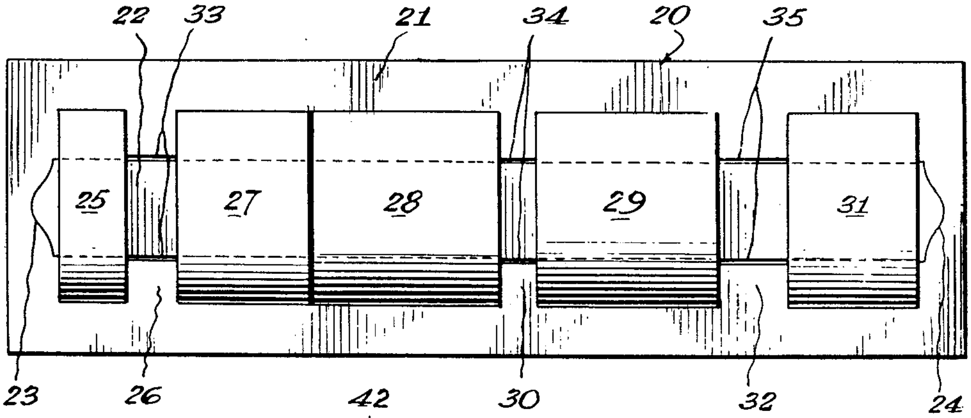
Fig. 1.



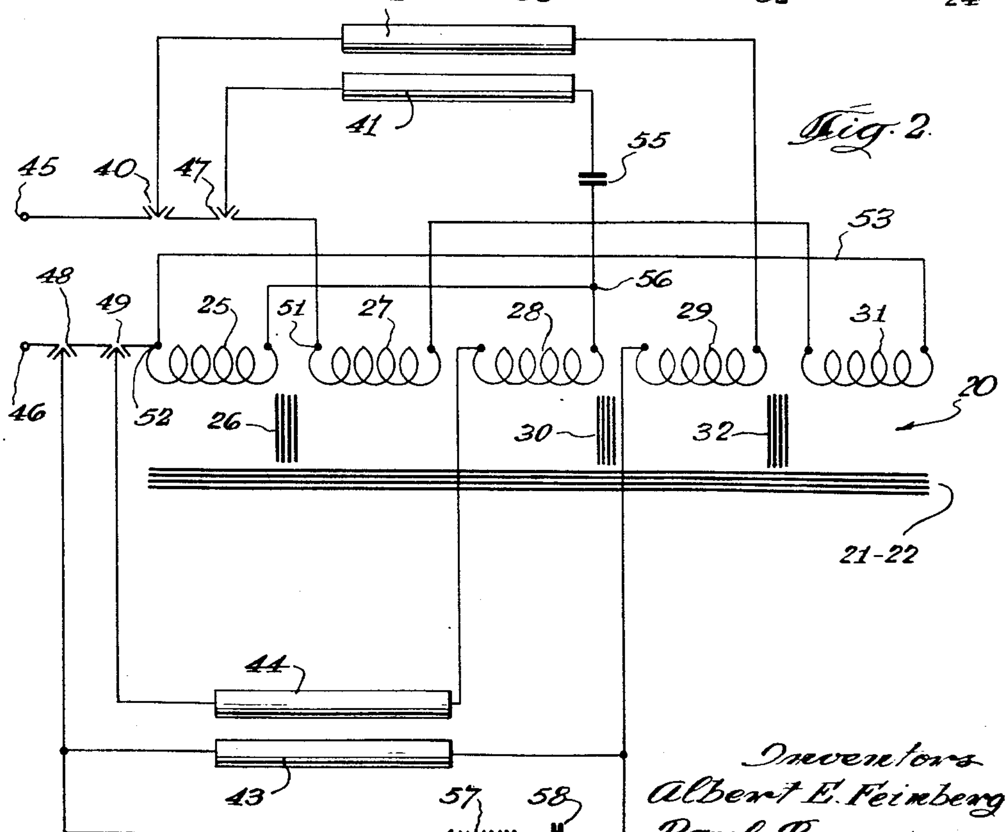


Fig. 2.

Inventors
Albert E. Feinberg
Paul Berger
By I. Irving Silverman
Attorney

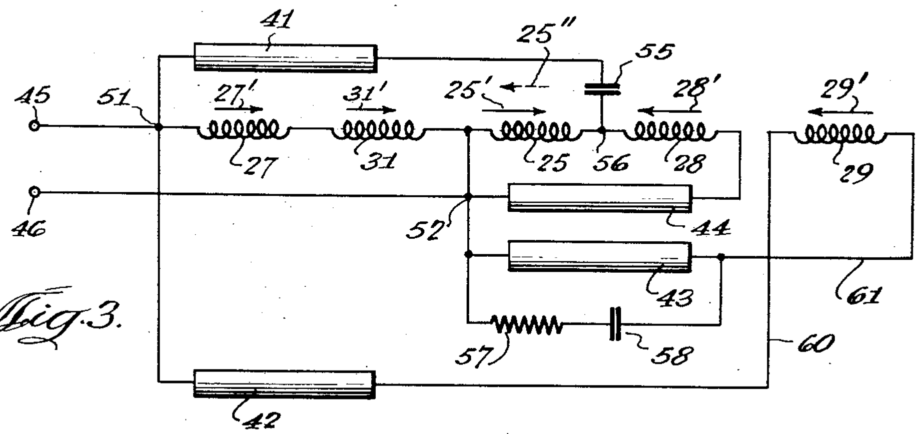


Fig. 3.

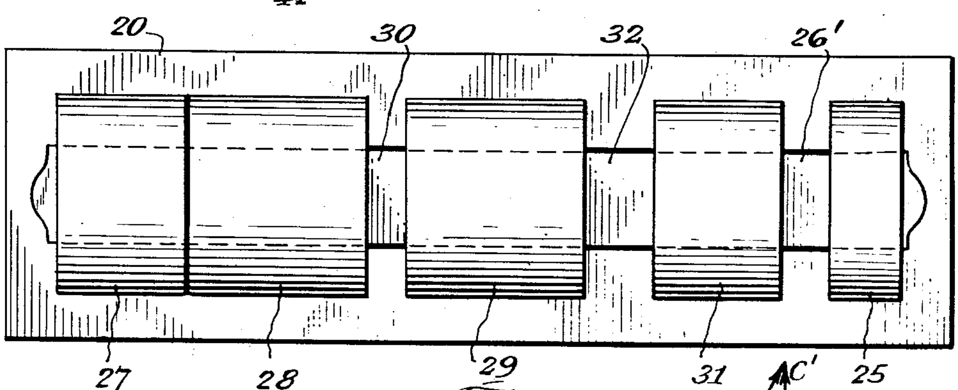


Fig. 4.

