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3,392,310

HIGH LEAKAGE TRANSFORMER AND GASEOUS DISCHARGE LAMP

CIRCUIT REGULATED BY SUCH TRANSFORMER

Filed May 31, 1955

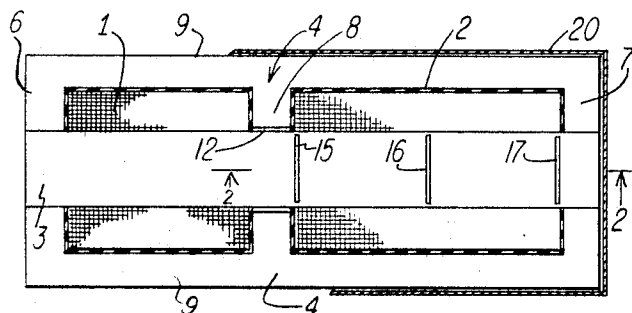


FIG. 1

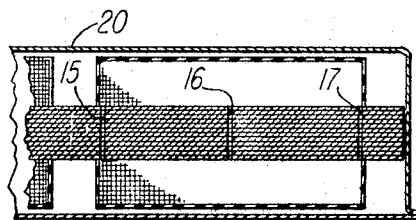


FIG. 2

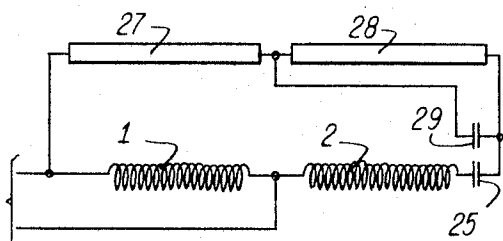


FIG. 3

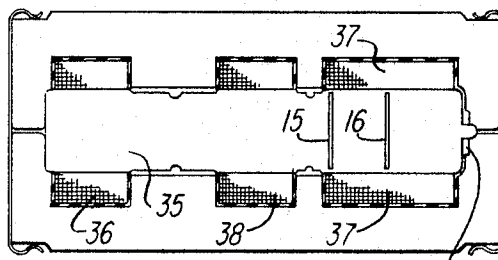


FIG. 4

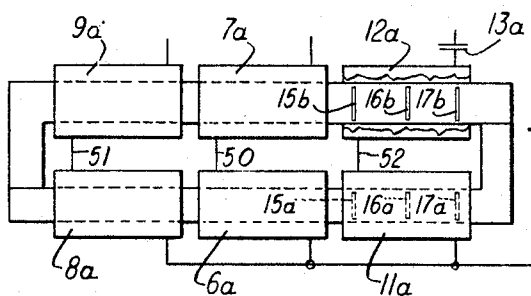


FIG. 5

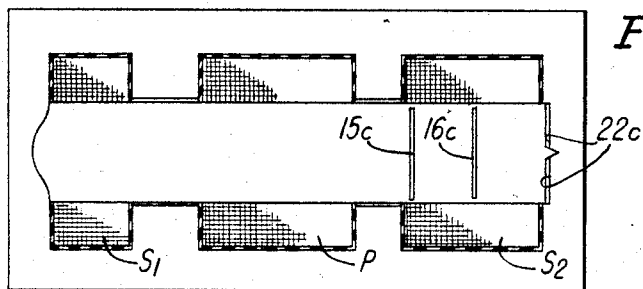


FIG. 6

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HIGH LEAKAGE TRANSFORMER AND GASEOUS DISCHARGE LAMP CIRCUIT REGULATED BY SUCH TRANSFORMER

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23 Claims. (Cl. 315-278)

This invention relates to transformers, particularly a transformer for a gaseous discharge tube or tubes which are connected in a circuit such that a coil of the transformer takes a leading current. The present invention is more particularly concerned with means for controlling the leakage reactance of a leading secondary coil of a transformer of the type commonly used for fluorescent lamps, or the like.

