Dec. 24, 1968 I. M. MILLER 3,418,527

BALLAST APPARATUS USING LEAKAGE REACTANCE OF SPLIT PRIMARY WINDING

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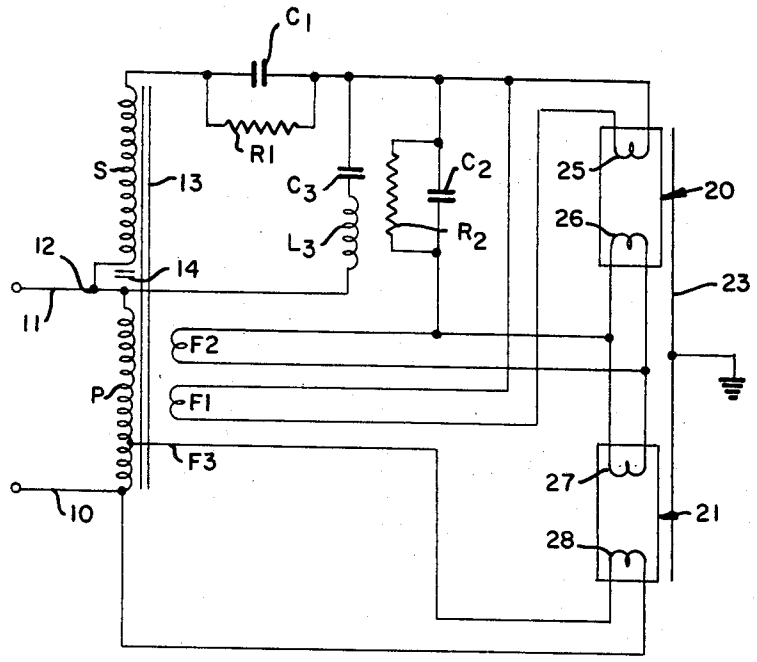