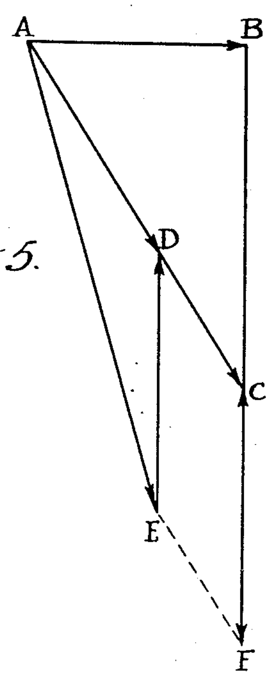


Fig. 5.

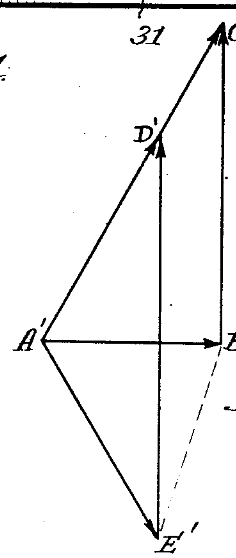


Fig. 6.

Inventors
Albert E. Feinberg
Paul Berger
By I. Irving Silverman
Attorney

Fig. 7.

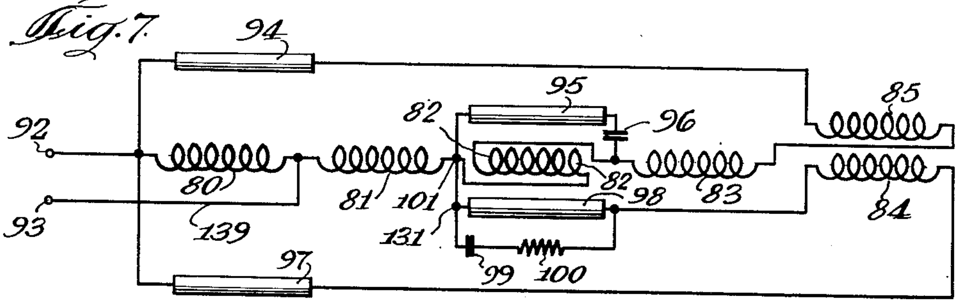
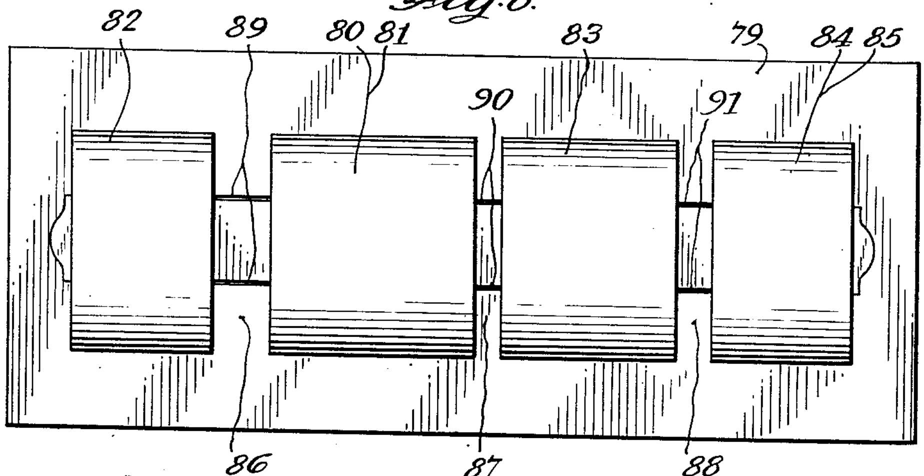


Fig. 8.



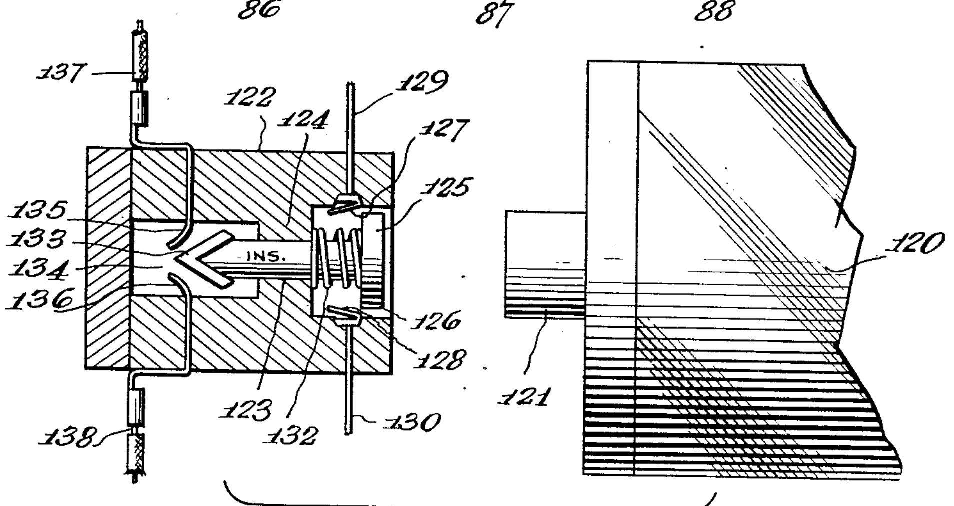


Fig. 9.

Inventors
Albert E. Feinberg
Paul Berger
By I. Irving Silverman
Attorney

Patented Aug. 3, 1954 2,685,662

UNITED STATES PATENT OFFICE

2,685,662

APPARATUS FOR IGNITING AND OPERATING GASEOUS DISCHARGE DEVICES

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

Application May 5, 1950, Serial No. 160,366

10 Claims. (Cl. 315—138)

This invention relates generally to apparatus for providing the ignition and operation voltage for a plurality of gaseous discharge devices, and more particularly is concerned with apparatus intended for igniting and operating fluorescent lamps connected in groups, and especially groups of four.

The type of apparatus which is contemplated by our invention is commonly known as a ballast, and one of the basic components of such apparatus is a transformer. The invention herein includes a transformer in which the windings are arranged in a novel manner to give certain beneficial results.