Lighting circuits for fluorescent lamps commonly utilize what is known as a high leakage reactance transformer. This consists of a primary and one or more secondaries, frequently with a magnetic shunt between the secondaries, and, in addition means for providing a loose coupling between the secondaries and the primary. This loose coupling may be obtained by mechanical spacing between the primary and the secondary or by a magnetic shunt between them, with an air gap. The secondary may be electrically insulated from the primary or may be connected therewith in step-up auto-transformer relationship. The operating current of the gaseous discharge tube or tubes is supplied through the secondary, and the regulation of the secondary current is in a measure dependent upon the leakage reactance. The present invention relates to the means for controlling the leakage reactance of a secondary which supplies current to a gaseous discharge tube over a circuit in which the current is essentially leading with respect to the primary voltage.

In the case of a transformer that supplies current to one or more gaseous discharge units through a circuit in which the current through the unit is essentially a leading current, it has been found necessary to place an air gap in the path of that magnetic flux which is common to both the primary and the secondary windings, in order to prevent saturation of the secondary winding. This is illustrated, by way of example, in the patent to Berger, No. 2,461,957. The vector relationship indicates that the voltage drop across the secondary coil in a leading high reactance ballast is greater than the initial open circuit voltage across this coil. As a result, there is a tendency for the current through this secondary to increase, causing a saturation of the core at the secondary. As the current increases through the secondary the leakage reactance decreases. This changes the total impedance which is equal to the capacity reactance minus the inductive reactance. The drop in impedance causes still further increase of the current flow which causes a further drop in impedance and again increases the current flow. This continues until the iron is magnetically saturated. When the iron is operated in a saturated condition the current wave shape through the lamp is highly peaked giving a very poor light output and decreasing the life of the lamp.

As set forth in the above-mentioned Berger patent, a gap in the magnetic circuit of the flux that is common to the primary and secondary will substantially diminish this saturation and the wave distortion, in that the gap introduces a high reluctance of a fixed value in series with the reluctance of the iron circuit, which latter reluctance varies at different values of flux density.

Commercial transformers of the type with which the present invention are concerned are generally made of a long and narrow construction. This shape is necessitated by either or both of two considerations. One is, it is neces-

sary to conform the ballast or transformer to the shape of the channels that are provided in the lighting fixtures in which the transformers are to be mounted, which channels are very narrow. The other consideration is that in order to maintain an economic ratio between the copper and the iron of the transformer the secondary turns must be of small diameter. The electrical conditions that must be satisfied by the transformer require the use of many turns of wire, and fix the size of the wire, which therefore results in a comparatively long secondary. This is particularly true where the transformer is to supply operating current to two 72 inch or 96 inch fluorescent lamps, commonly known as the rapid start type, and which are economically operated two lamps in series. I have found that in the case of a transformer having a very long secondary which supplies a current that is leading with respect to the primary voltage, the provision of an air gap in the secondary leakage flux path is insufficient to prevent saturation of the core by the secondary leakage flux. This is probably due to the fact that the longer the secondary the greater is the possible magneto-motive force that is responsible for the secondary leakage flux. Therefore, in the case of a long secondary, portions of the secondary are frequently so remote from the air gap that the magneto-motive force which produces the secondary leakage flux is sufficient to cause saturation of the magnetic structure of the transformer in the region of that flux.

I have found that by distributing the air gap so that it is in the form of a number of spaced apart gaps in series and at various locations with respect to the secondary that carries the leading current, the different ones of the gaps can introduce sufficient reluctance in any of the possible leakage flux paths so that saturation of the core is prevented.

Reference may now be had more particularly to the drawings which show the principles of the present invention applied to various types of transformer cores which are otherwise of standard construction.

In the drawings:

FIG. 1 is a sectional view of a transformer of a two lamp fluorescent ballast having a magnetic construction in accordance with this invention;

FIG. 2 is a fragmentary sectional view taken along the line 2-2 of FIG. 1;

FIG. 3 is a circuit diagram illustrating one typical connection for the windings of a ballast of the present invention; and

FIGS. 4, 5 and 6 are views similar to FIG. 1 and showing the present invention as applied to different types of transformer cores.

