July 5, 1955 A. E. FEINBERG 2,712,618

ELECTROMAGNETIC APPARATUS

Filed Aug. 30, 1950 2 Sheets-Sheet 1

Fig. 1.

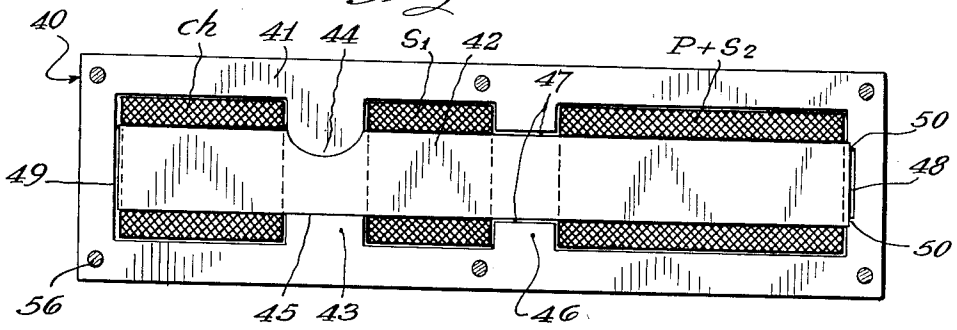


Fig. 1a.

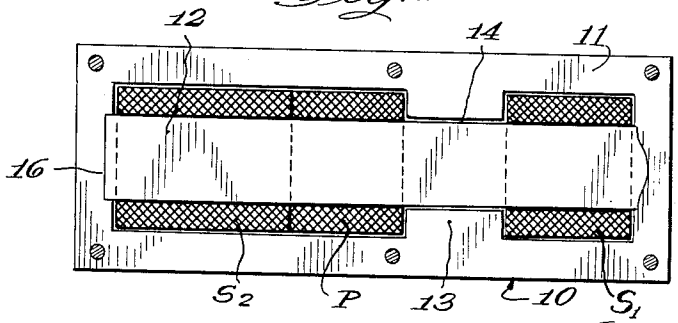


Fig. 3.

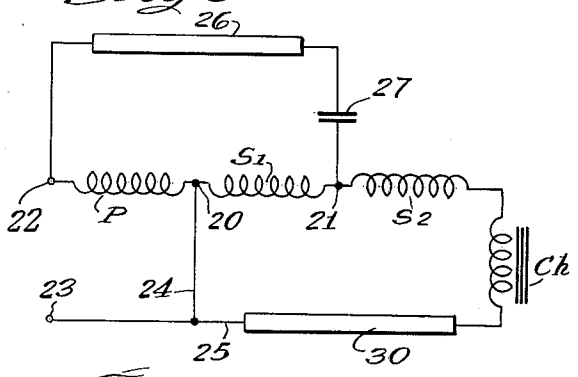


Fig. 2.

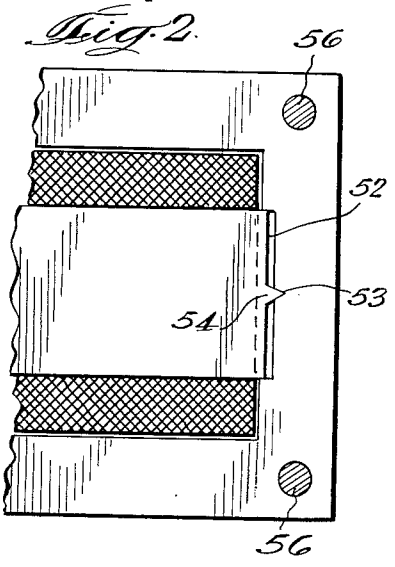
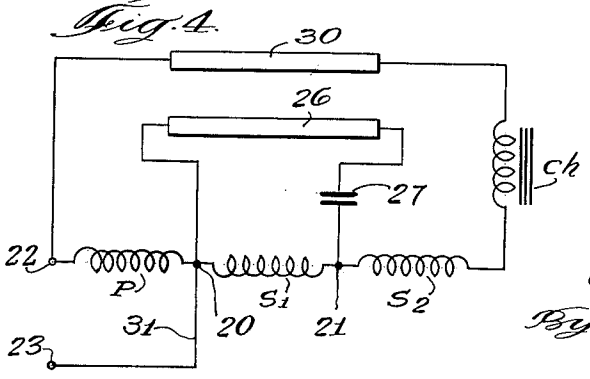


Fig. 4.



