2 and the combined windings S_3 and P . The shell 15 and the central winding leg 14 are formed of electrical steel laminations in the usual manner thereby providing a suitable iron core for the transformer 10.

In order to render the explanation clear, the conventional symbols representing an iron core and the magnetic shunts have been omitted from the circuit diagram of Figs. 2 to 4. Furthermore, the preferred orientation, as indicated in Fig. 1 is not followed in said circuit diagrams in that an attempt correctly to indicate the iron cores by symbols might be confusing.

The windings are mounted upon the central leg 14 with the secondary S_1 on the left end (as viewed in Fig. 1), the second secondary S_2 on the right end, and the other two windings P and S_3 positioned in the center. It is preferred that the central winding leg and the mounted windings be assembled and the whole pressed into the shell 15. Obviously the shell 15 is provided with suitable openings or windows to receive the windings, the size thereof being substantially the same as the respective windings and not readily apparent from the drawing. The right hand end of the winding leg 14 has a small central lug or projection 21 which spaces the major portion of said end from the shell 15 to form an end air gap 22. The opposite end of the winding leg 14 may be of any suitable mating construction as shown at 23.

Referring now to Fig. 3, I have illustrated the circuit diagram of apparatus described in my co-pending application referred to above. It will be noted that same consists of an association of windings mounted on a core which is constructed very much like that of Fig. 1 and whose arrangement and function are substantially identical to those of Fig. 1. Thus, there is a primary P , a secondary S_1 , and a second secondary S_2 . A gaseous discharge device, in this case comprising a fluorescent lamp 24 is connected across the windings P and S_1 , while a second lamp 25 is connected across the windings S_1 and S_2 . There is a condenser 26 in series with the lamp 24, and the primary P is adapted to be connected to line terminals 27 and 28 of a relatively low voltage A. C. line, such as for example, 118 volts, 60 cycle A. C. The windings P and S_1 are in voltage additive relationship, and the winding S_2 is in bucking voltage relationship. Circuit variations are possible as set forth in said co-pending application, but principally the reverse relationship between S_1 and S_2 is of importance. The windings P and S_1 combined will produce a sufficiently high voltage such that lamp 24 will ignite immediately upon power being applied to the terminals 27 and 28. Once current flows, the high leakage reactance of the first secondary S_1 will give rise to an out-of-phase voltage component which, when combined with the voltage induced in S_2 is sufficient to ignite the lamp 25 so as to cause such ignition to occur immediately thereafter. The winding S_1 provides the high leakage reactance referred to by reason of its extremely loose coupling relative to the primary P .

Once current has commenced to flow, the circuit of Fig. 3, functions as a series circuit. The amount of current which passes through the winding S_1 decreases to a few milliamperes because of the high leakage reactance thereof, and the major flow of current is through the

lamps and the secondary S_2 in series. The power factor of the line is controlled by the inductance of the winding S_2 , the capacitive reactance of the condenser 26 and the magnitude of the inductive magnetizing current and preferably is adjusted to be slightly capacitive.

Referring now to Fig. 2 which is a schematic diagram of the apparatus of the invention, it will be noted that the elements and organization thereof are identical with those of the circuit of Fig. 3 with one exception. An additional winding, namely, a third secondary S_3 , has been added in series with winding S_2 and in voltage additive relationship therewith, and closely coupled with the primary P. Thus, I have used the identical characters of reference for all other elements since they are identical, and function in the identical manner to operate the gaseous discharge devices. The lamps are designated 24 and 25, the line terminals 27 and 28, the condenser 26, and the three principal windings P, S_1 , and S_2 . The winding S_3 is inserted between the right hand terminal of the lamp 25 and the right hand terminal of the winding S_2 . In actuality the winding S_3 is an auxiliary part of the winding S_2 and hence can be termed a portion of the second secondary. The principal reason among others, for this concept is that the voltage of S_2 which was utilized in the apparatus, now includes the induced voltage of the winding S_3 .

The apparatus illustrated in Fig. 2 functions in the identical manner as that shown in Fig. 3 and hence a detailed explanation of the principles is not deemed necessary. The operation of the additional winding S_3 shortly will be elucidated. It is desired to point out that when both lamps have been energized and current is flowing the effective circuit is as shown in Fig. 4, that is, the winding S_1 is of minor importance. Under these circumstances, the circuit is a series circuit with the lamps 24 and 25, the condenser 26, and the windings S_2 and S_3 all in series across the primary P, with the power factor controlled by the reactance of the condenser and windings.

The addition of the winding S_3 enables the advantages enumerated above in connection with the objects to be achieved. Since the voltage which governs regulation ratio depends upon the open circuit voltage of S_2 and now there is added the voltage of the winding S_3 , the ratio is higher than it would be without the winding S_3 . In fact, the requirements for optimum ratio are easily met. With this requirement satisfied, S_2 may have less turns than otherwise required in view of the primary flux, so that its gap 22 can be smaller and its magneto-motive force lowered. The possibilities of saturation are eliminated, and the excessive leakage flux, because of high magneto-forces and a large end gap is no longer a problem.

The winding S_3 adds to the voltage of S_2 a voltage determined by its turn relationship with P. Since it is quite closely coupled with P and preferably wound on top of the primary P in the same window, it has no leakage inductance. Every electrical effect occurring in P is mirrored immediately in S_3 without time lag and the attendant effects produced thereby, namely, leakage inductance. Obviously I have not materially added to the magneto-motive force in the winding leg 14 which extends through the secondary S_2 , but I have increased the voltage available for regulation.

The requirements of the winding S_3 , are dependant as well upon the proper requirements of S_2 dictated by satisfactory operation. To prevent peaking of the current wave, which would be occasioned by a highly capacitive lamp circuit, the circuit must have an inductive reactance to offset this. The total limiting impedance of the circuit is then $Z = X_c - X_L$, where X_c is the capacitive reactance of the circuit, and X_L is the inductive reactance of the circuit. X_c is determined by the capacitive reactance of the condenser 26. The inductive reactance X_L is determined by the total leakage inductance of the windings in series with the lamps. The maximum ratio of X_c to X_L has been found to be 2 to 1 for a satisfactory wave shape in T-8 type fluorescent lamps which have a diameter of one inch. In the case of larger lamps such as the T-12 type, which have a diameter of one and one-half inches this ratio may be increased to as much as 2.7 to 1.

The above requirements for the amount of inductive reactance must be kept in mind in arriving at a proper design which will utilize my invention. I have discovered that for a T-12 fluorescent lamp, the voltage requirement for the winding S_2 , which, as has been explained, may be reduced from that determined as usual, is that from 45% to 50% of the total open circuit voltage of the transformer 10 should be provided by said winding S_2 , with the remainder namely, 50% to 55%, provided by the primary P and third secondary S_3 combined. When this construction is provided, and other factors adjusted, as will be explained, the apparatus operates with excellent results, without noise, and with very little heating. Obviously some variation between different types of discharge devices may be expected, but the suggested percentages are a suitable starting point toward good design.

While it is possible for one skilled in the art to achieve the above construction through experimentation and computation, I have devised a method of achieving the desired design in a facile manner, and without a great deal of effort. First, the total open circuit voltage of the apparatus is determined from a consideration of the lamp voltages, and other factors all well known. Then the regulating impedance Z is determined to give satisfactory regulation. X_c and X_L are determined by solving a pair of simple simultaneous equations:

$$(a) \quad Z = X_c - X_L$$

and

$$(b) \quad \frac{X_c}{X_L} = K$$

As explained hereinabove Equation a is an expression for the total limiting impedance of the circuit, and Equation b is an expression defining the factor K dependent upon lamp diameter.

I now utilize a simple device for determining the number of turns in S_2 which has given optimum results. I calculate, in any well-known method, the number of turns of wire which would be required to produce a value of X_L at the primary flux density (which is readily determinable), multiply that number by a factor of 1.5, and utilize the value as the number of turns on the secondary S_2 . After this has been determined, I vary the non-magnetic gaps 20 and 22 until the open circuit voltage of the winding S_2 is approximately equal to IX_L (where I is the lamp

current) and the operational power factor approaches unity.

The factor 1.5 is an approximate value that I have found to be quite satisfactory. It furnishes the basis for the lowered flux density in the secondary S_2 prior to ignition of the discharge devices so that during operation of the said devices, the flux density will approach that of the primary. In view of the manner in which the number of turns of S_2 is arrived at, it becomes apparent that the number of turns in S_2 can be said to be proportional to the number of turns in the primary P multiplied by 1.5.

Once the number of turns of S_2 and its approximate open circuit voltage have been determined, it is a relatively simple matter to determine the number of turns in the third secondary winding S_3 .

From the above, it should be seen that I have decreased the number of turns of S_2 by 50% more than normally would be required if S_2 were closer coupled with the primary P, and the end gap 22 were not used. I have in effect reduced the open circuit flux density in the core adjacent S_2 to about 66% of that of P so that the voltage developed in S_2 is only about half of the total open circuit voltage, and I have used another winding S_3 to supply that part of the open circuit voltage not supplied by the additional voltage of the primary P. I have effected a considerable saving in copper, because to achieve the same results as achieved by splitting the winding into S_2 and S_3 , a single winding would be required which has the total number of turns equal to the sum of the turns of S_3 plus S_2 (computed on the basis of the flux density of P) together multiplied by some factor substantially greater than unity.

I have produced and operated a successful example of apparatus using the principles and teachings of my invention in providing ignition and operating voltages for two T-12 instant start lamps, each 96 inches long, operating at a current of 430 ampere, having a wattage rating of 75 watts each, with an ignition voltage of about 750 volts. Such an apparatus had the following physical characteristics:

Stack dimensions.....	6 $\frac{3}{8}$ " x 3" x 1 $\frac{1}{4}$ "
Width of frame.....	.478"
Central leg 14.....	1.1" wide
S_1 window width.....	.84" (along length of the shell)
S_3 & P window length....	1 $\frac{3}{4}$ "
S_2 window length.....	1.57"
Shunt 16 and gap 17.....	$\frac{3}{4}$ " and .025"
Shunt 19 and gap 20.....	1.2 and .025"
Gap 22.....	.040"
S_1	2800 turns of #32 wire
S_2	1450 turns of #26 wire
S_3	640 turns of #26 wire
P.....	400 turns of #21 wire
Condenser 26.....	1.5 mfd. at 800 volts

As will be noted from Fig. 1, the primary P and the third secondary S_3 are wound in the same window.

The above example gave excellent results. The flux density in the vicinity of the winding S_2 at open circuit was found to be about 6000 gauss, and during operation about 13,000 gauss. The ignition voltage of 750 volts was easily achieved from the 118 volt, 60 cycle, A. C. line, and the resulting lamp current by the use of the apparatus had a crest factor of 1.45.

The above example was constructed, as indicated, with a stack height of 1 $\frac{1}{4}$ inches. It was desired to reduce the stack height to 1 inch, for decreasing the steel requirements of the transformer. The resulting example required more turns on the respective windings, but operated successfully. The changes in the physical characteristics were not great. The gap 22 was increased to .065"; the shunt 16 was reduced to $\frac{5}{8}$ " to allow more space for added turns of S_3 ; and the gap 17 reduced to .020". The open circuit voltage was slightly lowered without detrimental effect. As for the windings, P was increased by 70 turns, S_1 was increased by 50 turns, S_2 was increased by 50 turns, and S_3 was increased by 75 turns.

It should be appreciated that a wide range of variation in the details of the invention is possible without departing from the spirit of the same, all within the scope thereof as limited only by the appended claims.

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 a transformer having a primary winding, a first high leakage reactance secondary winding and a second high leakage reactance secondary winding, all of said windings being mounted on a unitary iron core, means for connecting said devices to said windings for seriatim ignition and substantially series operation thereof, and means for increasing the open circuit voltage of said second secondary without increasing the induced flux in the said core in the vicinity of said second secondary whereby to provide high voltage regulation ratio for said apparatus, which comprises a winding in voltage additive relationship with said second secondary and connected in series therewith, closely coupled to said primary winding whereby to have minimum leakage reactance induced thereby.

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 an iron core auto-transformer mounting a primary winding, a loosely coupled first secondary winding having one end connected to said primary winding, a loosely coupled second secondary winding having an end connected with the second end of the first secondary winding, and being in reverse open circuit voltage relationship thereto, means including a capacitive reactor for connecting one of said devices across the primary and first secondary winding, means for connecting the second of said devices across the first and second secondary windings, and means for connecting the said source across the primary, the secondaries having a turn relationship to the primary with the combined open circuit voltage of the primary and first secondary exceeding ignition voltage of said one device, the open circuit voltage of the second secondary being less than the ignition voltage of said second device to cause seriatim ignition of said devices, and the reactance of the first secondary being high relative to the second secondary to oppose flow of current through said first secondary whereby after the devices are both operating, the apparatus will form in effect a series circuit connected across the primary, said circuit consisting of the devices, the capacitive reactor and the second secondary, and a third secondary winding being an electrical extension of and in series with said second secondary, although

physically spaced therefrom and closely coupled with the primary.

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 iron core auto-transformer having windings comprising a primary, a loosely coupled first secondary serially connected with the primary, and a loosely coupled second secondary serially connected with said first secondary, said secondaries being arranged in reverse open circuit voltage relationship one to the other, means including a capacitive reactor connecting one of said devices across and in series with the primary and first secondary, means connecting the second of said devices across and in series with the first and second secondaries, means connecting the source across the primary, and a third secondary winding in series with the second secondary, connected between said second secondary and said second device and being closely coupled with said primary and magnetically spaced from the remainder of the second secondary.

4. 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 iron core auto-transformer having windings comprising a primary, a loosely coupled first secondary serially connected with the primary, and a loosely coupled second secondary serially connected with said first secondary, said secondaries being arranged in reverse open circuit voltage relationship one to the other, means including a capacitive reactor for connecting one of said devices across and in series with the primary and first secondary, means for connecting the second of said devices across and in series with the first and second secondaries, and means for connecting the source across the primary, and a third secondary in series with the second secondary being closely coupled with said primary and magnetically spaced from the second secondary, the turn relationship of the primary and the combined second secondary and third secondary being such that approximately half of the total open circuit voltage of the primary, second and third secondaries will appear across the primary and said third secondary, with the other half appearing across said second secondary.

5. 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 iron core auto-transformer having windings comprising a primary, a loosely coupled first secondary serially connected with the primary, and a loosely coupled second secondary serially connected with said first secondary, said secondaries being arranged in reverse open circuit voltage relationship one to the other, means including a capacitive reactor for connecting one of said devices across and in series with the primary and first secondary, means for connecting the second of said devices across and in series with the first and second secondaries, and means for connecting the source across the primary, a third secondary in series with said second secondary being closely coupled with said primary and magnetically spaced from the second secondary, the turn relationship of the said second secondary to the primary being defined approximately by the ratio

$$T_{s_2} = 1.5 T_p$$

where

T_{s_2} is the number of turns of the second secondary.

T_p is the number of turns normally required to provide a given inductive reactance in the circuit, calculated at the primary flux density.

6. Apparatus of 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 pair of said devices a unitary core of shell formation and having a central winding leg and a plurality of winding windows and windings mounted on said leg respectively disposed in said windows and including a primary, a first secondary, and a second secondary, magnetic shunts separating said windings one from another, and said windings being electrically connected one after the other in the respective order named with the secondaries in reverse open circuit voltage relationship one to the other and a third secondary winding connected in series with and in additive voltage relationship to said second secondary, but disposed upon said leg in the same window as said primary to closely couple therewith, a capacitive reactor in series with one of said devices and together therewith connected across the primary and first secondary, means connecting the second of said devices across all of the secondaries and means connecting the primary to the source.

7. Apparatus as described in claim 6 in which the primary and third secondary windings are disposed on the center of the winding leg and the magnetic shunt on the said first secondary side is substantially greater than that on the second secondary side.

8. Apparatus as described in claim 6 in which the first and second secondaries are disposed on opposite ends of the said winding leg and said leg has a non-magnetic gap therein adjacent said 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 windings comprising a primary, a loosely coupled first secondary serially connected with the primary, and a loosely coupled second secondary serially connected with said first secondary, said secondaries being arranged in reverse open circuit voltage relationship, one to the other, means including a capacitive reactor for connecting one of said devices across and in series with the primary and first secondary, means for connecting the second of said devices across and in series with the first and second secondaries, and means for connecting the source across the primary, and means for increasing the voltage available to said second device without increasing the leakage flux of said second secondary which comprises a third secondary connected in series with and in additive voltage relationship to said second secondary and arranged in minimum leakage inductive relationship to said primary.

10. 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 iron core auto-transformer having windings comprising a primary, a loosely coupled first secondary serially connected with the primary, and a loosely coupled second secondary serially connected with said first secondary, said secondaries being ar-

ranged in reverse open circuit voltage relationship one to the other, means including a capacitive reactor for connecting one of said devices across and in series with the primary and first secondary, means for connecting the second of said devices across and in series with the first and second secondaries, and means for connecting the source across the primary, said transformer including an iron core shell and winding leg, said primary and secondaries being mounted on said leg, and said leg having a gap therein adjacent said second secondary, and means enabling a higher open circuit voltage to be obtained from said second secondary without increasing the size of the gap which comprises an auxiliary winding connected in series with and additive to said second secondary, but closely coupled with said primary.

11. Apparatus of the character described including a pair of gaseous discharge devices adapted to be ignited and thereafter operated with suitable regulation from an A. C. source of relatively low voltage which comprises, an iron core auto-transformer having a primary winding, a first secondary winding serially connected with the primary winding and loosely coupled thereto, a second secondary winding serially connected with said first secondary winding and loosely coupled relative to the primary winding, the said secondaries being arranged on said transformer in reverse voltage relationship one to the other, one of said devices being connected in series with and across the primary and first secondary windings combined and having a series-connected capacitor in said connection, the second device being connected across and in series with both of said secondaries combined, the devices thereby forming two separate circuits having the said first secondary winding common to both circuits, leads for connecting the primary winding to the said source, a third secondary winding series connected with the said second secondary winding and being closely coupled with the said primary winding and being magnetically spaced from the said secondary winding.

12. Apparatus of the character described including a pair of gaseous discharge devices adapted to be ignited and thereafter operated with suitable regulation from an A. C. source of relatively low voltage which includes a unitary core of shell formation and having a central winding leg and a plurality of winding windows and windings mounted on said leg respectively disposed in said windows and including a primary winding, a first secondary winding, and a second secondary winding, magnetic shunts separating said windings one from the other, and said windings being electrically connected one after the other in the respective order named with the secondaries in reverse voltage relationship one to the other and a third secondary winding connected in series with and in additive voltage relationship to the said second secondary winding, but disposed upon said leg in the same window as the primary winding to closely couple therewith, one of said devices being connected across the primary and first secondary windings combined and having a series capacitor in the connection, and the second of said devices being connected across all of the said secondary windings, and lead means for connecting the primary winding to the source.

13. Apparatus of the character described for

igniting and operating gaseous discharge devices, comprising a pair of gaseous discharge devices, a source of A. C. power of voltage less than the igniting voltages of the devices, an iron core, a transformer on the core and formed of a primary winding, a first secondary winding, a second secondary winding, and a third secondary winding, the primary winding having first and second end terminals connected to said source, the second and third secondaries being together connected in series as a pair and said pair having end terminals, the first secondary winding being connected between the second terminal of the primary winding and the first terminal of the pair, with the open circuit voltages of the first secondary winding and the pair opposed, a capacitor, one gaseous discharge device being connected in series with the capacitor between the first terminal of the pair and one of the terminals of the primary winding, the second gaseous discharge device being connected from the second terminal of the pair to another of the terminals of the primary winding, the windings being arranged along the core with the primary winding having the third secondary winding tightly coupled therewith, the other secondaries being on opposite sides of the primary winding with the physical spacing between the primary and first secondary windings greater than the spacing between the primary and the second secondary windings.

14. Apparatus of the character described including, a pair of gaseous discharge devices adapted to be ignited and thereafter operated with suitable regulation from an A. C. source of relatively low voltage which comprises, an iron core, an autotransformer on the core having a primary winding provided with end terminals, a first secondary winding serially connected with the primary winding and loosely coupled therewith, a second secondary winding serially connected with the first secondary winding and loosely coupled with the primary winding, the said secondary windings being arranged on the core in reverse open circuit voltage relationship one to the other, there being a capacitor in series with one of said devices and said one device together with said capacitor being connected across a portion of the transformer windings including the first secondary winding but excluding the second secondary winding and connected to one end terminal of the primary winding, the second device connected across a portion of the transformer windings including at least the two secondary windings and being connected to the second end terminal of the primary winding, the end terminals of the primary winding being connected to the source, a third secondary winding additive to and serially connected with said second secondary winding and being closely coupled with said primary winding and magnetically spaced on the core from said secondary winding.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,025,471	Osborne	Dec. 24, 1935
2,382,638	Keiser	Aug. 14, 1945
2,461,957	Berger	Feb. 15, 1949
2,558,293	Feinberg	June 26, 1951
2,577,733	Bridges	Dec. 11, 1951