The transformer of FIG. 1 includes a primary coil 1 and a secondary coil 2 mounted on a magnetic core 3 which is assembled with a pair of similar yokes 4-4. The core and the yokes each comprises a similar number of transformer steel laminations stacked together and held in assembled relation in any desired manner. In the transformer illustrated in FIG. 1, the core and the yokes each comprises a stack of approximately fifty laminations having an overall thickness of the order of 1.25 inches. Each yoke 4 includes a pair of end legs 6-7 and an intermediate shunt 8, all joined by a longitudinally extending side 9. The two sets of preassembled yokes 4 are assembled with the preassembled core 3, on which the primary and secondary have been mounted, to form the transformer, and are held in assembled relationship in any desired manner. The shunts 8 extend almost up to the core 3 but leave air gaps at 12 which are of a height of the order of .04 inch from the core to the yoke. The core 3, in one construction, was one inch wide and approximately 7.8 inches long. The width of the iron structure of FIG. 1 was approximately 2.9 inches. Each of the

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longitudinal sides 9 was approximately $\frac{1}{2}$ inch wide as were each of the legs 6, 7 and 8. The primary and secondary coils extend through "windows" formed between the central core 3 and the yokes 4—4, and bounded by the shunt 8 and the end leg 6 in one case and the end leg 7 in the other. The iron core structure thus far described is a conventional structure known as a shell type structure.

In order to effect economies in the amount of copper used, it is customary to make the coils 1 and 2 of an appreciably greater axial length, that is, length in a direction parallel to the core 3, than their thickness in a direction from the core 3 to the yoke 4. In view of the size of the wire used and the number of turns required, it follows, therefore, that the coils, particularly the secondary coil, is of appreciable axial length. In one design, the primary had 350 turns of No. 20 copper wire and was $2\frac{1}{2}$ inches long and with an outside diameter of the order of 1.9 inches, whereas the secondary had 2020 turns of No. 22 copper wire, was of a length of approximately $3\frac{3}{4}$ inches and with the same outside and inside diameters as was the primary.

The core 3 has a series of air gaps 15, 16, 17 therethrough at the portion thereof that is surrounded by the secondary 2. Each of said air gaps 15—16—17 is of a width in a direction extending axially of the core 3, of the order of .05 inch and of a length extending substantially the full width of each core lamination 3, leaving only a small bridge at opposite ends of the air gap for maintaining the mechanical unity of the portions of the core 3 on opposite sides of the air gap. The distance from the air gap 16 to the primary 1 is, as may be seen from FIGURES 1 and 2, more than 30% of the length of the secondary. Also, the length of the secondary coil is greater than 1.5 times its diameter. The purpose of the air gaps 15—16—17 is to introduce distributed reluctance in the path of the secondary leakage flux for the purpose of preventing saturation of the magnetic structure by the secondary leakage flux.

FIG. 3 shows one standard circuit for the primary and secondary of FIG. 1. In this circuit, the primary 1 is connected across a line that supplies 120 volts 60 cycle current. The secondary 2 is connected in step-up auto-transformer relationship with the primary 1 and, in series with a condenser 25 (approximately 3 microfarads), supplies starting and operating current to two fluorescent lamps, indicated at 27 and 28, that are connected in series, the lamp 28 being shunted by a condenser 29. This is a conventional rapid start circuit wherein the condenser 29 by-passes the lamp 28 to supply starting voltage to the lamp 27. The lamps are conventional 72" T-12 or 96" T-12 gaseous discharge fluorescent lamps rated at 100 watts and operating with 800 milliamperes to 1 ampere. These lamps, operating two in series, require a total open circuit voltage of 530 volts. After the lamp 27 has started, the voltage thereacross drops, and there is then sufficient voltage to start the lamp 28 which then operates in series with the lamp 27.

The transformer of FIG. 1 together with the condensers, as illustrated in FIG. 3, is placed into a casing 20, which is generally of iron or steel, and in which the transformer fits snugly. The free space within the casing is filled with an insulating compound of tar-like consistency which excludes all air from around the transformer. The reluctance of the air gaps 15—16—17 reduces the flow of secondary leakage flux through the casing and thus reduces objections that are otherwise inherent in such a structure.

