Aug. 3, 1954 A. E. FEINBERG ET AL 2,685,663

APPARATUS FOR IGNITING AND OPERATING GASEOUS DISCHARGE DEVICES

Filed Dec. 12, 1950 3 Sheets-Sheet 1

Fig. 1.

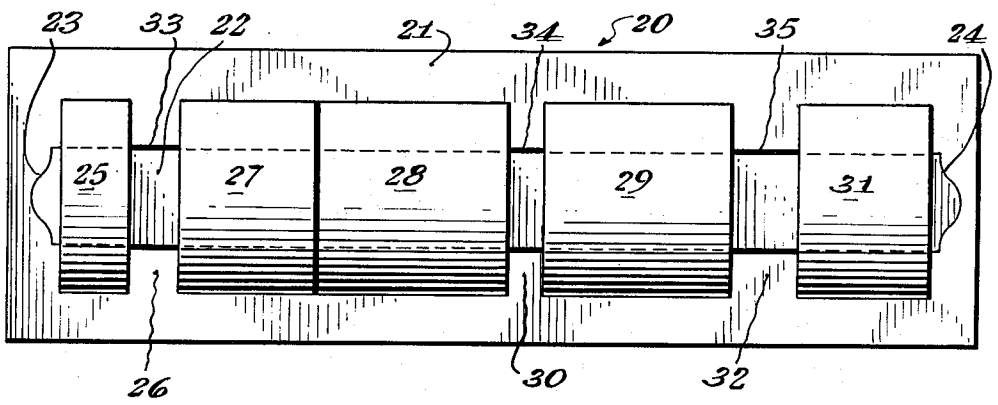

Fig. 2.

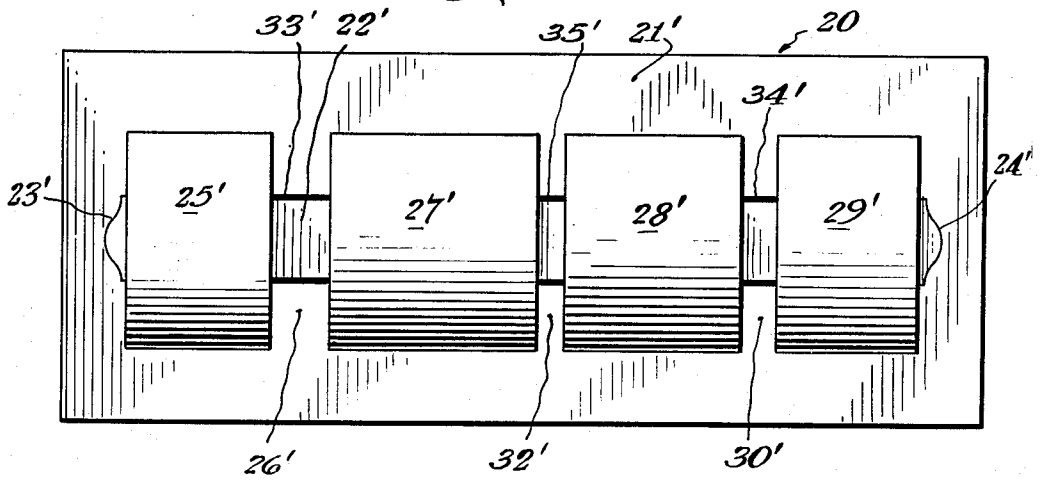

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Fig. 3.

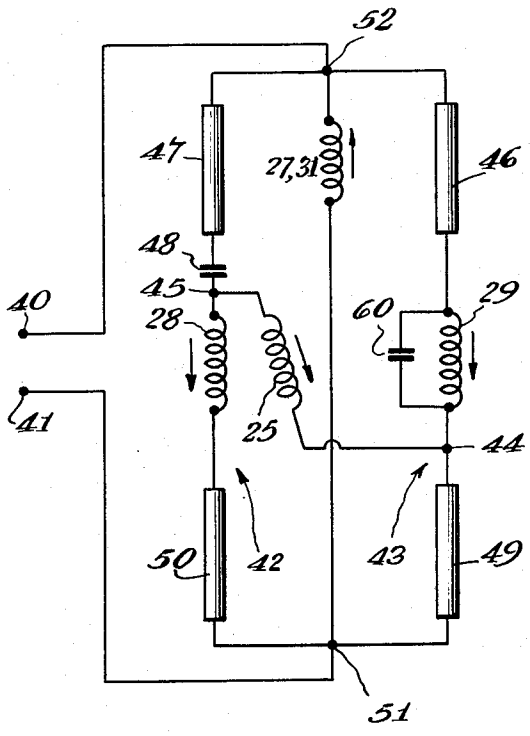

Fig. 4.

