April 9, 1957 A. E. FEINBERG 2,788,469

APPARATUS FOR IGNITING AND OPERATING GASEOUS DISCHARGE DEVICES

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Fig. 1.

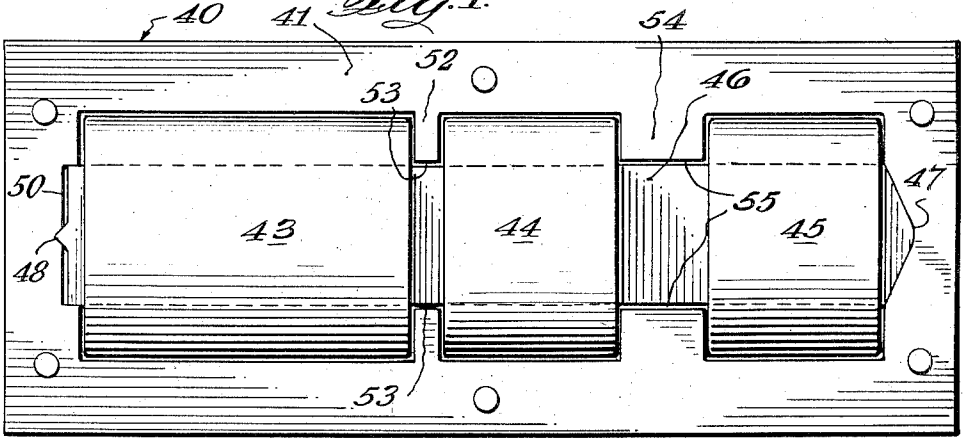



Fig. 2.

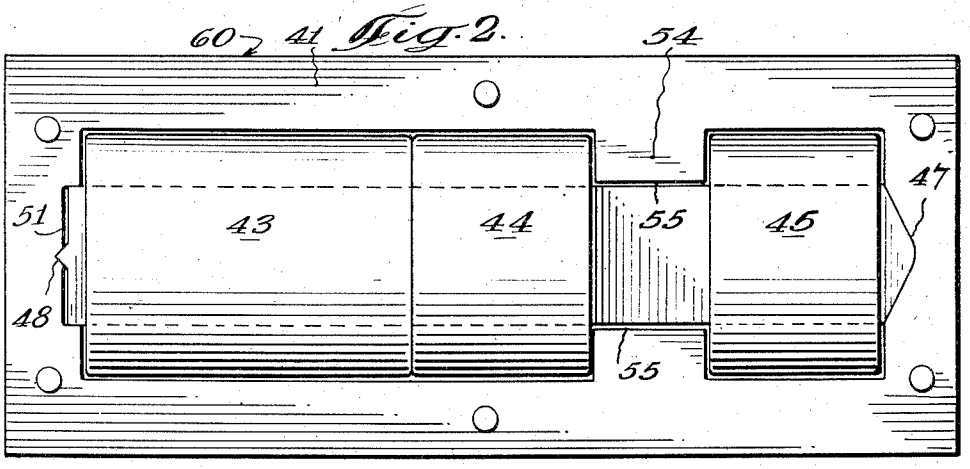



Fig. 3.

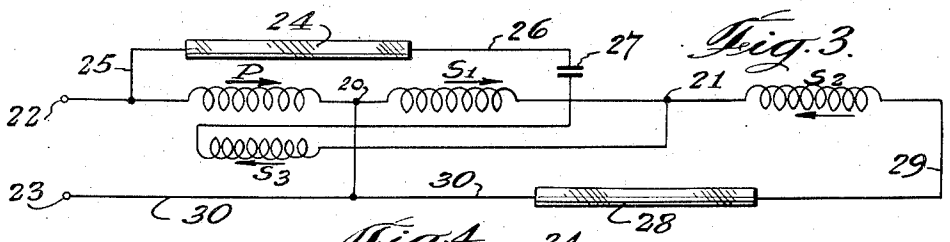
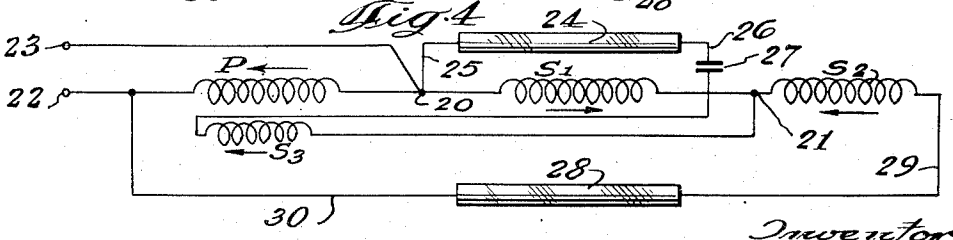