By placing two or more air gaps 15, 16 and 17 in the core of the secondary 2 it is possible to control the leakage reactance of the secondary so that the resulting current is fairly close to a sine wave. It is believed that the theoretical reason for the success of a multiplicity of relatively small air gaps as against the use of one large air gap lies in the ratios between the width and the cross

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sectional area of the air gap on the one hand, and the width and the cross sectional area of the window space between the core and the shell that is occupied by the secondary 2. In the transformer hereinabove described, this space was .45 inch, and the approximate length of the wire portion of the secondary coil was slightly over three inches. The reluctance of any air gap is proportional to the length of the gap divided by its cross sectional area. Since the height of the stack is the same relative to any air gap in the core and the window space itself, the reluctance of the window space overall will be inversely proportional to the length of the window, and the reluctance of the gap in the core will be inversely proportional to the width of the core. Therefore, if, for example, the air gap at the end of the core is approximately .05 inch and the total window length at the secondary, figuring both sides of the core, is six inches, the reluctance of the windows as a shunting path will have an area in the ratio of 1 to 6 for the end gap compared to the reluctance of the windows, if a single end located air gap were used. Therefore, taking into consideration the length of the gap as being .05 inch for such end gap, its reluctance would be in the ratio of .05 to 1. The reluctance of the window would be of the ratio of .45 to 6, so that it can be seen that there is hardly a 2 to 1 ratio in the reluctance of the window itself as compared to the reluctance of the air gap. Therefore, considering that the magneto-motive force of the long coil would tend to send flux into the air gap, and if it were limited only by the effect of an end air gap, the leakage through the window becomes quite a factor and is sufficiently large to permit saturation of the secondary despite any increase that may be made in the end air gap. However, if the air gaps are distributed along the length of the long secondary core, as illustrated in FIG. 1, and are magnetically in series, they will thereby considerably limit the flow of secondary leakage flux to any considerable portion of the core 3 and thence across the windows themselves. This thereby controls the secondary leakage flux to prevent saturation of the secondary by the leakage flux.

The ballast of the present invention is also quieter in its operation due to the fact that the distributive air gaps 15, 16 and 17 reduce the amount of leakage flux that can flow through the casing 20 and thereby eliminate or substantially reduce the hum that would otherwise be caused by a large secondary leakage flux flowing through the casing 20.

In the ballast of FIG. 1, the condensers 25 and 29 are housed within the casing 20.

The principles of the present invention are applicable to other types of transformers for gaseous discharge tubes wherein there is a secondary that takes a leading current and wherein the length of the secondary creates the saturation problem hereinabove set forth. In FIG. 4 there is illustrated a structure wherein the principles of the present invention are applied to a transformer core of the type shown in the patent to Brooks, No. 2,562,693, being particularly useful if the ballast requires a leading secondary coil 37 of appreciable length. The core of the ballast of FIG. 4 is identical with that shown in the Brooks Patent 2,562,693 and to which reference is made for a more complete description. This core differs from that of the Brooks patent only in that the length of the space for the leading secondary 37 is proportionately longer, and by the provision of two air gaps 15 and 16 which extend across the core 35 in the same manner as in FIG. 1 heretofore described. These two air gaps are in addition to the bridged air gap 47 the function of which is described in the Brooks patent, which air gap 47 has been, optionally, substituted for the air gap 17 of FIG. 1 of this application.

In the structure of FIG. 4 the primary is indicated at 38. A secondary 36 is connected in auto-transformer relationship with the primary and supplies a lagging current to a gaseous discharge device. A secondary 37 is con-

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nected in step-up auto-transformer relationship with the primary and is connected in series with a condenser to provide a leading current for a gaseous discharge device, as shown in the Brooks patent, or to provide a leading current for two series connected gaseous discharge devices, as illustrated in FIG. 3 of this application.

The principles of the present invention are applicable alike to core type transformers as well as shell type. To that effect, there is illustrated in FIG. 5 the core type transformer of Berger Patent No. 2,461,957 in which the end air gap of that patent has been omitted and in lieu thereof the core which comprises two stacks of L-shaped laminations has been provided with distributed air gaps 15a, 16a and 17a in one stack thereof and 15b, 16b and 17b in the other stack thereof, these air gaps being identical with the air gaps 15, 16 and 17 heretofore described. In this ballast, the coils 6a and 7a are connected in series by a conductor 50 and together constitutes a primary. The coils 8a and 9a are connected in series by a conductor 51 and together are connected in auto-transformer relationship with the primary and supply lagging current to a gaseous discharge tube. The coils 11a and 12a are connected in series by a conductor 52 and together constitute a secondary which is connected in step-up auto-transformer relationship with the primary and in series with a condenser 13a and supplies leading current to a lamp, as shown in the Berger patent, or to two or more lamps as shown in FIG. 3 hereof. The necessary loose coupling between the primary and the leading secondary 11a-12a is obtained by adequately spacing the secondary from the primary, or by a shunt and air gap between them, such as the shunt 8 and air gap 12 of FIG. 1.

