Dec. 27, 1966 M. ROSIAK 3,295,015

SINGLE LAMP RAPID START BALLAST

Filed Feb. 7, 1964

Fig. 1

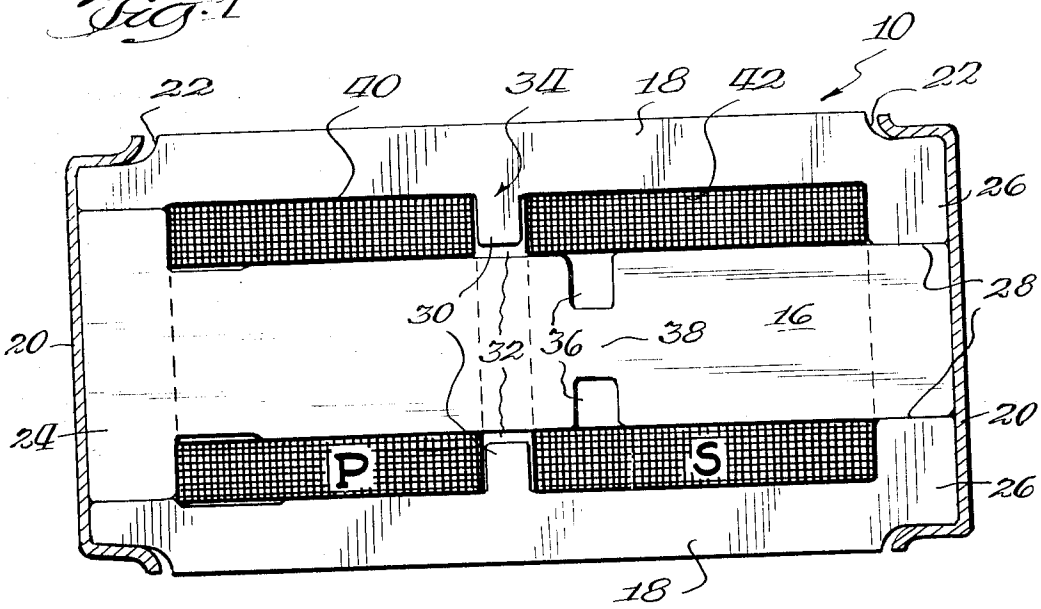

Fig. 2

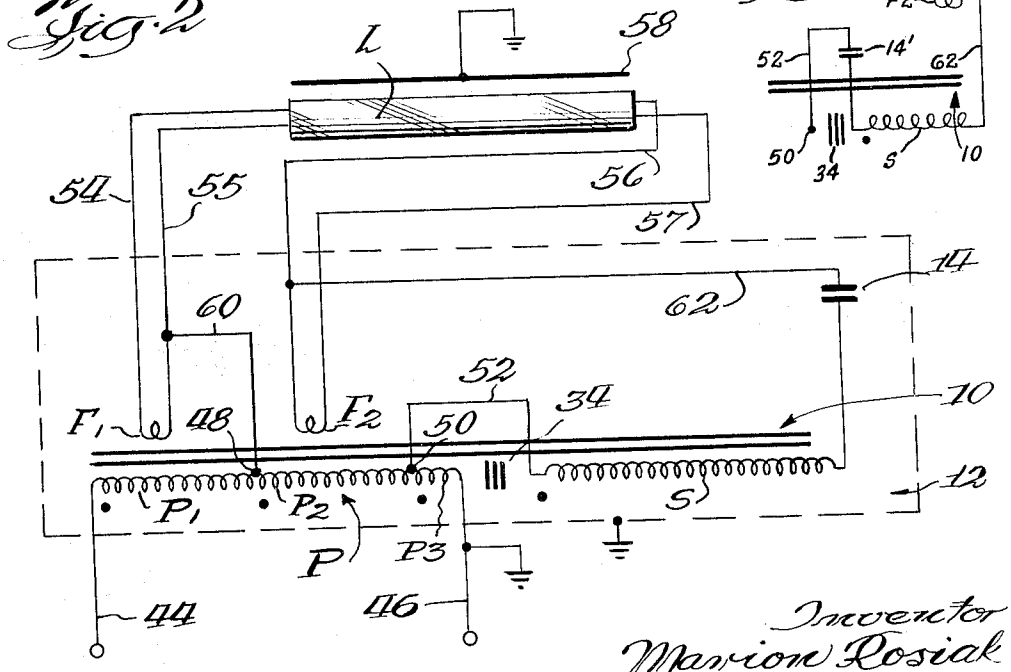

Fig. 3

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SINGLE LAMP RAPID START BALLAST

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This invention relates generally to fluorescent lamp ballasts but more particularly is concerned with a ballast for use with a single fluorescent lamp of the so-called rapid start type.