It is obvious that many types of ballasts exist which are intended for the ignition and operation of single lamps and pairs of lamps. It has been customary that the circuits include some manner of switch, so that the filaments of the lamps are heated to cause emission of clouds of electrons, and the application of suitable ignition voltage across any given lamp simultaneously with the heating of the filaments eventually will cause a breakdown of the gases in the lamp. Thereafter the lamp will pass current freely, at relatively low voltage, the current being limited by the impedance of the connected windings of the starting transformer. As an example, a so-called "hot cathode" lamp presently known as the T–12 and having a rating of 40 watts ignites at a voltage of approximately 200, and operates at approximately 110 volts.

The relatively long lapse of time between applying the line voltage to the apparatus and ignition of the lamps led to the development of the so-called "instant-start" type of lamp, in which the lamp is ignited almost the instant that the power is applied to the ballast. In such arrangements, obviously there is no need for preheating an electron-emitting filament. Instead a relatively high voltage is applied across the terminals of a lamp constructed to withstand the resulting stresses, and ignition occurs, with the usual decrease in voltage across the lamp as the current flows. Thus, a lamp known as the T–12, 96 inch 75 watt "hot cathode" fluorescent lamp will ignite at approximately 625 volts and operate at approximately 195 volts.

In practically all cases, the power line available for the operation of the lamps consists of 110 to 118 volts A. C. at 50 or 60 cycles per second. Obviously it is necessary to transform the voltage to a considerably higher value in order to ignite and operate instant-start lamps. Apparatus for instant-start fluorescent lamps is

shown and described in co-pending applications of Albert E. Feinberg, Serial No. 97,381, filed June 6, 1949, now Patent No. 2,509,188 issued May 23, 1950, and Serial No. 135,669, filed December 29, 1949, now Patent No. 2,558,293, issued June 26, 1951, said first application being entitled "Transformer" and said second application being entitled "Apparatus for Starting and Operating Gaseous Discharge Devices." As pointed out in the second of said applications, one manner of igniting the instant-start type of fluorescent lamps is to apply the starting voltage across the lamps seriatim whereby after one has started, ignition voltage is available to the second lamp.

The seriatim or series starting method is desirable because of the high voltages which must otherwise be used. Obviously if a voltage of 600 to 700 volts is required to start one lamp, two lamps connected in series will require twice that voltage. If the lamps are operated in parallel, equal voltages of the same value, namely, capable of causing ignition must simultaneously be developed across each lamp. The size and cost of the required transformers are considerable. It is not desirable to use high voltages for series connected simultaneously starting lamps in apparatus which is operated from a low voltage line, and which is associated with ordinary lighting fixtures. The problem of providing the necessary voltages is therefore increased many fold when it is desired to operate three or four lamps at one time, in one fixture.

The principal object of this invention is to provide novel apparatus for igniting and thereafter operating three or four gaseous discharge devices from a single transformer.

Heretofore, in th eevent that more than a pair of instant-start lamps were intended to be used, it was required that the starting apparatus for the pair be duplicated resulting in large, heavy, and expensive ballasts. By the use of certain ingenious arrangements we have been able to provide apparatus using a single transformer for the efficient ignition and operation of four instant-start lamps which is economical and simple in construtcion, which is efficient in operation, relatively small in size, and light in weight.

It has been desirable in operating pairs of fluorescent lamps from commercial 110 volt lines to utilize the so-called lead-lag circuits in which one lamp is operated with a leading power factor and the other with a lagging power factor so as not to upset the line power factor too greatly and also to eliminate to a great extent the stroboscopic effect of such lamps. The conventional manner of doing this has been to insert a condenser in the reactive circuit of one of the lamps. Our invention has also been devised with this in mind, namely to provide leading and lagging circuits to result as closely as possible in unity power factor in the line.

The safety requirements set up by certain standards committees and organizations for apparatus of the type contemplated herein are somewhat rigid, but by reason of our invention readily can be complied with in the construction of a ballast in accordance with the teaching thereof. One important requirement of practically all codes is that at no point in the entire circuit or apparatus shall there by any voltage which requires excessive insulation or unusually heavy lead wire. Obviously this requirement is to eliminate hazards to life, and possible flashovers. A second requirement is that the circuit of the apparatus must be arranged so that the removal of any lamp must completely deenergize the ballast. The sockets for instant-start lamps conventionally used at present consist essentially of two-contact devices normally open but bridged by the single terminal of the lamp. The sockets are connected in series with the line so that the removal of the lamp will open the line. This requirement means that each lamp of a group operated by a single ballast must have at least one end thereof arranged to be connected to the line.

Accordingly, it is another object of our invention to provide apparatus of the character described for operating a plurality of gaseous discharge devices in which each of the devices adapted to be operated thereby will be enabled to have one terminal contacting the line directly.

In the event that the second requirement above referred to need not be complied with, certain modifications of our invention enable the construction of a more economical ballast, as will be explained hereinafter, and certain other objects of the invention are concerned with the provision of this type of apparatus.

Considering the last mentioned type of apparatus, namely, in which certain of the fluorescent lamps connected therewith may not have at least one terminal thereof connected directly to the line, it should be obvious that the same could be used in fulfilment of the said second requirement in connection with sockets which have line switches associated therewith and arranged to operate when the lamp is inserted, but without establishing contact between the lamp terminal and the line. Such sockets are not of the present conventional type, but the feasibility thereof should be obvious to those skilled in the art when hereinafter pointed out.

Another important object of the invention is to provide apparatus for igniting and thereafter enabling the operation of four instant-start fluorescent lamps or similar gaseous discharge devices having negative resistance characteristics, which apparatus utilizes two series starting circuits arranged in parallel with each series starting circuit having two lamps therein.

Still a further object of the invention is to provide, in apparatus of the character described which includes leading and lagging series starting circuits, auxiliary starting means for each circuit having a reactive character opposite to that of the circuit.

Many other objects should occur to those skilled in the art to which this invention pertains, and many advantages will become apparent as the description proceeds. In connection with the description we have, for explanatory purposes, illustrated preferred embodiments of our invention, showing the manner of construction, assembly and use thereof, but it should be apparent that many variations are possible in the electrical circuits, value of the circuit elements, and size and shape of the parts of the illustrated device without departing from the spirit of the invention as set forth in the appended claims.