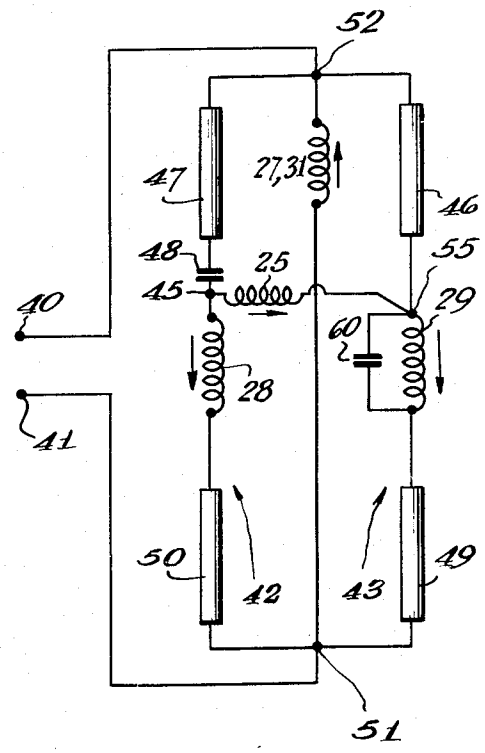

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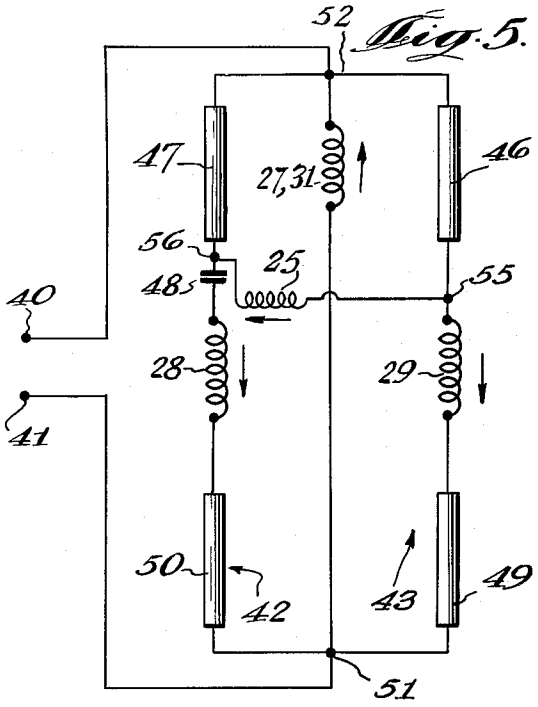
Fig. 5.



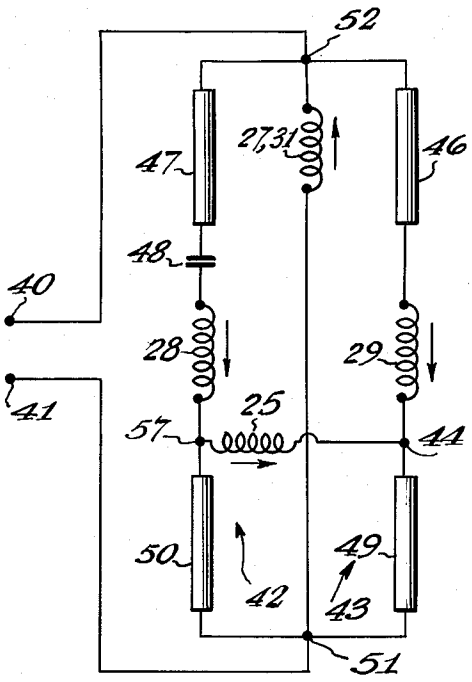


Fig. 6.