The rapid start fluorescent lamp differs from the instant start fluorescent lamp in that it has filaments in the envelope ends which are energized to produce clouds of electrons to aid in starting the lamp at a voltage lower than required for starting the instant start lamp. It differs from the pre-heat start lamp in that its filaments are continuously energized, instead of being heated momentarily during starting. The rapid start balast, therefore, has filament windings normally closely coupled with the primary winding, to supply the filament current.

The design of a ballast for a rapid start lamp demands the consideration of at least three aspects—one of which is concerned with requirements which give rise to good starting characteristics—the second of which is concerned with efficient operation—and the third of which is concerned with requirements of personnel safety. Various regulatory organizations set the requirements and standards which are to be followed, including ballast manufacturers, organizations, lamp manufacturers, specifications, and safety groups such as the Underwriters' Laboratories.

The invention herein is concerned with providing good starting and operating characteristics for a rapid start lamp ballast, while meeting the safety requirements determined as acceptable. This is achieved to some extent with prior circuits, but according to the invention herein, a novel circuit is provided which is simpler and cheaper than prior circuits, without sacrificing any of the requirements demanded.

The invention will be described in connection with a single lamp ballast for igniting and operating a 40 watt rapid start lamp, although the construction and principles may be applied to rapid start fluorescent lamps of other ratings.

For proper starting of a 40 watt fluorescent rapid start lamp, the voltage applied at open circuit across the lamp is specified as 227.5 volts R.M.S. at 60 cycles. The line voltage is full rated value, which may be assumed to be 120 volts A.C. The actual specification is given as 90% of rated line voltage at 205 volts R.M.S.

Further, a voltage must exist by capacitive coupling, from one end of the lamp to ground, represented by a metal fixture that is grounded, whose peak value must exceed 311 volts at full rated line voltage. This is specified as exceeding 280 volts at 90% of rated line voltage.

The achievement of the above R.M.S. and peak voltages do not pose severe problems in ballast design in and of themselves, but when added to the safety requirements demanded in ballasts by the Underwriters' Laboratories, for example, considerable expense has resulted in the past.

If a primary winding is energized such that a filament winding coupled thereto is heated, it is feasible for a person to hold the fluorescent lamp in one hand and to contact ground completing a circuit through the lamp. If the voltage is sufficiently high, the lamp will fire and could cause shock, burns, or even death. Consequently, the limitation placed upon ballasts for this type of fluorescent lamp calls for a maximum permissable R.M.S. voltage to ground from any end of the lamp not to exceed 180 volts, and a maximum peak to ground not to

exceed 325 volts, both of these values being those resulting at full rated line voltage.

While the requirement for safe open circuit peak voltage from an end of the lamp to ground is not inconsistent with the starting requirement, it is obvious that the safe open circuit R.M.S. voltage to ground from an end of the lamp is substantially less than the voltage required to ignite the lamp properly. To repeat the open circuit requirements in tabular form, they are as follows:

	R.M.S., volts	Peak, volts
For starting	227.5	311
For safety	180	325

All of these values are those existing at full rated line voltage; the starting voltages are the minimum required; the safety voltages are the maximum permitted.

The only difference between the values mentioned above relative to the manner in which they are measured, is that in the case of the safety voltages, these are the values to ground, while in the case of the starting voltages, the R.M.S. value given is that across the terminals of the lamp.

The prior circuits which have attacked this problem have taken two forms. One form uses a pair of so-called disconnect sockets in which the removal of the primary end of the lamp from its socket will open the primary winding. The other form of circuit isolates the secondary winding from the primary winding by a high ohmage resistor with the secondary winding providing the full open circuit peak voltage and the full R.M.S. voltage to the fixture.