In the figures:

Fig. 1 is a top 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 connections of the transformer of Fig. 1 in a circuit embodying our invention, same being connected with four fluorescent lamps for igniting and operating the same.

Fig. 3 is a schematic circuit diagram identical to that of Fig. 2 but rearranged for clarity in explanation.

Fig. 4 is a view similar to that of Fig. 1, but on a reduced scale, showing a modified form thereof.

Figs. 5 and 6 are vector diagrams of certain phenomena explained in the specification.

Fig. 7 is a schematic circuit diagram of a modified form of the invention.

Fig. 8 is a top plan view of a transformer constructed in accordance with the principles described in connection with Fig. 7.

Fig. 9 is a sectional view through a socket suitable for use in connection with the apparatus of Fig. 7.

Referring now to Figs. 1 to 3 inclusive we have shown a preferred embodiment of our invention incorporated into apparatus for starting and operating four fluorescent lamps. The reference character **20** designates generally the transformer upon which the inductive windings are arranged as will hereinafter be explained. The transformer **20** includes a stack of laminations forming an elongate rectangular shell **21**, having a plurality of windows (not visible in the drawings) formed therein. The windings are disposed in said windows, and we prefer arranging 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 production, the windings may be pre-assembled to the winding leg **22** which is then pressed home into the shell **21**.

Considering the windings, in the embodiment shown in Figs. 1 to 3 inclusive there are five windings, all commonly mounted upon the leg **22**. Starting with the left end of Fig. 1 these windings are as follows: First there is provided the winding **25** which is separated from the next winding by the magnetic shunt **26** and which shall be termed the auxiliary starting secondary winding; this is followed by the first primary winding **27**, and the leading secondary winding **28**; thereafter we dispose the lagging seondary winding **29** separated from the leading secondary winding by another magnetic shunt **30**; and finally the second primary winding **31** is mounted on the extreme right hand end of the winding leg **22** separated from the lagging secondary winding by a third magnetic shunt **32** somewhat larger than either of the other two.

The magnetic shunts **26**, **30**, and **32** are provided with non-magnetic gaps **33**, **34** and **35** which provide the high magnetic reluctance to cause the desired de-coupling between the adjoining windings whereby high leakage flux results and high reactances are achieved in the desired windings.

In Fig. 2 we have shown the circuit diagram of the apparatus with the windings of the transformer **20** oriented in the exact sequence described in connection with Fig. 1, and the core **21—22** is conventionally designated by the parallel lines extending throughout the length of all of the windings. Likewise, the conventional designation for the magnetic shunts **26**, **30** and **32** is used between the appropriate windings. While all connections properly have been made in Fig. 2, the parts have been re-oriented in Fig. 3 in order better to explain the operation thereof.

Four fluorescent lamps, designated **41**, **42**, **43** and **44** are connected in electrical association with the windings of the transformer **20** in a manner to be explained. As best shown in Fig. 2, the left hand terminals of the lamps **41** and **42** connect directly to one side **45** of a power line, say 60 cycle A. C. 110–118 volts, while the left hand terminals of the lamps **43** and **44** connect directly to the second side **46** of the same line. Since one terminal of each lamp connects directly with the line, it is a simple manner to arrange the connections so that the removal of any lamp will open the line on either side. The socket connections are shown schematically at **40**, **47**, **48** and **49** in Fig. 2 and the operation thereof is believed obvious. The exact construction of the sockets forms no part of this invention, although it should be appreciated that by reason of the invention, such sockets are capable of being used with all four lamps to open the line in the event of removal of any one lamp. For this explanation and example, the lamps will be considered as T–12 instant-start fluorescent lamps, having a rating of 75 watts each, 96 inches in length, with an ignition voltage of 625, an operating voltage of 195 at which a current of 425 milliamperes is drawn.

Referring now to Fig. 3, the two line terminals **45** and **46** connect to junctures **51** and **52** respectively. The first primary winding **27**, the left end of the lamp **41**, and the left end of the lamp **42** are all connected to the juncture **51**. The second primary winding **31** is connected in series with the first primary winding **27** by the lead **53**. The right hand end of the second primary winding **31** (as viewed in Fig. 3) is connected with the juncture **52** so that the entire primary is across the line terminals **45** and **46** and obtains therefrom the total line voltage. It is desired to point out at this time, however, that the primary is split, part being disposed on one end of the transformer **20** and part on the opposite end for purposes to be explained hereinafter. This is best understood by the arrangement of Fig. 2. Although we have termed the winding **27** the first primary winding and the winding **31** the second primary winding, the designation is purely arbitrary since the relative size is not intended to be limited thereby. The primary may be split substantially in half, or may be divided in portions having other than an equal division of the turns, depending upon other design factors capable of wide variation.

The auxiliary starting secondary winding **25** has its left hand end (as viewed in Fig. 3) connected to junction **52**, while its right hand end is connected to the left hand end of the leading secondary winding **28** and the condenser **55**, the juncture being designated **56**. Said condenser **55** is connected to the right hand end of the lamp **41**. The right hand end of the leading secondary winding **28** (as viewed in Fig. 3) connects to lamp **44**. The lagging secondary winding **29** is connected on its left hand end (as viewed in Fig. 3) to the lamp **42**, and on its right hand end to the lamp **43** whose left hand end together with that of lamp **44** is connected to juncture **52**. Lamp **43** is shunted by a resistance-capacitance branch consisting of a register **57** and a capacitor **58**.

The normal direction of instantaneous voltage in each of the windings is indicated by a solid line arrow shown parallel to the respective winding and designated by the same characters used to designate the windings, except that the characters are primed. In connection with the explanation of the operation of the device, note that the arrows **27′**, **31′** and **25′** are all directed to the right indicating that the voltages thereof are arranged to reinforce one another, while the arrows **28′** and **29′** are directed to the left indicating that the voltage from these windings reinforce one another, but in opposition to the voltage represented by the other three windings. Under certain conditions, the voltage in the auxiliary starting secondary windings acquires a quadrature component of such phase that the net resultant causes a reversal of voltage, giving rise to the effect indicated by the broken line arrow **25″** pointing in direction opposite to arrow **25′**.

The circuit described consists essentially of two pairs of series connected and operated lamps arranged in parallel. The series lamps are **41** and **44** connected in parallel with the series lamps **42** and **43**. Closing the circuit to the terminals **45** and **46** will result in ignition of all the lamps almost immediately thereafter, followed by proper regulation of the lighted lamps. The manner of operation of the apparatus in accomplishing this is believed to be as explained hereinafter.