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ELECTROMAGNETIC APPARATUS

Filed Aug. 30, 1950 2 Sheets-Sheet 2

Fig. 5.

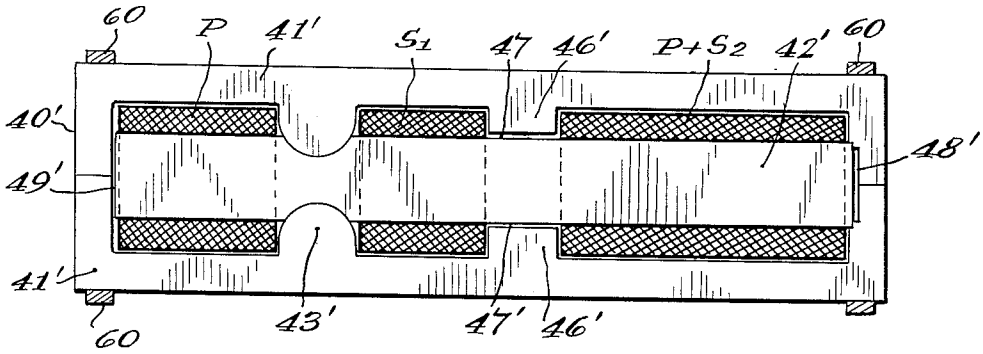


Fig. 6.

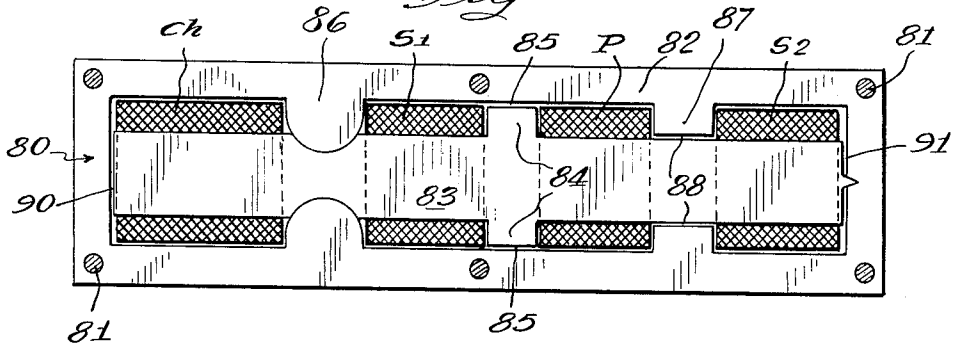
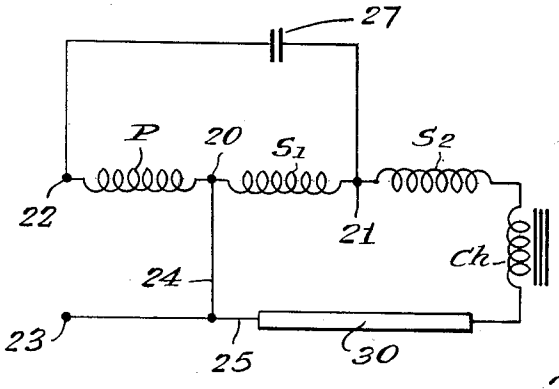


Fig. 3a



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ELECTROMAGNETIC APPARATUS

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Application August 30, 1950, Serial No. 182,212

12 Claims. (Cl. 315—138)

This invention relates generally to electromagnetic apparatus and more particularly is directed to apparatus for igniting and subsequently operating gaseous discharge devices.