The primary object of the invention as inferred above, is to provide a ballast for use with a rapid start circuit which achieves good starting characteristics and meets safety requirements, without the use of either disconnect sockets or isolating resistors. In the first instance, obviating the use of disconnect sockets means that the system into which the ballat is connected will be more economical, and thus result in saving for the installer or fixture manufacturer; in the second instance, the ballast manufacturer saves the cost and labor of connecting a resistor in the ballast circuit and the size of the secondary winding is smaller.

An important object of the invention is to provide a ballast of the character described in which the peak voltage to ground lies between 311 and 325 volts, the R.M.S. voltage across the lamp is over 227.5 volts, and the R.M.S. voltage to ground is less than 180 volts.

One of the common requirements of a fluorescent ballast is to keep the current drawn from the line as close to unity power factor as practicable, and preferably to have this current on the leading side. The inductive effect of a highly inductive secondary is normally offset by the use of a series condenser in the secondary circuit. The normal ballasts of today are of the high leakage reactance type, and practically all of these will have one or more condensers in their secondary circuits, but this gives rise to lamp currents producing peaked waves. Such current waves during operation are not conductive to maximum light output, and one technique for the obviation of such peak waves has been described in U.S. Patent 2,461,957 which consists of providing a high reluctance gap in the secondary magnetic circuit.

It is believed that the gap prevents saturation of the iron in the vicinity of the secondary winding. The magnetomotive force of the magnetic circuit partially expends itself in the gap and thereby limits the magnetic flux to a point where saturation with attendant drop in inductance during those portions of the cycle when the current wave is a maximum does not occur. Mechanical problems make

the provision of a complete gap difficult, hence the gap in such ballasts is usually bridged by an iron web or connection to enable the core to be assembled and held together.

In the instant invention, it is desired to have the peaked voltage described above for aid in starting, and this is achieved by the iron portion of the bridge saturating, but it is also desirable to have the good wave shape during operation. The use of a bridged gap accomplishes both ends, and in the circuit to be described, the provision of this structure comprises an important object of the invention.

Other objects and advantages will occur to those skilled in this art as a description of a preferred embodiment is set forth hereinafter, in connection with which the drawing illustrating the same should enable a complete understanding thereof.

In the drawing:

FIG. 1 is a plan view, with portions in section, showing the construction of the transformer portion of the invention.

FIG. 2 is a schematic diagram showing the electrical circuit of a system for operating a rapid start fluorescent lamp using the invention.

FIG. 3 is a portion of the schematic diagram of FIG. 2 showing a modification of the electrical circuit of the invention.

The objects and advantages of the invention are achieved by providing a transformer having a primary and a secondary winding, connected in auto-transformer relation across a fluorescent lamp, the transformer having two taps to enable the desired voltages to be achieved. A bridged gap in the magnetic circuit of the secondary winding provides a peak voltage in the secondary winding which is combined with the primary-induced otherwise sinusoidal voltage in the secondary winding to achieve the peak voltage falling between the desired limits of 311 and 325 volts from the end of the lamp to the grounded fixture. It also provides good current wave shape during operation. The R.M.S. voltage for ignition of the lamp is provided by choosing the proper tap on the primary into which the secondary winding is connected so that there is a portion of the primary winding bucking the secondary winding in its circuit to ground. About half of the primary winding is used in additive auto-transformer relationship with the secondary to achieve the desired ends.

Referring now to the drawing, the reference character **10** designates the transformer portion of a ballast **12** which is shown schematically in FIG. 2 by the broken line rectangle. A ballast of this kind has a metal canister in which the components are immersed in a potting compound. Electrical leads protrude from the canister. The only other component in the canister **12** besides the transformer is the series condenser **14** and a capacitor bleed resistor usually connected across the condenser and radio interference capacitors which are not shown.