Fig. 4.




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Fig. 5.

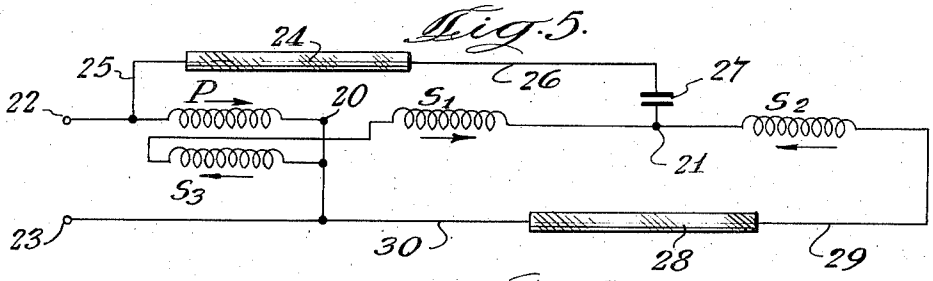



Fig. 6.

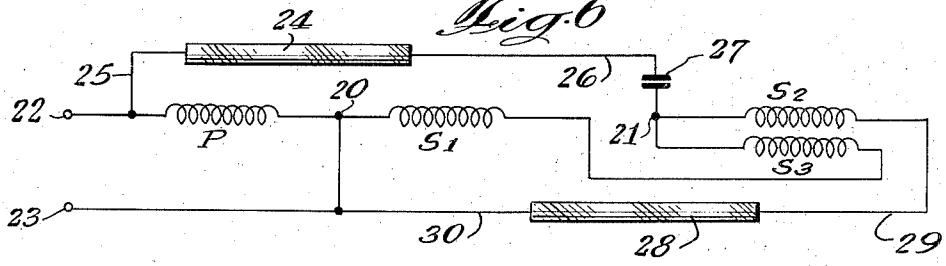



Fig. 7.

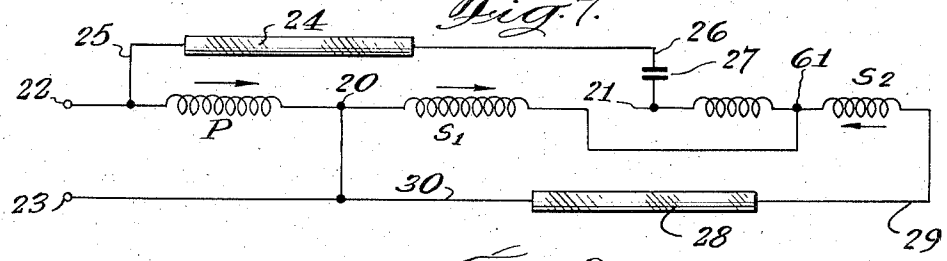



Fig. 8.