The invention resides in the construction of apparatus of the nature shown, described and claimed in my co-pending application Serial No. 135,669, filed December 29, 1949, and entitled "Apparatus for Starting and Operating Gaseous Discharge Devices," now Patent No. 2,558,293, issued June 26, 1951.

One of the objects of the invention is to provide apparatus of the character described which constitutes a modification of the apparatus of my above referred to co-pending application.

An important object of the invention is to provide apparatus for initiating the discharge of a pair of gaseous discharge devices in which, following the initiation of such discharge and during the flow of current through said devices, the apparatus is constituted in effect a series circuit for said lamps.

The circuit of the above referred to invention utilizes a three-winding transformer having means including a condenser for connecting gaseous discharge devices such as fluorescent lamps thereto. The windings comprise a primary, a first secondary, and a second secondary, and the first secondary is constructed to provide a high leakage reactance during operation of the device so as to impede the flow of current therethrough. The windings are connected one to the other with the high leakage reactance first secondary between the other two, the said secondaries being in reverse voltage relationship one relative to the other. The gaseous discharge devices are connected across the windings in such a manner that when the voltage is applied from the A. C. line which is across the primary, there is a voltage generated in the first secondary, which, either alone or in combination with the primary voltage (depending upon the manner in which the gaseous discharge devices are connected) is sufficient to ignite the first gaseous discharge device. Thereafter, due to the high leakage reactance of the said first secondary, a quadrature component of voltage is developed in the said first secondary which is now additive to the voltage developed in the second secondary, and which combines therewith to provide ignition voltage for the second gaseous discharge device. Thereafter, current flowing through the devices substantially will bypass the first secondary.

This invention modifies the circuit of the above described apparatus by providing a reactor in series with the second secondary, and by making certain other changes relative to the magnetic circuit of the apparatus. It is accordingly a further object of the invention to provide these changes and variations, both in the electrical circuit and in the magnetic circuit in order to achieve desired results, such as quiet operation, excellent wave form, in combination with many of the advantages inherent in the apparatus above described in general terms.

A further object of the invention resides in the provision of a core structure mounting a plurality of windings which comprise the electromagnetically associated windings of my apparatus as well as the choke winding which is electromagnetically independent of the other windings.

Certain objects reside in the provision of certain magnetic shunts and non-magnetic gaps in connection with novel winding arrangement for achieving the desired results.

Many other objects of the invention will become more apparent as a description thereof proceeds. I have illustrated in the accompanying drawing a preferred embodiment thereof, but it should be understood that variations of the parts are possible without departing from the scope thereof.

In the drawings:

Fig. 1 is a side elevational view of the core structure of my invention, the windings being illustrated in section in order to show the form of the lamination.

Fig. 1*a* is a view similar to that of Fig. 1, but illustrating a core construction of a different type than those comprising my invention.

Fig. 2 is a fragmentary view similar to that of Fig. 1 of a portion of a core structure in which the end non-magnetic gap is modified.

Figs. 3 and 4 are schematic views of electrical circuits used in connection with my invention.

Fig. 3*a* is similar to Fig. 3, but showing a slightly modified circuit.

Figs. 5 and 6 are views similar to that of Fig. 1 except illustrating modified forms of the core structure of my invention.

The core construction illustrated in Fig. 1*a* forms a transformer generally designated **10** which is connected with fluorescent lamps as illustrated by the circuits shown in Figs. 3 and 4 with the exception that the choke shown in said figures is not utilized. The transformer **10** comprises a rectangular shell **11** having a central winding leg **12** inserted therein. No end gaps are provided in the particular structure illustrated. The transformer is formed of laminations held together in any suitable manner. Mounted upon the central winding leg **12** there are provided three windings, the primary P, a first secondary winding S_1 and a second secondary winding S_2. The windings are arranged with S_2 and P side by side, and together separated from S_1 by a magnetic shunt **13** having non-magnetic gaps **14**.