FIG. 1
PRIOR ART

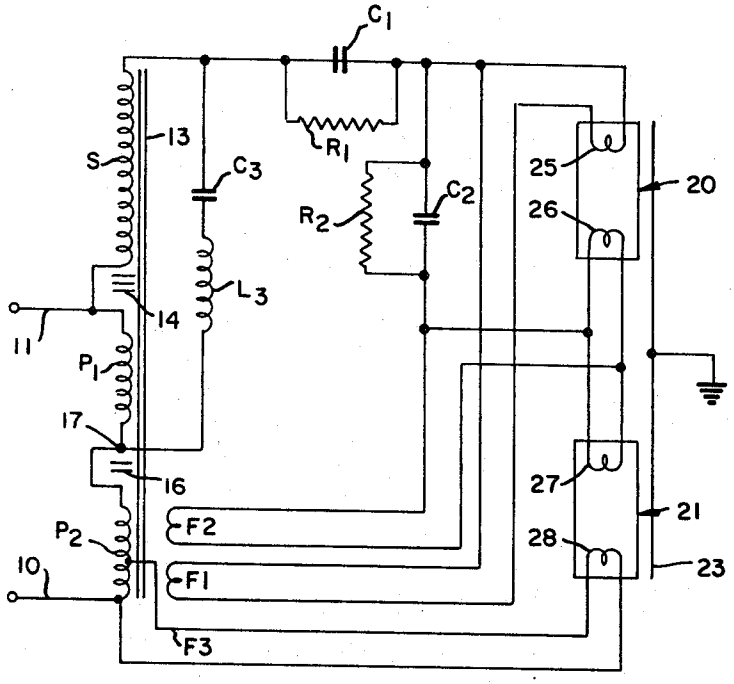


FIG. 1A
PRIOR ART

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FIG. 2

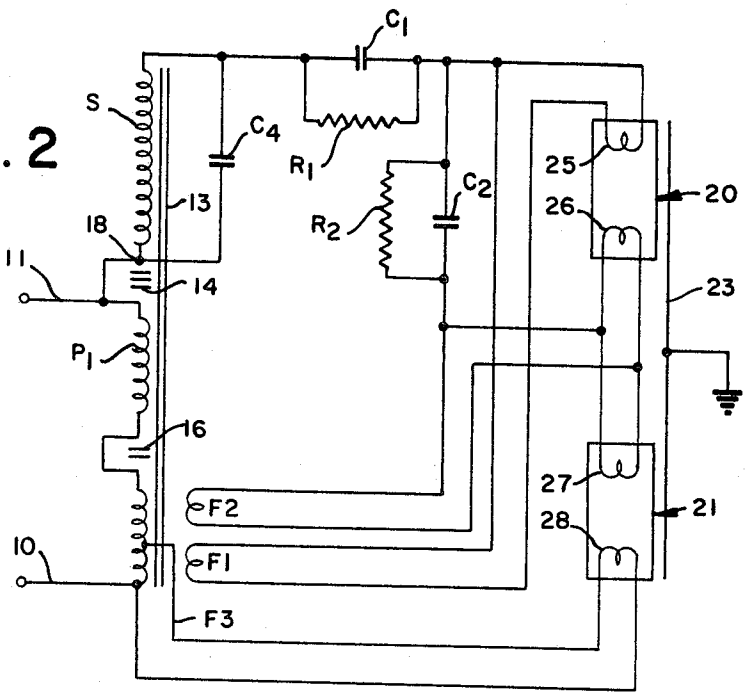
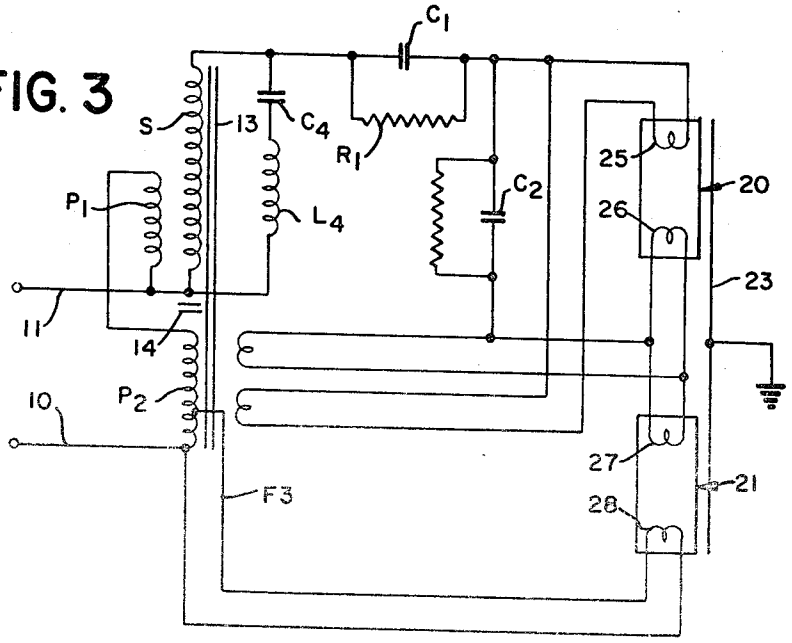