The transformer **10** has a shell type of core formed of stacks of T-shaped and F-shaped laminations, forming a central winding leg **16** and side legs **18** held together by clamps **20** engaging notches **22** formed in the corners of the side legs. The cross head **24** of the T-shaped central winding leg **16** forms the left end magnetic return yoke, and the in-turned ends **26** engage the right hand end of the central winding leg on opposite sides thereof at **28** to form the right end magnetic return yoke. The inwardly directed extensions **30** that are integral with the side legs **18** are spaced from the central winding leg by means of high reluctance non-magnetic gaps **32** to provide shunts at **34**. The core is preferably stamped in well-known scrapless technique so that the inner edges of the side legs **18** are identical in configuration to the outer edges of the central winding leg **16** but spaced therefrom outwardly and longitudinally. The space produced during stamping by the projections **30** results in notches **36** on opposite edges of the central winding leg and a necked portion **38**.

It will be appreciated that the necked portion **38** is in effect a narrowed cross section of the central winding leg and together with the notches **36** may be considered a bridged gap. Other constructions of core may be used with slots or notches or cuts to produce different forms of bridges or bridged gaps. The desired effect is to provide a peaked voltage wave on open circuit, in the secondary winding, while at the same time preventing peaked current waves in the secondary circuit during operation.

The two pairs of windows **40** and **42** are occupied respectively by the primary and secondary windings P and S, the windows **40** also having the filament windings F_1 and F_2 mounted therein closely coupled with the primary winding P.

Looking now at FIG. 2, the primary winding P has the leads **44** and **46** by means of which it may be connected to a line such as 120 volts 60 cycles A.C. The lead **44** is adapted to be connected to the so-called "hot" side of the line, and the lead **46** is intended to be connected to the grounded side of the line.

The primary is divided into three parts, designated **P1**, P2 and P3, by means of two taps at **48** and **50** and the polarity markings for all windings indicates that their instantaneous voltage relationship one to the other is additive along the length of the winding P. The secondary winding S has its left terminal connected by the lead **52** to the tap **50** and the polarity mark at the left of the winding S indicates that with respect to a circuit including the secondary winding S and the primary part P3 the winding S bucks P3, but with respect to a circuit including the secondary winding S and the primary part P2 the winding S adds to the winding P2.

Filament windings F1 and F2 are connected respectively to the leads **54–55** and **56–57** which extend out of the ballast canister. The leads **54–55** are adapted to be connected to one filament of a rapid start fluorescent lamp, such as for example the left hand filament of the lamp L shown in FIG. 2, while the leads **56–57** are adapted to be connected to the second filament of the same rapid start fluorescent lamp, for example the right hand filament of the lamp L. Lamp L is set in a fixture which has a grounded metal reflector or plate **58** in close proximity and capactive coupled relationship to the lamp.

Tap **48** connects by the jumper **60** to the lead **55**, and the secondary winding S connects through the series condenser **14** by way of the lead **62** to the lead **56**. Note that the winding S and the primary part P2 are connected in additive auto-transformer relationship at tap **50** (which may be termed an auto-transformer junction) across the lamp L so that the open circuit voltage of the secondary winding S which is peaked because of the bridged gap **36–38** will have superimposed thereon a virtual sinusoidal voltage produced in the primary. The reason that primary part P1 is not included in this circuit is because its voltage added to that of the part P2 and the voltage of the secondary winding S is more than needed for the open circuit voltage across the lamp. Its presence is needed for adjustment of the proper characteristics of the transformer with respect to currents, power and induced voltages. There may be circumstances where the primary parts P1 and P2 may be combined.

The secondary winding is chosen to give the proper step-up voltage and peaked voltage desirable for starting the lamp L. As explained, for a 40 watt rapid start fluorescent lamp the voltage across the lamp for starting is required to be about 228 volts R.M.S. and in the particular circuit described herein, only the primary part P2 is needed to augment the open circuit voltage of the secondary winding S. Adjustment of the tap **48** adjusts the R.M.S. starting voltage.

If one examines the circuit from the grounded lead **46** through the part P3, the auto-transformer junction **50**, the secondary winding S and the condenser **14** through the leads **62** and **56**, it will be seen that the voltage across the intervening space between the lamp and the metal member **58** is provided by an auto-transformer relation in

which the voltage of P3 is bucking that of S. This is the voltage which a person would be subjected to if he held the left hand lamp terminals in his hand while the right hand end was connected in circuit, and he touched the ground. The maximum R.M.S. permitted for this is 180 volts and in the structure described it turns out to be somewhat less than that.