In connection with the previously referred to co-pending application, and the brief explanation thereof the apparatus thereof may be embodied in this type of core construction. The primary P and second secondary S_2 are loosely coupled, and the first secondary S_1 is very loosely coupled relative to the other two windings. There is thereby established a high leakage reactance in said first secondary during operation which greatly assists in the regulation of the current of the gaseous discharge devices with which the transformer is associated.

Although the coupling between P and S has been referred to as "loose" with respect to Fig. 1*a* it should be appreciated that the principal reason for this expression is that it is compared with the coupling occasioned by winding two windings in the same window of a transformer i. e., one on top of the other. The coupling between P and S_2 is sufficiently tight to cause the majority of flux from both windings to seek the same magnetic paths. Under certain circumstances, the flux density will be high enough to result in core saturation in the vicinity of the winding S_2. The well-known results of this condition are distortion of the wave shape of the lighting current, with consequent decrease in lighting

efficiency and the accompanying increase in operation costs, etc.

To alleviate these difficulties, I have constructed improved versions of the construction in which an air gap is provided at the end 16 and a shunt is introduced between the windings P and S_2 to render their coupling less tight. The resulting wave shape of the current through the gaseous discharge devices is much less distorted because the initial flux density of the secondary S_2 is decreased. The gap and shunt force some of the flux on open circuit to find paths other than those followed by the flux from the primary P, decreasing the total density in the iron adjacent the secondary S_2. Immediately following ignition of the gaseous discharge devices, the magneto-motive force of S_2 will still be in close phase relationship with that of the primary P so that its flux density will rise approximately to that of the primary to give the necessary reactance for regulation.

The above referred to modification is also illustrated and described in the said co-pending application.

Certain arrangements require higher reactive volt-amperes than efficiently can be supplied by the circuit and core constructions thus far referred to. For example in the case of a single 40 watt instant start fluorescent lamp or lamps of small diameter such as 96 inch T–8 fluorescent lamps, a plurality of which are to be operated in series, the air gap required at the position such as indicated at 16 will be so great that a great deal of flux will emanate from the central winding leg to the can or metal container in which the transformer 10 is housed. It is almost universal in the manufacture of ballasts for use with fluorescent lamps to immerse the transformer and all other elements forming the ballast in pitch in an enclosed cannister. The flux travelling on leakage and stray paths through these cannisters produces disagreeable hum and vibrations.

In order to prevent such noise, and yet to provide the necessary reactive volt-amperes, I utilize a magnetically separate choke in the circuit of my ballast. Thus, referring to Fig. 3, I have illustrated a series-starting circuit which comprises a primary P, first secondary S_1 and a second secondary S_2, connected as shown end to end, and forming the junctures 20 and 21. The A. C. line terminals are 22 and 23 and the primary P is connected across the line by leads 24 and 25. A gaseous discharge device comprising a fluorescent lamp 26, preferably of the instant-start variety is connected from the line terminal 22 to the juncture 21 through a condenser 27. Another similar lamp 30 is connected in lead 25 from juncture 20 and lead 24 to the right hand terminal of the secondary S_2 through an independent choke *Ch*. The lamp 26 is thus connected across the primary P and first secondary S_1 and the lamp 30 is connected across the two secondaries S_1 and S_2 but in series with the choke *Ch*.

In operation, the voltage from line terminal 22 to juncture 21 is sufficient because of the additive arrangement of P and S_1 to ignite the lamp 26. Following the ignition of this lamp, there will be a component of voltage produced in S_1 which is in such phase relationship to the secondary S_2 as to be additive thereto, and the lamp 30 will be ignited. Current will then flow through the lamps and the primary P and secondary S_2 substantially bypassing the winding S_1 because of its high leakage reactance. The choke *Ch* provides reactive volt-amperes to regulate the current flow so that there will be little or no distortion and no hum due to excessive stray flux caused by large gaps at the end of the winding leg.