With application of 110 volts across the terminals **45** and **46**, there is a voltage applied to the primary windings **27** and **31** reinforced by the voltage in the auxiliary starting secondary winding **25** which is connected thereto in autotransformer relationship, so that the total voltage which will be induced between terminals **51** and **56** will appear across the lamp **41**. Through proper design of the windings, this voltage will be of the order of 800 volts, with practically no drop occurring across the capacitor **55** since no current flows prior to ignition. The voltage is more than sufficient to ignite lamp **41** and with ignition, current will begin to flow through the lamp **41**, causing the voltage to drop to approximately 250 volts, which is slightly higher than operating voltage for the T–12 75 watt instant-start fluorescent lamps. The flow of current causes a quadrature component of voltage to appear in the winding **25** such that the resultant voltage is actually opposite in direction to that giving rise to the voltage **25′**. Hence, with flow of current, the resulting voltage becomes **25″**.

Referring now to Figs. 1 and 2 it will become apparent that the winding **25** is physically separated from the primary winding **27** by a magnetic shunt **26** whose effect is to constitute the winding **25** a high leakage reactance very loosely coupled with the primary winding **27**. The looseness of the coupling is even more enhanced by the fact that the second primary winding **31** is remote from the auxiliary winding **25**. This arrangement aids in the voltage reversal which is so desirable, in a manner to be pointed out, and the splitting of the primary winding has an additional purpose, which will also be set forth. With the voltage of winding 25 reversed, same is additive to the leading secondary winding 28. The winding 25 has a great many turns compared with the turns of the windings 27 and 31 constituting the primary and hence a large voltage is induced therein, so that the component in phase with that of leading secondary winding 28 is sufficient to cause ignition of the lamp 44.

The circuit now becomes a series circuit, since the leakage reactance of the winding 25 is very high compared with the reactance of the branch including the leading secondary winding 28 and condenser 55. The effect is that the current flows from juncture 51 through lamp 41, condenser 55, juncture 56, winding 28, and lamp 44 to the juncture 52. The condenser 55 is chosen so that the resulting power factor is leading to balance the lagging power factor of the second branch whose operation will now be explained. Prior to going into such explanation, it is desired to point out that the operation of the leading branch of the circuit is substantially identical to that described in connection with the above referred to application of Feinberg Serial No. 135,669.

Considering now the inductive, or lagging branch of the apparatus, note that the lagging secondary winding 29 is separated from the second primary winding 31 by a considerable magnetic shunt to aid in the decoupling effect therebetween and likewise is separated from the leading secondary winding 28 for the same reason. This is to prevent interference between the respective fluxes. However, if the circuit which includes the primary windings 27 and 31 and the lagging secondary winding 29 is traced, it will be noted that the induced voltages are all in the same direction. Because of this, upon the closing of the circuit to the line terminals 45 and 46, the voltages appearing in the primary windings 27 and 31 and in the lagging secondary winding 29 are additive. The total voltage which is of the order of 800 volts appears across lamp 42 and is sufficient to ignite the same.

Before ignition of lamp 42, there is no current flowing in the circuit which includes the lamp 43. Consequently the condenser 58 has very low impedance, and practically no voltage drop appears across lamp 43. After ignition, the voltage across the lamp 42 drops to substantially operating value and current flows in the leads 60 and 61, but by-passing the lamp 43 through the branch containing the resistor 57 and the capacitor 58. As for the entire circuit from juncture 52 to the juncture 51, through the lagging secondary winding 29, the impedance is lowered because of the counter-balancing effect of the high leakage reactance of the lagging secondary winding 29 with the leading reactance of the condenser 58. There is thus a relatively high flow of current therein, and the voltage resulting across the capacitor 58 is well over 600 volts and quite sufficient to ignite the lamp 43. The presence of the resistor adds slightly to this voltage, but is not considered essential. Actually the resistor 57 has a low ohmage, and its purpose is to dampen oscillating currents in the shunting branch of the lamp 43 in the well-known manner.

Once current has commenced flowing through the lamp 43, its voltage drops approximately to the operating value and due to the high impedance of the condenser 58 with the relatively low voltage drop across it, the circuit including the two lamps 42 and 43 becomes a series cir-

cuit in which current and hence operating voltages of the lamps are limited by the inductive reactance of the lagging secondary winding 29. The net power factor of this series circuit is thus lagging, and when considered in connection with the leading power factor of the circuit including the lamps 41 and 44, the net effect upon the line is that the apparatus draws current at a power factor approaching unity.

It should be appreciated that the two circuits, i. e., the leading and the lagging are energized simultaneously, so that first the lamps 41 and 42 are ignited, and thereafter the lamps 43 and 44 are ignited.

The physical position of the auxiliary starting secondary winding 25 may be varied from that shown. It may for example, be positioned at the opposite end of the transformer 20, that is, it may be arranged as shown in Fig. 4 where the first primary winding 27 is at the extreme left end of the transformer 20 and the windings 28, 29, and 31 follow in that order separated as shown by the magnetic shunts 30 and 32. The secondary winding 25 is now at the extreme right end and the magnetic shunt 26′ separates it from the second primary winding 31, serving the same purpose as the magnetic shunt 26 of Fig. 1. In all other respects the apparatus is the same as described above, and operates in the identical manner.

Analyzing the overall operation of our apparatus it will become apparent that the lead circuit is ignited by the aid of an inductive reactance, namely the auxiliary starting secondary winding 25, while the lag circuit is ignited by the aid of a capacitive reactance, namely the capacitor 58. We have found that the use of lagging impedance to start a leading circuit and a leading impedance to start a lagging circuit enables the eventual desired result for quick starting and long life of the fluorescent lamps to be achieved in a highly economical manner. Such long life is made possible only when all of the lamps carry substantially the same rated current during operation. The reason such an arrangement will provide the desired results is that after ignition of the first lamp of any two-lamp series circuit it becomes necessary to develop a high voltage across the first lamp without causing too great a circulating current through the auxiliary starting impedance. Our arrangement provides the necessary igniting voltage for the second lamp within the requirements set forth. Thus, an additional capacitor in the lead 61 between the lamp 43 and the coil 29 of a size sufficient to make the circuit leading would prevent the development of sufficient voltage across the lamp 43 to ignite the lamp while enabling sufficient current to pass to originally ignite lamp 42. In such case the voltage supplied by the primary windings and the lagging coil would have to be much higher to assure ignition of lamp 43. As a result coil 29 would have to be larger and the currents between lamps 42 and 43 would tend to be unbalanced.