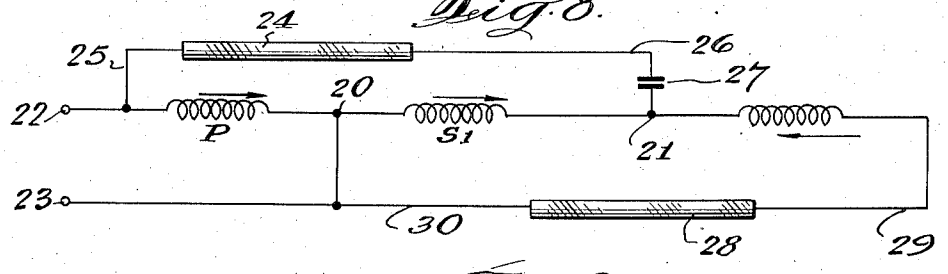
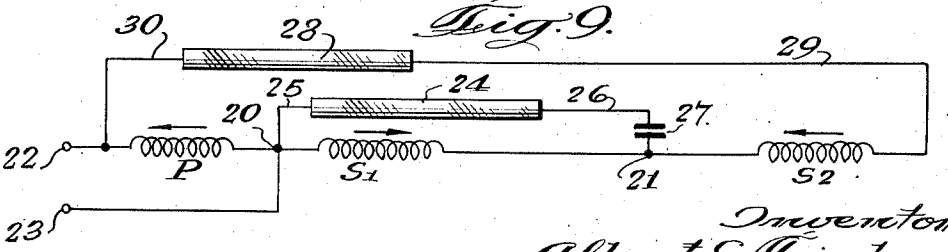



Fig. 9.




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Patented Apr. 9, 1957



2,788,469

# APPARATUS FOR IGNITING AND OPERATING GASEOUS DISCHARGE DEVICES

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Application April 26, 1951, Serial No. 223,070

13 Claims. (Cl. 315—138)

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

The invention is a modification of the invention 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, dated June 26, 1951. In that application I described apparatus for use principally with the so-called instant start type of gaseous discharge device which requires relatively high voltage to ignite 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, among other things, of an auxiliary starting secondary winding $S_1$ which provides very high leakage reactance due to its loose coupling with the other windings of the apparatus.

The apparatus is especially intended for use in connection with the ignition and operation of fluorescent lamps, serving as the ballast for a plurality of such lamps. The device described in my copending application above referred to is characterized by a three-winding transformer on an elongate shell core, the windings consisting of a primary P, a first secondary $S_1$ which has been mentioned above, and a second secondary $S_2$. The windings are connected end to end in the order named, although physically placed upon the core with the primary P in the center, and various shunts and air gaps arranged to give rise to the desired characteristics. Generally, it can be said that the primary P and the first secondary $S_1$ have a much looser coupling than the primary P and the second secondary $S_2$. One lamp is connected across the combined primary P and secondary $S_1$ and in series with a condenser, while the other lamp is connected across the combined secondary $S_1$ and secondary $S_2$. In another example of the same apparatus, the lamp and series condenser are connected only across the secondary $S_1$, while the second lamp is connected across all three windings. One of the essential features of the described apparatus is that the secondaries are in voltage bucking relationship.

In operation, when power is applied to the primary of either of the above described circuits, a voltage is generated in the secondary $S_1$ which is sufficient, either combined with the primary voltage in one case, or alone, as in the second case, to ignite the first lamp which is in series with the condenser. When current flows in this lamp, there is an out of phase voltage set up in the secondary $S_1$ which now combines with the voltage of $S_2$, and in the case of the second described apparatus, with the voltage of the primary P in addition, to provide igniting voltage for the second lamp. The high impedance of the secondary $S_1$ opposes the flow of current therethrough so that very little current will take the path through that winding. Thus, the circuit during operation acts as a series circuit.



The current through the winding $S_1$ being very low, it has been possible to utilize a physical winding whose number of turns is very great while the gauge of wire is very small. Thus, with a very small ballast, high ignition voltages easily can be achieved without considering the problems of high current flow through the winding $S_1$.

It has been found that the above described circuit of my copending application will operate satisfactorily for a large variety of discharge devices. For example, excellent results have been obtained when same is used with lamps known as 40 watt, T–12, forty eight inch fluorescent lamps having an ignition voltage of approximately 450 and an operating voltage of 109 volts; with 75 watt, 96 inch T–12 lamps which ignite at about 625 volts and operate at about 195 volts; and with many other lamps whose operating current is substantially less than 425 milliamperes and of the order of 200 milliamperes. The former value of current i. e. 425 milliamperes is for 96" T–8 lamps which operate at 285 volts. As for these discharge devices, the circuit of the co-pending application can be made efficiently to operate by varying the circuit constants in accordance with the teachings of the said disclosure, but in certain applications the expense and size of the ballast may be unnecessarily increased.