FIG. 3



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FIG. 4

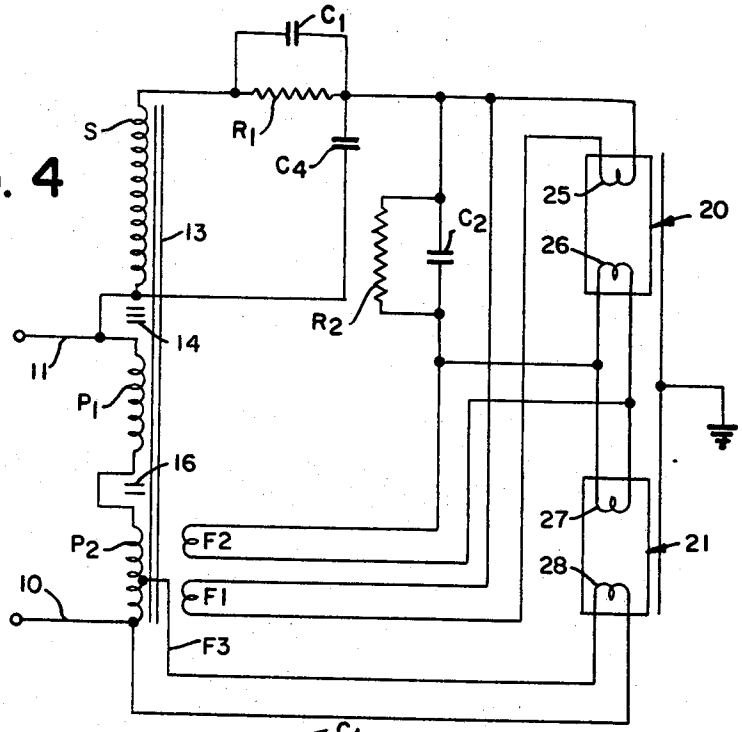
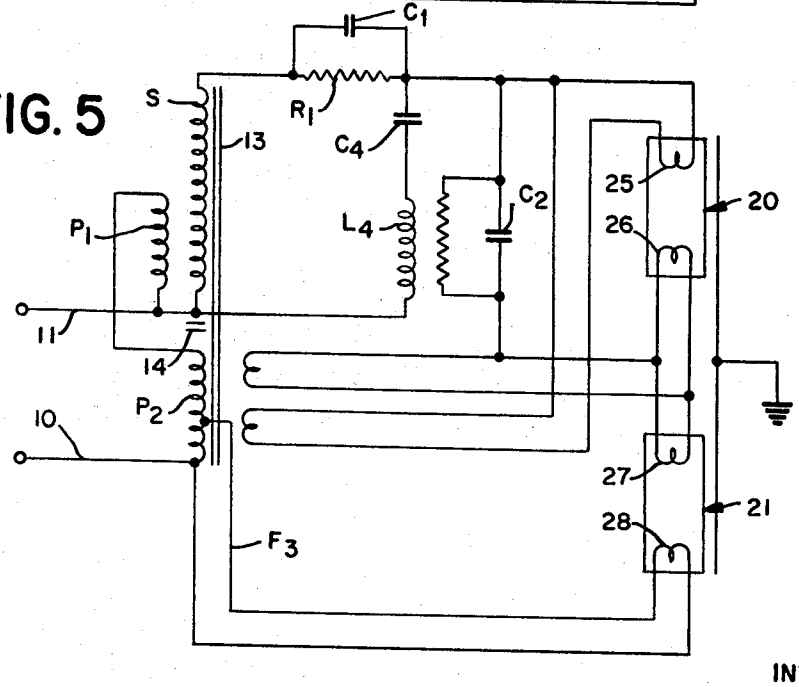


FIG. 5



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FIG. 6

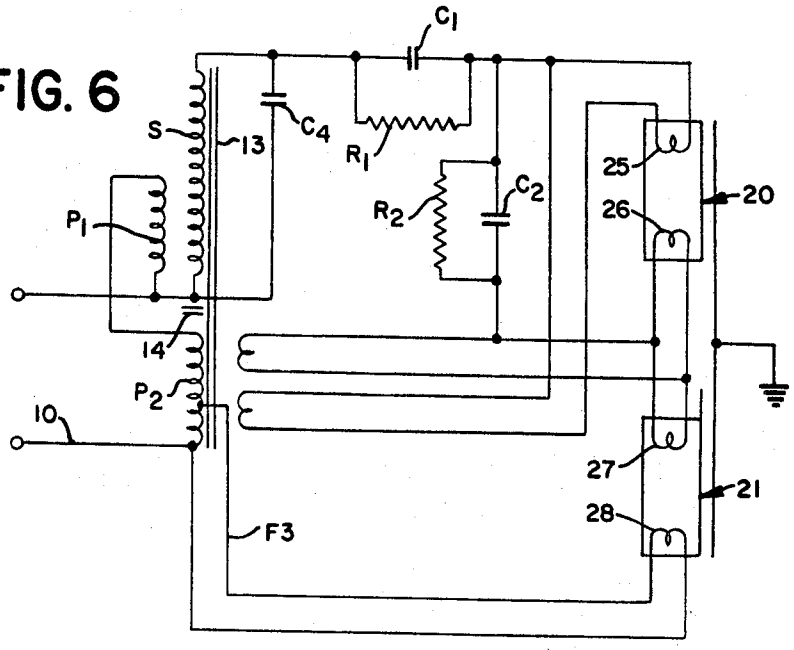
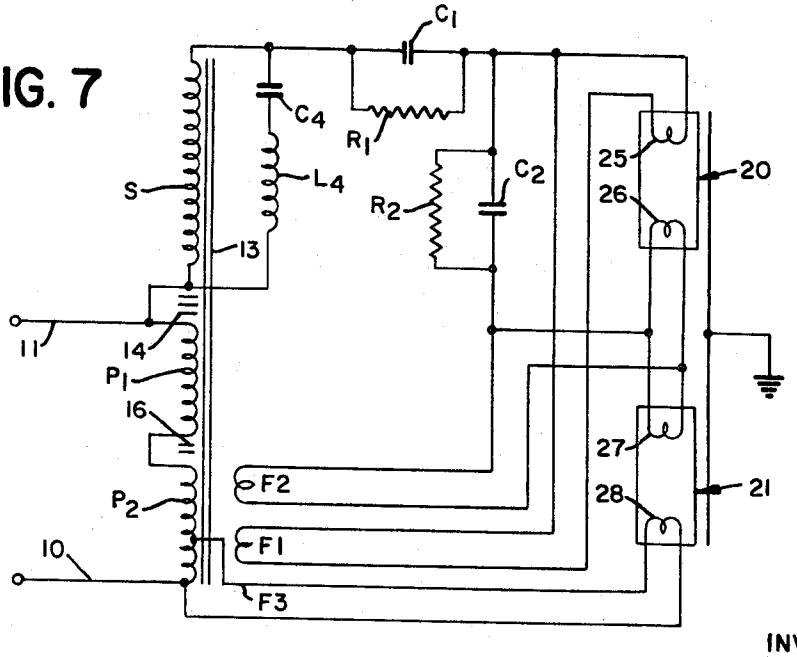


FIG. 7



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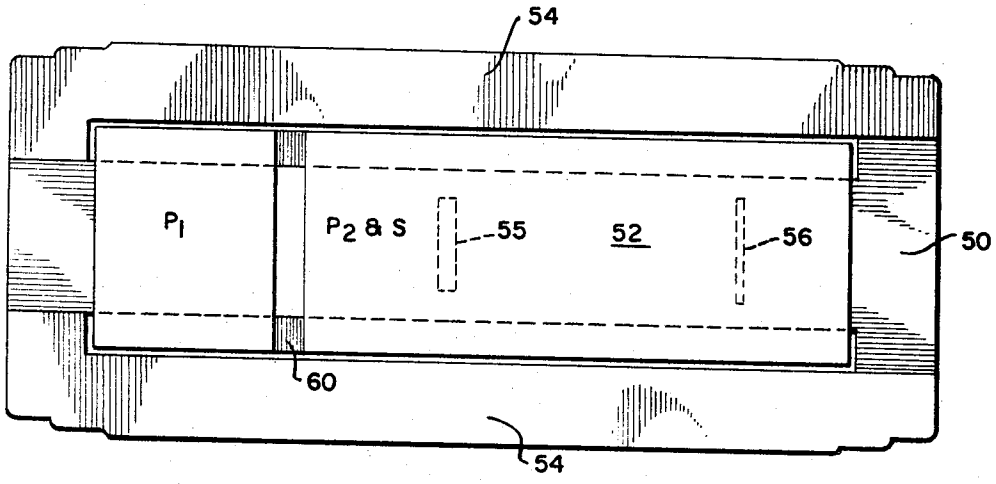
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FIG. 8



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BALLAST APPARATUS USING LEAKAGE REACTANCE OF SPLIT PRIMARY WINDING

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Filed Mar. 3, 1967, Ser. No. 620,334
12 Claims. (Cl. 315—244)

ABSTRACT OF THE DISCLOSURE

Ballast transformers for fluorescent lamps in which a circuit is used in shunt with a secondary winding of the transformer to resonate with it and increase the open circuit starting voltage. The primary winding of the transformer is split and the shunt circuit is discharged through the split primary to damp the discharge.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to ballast apparatus for starting and operating gaseous discharge lamps and more particularly to an improved ballast apparatus employing high reactance transformers with a shunting capacitor connected in parallel circuit relation with the transformer secondary to increase the ballast output.

Description of the prior art

High reactance ballast transformers are commonly used to provide the voltages required for starting and operating one or more fluorescent lamps. Such transformers usually comprise a shell-type core of magnetic saturable material with an elongated center leg on which the primary and one or more secondary windings are located in an inductive coupled relationship. A capacitor also is usually connected in series circuit with a secondary winding and the running circuit of the lamp or lamps to provide a net capacitive reactance (lead current) in the lamp circuit during normal running operation.