The same analysis can be made to show that it is inadvisable to use an inductive impedance as the auxiliary starting element for a series lagging circuit.

As well-known in the art, it is highly advantageous to achieve as closely as possible, perfectly sinusoidal wave shape in this type of apparatus. The maximum of lighting efficiency and minimum losses are among the most important of these advantages. In our apparatus, novel means for accomplishing this have been devised. The principal circuit in which this must be done is the leading circuit. The common method of doing this has been to utilize a separate choke in the leading circuit. As noted, this is eliminated by our invention. The method shown and described in Berger Patent No. 2,461,957 is not feasible in our apparatus because of the high magnetizing current developed in our primary.

The problem of non-sinusoidal wave form is important in the case of apparatus providing leading lamp currents because of the ease with which saturation of iron cores is reached under those circumstances. Thus, it must be expected that saturation will occur in transformers used in the type of apparatus described unless something is done to prevent it. In order best to consider the manner in which we have prevented the occurrence of saturation of the transformer core, attention is invited to the vector diagram of Fig. 5. This shows the common condition giving rise to saturation. In Fig. 6 another vector diagram shows the manner in which our construction alleviates this disadvantageous phenomenon.

Considering first Fig. 5, there is shown a vector diagram of the voltages (and hence the fluxes) occurring in an iron core transformer which is serving a leading fluorescent lamp circuit having a capacitor therein. The transformer was designed for a secondary open circuit voltage of AD with its corresponding flux density. Presume a transformer having a primary and a secondary with a lamp connected in series with the secondary and having a condenser in the circuit to make the circuit draw leading current. Let AB of Fig. 5 represent the voltage across the fluorescent lamp during steady state operation (disregarding the inductance of the lamp). Let BF represent the voltage drop across the condenser and FC the drop across the secondary, tending to balance out the capacitive drop, making a net voltage of BC as the effective net capacitive drop. Now, if AC is the total open circuit voltage (considering the transformer as an auto-transformer), it must consist of the primary voltage DC and the secondary voltage AD. Now the voltages AB and DC must vectorially add to give AC, and since DC is fixed as the open primary voltage, we may consider that all of the reactive impedance occurs in the secondary, and therefore, we may transfer the vector FC to the point D to determine the actual secondary voltage. The transferred reactive voltage is represented by the vector ED. The resultant voltage is then AE, the voltage of the secondary which obviously is substantially larger than the secondary open circuit voltage for which the transformer was designed, namely AD. The voltage AE therefore represents a flux density greatly in excess of optimum causing the iron core to be saturated with resulting distortion of the current feeding the lamp.

The above explanation is to demonstrate why it is most likely that saturation will occur in the leading circuits of apparatus described. We have provided means for preventing such saturation. In our apparatus it will be noted that we have positioned a portion of the primary physically remote from the remainder of the primary winding. Thus, referring to Figs. 1 and 2, note that the primary consists of the first primary winding 27 and the second primary winding 31 which is separated therefrom by the windings 28 and 29, and the magnetic shunts 30 and 32. Actually, in the apparatus described, the shunts were ⅜″ and ¾″ respectively. A considerable leakage of flux will occur across the lagging secondary winding 29 and through the shunts. The leading secondary winding 28 is thus effectively separated from the second primary winding 31 as is the first primary winding 27.

When the leading circuit is in operation, with the lamps 41 and 44 ignited, the resultant voltage appearing across the leading secondary winding 28 and giving rise to the flux or voltage represented by the arrow 28′ would normally tend to saturate the core of the transformer 20. This voltage is the equivalent of the voltage AE represented in Fig. 5. However, the magnetic flux which tends to produce the voltage in the winding 28 is to a considerable extent by-passed by the leakage across the lagging secondary winding 29 and through the magnetic shunts 30 and 32 whose reluctance to the passage of flux is considerably less than that of the saturated core adjacent the leading secondary winding 28. The open circuit voltage of the winding 28 (corresponding to the vector AD in Fig. 5) will thus drop, causing a corresponding drop in the resultant voltage and a partial elimination of the saturation condition.

The remaining correction of the flux shape is provided by the proper arrangement of the lagging secondary winding 29 which, it will be noted in Fig. 3, produces a flux represented by the arrow 29′ in bucking relationship relative to the primary windings 27 and 31. In order best to explain this corrective action, attention is invited to the vector diagram of Fig. 6.

Consider a simple auto-transformer circuit having a lamp in series with the secondary. The voltage drop through the lamp is A′B′ and the reactive voltage drop is now B′C′ which is due to the leakage reactance of the secondary. The total open circuit voltage is A′C′ made up of the primary open circuit voltage D′C′ and the secondary open circuit voltage A′D′. As in the case of Fig. 5, the voltage of the primary D′C′ being fixed, the total reactance drop must occur across the secondary and can be shown by transferring the voltage B′C′ to the point D′ to give rise to the shifted vector E′D′. The resultant voltage across the secondary is now the sum of the voltages A′D′ and E′D′ which vectorially gives the voltage A′E′. As will be noted, this may be considerably less than the voltage A′D′ and of substantial phase difference. The flux caused by the voltage A′E′ will be proportional thereto and of the same phase.

Now note that the lagging secondary winding 29 will produce the type of flux mentioned in connection with the vector diagram of Fig. 6, and proportional to the voltage described as A′E′. This winding is positioned between the leading secondary winding 28 and the second primary winding 31, being physically separated from them by the shunts 30 and 32 respectively. Since the flux through the winding 29 is less than normal and shifted in phase, the flux between the second primary 31 and the leading secondary winding 28 tends to be reduced, and the resultant voltage across the leading secondary winding will be reduced in addition to the factor caused by splitting the primary. The resulting wave shape of current approaches sinusoidal quite satisfactorily.

The same effect, namely the counteraction of the saturation flux caused in the leading secondary winding 28 can be achieved in the transformer 20, by winding a portion of the leading secondary winding 28 directly upon the lagging secondary winding in reverse relationship in order to provide the benefits of the bucking flux and reducing the total flux density and hence the resultant voltage in the leading secondary. Such an arrangement is shown and described in Feinberg co-pending application Serial No. 97,381 hereinabove referred to. This expedient may be used to advantage under circumstances where the position of the lagging secondary winding 29 is insufficient to provide counter-flux, or other design considerations prevent the use of the construction illustrated in Fig. 1.