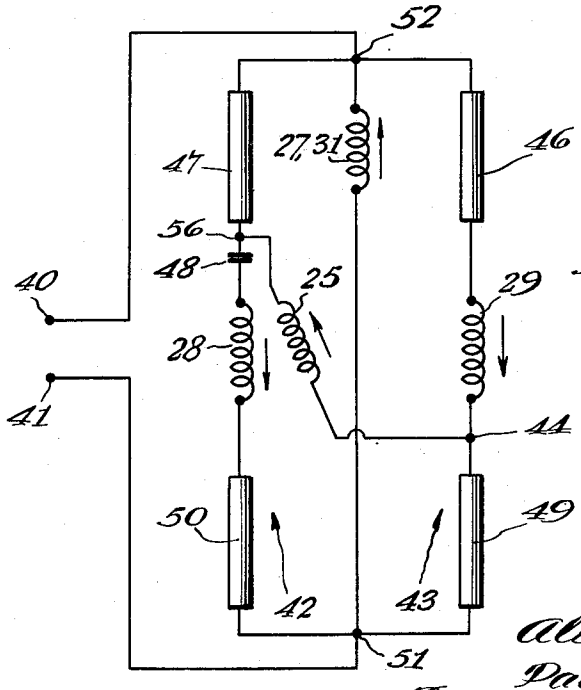


Fig. 7.

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APPARATUS FOR IGNITING AND OPERATING GASEOUS DISCHARGE DEVICES

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Application December 12, 1950, Serial No. 200,472

9 Claims. (Cl. 315—187)

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This invention relates generally to apparatus for providing the ignition voltage for a plurality of gaseous discharge devices and providing impedance required for enabling steady state operation of said devices. The invention is especially intended for providing apparatus for discharge devices connected for seriatim ignition and series operation.

This is a continuation-in-part of our co-pending application Serial No. 160,366 filed May 5, 1950, and entitled "Apparatus for Igniting and Operating Gaseous Discharge Devices."

In the co-pending application above referred to there were described and illustrated different types of apparatus whose principal use was in connection with circuits for operating four fluorescent lamps. The lamps especially concerned were the so-called instant-start type which need no appreciable pre-heating, but which require the application of an appreciable voltage across the terminals in order to ignite the same. There were described devices which enabled a single terminal of each lamp to be connected to one or the other of the line terminals so that removal of the lamp completely will de-energize the circuit. Certain other circuits were disclosed in which the discharge devices were connected into the circuit in such a manner that some of the lamps were not terminated at a line. This invention is concerned with the former type of apparatus.

One of the principal objects of this invention is to provide a novel and economical circuit for providing ignition voltage for a plurality of gaseous discharge devices, and for providing the regulating reactance to permit normal operation of said devices.

Another object of the invention is to provide apparatus for igniting and subsequently operating a group of four gaseous discharge devices, said devices being connected in two pairs, one of the devices of each pair being ignited seriatim, and the pairs thereafter operating as effectively series circuits.

Still another object of the invention is to provide apparatus for igniting and operating a group of four gaseous discharge devices which includes a transformer of novel construction having certain winding and magnetic shunt arrangements giving rise to the desired functions and advantages of the invention.

Still another object of the invention is to provide apparatus for igniting and subsequently regulating the operation of a group of gaseous discharge devices which apparatus is formed of

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few parts and hence is highly economical and simple.

Still a further object of the invention is to provide a four lamp ballast in which the deactivation of any single lamp immediately can be detected notwithstanding the connection thereof for substantially series operation.

Many other advantages will occur to those skilled in the art as the description of the invention proceeds. In connection therewith we have illustrated preferred embodiments of our invention and pointed out the details and the manner of constructing and using the same.

In the drawings:

Fig. 1 is a top plan view of transformer constructed in accordance with our invention in order to show the arrangement of the windings upon the core.

Fig. 2 is a view similar to that of Fig. 1 but showing a transformer in which the primary winding is not split.

Fig. 3 is a schematic circuit diagram of the connections of the transformers of Fig. 1 or Fig. 2 in a circuit embodying our invention, same being connected with four fluorescent lamps for igniting and operating the same.

Figs. 4 to 7 inclusive are schematic circuit diagrams similar to Fig. 2 except showing variations in the connections thereof.

The advantages and benefits to be obtained through the use of a ballast which is designed to ignite and operate four lamps have been set forth in some detail in our co-pending application above referred to. Briefly the elimination of an additional unit at the expense of only a small increase in weight, is an important end achieved by the invention herein as well as that previously described. The general constructional details of the transformer used therewith; the arrangement of the windings and shunts for achieving the desired leakage reactance and quadrature voltage for ignition; and the general principles are similar.

