

Aug. 23, 1955

A. E. FEINBERG ET AL

2,716,205

APPARATUS FOR OPERATING GASEOUS DISCHARGE DEVICES

Filed April 5, 1950

3 Sheets-Sheet 1

Fig. 1.

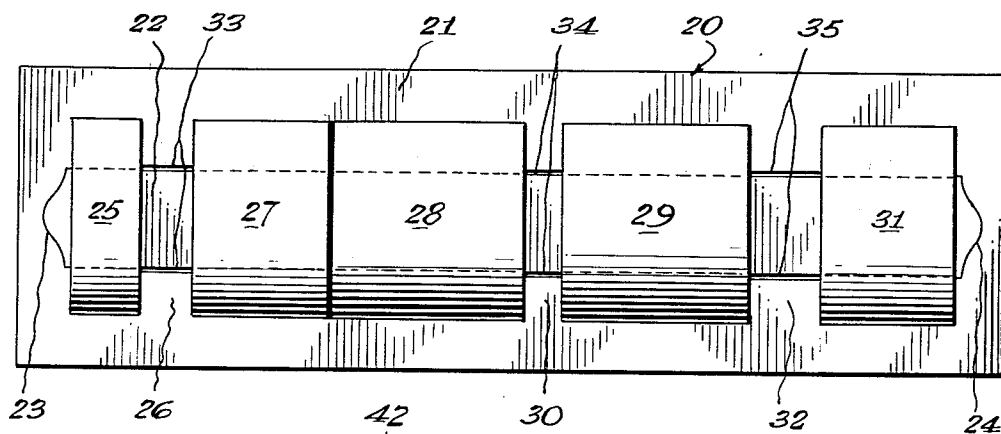
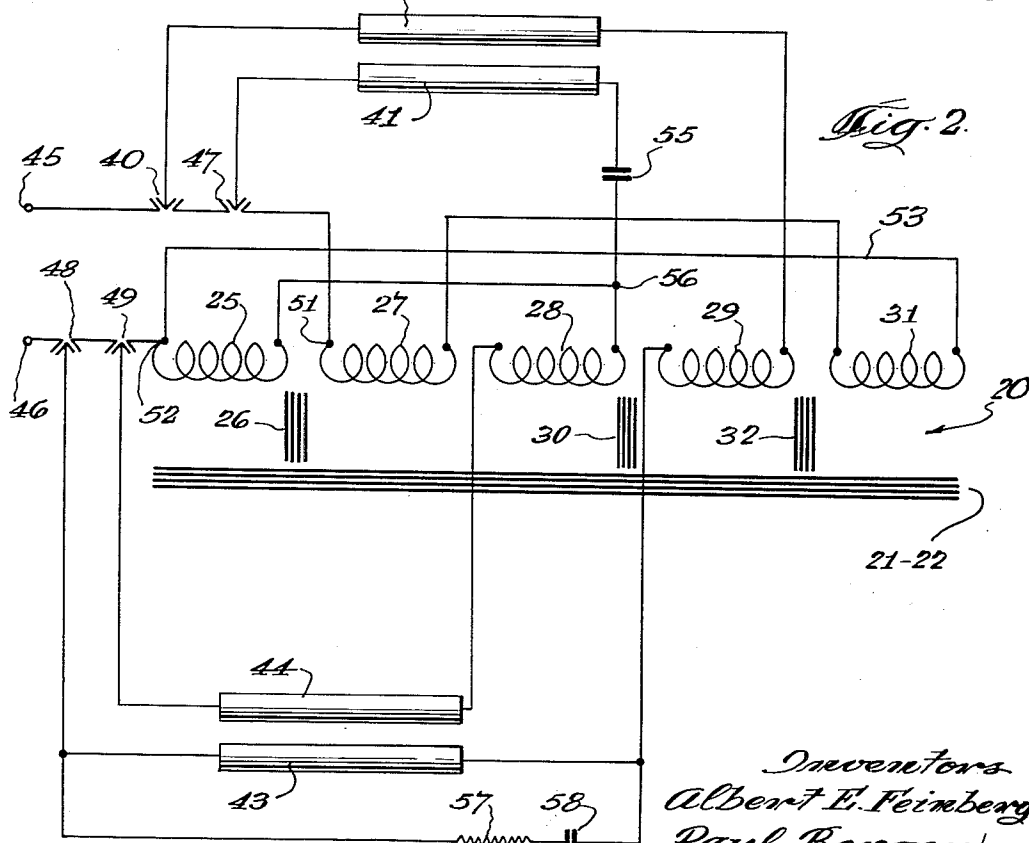


Fig. 2.

Inventors
Albert E. Feinberg
Paul Berger
By *J. Irving Silverman*
Attorney

Aug. 23, 1955

A. E. FEINBERG ET AL

2,716,205

APPARATUS FOR OPERATING GASEOUS DISCHARGE DEVICES

Filed April 5, 1950

3 Sheets-Sheet 2

Fig. 3.