The circuit shown in Fig. 4 is a modified form of circuit which operates in practically the same manner as that of Fig. 3. Here the line terminals 22 and 23 are connected across the primary P through lead 31. The lamp 30 is connected across all three windings, while the lamp 26 and its series connected condenser 27 is connected across the first secondary S_1. Note in this case that the primary P is in voltage additive relationship to the second secondary S_2 and in reverse relationship to the first secondary S_1. As in the case of Fig. 3 the secondaries are in reverse voltage relationship one to the other. The lamp 26 will ignite first and provide a component of voltage in S_1 which when added to the voltages of the windings P and S_2 will be sufficient to ignite lamp 30. Thereafter the circuit is a series connected circuit through the choke *Ch*.

With the use of a separate choke such as *Ch* it is no longer necessary loosely to couple P and S_2. As a matter of fact it is preferable to couple them tightly, winding them one on top of the other so that their flux threads the same path. The gap at the end of the winding leg is retained, but it is small because of the choke *Ch*. The flux threading the iron in the vicinity of S_2 is now all produced only by P with no counter-E. M. F. set up in S_2 producing additional flux, since the effects of the primary P are immediately produced in the secondary S_2 without delay.

The above referred to construction of ballast can include a physically separate choke *Ch*, but I prefer the construction illustrated in Fig. 1. Here is shown a unitary electromagnetic device 40 which consists of a rectangular shell 41 having a central winding leg 42 all formed of stacked laminations. The windings *Ch*, S_1 and the primary P combined with second secondary S_2 are mounted on the winding leg 42 which is adapted to be pressed into the shell 41. The shell includes a magnetic short circuit 43 separating the windings *Ch* and S_1 which may have dissimilar junctures between the inwardly extending arms and the winding leg 42 as indicated at 44 and 45. 44 is arcuate and 45 is rectilinear. This of course is merely a matter of choice and aids assembly. There is a shunt 46 between S_1 and the combined winding having a gap 47 on opposite sides of the leg. A gap is provided at 48 on the right hand end of the leg 42, and another is provided on the left hand end as shown at 49. The gap 49 is the gap in the magnetic circuit of the choke *Ch* which, because of the short circuit 43 is magnetically independent of the remainder of the device 40. The gap 48 may be formed by providing a narrow recess as shown having a length less than the width of the winding leg 42 and shoulders at 50 to support the end of the winding leg.

In Fig. 2, a gap less likely to produce noise is shown. The construction of the remainder of the device 40 is identical. The gap is a recess 52 having a central groove 53 in which is supported a projection 54 on the end of the winding leg 42.

It should be appreciated that the above electromagnetic apparatus includes a complete transformer and a complete choke *Ch* and hence is referred to as an electromagnetic device only for convenience. The laminations are formed from one die in one stamping operation and assembled in any suitable manner such as for example, by rivets 56 resulting in a small, compact, economical device which is extremely quiet in operation and provides good regulation and excellent wave shape.

The identical apparatus above described as the device 40 can be formed from lamination halves clamped together. Thus in Fig. 5 I have shown a similar electromagnetic device 40′ which has identical core halves 41 provided with extensions 43′ forming the magnetic short circuit between the choke *Ch* and the first secondary S_1; the central winding leg 42′; the extensions 46′ and gaps 47′; the end gaps 48′ and 49′. The laminations may be stacked in any manner and held together by clamping means such as schematically illustrated at 50. In operation the apparatus is identical to that of Fig. 1.

There are many advantages of a core construction such as illustrated in Figs. 1 and 5 over a construction such as illustrated in Fig. 1*a* which is intended to be used with a physically separate choke. The structure of Figs. 1 and 5 may be manufactured as though it were a transformer. There need be no separate tools and dies for the choke;

the windings are all mounted on one member; there is no duplicate handling; the labor in connecting the choke and transformer within the cannister is eliminated; considerable space and iron are saved; the possibilities of noise in the ballast cannister are considerably less.