The problem which becomes manifest arises by virtue of the fact that the primary voltage in the greater majority of commercial applications of the device is of the order of 118 volts A. C. This places a limitation upon the physical constants of the apparatus, and prevents a certain amount of flexibility of construction which could be achieved for varying conditions if the primary voltage could be more conveniently chosen. When the discharge devices have high operating voltages, the current which passes through the winding $S_1$ increases. Under these circumstances, and considering that the device is formed of a pair of lamp circuits in parallel and having a common leg $S_1$, the impedance in each branch will certainly not be the same. So the current will not evenly divide in the branches, and one lamp will be operating at a greatly different current than the other. Obviously, both lamps under these circumstances are not operating at rated wattage. The effect upon lamp life and lighting efficiency becomes very important. On the deficient lamp, the light output will be decreased, and upon the lamp with more than rated current, the life will be decreased.

The principal object of the invention is therefore to provide a balanced circuit of the character described in which both lamps will be operating at substantially the same wattage.

In addition to the above, while not totally essential, in certain cases this balance can be achieved with a coincidental decrease in the current flowing through the secondary $S_1$ and an ancillary object of the invention is the provision of apparatus of the character described in which this current is kept low.

Other objects of the invention are to provide apparatus which is capable of providing high ignition voltage and subsequent high operating voltage for gaseous discharge devices connected to ignite seriatim and operate substantially as series connected devices, such apparatus being constructed in various manners including additional windings, or in other cases, tapped connections whereby the desired voltage balance in the gaseous discharge devices is achieved.

Other objects will become apparent as a description of the invention is set forth hereinafter, in which I have shown and described ballasts for gaseous discharge devices which are constructed and operate in accordance with my invention. Such description and illustrations are detailed to assist in an understanding of the invention and are not by way of limitation, since it is intended that the

claims shall determine the extent and scope of the invention. Obviously many variations are possible within the purview of the invention.

In the illustrations there are figures of electrical diagrams and apparatus in connection with which the description will be carried out, and the same characters of reference will be used to designate the same or similar part or element throughout the several figures of the drawing in which:

Fig. 1 is a side elevation view showing a transformer construction capable of being used with the invention.

Fig. 2 is a similar view of another form of transformer construction.

Fig. 3 is a diagrammatic view of the electrical circuit of my apparatus, constructed in accordance with the invention.

Figs. 4, 5, 6 and 7 are similar views of modified forms of the apparatus of the invention.

Figs. 8 and 9 are diagrammatic views of the electrical circuit of the invention shown and described in the above referred to copending application.

Basically the invention consists of adding an in-phase component to the circuit of the gaseous discharge device which is affected by the current unbalance in the starting secondary. This is done by providing a third secondary winding $S_3$ which is arranged in close coupled relationship to a source of voltage substantially of the same phase as the voltage of the discharge device, and connecting said winding in the circuit of the device, although in voltage opposition thereto.

In order to render this explanation clear, I have illustrated in Figs. 8 and 9 the circuits of the invention of the copending application referred to above It will be seen that in each there is a primary P, a secondary $S_1$, and a secondary $S_2$. The windings are connected end to end, forming junctions **20** and **21**. The primary is connected across the line terminals **22** and **23** from which it is energized by suitable A. C. power. One gaseous discharge device, consisting of a lamp **24** is connected from terminal **22** to juncture **21** by leads **25** and **26**. There is a series condenser **27** in the lead **26**. A second fluorescent lamp **28** is connected from the free end of winding $S_2$ to the juncture **20** by the leads **29** and **30**. Obviously the lead **30**, terminal **23**, and juncture **30** are all at the same potential.

As explained, the windings $S_1$ and $S_2$ are in voltage opposition arrangement, and in this instance the primary P is in voltage additive relation to the starting secondary $S_1$. The operation of this apparatus is as explained herein and in said copending application.