The split primary feature of our invention is described and claimed in co-pending application Serial No. 154,094, filed April 5, 1950, entitled "Apparatus for Operating Gaseous Discharge Devices."

With respect to maintenance of fluorescent lighting fixtures, one feature of the apparatus described above is advantageous. In the event that lamp 41 should become deactivated, both lamps 41 and 44 will become extinguished. In the event lamp 44 becomes de-activated, then lamp 41 will glow because there will be a small amount of current passed by the winding 25. Thus, it is a simple matter to determine which lamp needs replacing. If both lamps 41 and 44 are extinguished, the faulty lamp is probably 41, or possibly both lamps, while if lamp 44 is extinguished and lamp 41 glows, the fault lies in lamp 44.

Similarly, with respect to the lagging circuit, in the event lamp 42 is faulty both lamps will extinguish, while if lamp 43 is de-activated lamp 42 will still glow. Thus one knows which lamp of this circuit must be replaced.

In the event that the fluorescent lamps need not be connected directly to the power line modifications in our apparatus will decrease the cost thereof. In the event it is still desired that the removal of the lamp open the power circuit, special sockets may be used which operate as will be described hereinafter. Such apparatus is less expensive because of the advantage that certain parts of the windings may be combined.

Thus, in Fig. 7 we have shown apparatus for igniting and subsequently operating four fluorescent lamps. The arrangement of the windings is shown in Fig. 8. The transformer 79 is constructed substantially the same as the transformer 20, although it may be considerably smaller. The windows carry the windings 80, 81, 82, 83, 84 and 85 as will be described. Three magnetic shunts 86, 87, and 88 with their associated non-magnetic gaps 89, 90, and 91 separate the windings in a manner to be described. The primary winding 80 is connected across the line terminals 92 and 93 and is in autotransformer relationship with the secondary winding 81 with which it is closely coupled. The primary and secondary windings 80 and 81 are wound one on top of another in the same window. The winding 82 is the auxiliary starting winding having a function similar to the winding 25 hereinabove referred to, but now with its voltage in reverse relationship to windings 80, 81 and 83 and said winding 82 is in series with the winding 81, but is positioned in the first window of the transformer 79 as will be noted in Fig. 8. The leading secondary winding 83 is in series with the winding 82, and is physically positioned in the third window, separated from the primary and secondary windings 80 and 81 by the narrow shunt 87. The lagging secondary winding 84 is positioned at the extreme right end of the transformer 80 and has the bucking leading secondary winding 85 wound thereon and closely coupled therewith.

The leading series circuit consists of the lamp 94 connected in series with the leading secondary windings 83 and 85, and the lamp 95 connected in series with a condenser 96 across the auxiliary starting secondary winding 82. The lagging series circuit consists of the lamp 97 connected in series with the lagging secondary winding 84, and the lamp 98 shunted by the condenser 99 and resistor 100 in series with the winding 84. The left hand ends of the lamps 94 and 97 as viewed in Fig. 7 are connected to the terminal 92 of the line, while the left hand ends of both lamps 95 and 98 are connected to the juncture 101.

The leading and lagging secondary windings 83 and 84 can be made very much smaller than in the case of the apparatus described in Figs. 1, 2, and 3. For the same open circuit voltage, one turn can be removed from each of these windings and placed upon the secondary winding 81, in a manner described in detail in co-pending application of Feinberg Serial No. 97,381. Likewise, each turn removed from the leading secondary winding 83 enables a turn to be removed from the bucking leading secondary winding 85. The function of the winding 85 is to correct wave shape in the manner explained in said Feinberg application Serial No. 97,381. Note that the two lamps 95 and 98 do not terminate at places where their removal can open the line.

Referring now to Fig. 9, there is illustrated a socket which can be used in connection with the embodiments illustrated in Figs. 7 and 8. The lamp 120 has a single male contact terminal 121 adapted to be associated with socket 122. Socket 122 has a central movable member 123 loosely mounted in a transverse wall 124 and adapted to slide right and left. The right end has a head 125 and slides in a cavity 126 adapted to receive the terminal 121. The cavity 126 has opposed contacts 127 and 128 connected with leads 129 and 130 respectively. Obviously inserting the terminal 121 into cavity 126 will connect leads 129 and 130 while the lamp 120 will be likewise connected to the juncture. Such a juncture could be that represented at 131 in Fig. 7, for example. The member 123 is biased to the right by spring 132 which is disposed about the body of member 123. The left end of the member 123 is provided with a conical metal contact tip 133 which is slidable in cavity 134. Juxtaposed contacts 135 and 136 are connected with the respective leads 137 and 138. When the member 123 is moved to the left it will cause electrical contact to be made between leads 137 and 138 thereby closing the circuit of such leads. This point could be at 139 in Fig. 7, for example.

It will be seen that by the use, with the fluorescent lamp fixtures, of sockets 122 such as shown in Fig. 9, a cheaper construction of ballast is possible. Note that the circuits represented by leads 137—138 and 129—130 are in no way electrically connected since the body of member 123 is formed of any suitable insulating material.

It will be apparent that a general feature that the embodiments of our invention have in common is their use of two apparently separate series circuits, each having two lamps therein arranged for series starting and series operation, but all operating off a single transformer. The two circuits of each embodiment are opposite in their overall reactive character, that is to say, one is inductive and the other capacitive so that not only is the stroboscopic effect of the lamps materially reduced, but as well, the line power factor may approach unity. Since the lamps of each circuit light one after the other, one lamp of each circuit may be eliminated if desired. The necessary circuit constant adjustments for proper operation can readily be made. The resulting circuit will thus operate two lamps or three. Thus, in the circuit shown in Figs. 1 to 3 inclusive, the lamp 41 may be eliminated, so that the apparatus will ignite and operate three lamps. The condenser 55 in this case would be connected with the juncture 51. Illustration of this modification is not made since it is simple and readily understood.

In the same apparatus, as an alternative, or in addition, the lamp 43 and its shunt could be eliminated leaving the remainder of the circuit, in case it is desired to have only one lamp on the lagging side. This would provide either a three-lamp ballast or a two-lamp ballast. As a two-lamp ballast, the construction would be expensive, but same is described herein to illustrate that the two circuits are effectively independent of one another. The modifications to the lagging circuit are believed obvious enough not to require illustration.