Four discharge devices are connected into the circuit of the apparatus in the form of two parallel circuits. One lamp of each pair is lighted at first, followed by a voltage reversal in the starting winding, in a manner described in said co-pending application, followed by the ignition of the second two lamps. After all lamps have become ignited, the high leakage of the starting winding prevents any but a small current to flow therethrough so that in effect the circuit acts like two pairs of parallel connected series circuits of

two discharge devices, each with a capacitive reactor in one of the series circuits.

In a modified form of the invention, shown in Fig. 7, the above referred to reversal of voltage sense in the auxiliary starting winding is not essential.

Coming now to the details of the invention, in Fig. 1 there is illustrated an elongate laminated core transformer 20, formed of a plurality of laminations stacked and fastened together to provide the rectangular shell 21 having a plurality of central windows (not readily apparent in the drawings) within which are disposed the various windings. As noted, we prefer mounting the windings upon a central elongate winding leg 22 which matingly seats in the shell 21 as indicated by the end joints 23 and 24. In assembling the transformer 20, the windings may be preassembled to the winding leg 22 and the assembly pressed home into the shell.

Considering the windings, all of which are mounted upon the central winding leg 22, there are shown five in Fig. 1. Starting on the left hand end of the transformer 20, there is the winding 25 which comprises the auxiliary starting winding followed by a magnetic shunt 26 and the windings 27 and 28. The windings 27 and 28 are arranged side by side as will be noted from the illustration so that their coupling is fairly close, and certainly much closer than the coupling of the winding 25 with either of said windings. The winding 27 comprises the first primary winding, or more accurately, a part of the whole primary, and the winding 28 comprises the leading secondary winding. Immediately to the right of the winding 28, but separated therefrom by a magnetic shunt 30, is the lagging secondary winding 29. The last winding on the right hand end of the transformer 20 is the second primary winding 31, or more accurately, the remainder of the whole primary, separated from the winding 29 by the magnetic shunt 32. The purpose of separating the primary into two windings, i. e. splitting the primary, is to provide a better wave shape and more efficient lighting, and hence our invention also contemplates a primary which is not split. In the circuit diagrams therefore, the primary winding is shown as a single winding and is designated 27, 31. The separation of the primary into two parts prevents saturation of the shell 21 in the vicinity of the leading secondary winding 28. The exact manner in which this is done is described in our co-pending application Serial No. 154,094 filed August 5, 1950 and entitled "Apparatus for Operating Gaseous Discharge Devices." Since the details are set forth therein, no further reference thereto need be made here.

The magnetic shunts are each provided with suitable non-magnetic gaps to present high reluctance magnetic paths through the shunts for the passage of the magnetic flux, said gaps being designated respectively from left to right 33, 34, and 35 associated with the shunts 26, 30, and 32.

In Fig. 2 we have illustrated a transformer 20' in which the primary is not split. The transformer 20' is formed of a core 21' made up of electrical laminations stacked and fastened together. There is a central winding leg 22' fitting into the core 21' as shown at 23' and 24'. The auxiliary starting secondary winding is designated 25' on the left hand end of the view; it is separated from the primary 27' by a magnetic shunt 26' having gaps 33'; the leading secondary winding 28' is positioned to the right of the primary 27', being separated therefrom by a small shunt 32' and gaps 35' if desired; and the lagging secondary winding 29' is on the right hand end of the transformer 20' separated from the leading secondary 28' by the shunt 30' and gaps 34'. The transformer 20' is the full equivalent of the transformer 20 and operates in substantially the same way. The circuit diagrams illustrated in Figs. 3 to 7 therefore apply equally, the elements as to the transformer 20' being designated in the same manner except that the reference characters are primed.

In Fig. 3 we have shown the connections of our apparatus, same being illustrated as having four fluorescent lamps associated therewith. The line terminals 40 and 41 lead to a source of power such as for example a 118 volt A. C. line. The primary 27, 31 is connected across the line from the terminals 51 to 52. Across said terminals are two series branches including the lamps and the remainder of the coils. Thus, on the left hand side we have shown a series branch 42 containing two lamps, and on the right hand side we have shown another series branch 43 containing two additional lamps.