In FIG. 6 there is illustrated a transformer such as shown in FIG. 1 of the patent to Feinberg, No. 2,683,243, to which patent reference is made for a more complete description thereof. The transformer of FIG. 6 differs from that of Patent 2,683,243 in that here there have been added the air gaps 15c and 16c which correspond to the air gaps 15 and 16 of FIG. 1 hereof. The end air gap 22c which corresponds to the air gap 22 of Patent 2,683,243 may be used in lieu of the air gap 17 of FIG. 1. In this ballast S₁ and S₂ are secondaries, and between them is a primary P which may combine a primary and a third secondary. The coils S₁, P and S₂ correspond to the coils bearing the same reference numerals in Patent 2,683,243 to which reference is here made. This ballast is connected in circuit the same as illustrated in the above referred to Feinberg patent to which reference may be had, for a more complete description.

In the descriptions above given of the structures of FIGS. 4, 5 and 6, I have omitted detailed descriptions of those portions of the respective ballasts that have not been changed by the present invention, and reference is here made to the disclosure in the corresponding patents above referred to for the details of construction of the respective ballasts or transformers of FIGS. 4, 5 and 6 just as though those details were incorporated in the present specification.

The transformers of FIGS. 4, 5 and 6 together with their associated condensers are enclosed in casings such as the casing 20 of FIGS. 1 or 2. From the above specification it is apparent that the principles of the present invention are applicable to a wide variety of transformers. The advantages of the forced core construction of FIG. 8 or the semi-forced core construction of FIG. 5 may be utilized in connection with the principles of the present invention.

In compliance with the requirements of the patent statutes I have here shown and described a preferred embodiment of my invention. It is, however, to be understood that the invention is not limited to the precise construction here shown, the same being merely illustrative of the principles of the invention. What I consider new and desire to secure by Letters Patent is:

1. Apparatus for supplying a leading current to a gase-

ous discharge device comprising primary and secondary coils and an iron core coupling the two, the secondary being of an axial length greater than 1.5 times its diameter, said core having a magnetic portion extending lengthwise of the secondary and adjacent thereto and constituting a part of the leakage flux path of the secondary and having non-magnetic gaps in series with one another and spaced from one another lengthwise of the secondary by an amount which is a substantial fractional part of the axial length of the secondary, the width of the magnetic material left in the primary flux path of the magnetic portion at each gap being a minor fractional part of the distance between adjacent gaps.

2. An apparatus as defined in claim 1 wherein said magnetic portion with its non-magnetic gaps is in the path of the primary magnetizing flux and outside of the primary leakage flux.

3. An apparatus as defined in claim 1 wherein the portion of the core that includes the non-magnetic gaps is surrounded by the secondary.

4. An apparatus as defined in claim 1 wherein there is a condenser in series with the secondary coil and of a capacity sufficient to cause the current flowing through the secondary to be leading with respect to the primary voltage.

5. An apparatus as defined in claim 2 wherein each of the non-magnetic gaps is bridged by a magnetic portion of the core.

6. An apparatus as defined in claim 3 wherein there is a magnetic casing for said apparatus, the casing being closely adjacent to the secondary and, together with the magnetic portion and the series air gaps, constitutes a part of the path for secondary leakage flux.

7. Apparatus as defined in claim 6 wherein there is a condenser in the casing and in series with the secondary coil and of a capacity sufficient to cause the current flowing through the secondary to be leading with respect to the primary voltage.