The circuits of Figs. 3 and 4 can be modified by eliminating the fluorescent lamp 26. The resulting circuits are intended for use with only a single lamp. The invention described herein applies equally as well to this type of circuit. An example of such a modification is shown in Fig. 3*a*, and the circuit is shown, described and claimed in my co-pending application Serial No. 168,219, filed June 15, 1950, entitled "Apparatus for Operating Gaseous Discharge Devices."

In Fig. 6 there is illustrated a modified form of electromagnetic device 80 which is formed of laminations held together by rivets 81. The core is formed of a rectangular shell 82 having a central winding leg 83 with lateral extensions 84 forming a magnetic shunt with the gaps 85. The choke *Ch* is isolated from the remainder of the ballast by the magnetic short circuit 86 and in this construction, the windings P, S_1 and S_2 are all separated. There is a magnetic shunt 87 with gaps 88 between the windings P and S_2. The form of the windings leg 83 is conductive to efficient assembly. In other words, the windings are all pre-formed and slipped over the winding leg. On the left end, first winding S_1 is seated against extension 84, and then winding *Ch* is positioned alongside the arcuate joint of the magnetic short circuit 86. On the right hand end, the windings P and S_2 are mounted in a similar manner in that order. Thereafter the entire assembled center leg 83 with all windings is pressed home into the shell 82. This method of assembly is preferred, and is not to be considered as a limitation.

Gaps 90 and 91 are formed at the opposite ends of the winding leg 83 in any suitable manner. The gap 90 is utilized by the choke, and gap 91 by the transformer proper.

The modification illustrated in Fig. 6 may utilize any of the circuits above described. The primary P and second secondary S_2 have now been separated by a magnetic shunt 87 which gives rise to a higher leakage reactance generated in S_2 than the previously described versions. This construction can be used under certain circumstances where the reactive volt-amperes required are less than for the constructions described herein. Thus, with the production of some leakage reactance in S_2 the size of the choke *Ch* may be decreased with savings in copper, and without the introduction of too much saturation.

It is desired to point out that the use of the choke *Ch* is required only in connection with the operation of the gaseous discharge devices and not in starting. Therefore, same need not be connected exactly as shown in the circuits illustrated. It may be in series with the condenser 27 with the identical results.

I have built and satisfactorily operated practical embodiments of my invention as exemplified herein. Said embodiments have been made by modifying the examples set forth in my co-pending application in accordance with the teachings hereof. One of such embodiments, constructed in the manner illustrated in Fig. 1 had the following physical specifications (for one 40 watt instant start lamp using circuit of Fig. 3*a*):

Size of core shell 41—2.125″×8.417″
Stack height—1″
Width of leg 42—.835″
Width of short circuit 43—$\frac{13}{16}$″
Width of shunt 46—$\frac{5}{8}$″
Frame of shell—.365″
Primary P—640 turns of #26 wire
Secondary S_1—2800 turns of #34 wire
Secondary S_2—850 turns of #26 wire
Choke *Ch*—1060 turns of #25 wire
Gap 47—.030″, gap 48—.045″, gap 49—.030″
Open circuit voltages—440 volts across lamp 30
Operational voltages—109 volts across lamp 30; 472 volts across condenser 27

Currents:
Open circuit—
In P, 1.38 amp.
In S, 0.162 amp.
Operation—
In P, .435 amp.
In S_1, .070 amp.
In S_2, .420 amp.
In lamp 30, .420 amp.

Obviously the variations of the invention will require variations in the above constants, but it is believed that same readily can be derived by one skilled in the art from the teachings hereof, and it is intended to claim all such variations as being within the scope and purview of the invention.

No limitation is intended by the theoretical explanation of the manner of operation of the invention.