Looking at the left or leading branch 42, starting from the top of the diagram, same has the following elements connected in series: the lamp 47, the capacitor 48, the leading secondary winding 28, and the lamp 50. Looking now at the right hand or lagging branch 43, starting from the top of the diagram, same has the following elements connected in series: the lamp 46, the lagging secondary winding 29, and the lamp 49.

As thus far described, each of the modified forms described in connection with Figs. 4 to 7 inclusive has the identical elements, placed in the identical manner. There may be some variation in the proportional sizes of the windings, but otherwise they are the same. In all cases, the physical position of the auxiliary starting winding is the same with respect to the transformer, the variation being in the manner of connection of the auxiliary starting winding into the circuit and the proportions of the windings.

Considering now Fig. 3, note that we have provided arrows alongside each of the windings to show its voltage sense, that is, the direction of instantaneous voltage at any time. This sense is obtained in manners well known in the art. Note that the sense of the voltage of the primary 27, 31 is up, while the sense or direction of the instantaneous voltage of the two secondaries 28 and 29 is down. This voltage direction prevails throughout all examples shown and described herein.

In Fig. 3, the auxiliary starting winding 25 is connected from a point 45 between the capacitor 48 and the leading secondary winding 28 to a point 44 between the lagging secondary winding 29 and the lamp 49. It is connected so that its voltage sense is to the right. As described in the copending applications the winding 25 has a very high leakage reactance because of its physical placement upon the transformer 20.

In order to explain the manner of operation of the invention, it will be assumed that the line voltage is 118 and that the lamps are all T-12 instant start fluorescent lamps, 96 inches in lengh, requiring a starting voltage of 625 volts and operating at about 200 volts with a current of 425 milliamperes. Obviously for different kinds of gaseous discharge devices, changes in proportions will be required, but the principles will be the same.

In the circuit of Fig. 3, if the secondaries 28 and 29 are constructed to have an open circuit voltage of 400 volts each and the auxiliary starting secondary 25 is proportioned so that its number of turns provides an open circuit voltage of approximately 1200 volts, we provide sufficient voltage to start two of the lamps when power is applied to the line terminals 40 and 41. The total voltage is considered in a circuit starting at the terminal 51, extending up through the primary 27, 31 which provides 118 volts to the terminal 52, then to the left branch 42, through the lamp 47, capacitor 48 to terminal 45; thence through the 1200 volt secondary 25 to terminal 44, through lamp 49 and back to the terminal 51. In this complete circuit there is generated well over 1200 volts, or sufficient to start both lamps 47 and 49.

It is pointed out that the voltage required to start two lamps in series is approximately 1.8 to 1.9 times the starting voltage of one.

Once lamps 47 and 49 have started, current flows in the circuit including the winding 25 and the capacitor 48. The circuit constants are chosen so that there is a resonant condition engendered, but on the lagging side of maximum resonance. The result will be a phase shift of the voltage in the auxiliary starting winding 25 made possible because of its high leakage reactance. The voltage in the winding 25 after ignition will thus have a component which has a voltage sense to the left and the value of this voltage will be substantial. It may thus be as high as 900 volts under the conditions described.

With the voltage in winding 25 being a high value of approximately 900 and the sense being to the left, if we consider the circuit from terminals 52 to 51 including the two lamps 46 and 50, we will note that the voltages are additive. The circuit is as follows: from terminal 52 through lamp 46, winding 29, terminal 44, winding 25, terminal 45, winding 28, lamp 50, and terminal 51, with the sense of the primary voltage being also additive. The total of 900 plus 400 plus 400 volts in this circuit is well over the ignition voltage of lamps 46 and 50, and hence these two will then ignite.

The amount of phase shift of the auxiliary starting secondary and the reverse voltage obtained are easily controlled by varying the inductance of the winding to alter the resonance point thereof.

With all lamps ignited, proper current flows in the branches 42 and 43, with practically no current flowing in the winding 25 due to its high leakage reactance, so that in effect, we have two series lamp circuits 42 and 43, connected in parallel with the primary winding 27, 31 across the terminals 52 and 51. The voltages of the windings 28 and 29 combined with the voltage of the primary 27, 31 are sufficient to sustain the current in the lamps.

Referring now to Fig. 4, note that the auxiliary starting winding 25 is connected in a different manner. The left hand end thereof is connected to terminal 45 as before, but the right hand end is now connected at point 55 between the lamp 46 and the winding 29. In this case, the voltage sense of the winding 25 is the same, but the open circuit voltage thereof need not be so high as before. With an open circuit voltage of 900 volts in the starting secondary 25, there will be a series circuit including the lamps 47 and 49 which has a total of 1300 volts, since it now includes the open circuit voltage of winding 29. In this case, a greater phase shift after ignition is required,

and hence the inductance of the winding 25 must be chosen to bring the combination of capacitor 48 and winding 25 closer to resonance than before. After ignition of the two lamps 47 and 49, a reverse voltage of approximately 700 voltage will combine with the voltage of the winding 28, chosen again as 400, to ignite the remaining two lamps. Thereafter the lamp circuits operate in the manner described above.

It is desired to point out that the presence of the condenser 48 in the branch 42 makes this the leading branch, while the other branch is lagging so that desirable power factor and anti-stroboscopic characteristics are obtained.

Referring now to Fig. 5, we have the identical circuit, except that here the auxiliary starting secondary 25 is connected across the lower terminals of the lamps 46 and 47 from the point 55 to the point 56. The voltage sense of the winding 25 is now to the left, and the proportions are chosen so that its open circuit voltage is approximately the same as in the case of Fig. 3. The operation is the same as in the case of Fig. 3 except that the lamps 46 and 50 will ignite first. We have found this a slightly better starting circuit, because in the case of the circuit of Fig. 4, some difficulty is sometimes experienced in obtaining sufficient voltage to start lamp 46 after 47 and 49 have been started. In such cases we can add a condenser across the lagging secondary 29, but this will be discussed hereinafter.

Referring now to Fig. 6, we have shown here another variation of the circuit. Here the auxiliary starting winding 25 is connected across the upper terminals of lamps 49 and 50 from point 44 to point 57. This circuit operates in the same manner as described, with the lamps 47 and 49 igniting first.

In Fig. 7 we have shown a circuit which utilizes the general principles described, but in which a resonance condition is not required. The open circuit voltages of the windings 28 and 29 are chosen to be greater than for the examples thus far described. In the case of the T–12 lamps referred to, the respective open circuit voltages are 700. The winding 25 on the other hand has a much lower open circuit voltage, same being of the order of 600 volts. The winding 25 is connected from point 56 to 44. The initial ignition circuit includes lamps 46 and 50, as well as all three secondaries, thus giving well over the required ignition voltage. After ignition there will be sufficient voltage in the circuit including the remaining two lamps to ignite them. There is no need for a reverse voltage in the auxiliary starting winding, since the voltages of the two secondaries 28 and 29 in series with the lamps 46 and 50 will provide sufficient igniting voltage.

In the case of the circuit of Fig. 6, the deactivation of any one of the lamps immediately will identify the defective lamp. Since there is sufficient voltage from the windings to sustain current in all of the other lamps, even the mate in the series circuit in which the defective lamp is connected, and by virtue of the small current through the starting secondary 25, there will be at least a glow in the mate. The other two lamps will continue to operate and give light. Thus, if the lamp 47 of Fig. 6 becomes defective and extinguishes, lamp 50 will glow and lamps 46 and 49 will continue to operate with no apparent decrease in light output. Under these circumstances, it is a simple matter to find and replace the defective lamp. The only disadvantage of this arrange-

ment is minor, and is concerned with the increase of the physical size of the transformer 20 in order to accommodate the larger windings. This expedient is still more economical, however, than providing two physically separate two-lamp ballasts for the same purpose.

We have been able to improve the starting qualities of the apparatus by connecting a small condenser across the lagging secondary. This has been illustrated in Figs. 3 and 4 by the condenser 60 which, for the general physical constants referred to herein, may have a value of from about .1 to .2 microfarads, with a relatively high voltage rating, say about 600 volts. We have found that under certain conditions the fourth lamp to ignite may have insufficient voltage to effect instantaneous ignition. For example, considering Fig. 3, first lamps 47 and 49 ignite, and then the lamp 50 will ignite. There is a tendency for discharge devices in leading circuits to ignite before discharge devices in lagging circuits, and of course the lamp 50 is the series mate of the lamp 47 and its condenser 42. With full current flowing through the leading branch 42, there is a voltage drop across the condenser 48 which may be sufficient to upset the resonance condition involving the winding 25 so that the voltage available to the lamp 46 now becomes the voltage of the winding 29, plus the voltage of the primary 27, 31, minus the voltage across the lamp 49. The total available voltage may be insufficient to ignite the lamp instantaneously. The provision of the condenser 60 of a value to provide a leading resonance in the lagging secondary winding 29 eliminates this possible difficulty. The addition of the condenser 60, we have found, increases the speed of ignition of the second two lamps substantially.