8. Apparatus for connection to an alternating current source of fixed frequency for supplying leading current to a gaseous discharge device comprising primary and secondary coils, an iron core coupling the two, the secondary coil being of greater length than 1.5 times its diameter, said core having a plurality of high reluctance portions in series with one another in the path of the primary magnetizing flux, said portions being also in the path of the secondary leakage flux that links all of the secondary turns and being spaced from one another in a direction axially of the secondary so that such secondary leakage flux that links only a fractional portion of the turns of the secondary will pass through less than all of the high reluctance portions, the distance between adjacent high reluctance portions being greater than the radial thickness of the secondary.

9. Apparatus as defined in claim 8 wherein there is a condenser in series with the secondary and of a greater capacity reactance at the frequency of the source than the inductive reactance, at said frequency, of said secondary and the load connected thereto.

10. In combination with two series connected gaseous discharge devices, a condenser shunting one of the devices, means forming a leading circuit with said devices, said means including a high reactance transformer having an output voltage less than the sum of the starting voltages of the two devices and greater than the starting voltage of each device, said transformer including a primary coil and a secondary coil in axial alignment with one another and spaced axially of one another, so that successive portions of the secondary are progressively further from the primary and the secondary is outside of the path of the primary leakage flux, an iron core coupling the primary and secondary coils, the secondary being of an axial length greater than its diameter, said core having a plurality of high reluctance portions in series with one another in the path of the primary mag-

netizing flux and also in the path of the secondary leakage flux that links all of the secondary turns and being spaced from one another in a direction axially of the secondary so that such secondary leakage flux that links only a fractional portion of the secondary will pass through less than all of the high reluctance portions, the distance between adjacent high reluctance portions being greater than the radial thickness of the secondary, the primary and the secondary being loosely coupled and connected in step-up auto-transformer relationship, a condenser in series with the secondary and in series with the circuit including the two series-connected gaseous discharge devices, said condenser being of greater capacity reactance at the operating frequency of the apparatus than inductive reactance of the circuit that includes the secondary, so that the secondary load current is a leading current, the first mentioned condenser being of a capacity substantially smaller than the capacity of the second mentioned condenser and constituting a by-pass around one of the devices for providing substantially the entire voltage of the transformer to be applied to the other device to start it, whereupon the second device will then start.

11. A high reactance ballast transformer comprising a shell type magnetic core, having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps in the magnetic circuit of said secondary winding, one of said bridged-gaps being no more than 20% of the length of the secondary winding away from said primary winding, and the other bridged-gap being no less than 30% of the length of said secondary winding away from said primary winding.

12. The high reactance ballast transformer of claim 11 wherein said primary and secondary windings are connected in autotransformer relationship.

13. A high reactance ballast transformer comprising a shell type magnetic core having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps in the magnetic circuit of said secondary winding, one of said bridged gaps being proximate to said primary winding.

14. The high reactance ballast transformer of claim 13 wherein the other bridged-gap is located remote from said primary winding.

15. A high reactance ballast transformer comprising a shell type magnetic core having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps therein, one of said slots being located essentially in the magnetic leakage flux circuit of said secondary winding only and the other of said bridged-gaps being located adjacent to that end of the secondary winding that is closer to the primary winding.

16. Ballast apparatus for starting and operating fluorescent lamps comprising a high reactance transformer including a shell type magnetic core having an elongated central core leg and a pair of elongated yoke core legs defining coil receiving windows with said central core legs, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, a capacitor connected in series with said secondary winding for connection in series with a fluorescent lamp across said primary winding, and said central core leg having a pair of spaced transverse slots forming bridged-gaps therein, one of said bridged-gaps

being located essentially in the magnetic circuit of the leakage flux of only said secondary winding; and the other bridged-gap being closed adjacent to that end of the secondary winding that is closer to the primary winding.

17. Apparatus for igniting and operating gaseous discharge means from a source of alternating voltage which comprises an iron core transformer including an elongated flux conductive element, a primary winding and a secondary winding each coaxially mounted on a different portion of said element and coupled relative to one another to provide leakage reactance in the secondary winding during operation of said apparatus, said primary winding being adapted to be connected to said source, a capacitive load circuit including gaseous discharge means connected with said secondary winding to have the current of said secondary winding flowing therein of leading character, and means for limiting the secondary leakage flux comprising a plurality of spaced apart reductions of area of said portion of said element upon which said secondary winding is mounted of dimensions to provide localized reduced core portions of non-linear permeability confined between the ends of said secondary winding.