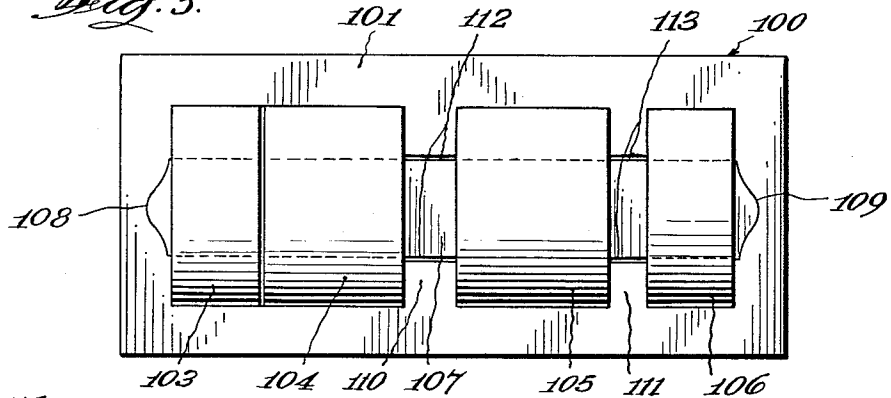


Fig. 4.

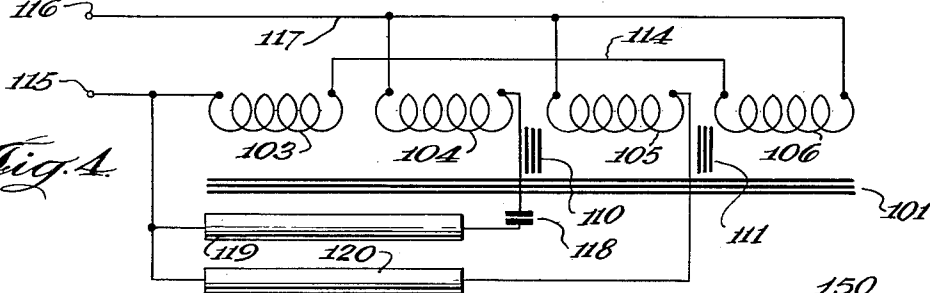


Fig. 5.

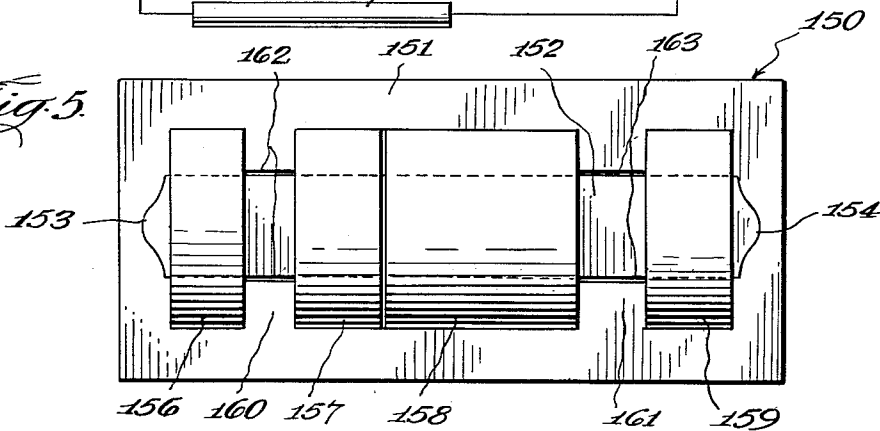
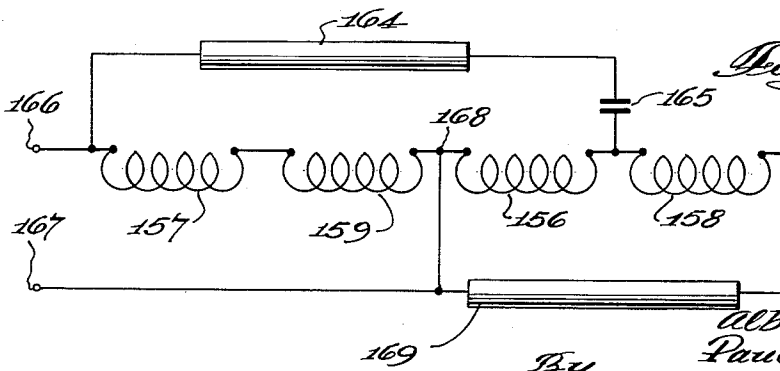


Fig. 6.