We believe that the establishment of leading resonance in the lagging secondary winding 29 increases the flux in the core 21 adjacent the windings 29 to a point of saturation thereby raising the voltage normally obtainable from the winding 29, so that there is a greater voltage available to assist in the ignition of the fourth lamp 46. While the lamps 50 and 46 will ignite in practically all cases irrespective of the provision of the additional condenser 60, such ignition may be sluggish.

In connection with the construction of a practical example of our invention it is believed that the examples set forth in our co-pending application give sufficient information to make it unnecessary to give such details here. It is desired to point out in the technique of constructing such ballasts that the main current carrying windings, namely, the primary 27, 31, and the two secondaries 28 and 29 should have as few turns and as low open circuit voltages as practical in order to keep the size of the ballast small. Every advantage should be taken of the ability of two lamps in series to have a low total sustaining voltage which will provide sufficient regulation therefor. For example two of the T-12 lamps above referred to which operate at approximately 200 volts each adequately will be regulated with a total sustaining voltage of about 500 volts. By the same logic, since the auxiliary starting winding 25 carries practically no current during operation, there is no need to make the same of heavy wire. Thus, the size can be very small, and yet comparatively large open circuit voltages developed therein, resulting in a saving of copper.

It is believed that our invention has adequately been described to enable one skilled in the art to know how to practise same and construct apparatus as described therein for the purposes set forth. The theoretical explanations herein are not by way of limitation, but only for aiding in an understanding of the invention, it being intended only to be limited by the breadth and scope of the claims hereinafter appended.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. Apparatus of the character described for igniting and operating gaseous discharge devices from a source of A. C. power having a voltage substantially less than the ignition or operating voltage of a single device which comprises, four gaseous discharge devices, a transformer having a unitary laminated core and having a primary, leading and lagging secondaries with the leading secondary closely coupled to the primary and the lagging secondary loosely coupled relatively thereto, and an auxiliary starting secondary being loosely coupled to the remainder of the transformer whereby to provide high leakage reactance therein, said transformer being connected in circuit with said four gaseous discharge devices to form two series circuit branches each containing two of said gaseous discharge devices, one having the leading secondary and a capacitive reactor connected between the two devices, and the other having the lagging secondary connected between its two devices, and the starting secondary being connected across the two branches from a point between the two devices of one to a point between the two devices of the other.

2. Apparatus as described in claim 1 in which the first of said last mentioned points is located so that a discharge device and capacitor of the one branch are on one side thereof and the second discharge device and the leading secondary winding are on the other side thereof, while the second point is located so that the lagging secondary and one device of the second branch are on one side thereof while the second device of that branch is on the other side thereof, and the voltage sense of said secondary being in a direction from the first branch to the second and said voltage being of a value sufficient to ignite one device in each branch when said apparatus is connected to said source.

3. Apparatus as described in claim 1 in which the first of said last mentioned points is located so that a discharge device and capacitor of the one branch are on one side thereof and the second discharge device and the leading secondary winding are on the other side thereof, while the second point is located so that the lagging secondary and one device of the second branch are on one side thereof while the second device of that branch is on the other side thereof, and the voltage sense of said secondary being in a direction from the first branch to the second and said voltage being of a value sufficient to ignite one device in each branch when said apparatus is connected to said source, said capacitor and auxiliary starting secondary being resonant after the ignition of the said one device of each branch whereby thereafter to provide a reverse phase voltage which, when combined with other circuit voltages is sufficient to ignite the remaining devices.

4. Apparatus as described in claim 1 in which the said points are an inner terminal of a device of each branch.

5. Apparatus of the character described for igniting and operating gaseous discharge devices

from a source of A. C. power having a voltage substantially less than the ignition or operating voltage of a single device which comprises, four gaseous discharge devices, a unitary laminated core transformer having a primary winding, a leading secondary winding, a lagging secondary winding and a high leakage reactance auxiliary starting secondary winding, the windings all being in the same magnetic circuit and loosely coupled one to the other but with the leading secondary and primary windings substantially closer coupled one to the other than any of the windings, and the coupling of the auxiliary starting secondary and primary windings one relative to the other substantially looser than the coupling between any of the windings, electrical lead means having a series capacitor and connecting the leading secondary winding between two of said gaseous discharge devices and forming a first series branch circuit therewith, the lagging secondary winding being connected between the other two gaseous discharge devices and forming a second series branch circuit therewith, the devices of each branch circuit end being connected across the line to parallel the branch circuits one with the other and with the primary winding, the auxiliary starting secondary winding having each terminal thereof connected to a different branch circuit at a point between the connections with the devices, the instantaneous voltage sense of both branch circuits being in the same direction and opposite to the direction of the voltage of the primary winding, and the starting secondary winding having sufficient turn ratio relative to the primary winding such that upon energization of the primary winding there will be a series connection between terminals of said primary winding through one device in each branch circuit, a part of the respective branch circuits and said auxiliary starting secondary winding, said series connection having a total series voltage sufficient to ignite both of said last-mentioned devices and thereafter cause the remaining devices to be supplied with sufficient voltage to ignite, the leakage reactance of said auxiliary starting secondary winding being high such that when all devices have been ignited all current will effectively flow through the branch circuits in parallel with practically none flowing in said auxiliary secondary winding.

6. Apparatus of the character described for igniting and operating gaseous discharge devices from a source of A. C. power having a voltage substantially less than the ignition or operating voltage of a single device which comprises, four gaseous discharge devices, a unitary laminated core transformer having a primary winding, a leading secondary winding, a lagging secondary winding and a high leakage reactance auxiliary starting secondary winding, the windings all being in the same magnetic circuit and loosely coupled one to the other but with the leading secondary and primary windings substantially closer coupled one to the other than any of the windings, and the coupling of the auxiliary starting secondary and primary windings one relative to the other substantially looser than the coupling between any of the windings, electrical lead means having a series capacitor and connecting the leading secondary winding between two of said gaseous discharge devices and forming a first series branch circuit therewith, the lagging secondary winding being connected between the other two gaseous discharge devices and forming a second series branch circuit therewith, the devices of each branch circuit end being connected across the line to parallel the branch circuits one with the other and with the primary winding, the auxiliary starting secondary winding having each terminal thereof connected to a different branch circuit at a point between the connections with the devices, the instantaneous voltage sense of both branch circuits being in the same direction and opposite to the direction of the voltage of the primary winding, and the starting secondary winding having sufficient turn ratio relative to the primary winding such that upon energization of the primary winding there will be a series connection between terminals of said primary winding through one device in each branch circuit, a part of the respective branch circuits and said auxiliary starting secondary winding, said series connection having a total series voltage sufficient to ignite both of said last-mentioned devices and thereafter cause the remaining devices to be supplied with sufficient voltage to ignite, the leakage reactance of said auxiliary starting secondary winding being high such that when all devices have been ignited all current will effectively flow through the branch circuits in parallel with practically none flowing in said auxiliary secondary winding, the inductance of said starting secondary winding and capacitance of said capacitor having a relationship to produce lagging resonance after the starting of the first two devices aforesaid such that a phase shift will be produced in said auxiliary starting secondary winding providing a reverse sense voltage of substantial value to assist in igniting the second two devices.

7. Apparatus as described in claim 5 in which said auxiliary starting secondary winding is connected to form a series circuit with said capacitor, a gaseous discharge device of each branch circuit and the primary winding in additive voltage relationship thereto, the auxiliary starting secondary winding having a turn relationship to the primary winding to provide ignition voltage for the gaseous discharge devices of said last-mentioned series circuit, the said last-mentioned gaseous discharge devices being the first of the four to ignite.

8. Apparatus of the character described in claim 5 in which the auxiliary starting secondary winding has one terminal thereof connected to a terminal of a device in one branch circuit and the other terminal of said auxiliary starting secondary winding connected to a terminal of another device in the second branch circuit.

9. A structure as described in claim 5 in which there are means associated with the lagging secondary winding to abnormally increase the flux produced thereby during ignition to provide higher than normal voltage at that time which comprise a parallel-connected resonance producing condenser.

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