The peak voltage needed between the lamp and ground is achieved by the secondary winding S operating in conjunction with the bridged gap **36–38**. This peaked voltage occurs on open circuit as a result of the bridged gap **36–38** being unsaturated at the time that the flux of the primary winding passes through zero. The voltage induced in S will suddenly rise at this point because the change in flux with respect to time is maximum as it passes through zero, and voltage is proportional to change in flux.

The auto-transformer junction **50** provides an easy way of adjusting the peak voltage, because it subtracts a sinusoidal voltage from that appearing in the secondary winding. The size of the bridged gap **36–38** and the location of the tap or junction **50** provides two parameters which can be varied to suit conditions. The total peak voltage from the lamp to ground was chosen as one which is less than the 325 volts A.C. considered dangerous by Underwriters' Laboratories, and more than 311 volts A.C. considered the minimum by lamp and ballast manufacturers' standards for reliable starting of the 40 watt rapid start lamp.

A practical example of a ballast was constructed in accordance with the invention for igniting and operating a 40 watt T–12 rapid start lamp from a 120 volt, 60 cycle line. The details of construction of the ballast were as follows:

	Inches
Total length of the core	4.26
Width of core (assembled)	2.08
Width of winding leg	.76
Width of windows	.31
Width of extensions **30**	.19
Width of side legs **18**	.35
Width of cross head **24**	.39
Width of ends **26**	.39
Length of windows **40**	1.58
Length of windows **42**	1.72
Length of extensions **30**	.225
Air gaps **32**	.085

All of these dimensions are approximate within a few thousandths, except for the last two given. These latter are typical for one construction. An effort has been made to draw the structure of FIG. 1 to scale. The stack height was .8 inch, and the laminations were of 24 gauge silicon steel, although good results would be obtained using cold rolled types.

With respect to the windings and related details, the following obtained:

	Turns	A.W.G. wire
P1	336	27
P2	420	27
P3	56	27
F1	26	27
F2	26	27
S	1,600	28

The capacitor **14** was one having a capacity of 3.83 microfarads and was rated at 285 volts, A.C.

Measurements were made on the circuit under various circumstances, and those of pertinence were as follows: The voltage measured from the lead **56** to ground at **58** was 176 volts R.M.S. and 314 volts peak. The open circuit voltages measured across the various portions of the ballast were 50 volts across **P1**, 62 volts across P2, 8 volts across P3 and 182 volts across S—all of these being

R.M.S. The open circuit starting voltage across the lamp L from lead **54** to the lead **56** was 246 volts R.M.S.

During operation of the lamp, the line current was 475 ma. and the lamp current was 422 ma. the power factor being 97.5. The condenser voltage was 272 volts.

The ballast operated with good regulation over the range of variation normally expected in line voltage, and within the temperature range permitted for such a device by Underwriters' Laboratories requirements.

The construction of the ballast may be varied without sacrificing the advantages of the invention. As shown in FIG. 3, a condenser **14'** conveniently may be located in lead **52** instead of in the lead **62** as shown in FIG. 2. If the peak voltage achieved by means of a given core structure were low enough to fall in the desired range, there may not be need for the secondary to be tapped into the primary at **50**, but it may be connected directly to lead **46**. Under such circumstances, the tap **48** would be the only adjustment for proper open circuit voltage. Variation of air gap and bridged gap dimensions would affect these voltages.

Lamps other than 40 watt T–12 rapid starts would also require some modifications. None of such changes are believed outside the scope of the invention.