Inventors

Albert E. Feinberg

Paul Berger

By *J. Irving Silverman*
Attorney

Aug. 23, 1955

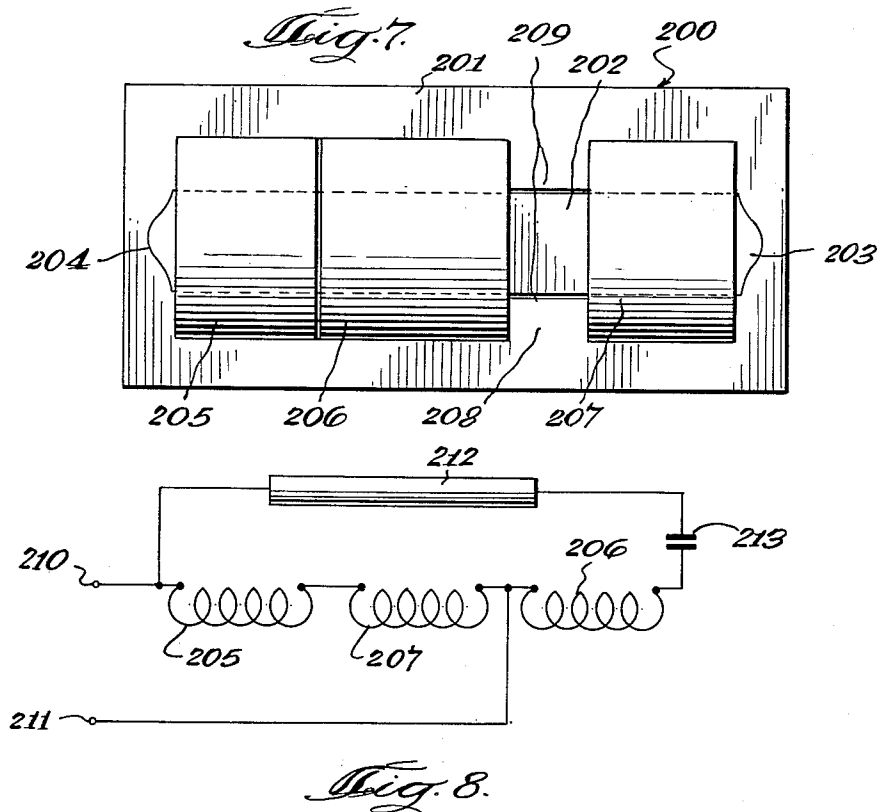
A. E. FEINBERG ET AL

2,716,205

APPARATUS FOR OPERATING GASEOUS DISCHARGE DEVICES

Filed April 5, 1950

3 Sheets-Sheet 3



Inventors
Albert E. Feinberg
Paul Berger
By J. Irving Silverman
attorney

2,716,205

APPARATUS FOR OPERATING GASEOUS DISCHARGE DEVICES

Albert E. Feinberg and Paul Berger, Chicago, Ill., assignors to Advance Transformer Co., Chicago, Ill., a corporation of Illinois

Application April 5, 1950, Serial No. 154,094

9 Claims. (Cl. 315—138)

This invention relates generally to apparatus for use in igniting and operating gaseous discharge devices and more particularly is directed to apparatus having novel means for correcting the wave shape of the current fed by such apparatus to the said gaseous discharge devices.

Our invention is especially concerned with apparatus for operating a plurality of fluorescent lamps from low voltage circuits, such as for example, from an A. C. line whose voltage is substantially one-half the operating voltage of any one lamp and substantially one-sixth the ignition voltage of any one lamp. Thus, for example, we have constructed satisfactory apparatus for operating a plurality of instant-start T-12 75 watt lamps from a 110 volt A. C. line. Such lamps operate at a voltage of 195 and require about 625 volts for ignition.

Obviously transformers can be constructed with sufficient iron and copper to handle high voltage transformations in the conventional manner, but it is pointed out that the transformer and additional elements, in the case of fluorescent lamps, are intended to be installed in fixtures which have limited available volume and further the cost thereof must be low in order to bring the eventual price of the fixture within reach of a greatest market.

One of the principal objects of the invention therefore is to provide apparatus of the character described which will enable small ballasts for fluorescent lamps and similar devices to be constructed very cheaply, but which ballasts will operate with great efficiency.

In the use of iron core transformers to aid in the starting of fluorescent lamps, and to limit the current once the lamps have been started, where the amount of iron is insufficient freely to conduct the flux resulting from the induced and applied voltages, the iron saturates. In this condition, the flux remains at a constant value irrespective of the voltage applied so that the resulting wave shape of current flowing in the windings adjacent the saturated iron will depart from sinusoidal, and instead have a distortion which, besides causing losses in the iron, will give lowered lighting efficiency. One method of curing this disadvantage has been proposed by Berger in U. S. Patent No. 2,461,957, but this construction cannot readily be used in certain types of circuits, such as for example in apparatuses where the magnetizing current will become very high as a result of such use.

Another object of our invention therefore, is to provide a device of the character described in which novel means are utilized for the correction of the wave shape of the current in the apparatus.

Still another object of the invention lies in the provision, in apparatus of the character described, of a split primary whose parts are so separated one from the other that the total leakage of flux through the intervening portions of the apparatus is sufficient materially to decrease the flux in any one part of the iron to prevent saturation thereof.

Still a further object of the invention is to provide means, in an elongate transformer, for closely coupling

a portion of the primary with the lagging secondary winding whereby to decrease the inductance of the said secondary winding and thereby improve the ignition voltage characteristic for the lagging circuit.

Other objects will appear as the description of the invention proceeds.

In order to point out the salient features and the exact nature of our invention, we have illustrated preferred embodiments in the drawings in which:

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

Fig. 2 is a schematic circuit diagram showing the connection of the transformer of Fig. 1 in a circuit for igniting and operating four fluorescent lamps.

Fig. 3 is a plan view of a transformer of modified form constructed in accordance with our invention.

Fig. 4 is a schematic circuit diagram showing the connection of the transformer of Fig. 3 in a circuit for igniting and operating two fluorescent lamps.

Fig. 5 is a plan view of a transformer of another modified form constructed in accordance with our invention.

Fig. 6 is a schematic circuit diagram showing the connection of the transformer of Fig. 5 in a circuit for igniting and operating two fluorescent lamps.

Fig. 7 is a plan view of still another modified form of transformer constructed in accordance with our invention.

Fig. 8 is a schematic circuit diagram showing the connection of the transformer of Fig. 7 in a circuit for igniting and operating one fluorescent lamp.

The usual apparatus or ballast as it is termed, for exciting fluorescent lamps has provision for operating two branches, each containing one or more fluorescent lamps. The current in the respective branches is leading and lagging, so that not only will the net results upon the line power factor be minimized, but the stroboscopic effect of operating all lamps in phase substantially will be eliminated. The distortion caused by saturation of the iron core, which has been referred to above, occurs to the greatest extent in the leading circuit, and hence the major correction must be applied to this portion of the apparatus.