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

1. Apparatus of the character described for igniting and operating gaseous discharge devices comprising an auto-transformer having a unitary core, three windings mounted on the said core comprising a primary, first secondary, and second secondary connected respectively one to the other end to end in the order named, but disposed on the core with the primary and second secondary windings arranged at one end of the core with the first secondary winding spaced therefrom, there being a high reluctance magnetic shunt in the core between the first secondary winding and the other two windings, an end air gap in the core adjacent the primary and second secondary, a choke winding mounted on said core but at the second end thereof and having a magnetic short circuit separating said choke winding from the first secondary winding, a source of A. C. voltage of value less than the igniting voltage of said gaseous discharge devices, said primary being connected to said source, a gaseous discharge device connected in a loop across transformer windings including at least said first secondary but excluding the second secondary and having a series connected condenser in said loop, and a second gaseous discharge device connected in a loop across windings of the transformer including at least both secondaries, said choke winding being connected in series with one of said gaseous discharge devices.

2. Apparatus for igniting and operating gaseous discharge devices including an A. C. source of lower voltage than the ignition and operation voltages of the respective devices, which comprises an auto-transformer having a primary winding, a loosely coupled high leakage reactance first secondary winding of greater than unity turn relationship to the primary winding and connected in additive voltage relationship therewith, and a second secondary winding also of greater than unity turn relationship to the primary winding and connected in voltage opposing relationship to the first secondary winding, a first juncture between the primary winding and the first secondary winding, and the opposite side of the first secondary winding being connected with the second secondary winding forming a second juncture, the primary winding being also connected across the source, one of the said devices being connected from the side of the primary winding opposite said first juncture to the second juncture and having a condenser in series therewith, and a second discharge device connected from the first juncture to the end of the second secondary winding opposite the second juncture and having an electromagnetic choke in series therewith, the first secondary winding being very loosely coupled relative to the primary winding to provide high leakage reactance, whereby the lamps will ignite seriatim and operate substantially in series.

3. Apparatus for igniting and operating a pair of gaseous discharge devices which includes a source of A. C. voltage, an auto-transformer having a unitary core, three windings disposed on the core comprising a primary winding, a first secondary winding, and a second secondary winding, connected respectively one to the other end to end, but disposed on the core with the primary and second secondary windings arranged at one end of the core and having the first secondary winding physically spaced therefrom and subject to the same magnetic flux, there being a high reluctance magnetic shunt provided with gaps in the core between the first secondary winding and the other two windings, a gap in the core end adjacent the primary and second secondary windings, a choke winding also mounted on the same core, a magnetic short circuit separating said choke winding from the remainder of the core, one gaseous discharge device being connected in a load circuit across certain of the windings, and a second gaseous discharge device having the choke winding in series therewith being connected in a second load circuit across certain of the windings, the primary winding being connected to said A. C. source, the two load circuits having the first secondary winding connected therein as a common winding, and the second secondary winding being connected only in the second load circuit.

4. Electromagnetic apparatus connected to an A. C. source for igniting and operating at least two gaseous discharge devices which comprise, a unitary iron core of generally elongate shell formation and having a central winding leg and providing gaps at opposite ends thereof between the winding leg ends and the shell, a choke coil mounted on said winding leg adjacent one end of the core, a three winding transformer mounted on the leg opposite the choke coil and a magnetic short circuit between the choke and transformer, the transformer comprising a primary, first and second secondary windings, the primary and second secondary windings being mounted on the end of the leg opposite the choke coil whereby the end gap thereat will be immediately alongside the second secondary winding, the first secondary winding being loosely coupled to the other two windings of the transformer whereby to develop high leakage reactance therein during operation of the apparatus, the secondaries being in voltage opposition one with respect to the other, the primary, first secondary winding, second secondary winding, and the choke coil being connected end to end one after the other in the order named, the primary being connected across the source, one device having the choke coil in series and together therewith being connected across windings including at least the second secondary winding and first secondary winding, and the second device being connected across other of said windings which includes at least the first secondary winding and excludes the second secondary winding, said second device being electrically effective when energized to assist in the ignition of the first gaseous discharge device.