What it is desired to secure by Letters Patent of the United States is:

1. A ballast for igniting and thereafter operating a gaseous discharge lamp of the rapid start type from an A.C. power line one side of which is grounded and the lamp adapted to be mounted adjacent to and capacitively coupled with a grounded metal member, said ballast comprising: an elongate magnetic core, a transformer mounted on said core and having a primary winding and a secondary winding loosely coupled relative one another, the primary winding having first and second end terminals with the lead means for connecting the respective end terminals to the ungrounded and grounded sides of said A.C. line, respectively, said primary winding having first and second taps dividing said primary winding into three parts with all parts additive within the primary winding, the first primary part being between the first tap and the first end terminal, the second primary part being between the first and second taps, and the third primary part being between the second tap and the second end terminal, the secondary winding being connected in additive auto-transformer relationship with the second primary part only and together therewith having lead means including a series condenser for connecting the combined second primary part and secondary winding across the terminals of said lamp, and the secondary winding forming a branch series circuit with the third primary part in which the secondary winding bucks the third primary part, said core having a bridged gap in the vicinity of the secondary winding whereby to provide a peaked voltage wave on open circuit for starting the lamp.

2. A ballast as claimed in claim **1** in which there is a shunt having a high reluctance air gap in the core between the primary and secondary windings, the core has a central winding leg and the windings are mounted on the central winding leg, the bridged gap comprises a pair of opposed notches formed in respective opposite edges of the central winding leg with a necked portion therebetween, and the bridged gap is fully enclosed by the secondary winding.

3. A ballast as claimed in claim **1** in which the series condenser has one terminal thereof connected to one end of the secondary winding, and the other end of the secondary winding is connected to the second tap.

4. A ballast adapted to provide proper igniting voltage for a rapid start type of fluorescent lamp while providing safe open circuit voltages when said lamp and ballast are connected to an A.C. source one side of which is grounded and there is a grounded metallic member in the vicinity of the lamp, which comprises: a transformer having an elongate metal core with a central winding leg, a primary winding and a secondary winding disposed on the central

winding leg coaxially, but spaced from one another, a magnetic shunt including an air gap between the windings, lead means for connecting the first and second primary winding end terminals to the grounded and ungrounded sides of the source, respectively, the secondary winding having one end terminal thereof connected to the primary winding at an auto-transformer junction proximate to the first end terminal of the primary winding, means including a series condenser for extending connections from the secondary winding and one part of the primary winding on one side of said auto-transformer junction to the terminals of the lamp with the said one part and secondary winding connected in additive auto-transformer relation across said lamp, a tap on said primary winding between said second end terminal and said auto-transformer junction forming between said tap and second end terminal another part of said primary winding additive to said one part, said tap being a portion of said means, and there being a bridged gap in the secondary portion of the metal core.

5. A ballast adapted to be connected to a fluorescent lamp of the rapid start type and also adapted to be connected to a source of A.C. voltage to ignite and operate the said lamp when connected in a system including both the lamp and source, and in which there is a grounded side of the source and a grounded metal member in the vicinity of the lamp for aiding in starting the lamp, which comprises: an iron core mounting a primary winding and a secondary winding in loosely coupled voltage step-up inductive relation, the secondary winding being connected in additive auto-transformer relation with one part of said primary winding to form one circuit, said one circuit having lead means for extending connections from said one circuit to the terminals of said lamp whereby to impress the voltage of said circuit across said lamp when said lamp is connected to said lead means, the secondary winding being connected in subtractive auto-transformer relation with a second part of the primary winding to form a second circuit, said second circuit having one terminal common with one of said lead means and adapted to have a second terminal for extending a connection to ground, the primary winding having a third part which is included in neither of said first and second circuits, but is effective to produce flux for linking with the secondary winding, whereby when said ballast, lamp and source are connected together, the R.M.S. open circuit voltage from either lamp terminal to ground will be substantially lower than the voltage across the lamp.

6. A ballast as claimed in claim 5 in which there is a series condenser in the said one circuit.

7. A ballast as claimed in claim 6 in which there is magnetic shunt with high reluctance gap between the primary and secondary windings to provide the loose coupling and there is a bridged gap in the magnetic circuit under the secondary winding to produce a peaked starting voltage while preventing saturation in the magnetic circuit during operation of the lamp.

8. A ballast as claimed in claim 5 in which said primary winding has at least one tap dividing same into said two parts, and the primary winding has end terminals for extending connections to said source, the second part being electrically adjacent to that end terminal adapted to extend to the grounded side of the source.