In high reactance transformers of the type described above, saturation of the magnetic core is relied upon to provide current limiting and output voltage regulation during operation of the lamps. In general, the transformer is designed to provide a desired value of open circuit voltage for lamp starting. The open circuit starting voltage is usually substantially higher than the running voltage. However, the high open circuit voltage is preferably produced with a minimum number of secondary winding turns. The secondary turns are minimized in order to maintain the transformer leakage reactance at the lowest possible value consistent with good performance. However, sufficient turns are used to provide good regulation of the secondary current.

As is known, the open circuit RMS (root mean square) voltage required for starting a particular fluorescent lamp, or lamps, varies with the lamp length. Also, for any given lamp length a peak voltage requirement is imposed for reliable starting which peak voltage in large measure depends upon the lowest temperature of the environment in which the lamp is to be started and operated. Thus, even though the secondary turns are desirably held to a minimum the transformer still is usually required to produce a high output voltage for starting, which voltage must be higher for longer length lamps.

To produce the high starting voltages needed for longer length lamps some ballasts utilize a resonant circuit formed by a series connected inductor and a capacitor. At least the capacitor of the resonant circuit is connected in shunt with a lead secondary winding of a high reactance ballast transformer. The shunt circuit provides one or more

preselected harmonic components in the secondary winding which are combined with the transformed line voltage to produce a higher voltage to aid in starting. In effect, the shunt circuit produces a higher RMS open circuit voltage for a given number of secondary turns, resulting in a reduction in the total number of secondary turns needed for a given starting voltage requirement, and also causes a decrease in leakage reactance. The latter gives rise to an increase in the coupling between the transformer primary and secondary windings.

While the shunt capacitor in the resonant circuit of the type of ballast described above is effective in increasing the lamp starting voltage, it introduces at least one major problem in that it makes the current flowing through the lamps have sharp spikes. These sharp spikes are unwanted since, in some cases, when they reach sufficient amplitude they seriously harm the lamp. The magnitude of these undesirable spikes increase with lamps operating in a cold environment, e.g. 20° C. and below, because of changes in the impedance of the lamps which are in the capacitor's discharge circuit.

Several circuit arrangements have been proposed for eliminating the spikes when using the shunt capacitor as part of a resonant circuit in the ballast secondary. One such arrangement is described in Hume Patent 3,225,255. In that patent, a reactive impedance is connected in series with the shunt capacitor to form the shunt circuit across the lead secondary winding. The alleged purpose of this impedance is to control the discharge of the shunt capacitor in each half-cycle of lamp operation and thereby damp the spikes. While this arrangement is operative in most respects, it is undesirable since an additional reactor (impedance), usually an inductor, must be utilized.

In another type of transformer using a harmonic producing shunt circuit capacitor, a split primary winding is also used wherein only a portion of the primary winding is coupled with the secondary winding. Hence, the shunting circuit is connected across both the secondary winding and one of the split primary windings. This expedient further increases the coupling factor of the ballast transformer thereby further reducing the number of secondary turns needed for a given RMS voltage requirement while not reducing the leakage reactance. However, an inductor still must be used in series with the capacitor to damp the spikes.

SUMMARY OF THE INVENTION

It is the purpose of the present invention to provide a high reactance type ballast transformer for fluorescent lamps using a capacitor in shunt with the secondary winding in which no additional reactor is required to damp the voltage spikes produced by the capacitor during operation at normal temperatures, i.e. above about 20° C. Also, according to the present invention, when the ballast is to be used in a low temperature environment a reactor of substantially smaller size is required as compared to prior art ballasts. In both cases, a substantial savings in material and other manufacturing costs is effected.

In accordance with the preferred embodiment of the invention, a transformer with a split primary winding is used in which the discharge path of the secondary winding shunting capacitor is through the entire primary winding. Since the split primary winding is provided with its own leakage reactance, it damps the discharge of the shunting capacitor, thereby smoothing out the waveform of the current flowing through the lamp or lamps. In another embodiment of the invention, which is particularly useful in low temperature applications where a higher starting voltage is needed, a reactor is used in series with the shunting capacitor. Here, the discharge path of the shunting capacitor is still through the entire split primary winding, so that the size of the reactor is reduced from

that which would normally be required in prior art ballasts with a consequent saving in cost. In both embodiments of the invention the main capacitor usually provided in the operating lead circuit can be made a part of or used externally to the shunting circuit.

It is therefore an object of the present invention to provide an improved ballast apparatus for starting and operating one or more fluorescent lamps in an improved series lead circuit arrangement.

Another object is to provide an improved ballast apparatus using a shunting capacitor across the secondary winding to form a tuned harmonic producing circuit, with the discharge of the capacitor through lamps being damped by the split transfomer primary winding.

A further object is to provide a ballast transformer having a split primary winding and a capacitor in shunt with the secondary winding, the discharge path of the capacitor being through the entire split primary winding.

An additional object is to provide a ballast transformer with a split primary winding and a series connected reactor and capacitor in shunt with the secondary winding, the discharge path of the series connected components being through the entire split primary winding.

Other objects and advantages of the present invention will become more apparent upon reference to the following specifications and annexed drawings, in which:

FIGS. 1 and 1A are schematic diagrams of prior art high leakage reactance ballast transformers with a capacitor shunting the secondary winding;

FIG. 2 is a schematic diagram of a ballast transformer in accordance with the present invention;

FIG. 3 is a schematic diagram of a ballast transformer constructed in accordance with another embodiment of the invention;

FIGS. 4 and 5 are schematic diagrams showing variations of the embodiments of FIGS. 2 and 3, respectively;

FIG. 6 is a schematic diagram of a ballast which is a modification of the ballasts of FIGS. 2 and 4;

FIG. 7 is a schematic diagram of a ballast which is a modification of the ballasts of FIGS. 3 and 5; and

FIG. 8 is a plan view of one form of ballast constructed in accordance with the present invention.

FIG. 1 shows a prior art type ballast transformer using a tuned circuit across the secondary winding to produce the harmonics for higher starting voltages. Here, a continuous wound primary winding P of the transformer has its ends connected by a pair of leads **10** and **11** to a suitable source of alternating current (not shown). The lower end of the secondary winding S is autotransformer connected to the upper end of the primary at junciton **12**. The primary P and secondary S are wound on a core shown schematically at **13** and a flux leakage path **14** is provided between windings P and S. In one common configuration the transformer is of the shell type whose laminations have a central leg surrounded by an outer frame, all of which is made of magnetic saturable material. The center leg corresponds to element **13** of FIG. 1. The flux leakage path **14** may be formed, if desired, by non-magnetic material, such as an air gap between the primary and secondary. It also can be formed of magnetic material such as by projecting shunt legs formed on the transformer laminations or by shunts inserted between the primary second windings.

Secondary winding S supplies a pair of fluorescent lamps **20** and **21** of conventional construction and they are preferably positioned in a mounting fixture (not shown) preferably in close proximity to a grounded conductive fixture member or plate **23**, so that the lamps are disposed in capacitive relationship therewith. The filament-cathodes **25** and **26** of lamp **20** and the filament-cathodes **27** and **28** of lamp **21** are provided with current during operation by a plurality of filament windings F1, F2 and F3. Cathodes **25** and **26** are supplied with current by leads connected to windings F1 and F2, while cathodes **27** and **28** are supplied by windings F2 and F3. Windings F1 and F2 are preferably tightly coupled to the primary winding P and may, if desired, be wound directly over the primary while winding F3 is an extension of the primary winding.

The upper end of secondary winding S is connected by a capacitor C1 to the electrode **25** at one end of lamp **20**, and electrode **28** at the lower end of the series connected lamp **21** is connected by one of the leads of filament winding F3 to the lower end of primary winding P. The other two electrodes **26** and **27** of the two lamps are connected together by the fixture wiring .Thus, the full transformer voltage of autotransformer connected windings P and S is applied across the series connected lamps **20** and **21**. Capacitor C1 provides a net capacitive reactance in the running lamp circuit, i.e. during operation after starting.

A starting capacitor C2 is connected across lamp **21** so that the transformer's open circuit starting voltage is initially applied only across lamp **21**. Resistors R1 and R2 are connected in parallel with the respective capacitors C1 and C2 to discharge these capacitors when the ballast is inoperative.

In the prior art ballast of FIG. 1, the secondary winding S is shunted by the series connected circuit of R1 and C1 in parallel, a capacitor C3, and a reactive impedance illustratively shown as an inductor L3. In general, the shunting capacitor C3 provides sufficient capacitive reactance in the secondary circuit to resonate with the other series circuit elements at a preselected harmonic frequency and produce a harmonic voltage component which is added to the transformed secondary voltage of 60 Hz to produce an overall higher voltage. The harmonic frequency selected may be, for example, the seventh harmonic of the line voltage, 420 Hz. The purpose of the inductance L3, for example as described in Hume Patent 3,225,255, is to control the discharge of capacitor C3 in each half cycle of lamp operation so that unnecessarily large current spikes which might damage the lamp will not be produced by the shunting capacitor C3.

FIG. 1A shows another prior art circuit for producing the harmonic voltage in which the same reference characters and numbers are used for the same parts. Here, the primary winding is split into two sections P1 and P2 with a high leakage reactance **16**, similar to leakage reactance **14**, located between the two sections. In this circuit, the running capacitor C1 and its parallel connected discharge resistor R1 are connected outside of the resonant harmonic producing circuit formed by the series connected capacitor and inductor, C3 and L3. The latter two components are connected from the upper end of the secondary winding S to the junction point **17** of the split primary sections. As in the circuit of FIG. 1, the reactor L3 serves to damp the discharge of capicitor C3. The lower primary section P2 also provides some damping action here but the leakage reactance **16** is not effectively in the damping circuit. The latter is true because junction **17** is effectively across both sides of the shunt **16**, i.e., no current from C3 and L3 passes through both P1 and P2 to be affected by leakage reactance **16**.

While the circuits of FIG. 1 and 1A are operative, they have at least one major disadvantage in that they require the extra inductor (choke) L3 to dampen the discharge of the shunting capacitor C3. Such an arrangement adds to the cost of the ballast due to the requirement of the extra component L3 and the extra assembly steps and parts needed to put it in the circuit.

FIG. 2 is a schematic diagram of a ballast apparatus made in accordance with the present invention. Similar reference numerals are used where applicable for the same components shown in FIGS. 1 and 1A. In the ballast of FIG. 2 the primary winding is split into two portions P1 and P2 which are separated by the leakage reactance **16**. The latter may be formed either by an air gap, shunt legs on the laminations, or by shunts inserted between the two sections of the primary winding, the same as the leakage reactance **14**. The secondary winding S is shunted

only by a capacitor C4 connected to the lower end **18** of the secondary. There is no impedance in series with this capacitor in the portion of the circuit shunting secondary winding S. The remaining components of the ballast apparatus of FIG. 2 are the same as those shown in FIG. 1A and they perform the same function.

The operation of the ballast of FIG. 2 is similar to that of FIG. 1A. Here, capacitor C4 is tuned with the secondary winding S to be resonant at a selected harmonic of the line frequency. This produces the increased voltage for application to the lamps. In this circuit, however, rather than controlling the discharge of capacitor C4 by a seperate reactance member such as L3 in series with the shunt capacitor, the discharge of capacitor C4 is damped by the high leakage reactance **16** between the split primary windings P1 and P2. The entire primary winding P1 and P2 from the connection point of the capacitor C4 and the secondary S down to the wire **10**, which is actually the common side of the transformer, forms the discharge path for capacitor C4. Since the capacitor discharge current flows through both P1 and P2, the high leakage reactance **16** is in the capacitor's discharge circuit. Leakage reactance **16** substantially damps the discharge of the capacitor C4 on each half-cycle to smooth out the waveform, so that no current spikes appear which might damage the lamps **20** and **21**.

FIG. 3 shows another embodiment of the invention which is similar to the ballast of FIGURE 2. Here, the split primary winding P1 and P2 is utilized, and P1 is tightly coupled (for example, wound over) to S. Leakage reactance **14** is common between both P2 and S, and P1 and P2. This reduces the total leakage reactance in transformer and increases its open circuit output voltage. In this ballast an inductor L4 is inserted in series with the shunting capacitor C4. Capacitor C4, inductor L4 and S are tuned to resonate at the desired harmonic frequency. The discharge path of C4 is through L4, P1, leakage reactance **14** and P2.

The ballast of FIG. 3 finds particular use in low temperature environments since it is capable of producing a somewhat higher starting voltage and operating voltage than the ballast of FIG. 2. It should be noted however that the inductor L4 used in the secondary shunting circuit can be made considerably smaller than the inductor L3 in the shunting circuit of the ballast of FIGS. 1 or 1A. This again is due to the fact that inductor L4 itself is not itself used to damp out the discharge of the shunting capacitor C4 since this is in large measure accomplished by the high leakage reactance **14** between the split primary windings P1 and P2.

FIGS. 4 and 5 show circuits similar to FIGS. 2 and 3, respectively. The only difference is that in each case the running capacitor C1 has been moved to be in series with shunt resonating capacitor C4 across secondary S. C1 now becomes a part of the resonant circuit. Operation of these two circuits is otherwise the same as in FIGS. 2 and 3.

FIG. 6 shows a further modification of the ballasts of either of FIGS. 2 or 4. Here, P1 is tightly coupled to S, as in the ballasts of FIGS. 3 and 5, and leakage reactance **14** is common to both P2 and S, and P1 and P2. Leakage reactance **14** is in the discharge circuit of capacitor C4 and serves to damp the discharge. As in FIGS. 2 and 4, there is no other inductor, such as L4, in the discharge circuit. While the ballast of FIG. 6 has the running capacitor outside of the resonant loop of C4 and S, it can be placed inside.

FIG. 7 shows a further modification of the ballasts of either of FIGS. 3 or 5. Here, P1 and P2 are split and separated by the leakage reactance **16**. A separate inductor L4 is used to improve the low temperature characteristics of the ballast, with leakage reactance **16** still providing a large portion of the damping action. While C1 is shown outside of the resonant circuit, it can be placed inside.

FIG. 8 shows a plan view of a typical ballast transformer made in accordance with the invention. The transformer

has a shell type core formed by a T lamination member **50** with a center leg **52** and two L lamination members **54** whose short legs abut the side of the long leg of the T member adjacent its end. A stack of these laminations are used and the slots **55** and **56** perform their usual function of providing high reluctance areas on the center leg. The primary winding P1 is placed on the long leg **52** separated from the second primary winding P2 and the secondary winding S by the magnetic shunts **60** which form the leakage reactance **14**. As shown, S is wound over P2 so that the magnetic shunts **60** are common to both P2 and S.

The ballast circuits of the subject invention also can be used with shunting capacitors (C_4) which inherently possess an amount of inductance. It is known that capacitors can be built with a considerable amount of inherent inductance by suitably constructing their electrodes and/or connecting tabs. Thus, such capacitors can be used to either entirely eliminate the need for the separate shunting inductor L_4 or to reduce its size even in low temperature applications of the ballasts of the subject invention where such additional inductance is sometimes required.

What is claimed is:

1. A ballast apparatus for one or more fluorescent lamps comprising a high reactance transformer with a primary winding and a secondary winding inductively coupled on a magnetic core to produce a voltage transfer therebetween when voltage is applied to the primary winding, said primary winding being divided into two sections, leakage reactance means between said two sections, shunting circuit means connected across said secondary winding in parallel circuit relation to increase the starting voltage of the transfer, and means connecting said shunting circuit to said primary winding to provide a discharge path therefor through both sections of the primary winding and the leakage reactance means.

2. Ballast apparatus as set forth in claim **1** wherein said shunting circuit means comprises a capacitor.

3. Ballast apparatus as set forth in claim **1** wherein said shunting circuit means comprises a capacitor and an inductor connected in series.

4. Ballast apparatus as set forth in claim **1** wherein said shunting circuit means is resonant with said secondary winding at a selected harmonic of the frequency of the voltage applied to the primary winding.

5. Ballast apparatus as set forth in claim **4** wherein said shunting circuit means is a capacitor.

6. Ballast apparatus as set forth in claim **4** wherein said shunting circuit means comprises a capacitor and an inductor connected in series.

7. Ballast apparatus as set forth in claim **1** wherein one of said sections of said primary winding is tightly coupled to the secondary winding.

8. Ballast apparatus as set forth in claim **7** wherein said one section of said primary winding is wound over at least a portion of said secondary winding.

9. Ballast apparatus as in claim **1** further comprising a capacitor connected to one of the output leads of the secondary winding and in the lamp running circuit, said capacitor being outside of the parallel circuit formed by the secondary winding and the shunting circuit means.

10. Ballast apparatus as in claim **1** further comprising a capacitor connected to one of the output leads of the secondary winding and in the lamp running circuit said capacitor connected in series with said shunting circuit means to form part of the circuit in parallel with said secondary winding.

11. Ballast apparatus as in claim **1** further comprising a separate leakage reactance means between one of said sections of said primary winding and said secondary winding.

12. Ballast apparatus as in claim **1** wherein said leakage reactance means is also between one of said sections of said primary winding and said secondary winding.

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U.S. Cl. X.R.

315—97, 98, 189, 278, 282; 336—165