The manner of correction suggested by the Berger patent above referred to uses a non-magnetic gap in the magnetic circuit adjacent the leading coil in a transformer mounting multiple coils, but this expedient is limited to conditions where the magnetizing currents handled by the apparatus are not very great. In case the currents run over a few hundred milliamperes, as in the case of ballasts for use with instant-start fluorescent lamps, the insertion of a gap in the main magnetic circuit will cause prohibitive increases in the magnetizing currents not readily handled by the type of windings used.

Our invention is therefore especially suitable for use where high voltages and currents are encountered, but is not limited thereto, being equally as effective under conditions of lower voltages and currents. For example, in the apparatus of Figs. 1 and 2 the voltages handled are of the order of 600 to 800, while the currents run as high as 400 milliamperes.

Referring now to the Figs. 1 and 2, the transformer 20 is formed of a stack of laminations in the shape of a rectangular shell 21 having a plurality of windows therein. The transformer windings are disposed in the windows and completely fill the same, and hence we have not deemed it necessary to illustrate same. We prefer arranging the windings upon a central winding leg 22 which matingly seats in the shell 21 as indicated by the end joints 23 and 24 and divides each window into two parts in the well-known manner. In production, the

windings may be pre-assembled to the winding leg 22 which is then pressed home into the shell 21.

We have shown five windings upon the transformer 20 consisting of, starting at the left hand end: the auxiliary starting secondary winding 25, separated from the next winding by the magnetic shunt 26; the first primary winding 27; the leading secondary winding 28 separated from the next winding by the magnetic shunt 30; the lagging secondary winding 29 separated from the next winding by the magnetic shunt 32; and finally the second primary winding 31 at the extreme right of the winding leg 22. As indicated in Fig. 1, the magnetic shunt 32 is somewhat larger than either of the other two. Each shunt has non-magnetic gaps designated 33, 34 and 35 respectively from left to right.

It will become immediately apparent that the first and secondary primary windings 27 and 31 are electrically connected to act as a single winding which collectively will be termed the primary, but that physically and magnetically they are substantially remote one from the other and separated by other windings and magnetic shunts. This is the expedient which causes great correction of wave shape as will become readily apparent from the explanation hereafter.

Referring to Fig. 2, we have shown four fluorescent lamps 41, 42, 43, and 44 connected to the transformer 20 to be ignited and operated thereby. For the purposes of this explanation, the lamps will be considered a type known in the trade as T-12 75 watt lamps, being 96 inches in length, and normally drawing currents of 430 milliamperes each at 195 volts A. C., and having an ignition voltage of approximately 625 volts. The lamps are of the hot cathode type and are known as instant-start lamps because the filament heating time is negligible and the cathodes are heated by the operating current. Obviously, other types of lamps can be used, but the conditions which must be met for the type referred to for illustration, are rather stringent.

The line terminals are designated 45 and 46, and it will be noted that the left hand terminals of lamps 41 and 42 are connected to the line terminal 45 at 47 and 40 respectively, while the left hand terminal of the lamps 43 and 44 are connected to the line terminal 46 at 48 and 49 respectively. The line terminals 45 and 46 connect to the junctures 51 and 52 respectively. The first primary 27, the second primary winding 31, the auxiliary starting secondary winding 25, and the leading secondary winding 28 are all connected in series, that is to say, end to end, with the juncture 51 at the left hand end of the first primary winding 27, the juncture 52 between the windings 31 and 25 (which are connected by the lead 53) and with the connection between the windings 25 and 28 designated as the juncture 56.

The lamp 41 is in series with a condenser 55 and connects between the juncture 51 and 56. The lamp 42 is connected in series with the juncture 51 and the right end of the lagging secondary winding 29, whose opposite end connects with the juncture 52 through the lamp 43 which is shunted by a resistor 57 and condenser 58 in series. The lamp 44 is connected across the leading secondary winding 28 and the auxiliary starting secondary winding 25.

The operation of the apparatus is set forth in detail in our co-pending application Serial No. 160,366 filed May 5, 1950, entitled Apparatus for Igniting and Operating Gaseous Discharge Devices, now Pat. 2,685,662, Aug. 3, 1954. Suffice it to state herein that the operation of the circuit is as follows:

When 110 volt A. C. power is applied across the terminals 45 and 46, there will be a voltage applied to the lamp 41 which is the combined voltages of the primary windings 27 and 31, and the auxiliary starting secondary winding 25. The winding 25 has a great number of turns relative to the primary, and hence the total voltage will amount to well over the starting voltage for the lamp 41. Prior to starting there will be practically no voltage

drop across the condenser 55, but after starting it will serve as a capacitive reactance causing the lamp 41 (and lamp 44) to draw a leading current.

After current begins to flow in lamp 41 and its circuit, the high reactance of winding 25 will cause a reverse component of voltage to appear in the windings 25 which will be additive to the voltage of the windings 28, so that the sum voltages across the lamp 44 will be sufficient to ignite the same. With the flow of current in the lamp 44, the lamps 41 and 44 will be connected as a series circuit from juncture 51 to juncture 52 through the capacitor 55 and the winding 28. The high impedance of the winding 25 prevents flow of appreciable current therethrough. The impedance of the condenser 55 is predominant and hence the circuit will draw a leading current from the line. This described branch constitutes the leading circuit operated by the transformer 20, and conceivably it could have more or less than two lamps.

As for the lagging circuit, when voltage is applied across the terminals 45 and 46, there is an induced voltage in the lagging secondary winding 29 which is additive to the primary voltage and the combined voltage is sufficient to ignite lamp 42. Prior to ignition and with no flow of current in lamp 43, the shunt condenser 58 and resistor 57 were of negligible impedance. After ignition, and with flow of current in the shunt circuit, a high voltage is developed across the lamp 43 by the condenser 58 which is sufficient to ignite lamp 43. With current flowing in lamp 43, the circuit including the lamp 42 and the winding 29 is substantially a series circuit between the junctures 51 and 52, and draws a lagging current due to the inductance of the winding 29.

With the voltages and currents in the windings caused by reason of the high operating voltages and currents of the lamps, for any conventional construction of the transformer 20, it is quite likely that saturation of the iron will occur in the vicinity of the leading secondary winding 28. We have prevented this by splitting the primary into two physically separated windings 27 and 31. A substantial portion of the primary comprising the second primary winding 31 is separated from the closely coupled first primary winding 27 and leading secondary winding 28 by the large shunts 30 and 32 and the lagging secondary winding 29. A considerable leakage of flux will therefore occur through the winding 29 and the shunts 30 and 32, since the reluctance of these paths is much less than the iron of the core 21 in the vicinity of the leading secondary winding 28. The flux in the iron core 21 adjacent the winding 28 will therefore be reduced considerably compared with that normally present if the entire primary were closely coupled with said secondary winding 28, and hence saturation of the iron is prevented. Under such circumstances, the current in the lamps 41 and 44, namely, the leading circuit, is not materially distorted, but approaches very closely to sinusoidal configuration. This provides the greatest lighting efficiency of the apparatus during its operation and serves to keep the losses in the core to a minimum.

Another advantage of this arrangement is that the improvement of coupling between the lagging secondary winding 29 and the primary by reason of the proximity of the second primary winding 31 thereto more readily enables the development of the high voltage in the winding 29 required for ignition of the first lamp 42 of the lagging branch of the circuit.

The embodiment described above has been successfully built and operated for use with four T-12, 75 watt, 96 inch instant-start fluorescent lamps, whose ignition voltage is 625 volts, and whose operating voltage is 195 volts, and whose operating current is 430 milliamperes. The constructional details of the apparatus were as follows:

Overall length of the core	10 1/8 inches.
Width of core 21	3 inches.
Width of winding leg 22	1 inch.
Height of stack	1 1/4 inches.

5

Width of windows and windings:

Secondary winding 25	¾ inch.
Primary winding 27	1¾ inches.
Secondary winding 28	2 inches.
Secondary winding 29	2 inches.
Primary winding 31	1¾ inches.

Widths of shunts:

26	½ inch.
30	¾ inch.
32	¾ inch.

Widths of gaps:

33	.010"
34	.040"
35	.040"

Condensers:

55	1.25 microfarads rated at 900 volts A. C.
58	.2 microfarad rated at 900 volts A. C.

Resistor 57 500 to 1500 ohms.

Winding turns:

25	3200 turns of No. 34 wire.
27	200 turns of No. 18 wire.
28	2115 turns of No. 26 wire.
29	2070 turns of No. 26 wire.
31	200 turns of No. 18 wire.

The electrical characteristics of the apparatus were as follows:

	Volts
Open circuit voltage across the lamp 41	800
Open circuit voltage across the lamp 42	700
Open circuit voltage across the lamp 43	770
Open circuit voltage across the lamp 44	800

The voltages across lamps 43 and 44 were measured with lamps 41 and 42 in place and vice versa.

During operation the voltage across all lamps was approximately 200 volts, and the current flowing in each circuit was approximately 430 milliamperes. The line voltage was 118 volts and the current drawn from the line was 3.5 amperes.

In Figs. 3 and 4 we have shown apparatus embodying our invention which has been constructed for operating two T-12, 75 watt instant-start fluorescent lamps from a 110 volt A. C. line.

The transformer 100 consists of an iron core 101 formed of rectangular laminations as a shell-like member provided with windows for the windings. The windings consist of the first primary winding 103, the leading secondary winding 104, the lagging secondary winding 105, and the second primary winding 106. The windings are all mounted upon a central winding leg 107 which is adapted to be seated in mating recesses in the core 101 as indicated at 108 and 109. The magnetic shunt 110 separates the windings 104 and 105, while the magnetic shunt 111 separates the windings 105 and 106. The shunts are provided with non-magnetic gaps 112 and 113 respectively.

As will be seen in Fig. 4, the primary windings 103 and 106 are connected by the lead 114 and hence are in series across the line terminals 115 and 116. The windings 104 and 105 each have one terminal connected to the lead 117 which in turn is connected to terminal 116. The other terminal of the secondary winding 104 is in series with a condenser 118 and a fluorescent lamp 119 and is connected to the line terminal 115. The other terminal of the secondary winding 105 connects to the line terminal 115 through a fluorescent lamp 120. Thus it will be seen that the windings 104 and 105 are arranged in auto-transformer relationship, and that the winding 104 with the condenser 118 and the lamp 119 constitute the

6

leading circuit, while the winding 105 with the lamp 120 constitute the lagging circuit.

The operation of such circuit is relatively simple. The application of voltage to the line terminals 115 and 116 will cause sufficiently large voltages to appear across each of the lamps 119 and 120 to ignite the same, after which the current flow through each of the lamps will be limited by the impedance in the respective circuits. The leading circuit impedance will be capacitive due to the condenser 118, while the impedance of the lagging circuit will be inductive due to the large inductance of the winding 105. The net result will be that the apparatus will draw current from the power line at approximately unity power factor.

Due to the high voltages encountered in the apparatus when used with instant-start fluorescent lamps, the iron core in the vicinity of the leading secondary winding 104 tends to saturate and thereby cause distortion of the current flowing through the lamp 119. By reason of the physical displacement of a portion of the primary, namely the splitting of the primary into two windings 103 and 106 separated one from the other, whereby there is a large leakage path for the flux between the winding 104 and a substantial portion of the primary, the flux in the core 101 adjacent said winding 104 is materially reduced. This aids in preventing saturation and the resulting current approaches a sinusoidal configuration with resulting greater lighting efficiency. This has been set forth in connection with the explanation of the apparatus described in Figs. 1 and 2. Likewise, the coupling between the second primary winding 106 and the lagging secondary winding 105 has been improved whereby the ignition of the lamp 120 has been facilitated.

We have found that the physical separation and the quantity of leakage obtained between the windings 28 and 31 enables wave shape correction which is quite satisfactory. With respect to smaller transformers, such as shown in connection with Figs. 3 and 4, the wave shape correction afforded by splitting the primary may in some cases require augmentation by other means, such as for example gaps or larger shunts. Nevertheless, correction to some extent is obtained by so splitting the primary in smaller transformers.

With respect to the general physical characteristics of the type of apparatus described in connection with Figs. 3 and 4, attention is invited to Figs. 5 and 6 and the accompanying explanation. In connection with the latter a practical example has been set forth which is roughly the same as to its physical properties as the practical example of the apparatus of Figs. 3 and 4.

Our invention is applicable to certain types of apparatus wherein the coupling between the lagging secondary winding and the primary winding is of little importance. Such apparatus, for example, includes means for igniting and operating fluorescent lamps which have no winding that can be considered as a lagging secondary winding. Thus for example we have shown in Figs. 5 and 6 apparatus which includes a transformer 150 having a plurality of windings none of which is utilized as a lagging secondary winding. The transformer is constructed in substantially the same manner as described in connection with the previously described transformers, and includes a laminated iron core 151, a central winding leg 152, matingly seated into the core 151 as shown at 153 and 154.

The windings of the transformer 150 consist of an auxiliary starting secondary winding 156, a first primary winding 157, a leading secondary winding 158, and a second primary winding 159. There are two magnetic shunts 160 and 161 having the gaps 162 and 163 respectively. The winding 156 is loosely coupled to the primary consisting of both primary windings 157 and 159 by reason of the magnetic shunt 152 between it and the first primary winding 157. This causes the winding 156 to have a high leakage reactance and during starting a large volt-

age will be developed therein. The second primary winding 159 is loosely coupled with the leading secondary winding 158 by reason of the shunt 161.

The windings are all electrically connected in series as will be noted from the electrical diagram of Fig. 6. The lamp 164 and the series connected condenser 165 are connected across the primary windings 157, 159 and the auxiliary starting secondary 156. The left hand end of the primary winding 157 is connected to one terminal 166 of the line terminals 166 and 167. The juncture 168 between the windings 159 and 156 is connected to the terminal 167 so that the primary is across the line. The second lamp 169 is connected from the terminal 168 to the right hand end of the leading secondary winding 159.

The apparatus of Figs. 5 and 6 operates in the manner described in connection with the lamps 41 and 44 of the apparatus shown in Figs. 1 and 2 and hence it is believed that no further explanation is required except to state that since there is no lagging branch to compensate for the leading power factor, the impedance of the leading secondary winding 158 may be adjusted to compensate to a great extent for the capacitive impedance of the condenser 165. The splitting of the primary into the windings 157 and 159 and the arrangement of substantially large leakage path between the second primary winding 159 and the leading secondary winding provides for the wave shape correction hereinabove referred to. This is done, as previously described by at least partially preventing saturation of the iron core 151 in the vicinity of the leading secondary winding 158.

This type of apparatus may be used where it is desirable that the same draw leading current from the line. As in the case of the previously described apparatus of Figs. 3 and 4, due to the proximity of the second portion 159 of the primary to the secondary winding 158, the amount of correction is proportionally not as great as in the case of the apparatus of Figs. 1 and 2. Therefore, other corrective means may be required to obtain additional improvement in wave shape if desired.

A practical example of this device, constructed with only the split primary for correction of the current wave shape had the following characteristics:

The transformer was a one and one-quarter inch stack of laminations six and three quarters by three inches. The central winding leg 152 was 1.1 inches wide. The auxiliary starting secondary winding 156 was $\frac{3}{4}$ inch long and had 3000 turns of No. 34 wire; the first primary winding 157 was $\frac{7}{8}$ inch long and had 195 turns of No. 21 wire; the leading secondary winding 158 was 2 inches long and had 1940 turns of No. 26 wire; the second primary winding 159 was identical to the first primary winding 157. The shunts were both one-half inch wide, although the shunt 161 could be made wider in the event that the wave shape improvement by splitting the primary was insufficient. One embodiment had this width about $\frac{3}{4}$ inch. The gap 162 was .015 inch, and the gap 163 was .040 inch.

The same lamps were used as previously described, and the line voltage was the same. The open circuit voltage across the lamp 164 was 900 volts with the other lamp out of the circuit, and the open circuit voltage of the lamp 169 with lamp 164 operating was 800 volts. After ignition, both lamps operated at about 195 volts and drew about 450 milliamperes.

In Figs. 7 and 8 we have shown our invention as applied to apparatus for operating a single lamp. There is a transformer 200 which is constructed of laminated iron core 201 having a central winding leg 202 matingly seated in the core as shown at 203 and 204. There are only three windings upon this core consisting of the first primary winding 205 on the left end of the core closely coupled to the leading secondary winding 206 in the center of the core 201, and the second primary winding 207 on the right hand end of the transformer 200 separated from the leading secondary winding by the magnetic

shunt 208 having the gaps 209. As noted in the electrical diagram of Fig. 8, the two primary windings 205 and 207 are connected to the line terminals 210 and 211. The lamp 212 and the condenser 213 are connected in series across all three windings.

The device operates as a simple auto-transformer to provide sufficient ignition voltage to start the lamp 212. After flow of current has started, the same is limited by the impedance of the circuit including the leading secondary winding 206. In order to prevent the saturation of the core 201 in the vicinity of the winding 206 when this apparatus is used for high voltage fluorescent lamps, the splitting of the primary into the windings 205 and 207 causes the portion 207 to have a rather loose coupling with said secondary winding 206. There will therefore be a large leakage path for flux from said primary winding 207 through the magnetic shunt 209 which will prevent all of the flux from threading the iron core 201 in the vicinity of said secondary winding 206.

In the embodiments referred to in Figs. 5 to 8 inclusive, it should be appreciated that although the iron core in the vicinity of the leading secondary winding is not saturated during operation, the full benefit of the voltage from the total primary is available to the secondary for providing the ignition voltage for the fluorescent lamps involved.

It is also desired to point out that the wave shape improvement in all embodiments illustrated in Figs. 3 to 8 inclusive is not as proportionately great as in the case of the said Figs. 1 and 2, or in the case of transformers where the splitting of the primary will result in relatively great physical separation so that the leakage will be high. In such cases, namely smaller transformers, the invention enables at least partial improvement in wave shape, and in some cases may totally prevent saturation.

From the above explanation it will be seen we have provided means for improving the wave shape of current in the leading circuit of apparatus of the character described which in some instances may approximate sinusoidal. This has been done by preventing saturation of the iron core in the vicinity of the leading secondary winding by means of physically separating the primary winding into two parts and locating one part remote from the other. The intervening leakage paths for the flux from the primary winding which is most remote from the leading secondary winding prevents the maximum flux from threading the iron in the vicinity of the leading secondary winding. Likewise we have enabled closer coupling to exist between the lagging secondary winding and the primary in certain types of apparatus without materially decreasing the leakage reactance of the lagging secondary winding and thereby enabled a higher ignition voltage to be developed in the lagging secondary winding for starting.

Many variations of the invention are contemplated by us, and hence the dimensions and the physical characteristics assigned to the parts of the invention by way of example are not intended as limitations. The broad scope of the invention is set forth in the appended claims. Likewise, the theories which have been advanced or which may be inferred for the purposes of enabling a clear understanding of the apparatus and the operation thereof are not intended to limit the invention. We would rather have it understood that the invention lies in the general constructional features irrespective of the theories under which same operate, and irrespective of whether our understanding thereof is correct.

We claim:

1. Apparatus of the character described for operating a plurality of gaseous discharge devices from a relatively low voltage source of A. C. power comprising, two gaseous discharge devices, an elongate iron core forming a single magnetic circuit having flux threading the

same, a plurality of windings disposed along the length of the core, said windings forming a transformer and being connected to said gaseous discharge devices for igniting and operating the same, two windings being connected in series and in voltage additive relationship and together connected across the source to serve as parts of a primary, the primary parts being physically disposed at opposite ends of the said core, a third winding mounted upon said core in close coupled relationship with only one primary part, and connected in auto-transformer relationship with the full primary as a secondary winding thereof, a condenser, one gaseous discharge device being in series with the condenser and together therewith connected across said third winding and said full primary, a fourth winding mounted upon said core in loosely coupled relationship with all of the windings and connected in auto-transformer relationship with the full primary as another secondary winding thereof, the second gaseous discharge device being connected in series with the said fourth winding and across the full primary, the capacitive reactance of said condenser being dominant relative to the inductive reactance of said third winding in the circuit including said first gaseous discharge device whereby a leading current will flow through the third winding during operation of the apparatus, and the inductive reactance of the fourth winding being dominant in the circuit including the second gaseous discharge device whereby a lagging current will flow through the fourth winding during operation of the apparatus, there being magnetic shunts in the core on opposite sides of the fourth winding, the third and fourth windings being disposed upon said core physically between the primary parts.

2. Apparatus for igniting and operating a plurality of gaseous discharge devices from a relatively low voltage source of A. C. power, comprising, a pair of gaseous discharge devices, an elongate iron core providing a single magnetic circuit, a primary winding mounted upon the said core and connected to the source, a first secondary winding mounted upon said core, and a second secondary winding mounted upon said core, the windings being electrically connected end to end in the order named, there being a substantial physical separation providing a magnetic shunt between the first secondary winding and the primary winding to produce high leakage reactance in said first secondary winding during operation of the apparatus, a condenser, one gaseous discharge device being in series with the condenser and together therewith being connected across the primary and first secondary windings to be subjected to the sum of voltages developed in said last mentioned two windings, a second gaseous discharge device being connected across both secondary windings to be subjected to the sum of voltages developed in said secondaries, the primary being formed of two series connected additive portions physically separated one from the other along the length of the said core, a second magnetic shunt, the said second secondary and second magnetic shunt being disposed between said portions.

3. Apparatus as defined in claim 2 in which the first secondary winding is disposed at an end of the core and the first magnetic shunt is disposed between said first secondary winding and one part of the said primary winding.

4. Apparatus of the character described for igniting and subsequently operating a plurality of gaseous discharge devices from a source of A. C. voltage, comprising a single elongate iron core providing a single magnetic circuit, two igniting and operating circuits one being leading in character and the other being lagging in character, a primary winding mounted on the core and connected across the source, said circuits having said primary winding in common; said leading circuit including a first secondary winding and a second secondary winding both mounted on said core, the first secondary winding being

very loosely coupled with the primary winding compared with the coupling of the second secondary winding whereby to provide high leakage reactance therein, the secondary windings being in voltage opposition one to the other, a condenser, two gaseous discharge devices, one being in series with the condenser and together connected across the primary winding and first secondary winding to be energized thereby, and the second gaseous discharge device being connected across both secondary windings to be energized thereby, the primary and secondary windings being connected end to end in the order named, the capacitive reactance of the condenser during operation being dominant over the inductive reactance of the second secondary to provide a leading current through the said second secondary; said lagging circuit including a third secondary winding mounted on the said core and in auto-transformer connection with the said primary winding and a third gaseous discharge device connected in series with the third secondary winding and across the primary winding and energized thereby, the inductive reactance of said third secondary winding being dominant in said lagging circuit whereby to provide a lagging current through said third secondary winding; the primary winding consisting of two series connected, voltage additive parts physically separated along the core, the second secondary and the third secondary being disposed upon said core between the said parts, with the second secondary closely coupled with one part and separated from the other part by the third secondary winding.

5. Apparatus as described in claim 4 in which the third secondary winding has magnetic shunts on opposite sides thereof.

6. Apparatus for igniting and thereafter operating a gaseous discharge device from a relatively low voltage source of A. C. power which comprises, a gaseous discharge device, an elongate iron core forming a single magnetic circuit, a primary winding mounted thereon and connected with the source, a secondary winding also mounted on the core and connected in auto-transformer relationship with the primary, a condenser, said gaseous discharge device and condenser being connected in series and across the primary and secondary windings together, said primary windings being composed of two parts, the parts being connected electrically in additive series voltage relationship, the parts and secondary winding being disposed along the core one after the other along the length thereof with the secondary winding between the parts of the primary winding, but with the coupling between secondary winding and one part substantially different than the coupling between said secondary winding and the other part.

7. Apparatus for igniting and thereafter operating a gaseous discharge device from a relatively low voltage source of A. C. power which comprises, a gaseous discharge device, an elongate iron core forming a single magnetic circuit, a primary winding mounted thereon and connected with the source, a secondary winding also mounted on the core and connected in auto-transformer relationship with the primary, a condenser, said gaseous discharge device and condenser being connected in series and across the primary and secondary windings together, said primary being composed of two parts, the parts being electrically connected in additive series voltage relationship and being disposed upon the core physically separated with the secondary winding between, and a magnetic shunt in the core for providing leakage reactance, disposed between the secondary winding and one of said parts and rendering the coupling between said secondary winding and said one part looser than the coupling between said secondary winding and the other of said parts.

8. Apparatus for igniting and operating a plurality of gaseous discharge devices from a relatively low voltage source of A. C. power, comprising, a pair of gaseous discharge devices, an elongate iron core providing a single magnetic circuit, a primary winding having first and sec-

11

ond terminals mounted upon said core and connected to the source, a first secondary winding having first and second terminals mounted upon said core, a second secondary winding having first and second terminals mounted upon said core, the windings being electrically connected end to end in the order named with the second terminal of the primary winding common with the first terminal of the first secondary winding to form a first junction, and the second terminal of the first secondary winding common with the first terminal of the second secondary winding to form a second junction, there being a substantial physical separation providing a magnetic shunt between the first secondary winding and the primary winding to provide high leakage reactance in said first secondary winding during operation of the apparatus, a condenser, one gaseous discharge device being in series with the condenser and together therewith connected from the second junction to one of the terminals of the primary winding, a second gaseous discharge device connected from the second terminal of the second secondary winding to the other of the terminals of the primary winding, the primary winding being formed of two series connected addi-

12

tive portions physically separated one from the other along the length of the core, a second magnetic shunt, the said second secondary and second magnetic shunt being disposed between said portions.

9. Apparatus as defined in claim 8 in which the first secondary winding is disposed at an end of the core and the first magnetic shunt is disposed between said first secondary winding and one part of said primary winding.

References Cited in the file of this patent

UNITED STATES PATENTS

1,950,396	Boucher	Mar. 13, 1934
2,264,055	Stocker	Nov. 25, 1941
2,305,487	Naster	Dec. 15, 1942
2,352,073	Boucher et al.	June 20, 1944
2,355,360	Boucher et al.	Aug. 8, 1944
2,429,415	Lemmers	Oct. 21, 1947
2,465,031	Nathanson	Mar. 22, 1949
2,502,084	Foerste	Mar. 28, 1950
2,504,549	Lemmers et al.	Apr. 18, 1950
2,515,109	Berger	July 11, 1950
2,541,033	Cates	Feb. 13, 1951