We have constructed and successfully operated apparatus embodying our invention for igniting and operating groups of fluorescent lamps of the instant-start type from 118 volt A. C. power lines. Such lamps were of the type known as T–12 75 watt, 96 inch instant-start lamps, having an ignition voltage of 625, operating voltage of 195 volts and an operating current of 430 milliamperes. The constructional details (referring to Figs. 1 to 3) of the apparatus were as follows:

Overall length of the core	10⅛ inches.
Width of core 21	3 inches.
Width of winding leg 22	1 inch.
Height of stack	1¼ inches.
Width of windows and windings:	
Secondary winding 25	¾ inch.
Primary winding 27	1⅜ inches.
Secondary winding 28	2 inches.
Secondary winding 29	2 inches.
Primary winding 31	1⅜ inches.
Widths of shunts:	
26	½ inch.
30	⅜ 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.

The modifications shown in Fig. 4 was also constructed using the same general physical dimensions and characteristics. The variations from the embodiments of Figs. 1 to 3 were minor.

The invention has been described in connection with certain theories advanced which may or may not supply the exact reasons for the operation thereof. It is intended not to be limited by such theories, or by an absence of language describing other theories, but it is intended that the structures producing the desired results and engendering the described advantages, be covered in their broadest scopes. Examples of all possible variations of the structure have not been specifically detailed as to dimensions and characteristics since it is believed that from the specification herein, and other specifications herein referred to, one skilled in the ballast art could easily and readily construct same.

We claim:

1. A system comprising a transformer of elongate iron core formation and unitary construction providing a single magnetic circuit for igniting and operating gaseous discharge devices from an A. C. power line of voltage less than the igniting voltage of any device, including winding means providing a source of voltage mounted on said transformer core for serving secondary windings of said transformer, an A. C. power line leads connecting said source winding means to the said line, said source winding means having end terminals; two sub-circuits, one sub-circuit being a leading current circuit and having a first secondary winding with one side connected to one of said terminals, a second secondary winding connected to the second side of the first secondary winding, a first gaseous discharge device electrically connected from the second side of the second secondary winding to one of the terminals of the source winding means, a condenser, a second gaseous discharge device connected in series with the condenser and together therewith electrically connected from the second side of the first secondary winding to the terminal of the source winding means opposite that to which the first gaseous discharge device is connected, the first secondary winding being disposed on one end of said core and having magnetic shunt means between itself and the remainder of the transformer whereby same is loosely coupled to the source winding means to develop a high leakage reactance in said first secondary winding, and the second secondary winding being relatively closely coupled to the source winding means, the first and second secondary windings being connected in open circuit voltage opposition one relative the other, and a second sub-circuit being a lagging current circuit and having a third secondary winding connected in auto-transformer relation with the source winding means and

having a third gaseous discharge device in series therewith and connected across said source winding means, the third secondary winding being disposed on the core and there being magnetic shunt means physically spacing said third secondary winding from the other windings and the source winding means.

2. A system as described in claim 1 in which the second gaseous discharge device of said first sub-circuit is connected together with said series condenser only across said first secondary winding, and in which the first gaseous discharge device is connected across the combined windings of the first and second secondaries and the source winding means.

3. A system as described in claim 1 in which the second gaseous discharge device of the first sub-circuit is connected together with said series condenser across the combined first secondary winding and source winding means, while the first gaseous discharge device is connected across the first and second secondaries combined.

4. A system as described in claim 1 in which the source winding means comprises two series arranged windings with the said leads connected across one of the windings to constitute same a primary winding and the other a source secondary winding in auto-transformer relation, the source secondary winding being closely coupled to the primary winding.

5. A system as described in claim 1 in which there is a fourth secondary winding connected in series with and voltage additive relation to said second secondary winding but physically positioned on said core closely coupled with the said third secondary winding and in voltage opposition thereto, the said fourth secondary winding being electrically connected in said circuit as though it were a part of said second secondary winding.

6. A system as described in claim 4 in which there is a fourth secondary winding connected in series with and voltage additive relation to said second secondary winding but physically positioned on said core closely coupled with the said third secondary winding and in voltage opposition thereto, the said fourth secondary winding being electrically connected in said circuit as though it were a part of said second secondary winding.

7. A system as described in claim 1 in which said source winding means has said leads connected to said terminals, said second gaseous discharge device having one end thereof electrically connected to said opposite terminal, and said third gaseous discharge device has one end thereof electrically connected to a terminal, and in which said leads are provided with pairs of spaced apart contacts, there being as many pairs as discharge devices, and each device has a bridging conductor at the end thereof which is electrically connected to a terminal as aforesaid, said conductors engaging and bridging the contacts of the respective pairs to complete the connection between the power line and source winding means through said leads, only when all of said devices are connected in their respective sub-circuits.

8. A system as described in claim 1 in which the second sub-circuit includes a fourth gaseous discharge device also in series with said third secondary winding and having means shunting said fourth gaseous discharge device during starting of the third gaseous discharge device.

9. A system as described in claim 7 in which the second sub-circuit includes a fourth gaseous discharge device also in series with said third secondary winding and having a shunting impedance thereacross, and with an end of said fourth gaseous discharge device also electrically connected with a terminal, provided with a bridging conductor and engaged and bridged between a pair of spaced apart contacts of said leads.

10. A system as described in claim 1 and including a socket for one of said gaseous discharge devices, said device having a projecting conductor end and said socket having two pairs of spaced apart contacts, the first pair being in one of said leads, and the second pair being in a part of one of said sub-circuits not connected to a lead, the pairs being insulated from one another, a movable insulating member having a bridging contact for the first pair but said member being biased to non-bridging position, the movable member having an end disposed between the contacts of the second pair, said end adapted to be engaged by said conductor while said conductor is moved into engagement with said second pair whereby to move same against said bias.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,689,485	Hendry	Oct. 30, 1928
1,950,396	Boucher	Mar. 13, 1934
2,056,661	Foulke	Oct. 6, 1936
2,295,757	Russell	Sept. 15, 1942
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
2,427,225	Mueller	Sept. 9, 1947
2,429,162	Keiser	Oct. 14, 1947
2,429,415	Lemmers	Oct. 21, 1947
2,464,971	Flood	Mar. 22, 1949
2,502,084	Foerste	Mar. 28, 1950
2,504,549	Lemmers et al.	Apr. 18, 1950
2,510,209	Bridges	June 6, 1950
2,515,109	Berger	July 11, 1950
2,545,164	Naster	Mar. 13, 1951
2,552,111	Peterson	May 8, 1951