The apparatus illustrated in Fig. 9 is also shown, described, and claimed in said copending application as a modified form of the preferred embodiment. The only difference between it and the apparatus of Fig. 9 is that the lamp **24** is connected in this case across the juncture **20** and **21** so that for starting all of the voltage for the lamp must be developed in secondary $S_1$. After ignition of lamp **24**, the component of voltage developed in $S_1$ which is in phase with the voltage of $S_2$ combines also with the primary voltage to assist in igniting the second lamp **28**. As in the case of Fig. 8, the primary P, first secondary $S_1$, and second secondary $S_2$ are connected end to end by means of junctures **20** and **21**, the primary P is connected to line terminals **22** and **23**. The lamp **28** is, however, connected by leads **29** and **30** across all of the windings together, that is, from terminal **22** to the free end of winding $S_2$. The operation of this apparatus is substantially the same as that of Fig. 8.

It is to be noted that none of the symbols relating to iron cores have been used in order that the circuit diagrams be simple, but obviously such cores are present.

The apparatus of the instant invention has substantially the same mechanical construction features as that of the copending application. In Figs. 1 and 2 I have illustrated



the construction of transformers embodying the circuits of the invention. Referring to Fig. 1, there is illustrated a transformer **40** which comprises an iron core formed as a rectangular shell **41** made up of electrical laminations and maintained in assembled condition by any suitable clamps or rivets (not shown). The shell **41** is elongate and has three windows formed therein along the length thereof for housing three windings **43**, **44** and **45**. The windings fill the entire respective windows and hence the figure cannot show the windows. The windings are mounted upon a central winding leg **45** which is also laminated and the ends of which are adapted matingly to seat in the shell **41**. Thus, the right hand end of the winding leg **46** has a convex formation and the shell end has a concave seat to receive the same in intimate fit resulting in the joint illustrated at **47**. The left hand end of the winding leg **46** may be provided with a protruding tip adapted to engage a notch in a joint illustrated at **48**. The recess for the left end may have sufficient depth to form an air gap **50** or may be of a dimension to intimately engage the left end of the winding leg as shown at **51** in Fig. 2.

Referring again to Fig. 1, in this particular form of construction, there is a very small shunt between coils **43** and **44** having gaps **53** formed between the winding leg **46** and the shunt extensions. A larger shunt **54** is formed between coils **44** and **45** and having gaps **55** between the winding leg **46** and the shunt extensions thereat. In any event it can be seen that the coupling between the coil **45** and the coil **44** is much less than that between the coils **43** and **44**. The end gap **50** and the shunt **52** are means for improving wave shape.

The construction illustrated in Fig. 2 is a modification of that illustrated in Fig. 1. Thus the transformer **60** is substantially the same as transformer **40** except that the end gap **50** has been eliminated and the coupling between coils **43** and **44** increased by eliminating the shunt **52**.

The circuits to be described in detail are capable of being used in connection with either of the transformer constructions described above. The designation "coil" has been used since, depending upon the particular circuit, the coils of Figs. 1 and 2 may represent more than one winding. Throughout the figures, the auxiliary starting secondary $S_1$ is always represented by the coil **45**. The primary winding P is always similarly positioned and may be represented by the coil **44**, but in certain modified forms of the invention, the coil **44** will represent the primary winding P and a third secondary winding $S_3$ wound upon the primary P, or at least quite closely coupled thereto in the same window. The coil **43** usually represents the secondary winding $S_2$, but in one form it also represents $S_3$ and in another form, it represents $S_2$ with a tap.

Attention is now invited to Fig. 3 of the drawings in which I have illustrated a circuit embodying my invention. The same general arrangement of parts is used here as in the case of that circuit illustrated in Fig. 8, except that the lead **26** between the condenser **27** and the juncture **21** has been opened and a third secondary $S_3$ has been inserted in series with the condenser **27** and discharge device **24**. Thus, the windings P, $S_1$, and $S_2$ are connected end to end with the junctures **20** and **21** between them, and the primary P being connected to the line terminals **22** and **23**. The lamp **28** is connected from the free end of winding $S_2$ to the juncture **20** by leads **29** and **30** respectively. Again, lead **30**, juncture **20** and terminal **23** are at the same potential. The lead **25** connects the terminal **22** to the left hand side of the lamp **24**, while the right hand side of the lamp is connected by lead **26** to the series condenser **27** which in turn is connected to the third secondary $S_3$ and thence to juncture **21**.