5. Apparatus as described in claim 4 in which there is a condenser connected in series with said second device.

6. A system of the character described for igniting and thereafter regulating the operation of a pair of gaseous discharge devices and operating the same from a low voltage source of A. C. which comprises a source of A. C. voltage, a transformer having an iron core, three windings mounted upon the core and comprising a primary, a first secondary and a second secondary, each winding having two end terminals, the second terminal of the primary being connected to the first terminal of the first secondary, the second terminal of the first secondary being connected to the first terminal of the second secondary, a pair of gaseous discharge devices, one gaseous discharge device being connected across a part of the transformer to such of said terminals which include therebetween at least the first secondary and excludes the second secondary, the second gaseous discharge device connected across a second part of the transformer and having one end connected to the second terminal of the second secondary and its other end to a terminal such as to include between the connections at least both secondaries, the secondaries being connected and arranged on the core in voltage bucking relationship, and the first secondary being very loosely coupled to the other two windings, there being a series connected choke in series with the second gaseous discharge device and a condenser in series with the first gaseous discharge device.

7. A structure as described in claim 6 in which the choke is mounted on the same iron core but is separated from the transformer by a magnetic short circuit.

8. A structure as described in claim 6 in which there is an end gap in the iron core and the primary and second secondary windings are located adjacent the end gap, and the first secondary winding is separated from the rest of the transformer by means of a magnetic shunt.

9. A structure as set forth in claim 6 in which the first part of the transformer consists of the primary and the first secondary windings such that the first gaseous discharge device is connected from the first terminal of the primary to the juncture between the second terminal of the first secondary and the first terminal of the second secondary, and in which the second part of the transformer consists of the two secondaries such that the second gaseous discharge device is connected from the juncture between the primary and first secondary to the second terminal of the second secondary.

10. A structure as set forth in claim 6 in which the first part of the transformer consists only of the first secondary winding, while the second part of the transformer consists of all of the three windings of the transformer and the second gaseous discharge device is connected from the first terminal of the primary to the second terminal of the second secondary.

11. A structure as set forth in claim 8 in which there is also a second end gap in the core adjacent the choke.

12. A system for igniting and operating gaseous discharge devices which comprises, a pair of gaseous discharge devices, a source of A. C. voltage lower than the ignition voltage of either of said devices, a unitary shell core of elongate construction having a transformer and choke winding mounted thereon, the transformer comprising a primary winding, a first secondary winding, and a second secondary winding, with the primary and second secondary windings mounted on one end of the core, the first secondary winding mounted in the center of the core and the choke winding mounted on the second end of the core, a central winding leg mounting all of the windings and extending throughout the length of the core, but short of the opposite ends to provide non-magnetic gaps thereat, means cooperating with the winding leg between the choke winding and the other windings providing a magnetic short circuit thereat to prevent flux from the transformer from affecting the choke winding, and a magnetic shunt between the first secondary winding and the primary and second secondary windings, the primary, first secondary and secondary windings being connected end to end in the order named and each having two terminals, the first terminal of the primary winding being on one end of the resulting grouping of windings, the second terminal of the primary winding being connected with the first terminal of the first secondary winding to form a first junction, the second terminal of the first secondary winding being connected to the first terminal of the second secondary winding to form a second junction, the second terminal of the second secondary winding being on the opposite end of the resulting grouping of windings, a condenser, one gaseous discharge device being in series with said condenser and together therewith being connected from the second junction to one of the terminals of the primary winding, the second gaseous discharge device being connected in series with the choke winding and together therewith connected from

the second terminal of the second secondary winding to the terminal of said primary winding opposite said one terminal, the open circuit relationship between secondary windings being bucking.

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