9. A lighting system for a fluorescent lamp which includes a fluorescent lamp of the rapid start type arranged to be ignited and operated from a source of A.C. voltage having a grounded side and an ungrounded side, and including a transformer having a magnetic core, a primary winding mounted on the core and having one end terminal connected to the ungrounded side of the source and the second end terminal connected to the grounded side of the source, a metallic conductor in close proximity to the lamp and connected to ground, a secondary winding mounted on the magnetic core in step-up inductive relation with and separated from the primary winding by a magnetic shunt including an air gap, at least one tap on the primary winding defining a first primary part between said tap and the first end terminal and a second primary part between said tap and the second end terminal, whereby said second primary part is connected between the tap and ground, one terminal of the secondary winding being connected to said tap, the end of said first primary part opposite the tap being connected to one terminal of the lamp, the second terminal of the secondary winding being connected in series with a condenser and extending to the second terminal of the lamp, the secondary winding and first primary part being so connected that their open circuit voltages add in the circuit including the lamp and being connected in auto-transformer relation across the lamp by virtue of their arrangement, the secondary winding being connected in a second circuit in series with the second primary part from the second terminal of the lamp to ground, the secondary winding and secondary part being in bucking relation in said second circuit whereby the total R.M.S. open circuit voltage from the second terminal to ground will always be less than the R.M.S. open circuit voltage across the lamp, the end of the first primary part forming a second tap of the primary winding, there being a third primary part between said second tap and the said one end terminal the voltage of which is not included in either of said circuits, and there being a bridged gap in the magnetic core in the vicinity of the secondary winding to provide a substantially peaked voltage for starting and a substantially unpeaked current for operating the lamp.

10. A system as claimed in claim 9 in which the core includes an outer shell and an inner central winding leg, the windings are coaxially mounted end to end on the winding leg, the shunt includes portions of the core extending between the shell and winding leg with air gaps in series with said portions, and the bridged gap is located in the central winding leg within the secondary winding and between the ends thereof.

11. A ballast adapted to be connected to a single fluorescent lamp of the rapid start type and also adapted to be connected to a source of A.C. voltage to ignite and operate the said lamp when connected in a system including both the lamp and source, and in which there is a grounded side of the source and a grounded metal member in the vicinity of the lamp for aiding in starting the lamp, which comprises an iron core mounting a primary winding and a secondary winding in loosely coupled voltage step-up inductive relation, a tap on the primary dividing the primary into two parts, the secondary winding being connected in additive auto-transformer relation with one part and together with said part having a pair of leads for extending connections to said lamp, a condenser in series with said secondary winding, one of said leads being connected at said tap, the end terminals of said primary winding having means for extending connections therefrom respectively to the source, the said one part being disposed between the tap and that end terminal adapted to be connected to the grounded side of the source, the iron core having a voltage peak producing structure in the vicinity of the secondary winding so as to provide a peak to ground voltage from one of said pair of leads to meet starting and safety requirements, while at the same time having an R.M.S. starting voltage across said pair of leads substantially greater than the R.M.S. voltage from either to ground.

12. A ballast for a single rapid start lamp comprising a primary winding and a secondary winding mounted on an iron core in voltage step-up, loose, inductive relation, a part of the primary being in additive auto-transformer connection with the secondary and together therewith having leads with a series condenser in them for extending connections to the lamp, the core having a bridged gap in the secondary part thereof, the primary winding connected across a line, one side of which is grounded, one end of said one part of said primary being coupled to said

grounded side of said line, the amount of primary included in said auto-transformer connection and the turns ratio being chosen such that the open circuit R.M.S. voltage across the connections to the lamp is higher than the safe R.M.S. voltage from one of said connections to ground, the peak starting voltage from one of said connections to ground is less than the safe peak voltage to ground and is in excess of the open circuit R.M.S. voltage by approximately 30%.

13. A ballast as claimed in claim **12** in which the ballast is constructed to ignite and operate a single 40 watt rapid start lamp from a 120 volts 60 cycle line, and in which the open circuit R.M.S. voltage across the connections is at least 227.5 volts, the safe R.M.S. voltage to ground is

at most 180 volts, and the peak voltage to ground is between 311 and 325 volts.

14. A ballast as claimed in claim **12** in which the primary winding includes another part coupled between said one part and said grounded side of the line and connected to said secondary winding in bucking relationship.

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