The third secondary winding $S_3$ is closely coupled with the primary P, and is connected in additive voltage relationship with the other windings of the closed circuit including the lamp **24**, primary P, first secondary $S_1$ and

condenser 27. Therefore it is in voltage opposition to the voltage across the lamp 24 during steady state operation. The arrows throughout the figures of the drawings indicate the voltage sense of the pertinent winding.

If we consider the circuit of the lamp 28, which is a closed circuit including lamp 28, second secondary $S_2$ and the secondary $S_1$ we will note that the two lamp circuits are apparently connected in parallel and having a common leg which is the starting secondary $S_1$. Examining the elements around the respective circuits, it will be seen that their characteristics will be different. For example, the first mentioned circuit includes a condenser, a high impedance winding $S_1$ and the primary P (not considering for the moment the winding $S_3$). The other circuit has only the two windings $S_1$ and $S_2$. If $S_1$ is a voltage source, and the current passing through the winding is intended to divide, it is almost impossible that the same division will occur when transformer of Fig. 3 is serving 400 ma. lamps operating 109 or 185 volts as will occur when it is serving 200 ma. lamps operating at 385 volts the primary voltage being substantially the same in in both cases.

I have found that if I add the secondary winding $S_3$ in the manner shown, the current of $S_1$ will be divided fairly evenly between the two lamps so that both are operating substantially at their rated wattage and hence at their maximum efficiency. The winding $S_3$ functions to obtain an in-phase voltage component from the primary P to supply the lamp 24. The voltage of $S_1$ is principally utilized in balancing the leading voltage across the condenser 27 and very little remains as a component in phase with voltage of P to balance the in-phase voltage of the lamp 24. This being sufficient when the difference between line voltage and lamp voltage is not great, under such circumstances, the circuit of Fig. 8 is satisfactory to handle lamp operating voltages up to 195 volts when the primary is of the order of 118 volts. In the case of Fig. 9, no difficulty is experienced under the same circumstances. For higher voltages, however, there is insufficient voltage in the circuit of lamp 24 and whatever current is flowing in $S_1$ is divided unevenly. The lamp 28 may receive more than its share, while the lamp 24 will receive less. The added winding $S_3$ alleviates this effect.

It has been found that the addition of the winding $S_3$ may serve to increase the flow of current in $S_1$ but if the lamps are both operating at rated wattage, the series circuit effect is achieved and the small increase in current of $S_1$ is not harmful. In certain cases where transformers designed for operation in accordance with the circuit of Figs. 8 and 9 were modified to operate in accordance with the teachings of this invention and at higher lamp voltages, the current flowing in $S_1$ was still so very low when compared with lamp current that the desired feature, namely a large number of windings of small gauge wire, could still be used.

In Fig. 4 I have shown a modification of the circuit of Fig. 9 to operate in accordance with my present invention. Again, as in the case of Fig. 3, into the lead 26 I have inserted a winding $S_3$ which is closely coupled with primary P in order to acquire a voltage by transformation therefrom to help operate the lamp 24. In this case, prior to the addition of the winding $S_3$, the entire in-phase voltage component for lamp 24 was required to be obtained from the winding $S_1$. The operation of this circuit is believed obvious from what has been set forth above.

In Fig. 5 I have shown another modified form of my invention based upon the circuit of Fig. 8. The winding $S_3$ is actually a part of winding $S_1$ because from a voltage stand-point it is in series with $S_1$. The added voltage component gives rise to the voltage balance desired.

In Fig. 6 there is illustrated another form of the invention. In this case, the winding $S_3$ is a part of the winding $S_1$ since it is in series therewith, but the in-phase voltage component is not transformed from the primary P



but from the secondary $S_2$. Therefore the winding $S_3$ is wound on the winding $S_2$ or at least in the same window, and the two windings together would be represented in Figs. 1 and 2 by the coil 43. During operation the winding $S_2$ carries a current which is leading relative to the primary but its flux is practically in phase with the primary flux. Therefore, there will be a relatively large in-phase component available for transformation to $S_3$ and for use subsequently in balancing the circuit of lamp 24. The existence of this large in-phase component of flux in winding $S_2$ usually provides a sufficient voltage for proper operation of the lamp 28.

In Fig. 7, which is still another form of the invention based upon the circuit of Fig. 8, a part of the in-phase voltage of the winding $S_2$ can be obtained for use in balancing the voltages in the circuit of the lamp 24 by connecting the right hand end of the winding $S_1$ to a tap 61 of the winding $S_2$.

Practical examples of the above described apparatus have been constructed and successfully tested, using as physical constants those of the examples given in the copending application above referred to. The determination of the characteristics of the winding $S_3$ or of the location of the tap 61 is a relatively simple matter. The in-phase component to produce rated lamp current in a given loop should approximate the in-phase operating voltage of the lamp, or other gaseous discharge device. It should be recalled that the total voltage across a gaseous discharge device is the resultant of a component substantially in phase with the voltage of the primary, and an inductive component. For example, a 96 inch T–8 fluroescent lamp, with a wattage rating of 49 watts, and operating at a current of 200 milliamperes will have a resultant operating voltage drop of 285 volts and an in-phase voltage drop of 245 volts. The desired in-phase voltage in series with $S_1$ should be of the order of 245 volts (or slightly more since the voltage across the lamp is non-sinusoidal). This voltage can be obtained by simple computation of turns ratio required of a voltage to be produced by $S_3$ which when added to the in-phase voltage of P will give the desired value. Simple experimentation can aid in determining the desired characteristics of $S_3$ for a given set of circumstances.

It was found in the above mentioned fluorescent lamps, i. e., 96 inch T–8 lamps passing 200 milliamperes of current, that when the primary P alone was in the loop with $S_1$ the current unbalance i. e., the difference between the currents passing through lamps 24 and 28 was from 30 to 50 milliamperes, or a percentage of approximately 20. This is the circuit of Fig. 8. In the case of Fig. 9, the unbalance was from 50 to 70 milliamperes. With the addition of the secondary $S_3$ as in Fig. 3, of a value so that the sum of the in-phase voltages of P and $S_3$ approximated that of the lamp 24, the unbalance was reduced to from 10 to 20 milliamperes, or well within commercial tolerances.

The teachings of my invention have been set forth in a manner which may have inferred the operation of the apparatus being based upon certain theories or electrical principles. While I have attempted to show some logical reasoning for the operation of the circuits, it is not my desire to be limited thereby. These theories have been advanced only to aid in the understanding of the invention. It is known among those skilled in the art of ballasts and transformers for gaseous discharge devices that the exact nature of the phenomena produced is highly complex, and not too well understood by reason especially of the non-sinusoidal nature of the currents and voltages, by the peculiar interreaction between the windings and the magnetic circuit, and the effects of the negative resistance of the gaseous discharge devices. I have discovered that the desired results described herein are achieved by the constructions set forth, and the exact explanation of why such results are achieved is immaterial.

Substantial increase in the inductance of the loops may so limit starting current through $S_1$ as to decrease the life of the fluorescent tubes through ion bombardment of the filaments while cold. Therefore, the use of devices such as separate chokes to achieve balance, besides being expensive and increasing total ballast weight, could cause harmful effects upon the lamps being served.

It will be seen that I have provided apparatus in which all of the advantages of the invention of my copending application have been achieved, and in addition I have enabled the same to be used where the operating voltages of the lamps is many times greater than the voltage of the source. I have provided means for counteracting the unbalance which may arise under such circumstances by reason of the current from the winding $S_1$ dividing unequally between the lamp circuits and subjecting one lamp of the circuit including the winding $S_2$ to abnormal wattages.

It is believed that the invention has sufficiently been explained to obviate additional details, and it should be appreciated that the circuits are capable of wide variation in their elements and minor details without departing from the spirit or scope of the invention as defined by the appended claims.

What I desire to secure by Letters Patent of the United States is:

1. Apparatus of the character described comprising a pair of gaseous discharge devices, a source of A. C. voltage greater than the igniting voltage of the devices, an elongate iron core transformer having a primary winding providing a common source flux for all parts of the core, a first secondary winding, and a second secondary winding, each winding having first and second end terminals, the primary winding being physically located in the center of the core between the ends thereof and the first and second secondary windings being mounted on opposite sides thereof but the first secondary winding being much looser coupled to the primary winding whereby to provide high leakage reactance during operation and having reverse open circuit voltage relationship to the voltage of the second secondary winding, a third secondary winding also having first and second end terminals and closely coupled with one of said primary and second secondary windings whereby to have induced therein a voltage substantially in-phase with the voltage of said one of said windings, the terminals of the primary winding being connected across the source, a condenser, an electrical path comprising the first of said gaseous discharge devices in series with said condenser and the first and third secondary windings and said path being electrically connected to the first terminal of said second secondary winding, the first and third secondary windings being in additive open circuit voltage relationship in said loop, the said path being closed to a loop at one of the first and second terminals of the said primary winding, whereby upon ignition at least the voltage of the first and third secondary windings will appear across the said first gaseous discharge device, the second gaseous discharge device being connected from the second terminal of said second secondary winding to the other of the end terminals of the primary winding.

2. Apparatus as claimed in claim 1 in which the loop includes the primary winding so that upon ignition the first gaseous discharge device is connected effectively across the primary, first and third secondary windings and the second gaseous discharge device is connected across at least the first and second secondary windings but excluding the primary winding.

3. Apparatus as claimed in claim 1 in which the loop excludes the primary winding so that upon ignition the first gaseous discharge device is connected effectively across only the first and third secondary windings, and the second gaseous discharge device is connected across at least the first and second secondary windings and the primary winding.



4. Apparatus as claimed in claim 1 in which the loop excludes the primary winding and the third secondary winding has a terminal in common with the second terminal of the first secondary winding and the first terminal of the second secondary winding, whereby the second gaseous discharge device is connected only across the primary, first and second secondary windings, the circuit after ignition and during operation comprising a substantially series circuit across the primary winding and including the two gaseous discharge devices and the condenser and the second and third secondary windings all in series, with the first secondary winding by-passed.

5. Apparatus as claimed in claim 4 in which the third secondary winding is closely coupled with the primary winding.

6. Apparatus as claimed in claim 1 in which the third secondary winding has a terminal in common with the second terminal of the first secondary winding and the first terminal of the second secondary winding, whereby the second gaseous discharge device is connected across windings which exclude said third secondary winding, the circuit after ignition and during operation comprising a substantially series circuit across the primary winding and including the two gaseous discharge devices and the condenser and the second and third secondary windings all in series, with the first secondary winding by-passed.

7. Apparatus as claimed in claim 6 in which the third secondary winding is closely coupled to the primary winding.

8. Apparatus as claimed in claim 6 in which the third secondary winding is closely coupled to the second secondary winding.

9. Apparatus as claimed in claim 2 in which the third secondary winding has a terminal in common with the second terminal of the first secondary winding and the first terminal of the second secondary winding, whereby the second gaseous discharge device is connected across only the first and second secondary windings connected as in series voltage-wise, to the exclusion of the third secondary winding, the circuit after ignition and during operation comprising a substantially series circuit across the primary winding and including the two gaseous discharge devices and the condenser and the second and third secondary windings all in series with the first secondary winding by-passed.

10. Apparatus as claimed in claim 1 in which that portion of the loop including the first and third secondary windings in series is connected from the first terminal of the second secondary winding to the second terminal of the primary winding, whereby the first and third secondary windings will both be by-passed during operation of the apparatus.

11. Apparatus as claimed in claim 10 in which the third secondary winding is closely coupled to the primary winding.

12. Apparatus as claimed in claim 10 in which the third secondary winding is closely coupled to the second secondary winding.

13. Apparatus as claimed in claim 2 in which that portion of the loop including the first and third secondary windings in series is connected from the first terminal of the second secondary winding to the second terminal of the primary winding, whereby the first and third secondary windings will be by-passed during operation of the apparatus, and the second gaseous discharge device is connected across and subject to the voltages of all three secondary windings connected as in series voltage-wise.

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