18. In apparatus for igniting and operating gaseous discharge means wherein said apparatus includes: terminals for connecting the apparatus to a source of alternating voltage, an iron core transformer having a flux conductive element, primary and secondary windings each coaxially mounted on a different portion of said element and said windings being loosely coupled one with the other, said primary winding being adapted to be connected to the said source, and a capacitive load circuit including said gaseous discharge means connected to said secondary winding to have the current of said winding flowing therein of a leading character; the improvement consisting of means for substantially limiting the secondary leakage flux comprising: a substantial reduction of cross-sectional area in said flux conductive element at a plurality of spaced apart locations in the portion of said element upon which said secondary winding is mounted, said reduced areas being each of dimensions to provide a localized reduced core portion of non-linear permeability entirely confined between the ends of said secondary winding.

19. A high reactance ballast transformer comprising a shell type magnetic core having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps in the magnetic circuit of the leakage flux of said secondary winding, the distance between said slots being in excess of half the length of said secondary winding, and one of said gaps being adjacent to that end of the secondary winding which is closer to the primary winding.

20. A ballast as set forth in claim 16 in which one bridged-gap in the secondary leakage flux circuit is located no less than 30% of the length of said secondary winding away from said primary winding, and the other bridged-gap is located adjacent to that end of the secondary winding which is closer to said primary winding.

21. Ballast apparatus for starting and operating fluorescent lamps comprising a high reactance transformer including a shell type magnetic core having an elongated central core leg and a pair of elongated yoke core legs defining coil receiving windows with said central core legs, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, means forming a leading current circuit including a capacitor and said secondary winding and at least one fluorescent lamp and said primary winding all in series, and said central core leg having a pair

of spaced transverse slots forming bridged-gaps therein, one of said bridged-gaps being located essentially in the magnetic circuit of the leakage flux of only said secondary winding, and the other bridged-gap being located at substantially that end of the secondary winding that is closer to the primary winding.

22. A high reactance ballast transformer comprising a shell type magnetic core having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having first transverse slot means forming at least one bridged-gap in the magnetic circuit of the secondary winding adjacent that end of the secondary winding which is closer to the primary winding and having second transverse slot means forming additional bridged-gaps in the magnetic circuit of said secondary winding, said additional bridged-gaps being spaced from the first mentioned gap in the direction towards the opposite end of the secondary winding and providing a combined core restriction greater than the core restriction of said first mentioned gap.

23. Ballast apparatus for starting and operating fluorescent lamps comprising a high reactance transformer including a shell type magnetic core having an elongated central core leg and a pair of elongated yoke core legs defining coil receiving windows with said central core legs, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, a capacitor connected in series with said secondary winding for connection in series with a fluorescent lamp across said primary winding, and said central

core leg having first transverse slot means forming at least one bridged-gap in the magnetic circuit of the secondary winding adjacent that end of the secondary winding which is closer to the primary winding and having second transverse slot means forming additional bridged-gaps in the magnetic circuit of said secondary winding, said additional bridged-gaps being spaced from the first mentioned gap in the direction towards the opposite end of the secondary winding and providing a combined core restriction greater than the core restriction of said first mentioned gap.

References Cited

UNITED STATES PATENTS

1,859,115	5/1932	Summers	336—178
2,432,343	12/1947	Short	336—165 X
2,470,460	5/1949	Bird	323—60
2,473,420	6/1949	Freeman	323—48
2,473,746	6/1949	Freeman	336—155
2,553,591	5/1951	Kronmiller	336—165 X
2,578,395	12/1951	Brooks	323—60 X
2,629,072	2/1953	Nathanson.	

FOREIGN PATENTS

72,223	6/1947	Norway.
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,392,310

July 9, 1968

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It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, lines 31 and 32, cancel "no more than 20% of the length of the secondary winding away from" and insert -- adjacent to that end of the secondary winding which is closest to --.
Column 8, line 3, "closed" should read -- located --.

Signed and sealed this 25th day of November 1969.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents