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BALLAST APPARATUS

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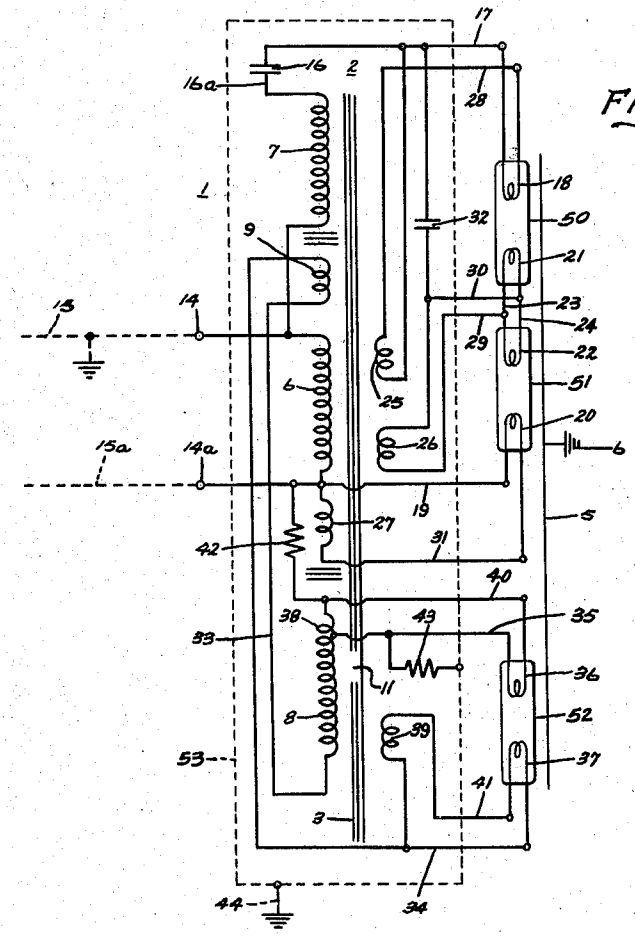
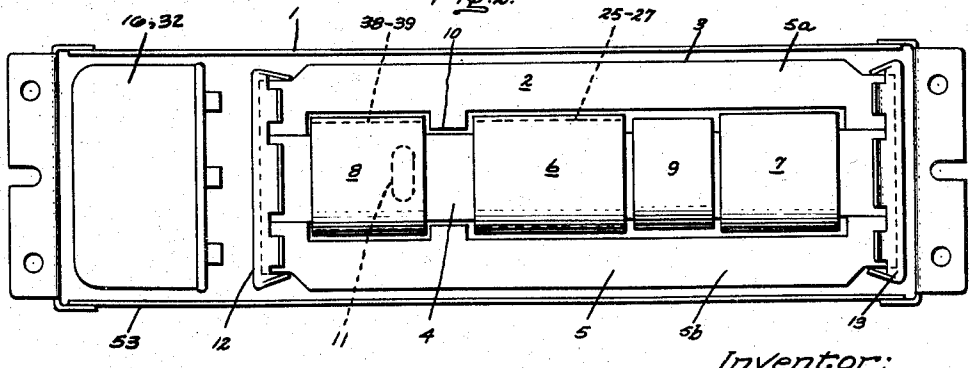


Fig. 1.

Fig. 2.



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BALLAST APPARATUS

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13 Claims. (Cl. 315—100)

My invention relates to ballast apparatus for starting and operating gaseous discharge lamps such as fluorescent lamps.

In most fluorescent lighting applications, the ballast apparatus for the lamp is mounted within the lamp fixture itself. Customarily, the ballast apparatus is secured in an enclosed channel in the upper portion of the fixture and leads extend from the ballast to the lamp holders through this channel. Generally, the fixtures are arranged to accommodate two lamps and the ballast is also designed for use with two lamps. There are, however, certain applications in which it is desired to mount three lamps within a single fixture, for example, to obtain an increased illumination level, and for these applications, the ordinary two-lamp ballast is obviously unsuited. It could, of course, be used for two of the lamps with a separate ballast being provided for the third lamp, but this would entail considerable expense. Thus, for reasons of economy, it is desirable that a ballast be provided for the three lamp fixtures, which is capable of handling all three lamps.

The three-lamp ballast must, of course, provide a good current balance between the lamps if the lighting effect from them is to be uniform. In other words, the ballast should cause approximately the same amount of current to flow through all three lamps to avoid objectionable differences in their light output. Also, for best operation with minimum power cost, it is ordinarily desirable that the ballast operate at unity power factor or at a slightly leading power factor. A further requirement of the ballast is that it be relatively small in width and shallow in height so that it can fit into the mounting channel in the usual fixture. The ballast can be relatively elongated since the channel usually extends for the length of the fixture, but ordinarily the size of the channel sets definite limits on the allowable height and width of the ballast.

Accordingly, it is a general object of my invention to provide a new and improved ballast for operating three fluorescent lamps; and it is a more specific object of my invention to provide a three-lamp ballast which is elongated and shallow for mounting within the fixture channel but yet gives a good current balance between the lamps and operates at high power factor.

Another object of my invention is to provide a three-lamp ballast which incorporates standard core punchings usable in two-lamp ballasts whereby the three-lamp ballast may be produced without appreciable design, tooling and other expense for its magnetic core.

A further object of my invention is to provide an improved arrangement of the windings in a ballast transformer, which is particularly advantageous for use in a three-lamp ballast but which may also be used in other ballast apparatus.

In carrying out my invention in one form thereof, I provide a ballast apparatus for starting and operating three fluorescent lamps which comprises a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member. A plurality of windings are disposed on the winding leg side by side relationship, these windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings. The lead circuit secondary winding is auto-transformer connected to the primary winding and is further connected in series circuit relation to a capacitive reactor to form a lead circuit for operating two of the lamps with leading current. The lag circuit secondary windings are electrically isolated from the primary winding and are serially interconnected to form a lag circuit for operating the third lamp with lagging current.

According to an important aspect of my invention, the windings are so arranged on the winding leg that the proper ballasting effect is obtained in both circuits to provide a good current balance therebetween. In particular, the one lag circuit secondary is located between the primary winding and the lead circuit secondary, with the other lag circuit secondary being located on the opposite side of the primary winding. A restricted section is provided in the winding leg under the last mentioned lag circuit secondary but otherwise the winding leg is of substantially uniform cross-section throughout. With this arrangement of the windings and the winding leg, the proper voltages and ballasting impedances are provided in both circuits for uniform lamp operation. The side by side arrangement of the windings also results in an elongated ballast which is shallow in height and width as desired for use with most lamp fixtures.

The subject matter which I regard as my invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. My invention, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing in which:

Fig. 1 is a schematic circuit diagram of a ballast apparatus embodying my invention; and

Fig. 2 is a plan view of the ballast apparatus included in the circuit of Fig. 1.

Referring now to the drawings, there is illustrated therein an improved ballast apparatus 1 for operating three gaseous discharge lamps such as the lamps 50, 51 and 52. The lamps 50, 51 and 52 are all mounted within a single fixture 5 and this fixture is preferably grounded as indicated at 6. The lamps are of the heated cathode type, each having a pair of filamentary cathodes which are illustrated in the form of a coil of tungsten wire. The lamps, for example, may be of the well-known rapid start type and their cathodes are continuously heated during operation as will be more fully described hereinafter.

The ballast apparatus for starting and operating the lamps comprises a high reactance autotransformer which is generally indicated at 2. The transformer 2 includes a magnetic core 3 having a center winding leg 4 and an outer yoke or flux return member 5. The yoke member 5, as shown, consists of oppositely disposed sections 5*a* and 5*b* which have end legs abutting the winding leg 4 at its opposite ends. The winding leg and the yoke sections are both formed of a plurality of stacked laminations of magnetic material, such as, for example, transformer steel.

Arranged on the winding leg 4 within the yoke member 5 are a plurality of windings or coils for starting and operating the fluorescent lamps 50–52. These windings include a primary winding 6, a lead circuit secondary winding 7 and a pair of lag circuit secondary windings 8 and 9. As shown, the windings are arranged in side by side relationship on the winding leg with the lag circuit secondary 9 being positioned between the primary 6 and the lead circuit secondary 7. The other lag circuit secondary 8 is positioned on the opposite side of the primary

6 from the lag secondary 9, and between the lag secondary 8 and the primary, flux leakage legs or shunts 10 are provided on the yoke member 3. The flux leakage legs 10 provide a flux shunting path between the primary 6 and the lag secondary 8 and, as shown, a small air gap is provided between the end of each leakage leg and the winding leg to make this shunting path of relatively high reluctance.

Besides the shunt path 10 the core is also provided with another very important means for controlling the flux linking the coil 8. This means comprises a slot or bridged gap 11 which is formed in the winding leg 4 in the region of the secondary 8. Specifically, in the illustrated embodiment, the bridged gap 11 is formed beneath the right-hand side of the coil. This bridged gap provides the winding leg with a portion of restricted cross-section, which determines the impedance of the coil 8 and specially reduces its impedance over that which would be present without such a gap. The purpose and effect of this bridged gap on the operation of the ballast apparatus will be explained in detail hereinafter. In the construction of the transformer 2, the coils 6–9 are formed independently and are slipped onto the winding leg over the ends thereof. When the coils are in place, the yoke sections 5*a* and 5*b* are then placed over them and abutted against the ends of the winding leg to complete the core. As shown, the entire core structure is held together by means of clamps 12 and 13 which are fitted over the opposite ends of the core.

Referring now to Fig. 1, it will be seen that the primary 6 is provided with suitable input leads 14 and 14*a* by which it may be connected to a suitable source of single phase alternating current such as is indicated by the supply lines 15 and 15*a*. The supply line 15 is shown as grounded and when the apparatus 1 is connected to a grounded supply, the input lead 14 should be connected to the grounded side of the line. The lead circuit secondary 7 is autotransformer connected to the primary 6 so that the two windings are placed in an additive voltage relationship. As shown, the autotransformer connection is made at the lead 14.

Besides being autotransformer connected to the primary, the lead circuit secondary 7 is also connected in series circuit relation to a capacitor 16 to form a lead circuit for energizing the lamps 50 and 51 with leading current. As shown, the lead secondary 7 is connected to the capacitor 16 by a lead 16*a* and from the other side of the capacitor, an output lead 17 extends out of the ballast for connection to the upper cathode 18 of the lamp 50. The other output lead for the lead circuit comprises the lead 19 which is connected to the end of the primary remote from the autotransformer and extends out of the ballast for connection to the lower cathode 20 of the lamp 51. The remaining two cathodes 21 and 22 of the two lamps are serially connected by means of the leads 23, 24 to complete the circuit for the lamps. It will be noted that in this circuit the primary 6, the lead secondary 7, the capacitor 16 and the lamps 50 and 51 are all connected in series circuit relation. As is shown in Fig. 2, the capacitor 16 is positioned at one end of the ballast case 53 which also encloses the high reactance autotransformer 2, and the connection 16*a* between the capacitor and the secondary 7 and the autotransformer connection between the primary and secondary 7 are both made within the case so that only the leads for the lamps extend out of the case.

As mentioned above, the lamps 50 and 51 are preferably rapid start lamps including heated cathodes, and suitable heating windings are mounted on the winding leg 4 for energizing the lamp cathodes during operation. Specifically, three heating windings or secondaries 25, 26 and 27 are provided on the winding leg in the region of the primary 6 so that they are tightly coupled thereto. As is indicated in Fig. 2 these heating windings 25–27 may be wound directly over the primary 6. The first heating winding 25 is connected across the cathode 18 by means of the leads 17 and 28 so that it continuously supplies heating current to cathode 18 during the lamp operation. The second heating winding 26 supplies heating current to the cathodes 21 and 22 through the leads 29, 30, 23 and 24. As shown, the cathodes 21 and 22 are connected in parallel across the heating winding 26 for heating purposes. The final heating winding 27 is connected across the cathode 20 by leads 19 and 31 so as to pass heating current through it. As shown, winding 27 may form an extension of the primary 6.

In order to start the lamps 50 and 51 sequentially, a starting capacitor 32 is connected between the leads 17 and 30 so that it is in parallel with the lamp 50. As indicated in Fig. 2, the starting capacitor 32 is preferably within the same can as the lead circuit capacitor 16. When the ballast apparatus is first placed in operation, i.e., when the primary 6 is first energized, the combined voltages of the primary 6 and the secondary 9 are applied across the lamp 51 through the capacitor 32. This causes the lamp 51 to ignite. Once the lamp ignites, current, of course, flows through the capacitor 32 which is of much greater impedance than the lamp 51 so that most of the voltage in the lead circuit then appears across it. This places a great enough voltage across the lamp 50 to cause it to ignite which action occurs substantially immediately. After lamp 50 ignites, the lamps 50 and 51 are then operated in series with the lamp 50 effectively forming a low impedance bypass around the starting capacitor 32. Due to the capacitor 16 in the series circuit, the circuit draws a leading current through the lamps 50 and 51. The circuit of lamps 50 and 51 therefore comprises what is known as a "lead circuit."

Besides starting and operating the lamps 50 and 51, the ballast 1 also serves the same function for the lamp 52. The lamp 52 is started and operated by the two lag circuit secondaries 8 and 9. As shown in Fig. 1, the windings 8 and 9 are serially connected in additive voltage relationship by means of a connection 33 within the ballast case 53. At their ends, remote from the connection 33, the two lag secondaries are connected to the lamp 52 by means of the output leads 34 and 35, and it will be seen that by reason of these leads the two lag secondaries 8 and 9 form a series circuit with the lamp 52.

In order to heat the cathodes 46 and 37 of the lamp 52 during operation, there are provided a pair of heating windings 38 and 39 which are located on the core in the region of the lag secondary 8. The heating windings 38 and 39 are closely coupled to the lag secondary 8 and in the illustrated embodiment, they are wound directly over the lag secondary 8 as is indicated in Fig. 2. The winding 38 is connected across the cathode 36 by means of the leads 35 and 40, and the winding 39 is connected across the cathode 37 by means of the leads 34 and 41. With these connections the windings 38 and 39 continuously supply heating current to the cathodes 36 and 37 during the operation of lamp 52. The heating winding 38 may be formed as shown in Fig. 2 as an extension of the lag secondary 8.

In the series operating circuit for the lamp 52 there is no reactance other than that provided by the lag secondaries 8 and 9. In other words, there is only inductive reactance in this circuit and thereby a lagging current is drawn by the circuit, which current, of course, passes through the lamp 52. This circuit is thereby known as a "lag circuit." Since this circuit draws lagging current while the circuit for lamps 50 and 51 is drawing leading current, the net result is that the ballast operates at quite a good power factor. In particular, in one embodiment of my invention, the ballast has been found effective to operate three F40T12/RS forty watt rapid start lamps with an input power factor of about 94%.

The construction and arrangement of the autotransformer 2 comprises a very important aspect of my invention. In particular, the successful operation of my

ballast apparatus depends upon the positioning and arrangement of the various secondaries relative to primary 6. I have found that by positioning the lag secondary 9 between the primary 6 and the lead secondary 17 and by positioning the lag secondary 8 on the other side of the primary with a bridged gap beneath it, a proper ballasting impedance can be obtained in both the lead circuit and the lag circuit to provide a good balance between the lamps. With this arrangement of the windings, sufficient voltage is provided to start the lamps, and once the lamps are in operation, the correct ballasting effect is produced to give good current balance between them.

It will be noted that all of the secondaries 7–9 are loosely coupled to primary, each having at least some leakage reactance. In a relative scale, the winding 8 is the most loosely coupled to the primary and the winding 9 is the most tightly coupled, with the winding 7 falling therebetween. The leakage flux path for winding 8, of course, comprises the shunt legs 10, while for windings 7 and 9, the flux leakage path comprises the air space between the winding leg and the yoke member. Since the coil 7 is more remotely positioned from the primary than coil 9, there is more leakage area for it whereby it is less closely coupled to the primary than winding 9.

As is well-known in the art, leading current flowing through a loosely coupled secondary winding tends to create additional in-phase flux in the magnetic circuit of that winding. In other words, leading current flowing through a loosely coupled winding tends to increase the voltage output of the winding. For this reason, it is ordinarily necessary to provide a bridged gap or other flux restriction in the magnetic circuit of a lead circuit secondary. However, by positioning the lag secondary 9 between the lead secondary 7 and the primary, I obviate the need for such a gap in the present ballast. The lagging current flowing in the secondary 9 during lamp operation creates a magnetomotive force that opposes the flux created by the primary 6 and thereby increases the reluctance of mutual flux path between the primary 6 and the lead secondary 7. The primary flux, instead of finding a low reluctance path to link the coil 7, rather tends to leak across the air gap in the region of the lag secondary 9, whereby a decoupling effect is provided between the primary 6 and the lead circuit secondary 7. In one embodiment of my invention including the illustrated arrangement of the windings, I have found that the voltage in the lead circuit secondary 7 rises only 33 percent from open circuit to operating conditions. This voltage rise is appreciably less than that which would occur without the lag circuit coil 9 between it and the primary 7. At this condition, an insufficient flux is created in the region of the secondary 7 to cause any considerable saturation of the winding leg 4 under secondary 7. Thus, the coil 7 presents a high ballasting impedance during operation and together with the capacitor 16 serves to ballast the lamps 50 and 51.

Without the positioning of the lag circuit secondary 9 between the lead circuit secondary 7 and the primary, the leading current in coil 7 together with the primary flux would very likely cause considerable saturation of the winding leg beneath the coil 7, thereby greatly reducing its impedance and allowing an over large current to flow in the lead circuit. Succinctly stated, the lag circuit secondary 9 by its magnetomotive force increases the reluctance of the mutual flux path between the primary 6 and the lead secondary 7 at the point in each half cycle of operation at which the lead secondary and the primary would otherwise saturate the winding leg beneath the lead secondary. By this effect, the lag secondary 9 prevents the primary and the lead secondary 7 from saturating the winding leg beneath the lead secondary and thereby reduces its ballasting impedance. As a result, no bridged gap or other restricted portion is needed in the winding leg in the region of the lead secondary 7.

Referring to the lag circuit, it will be understood that in order to obtain sufficient voltage for starting the lamp 52 in the lag circuit, the coil 8 must include a relatively large number of turns. However, unless a restriction is provided in the magnetic circuit of the secondary 8, its inductive reactance or impedance will be such as to limit the current in the lag circuit below the desired value. The bridged gap 11 in the winding leg beneath the lag secondary 8 raises the reluctance of the magnetic circuit of the secondary 8 and thereby causes it to present the desired impedance during operation. Besides determining the impedance of the winding 8, the bridged gap also has the effect of reducing its generated voltage from open circuit to operating condition. However, I have found that the voltage in the other lag secondary 9 tends to go up somewhat from the open circuit conditions to operating conditions due to the effect of the lead circuit, whereby sufficient voltage is provided in the lag circuit during operation. The leakage legs 10, of course, provide a shunt path for the primary flux between the secondary 8 and the primary 6 during operation. Due to the impedance value of the coil 8 as determined by the bridged gap, together with the rise in voltage in the other lag secondary 9 when operating current is flowing in both circuits, a current is produced in the lag circuit which is about the same magnitude as that in the lead circuit, thereby a good current balance is provided between the lamps with their light output being relatively uniform.

From all of the above, it will be seen that I have provided an improved ballast for use with three fluorescent lamps. This ballast provides operation of the lamps at a high power factor and with a good current balance between the lamps. Further, by reason of the side by side relationships of the winding within the core, the ballast may be relatively shallow in both height and width. This is, of course, desirable for use with most lighting fixtures. Also, the ballast may utilize the same core as is used for certain two-lamp ballasts for operating instant start lamps. Thus, no design, tooling or other expense is involved for the core, whereby the manufacturing cost of the ballast is very favorable.

In considering the operation of the lead and lag circuits, it will be noted that it is desirable for their proper operation that the heating windings be positioned as above described. With the lead circuit heating windings 25–27 positioned in the region of the primary winding, they are linked by approximately the same flux during lamp operation as during starting. Thus, they produce same heating current at all times which is, of course, very desirable for rapid start lamps. As for the lag circuit heating windings 38 and 39, their voltage and thereby the heating current goes down somewhat after lamp 52 is started due to the effect of the bridged gap 11 and the shunts 10 in the magnetic circuit of lag secondary 8. This reduction in the heating current does not, however, affect lamp operation or lamp life to an appreciable extent, and is much better in that regard than would be the increased heating current created if the heating windings 38 and 39 were wound over the other lag secondary 9. As pointed out above, the flux linking secondary 9 is somewhat greater during lamp operation than during starting whereby if the lag circuit heating windings were associated with it, the heating current would increase after the lamps were started. This would ordinarily quite adversely affect lamp life. It is generally impractical to wind the lag circuit heating windings over the primary since this would increase the number of leads and connections required within the ballast, and also because of other problems, such as insulating the heating windings from the primary and a lack of space in the primary winding of the core.

Referring now to Figs. 1 and 2, I have shown therein a pair of starting aid resistors 42 and 43 through which auxiliary circuits are completed under certain condition to ionize the gas around the lamp cathodes for initially igniting the lamps. To aid in igniting the lamps, it is desirable that the gas in the lamp envelope be ionized

around one or both of the cathodes. To effect such ionization, the capacitance between the cathodes and the metallic fixture **5** is used to pass an auxiliary current from the cathode of the lamp to be ignited to the fixture whereby the gas is ionized in the region of the cathode. The resistors **42** and **43**, which are of high resistance in the order of two megohms, appear in the circuits for creating these auxiliary currents as follows:

Referring first to the lag current, it will be seen that the resistor **43** ties the upper end of the secondary **8** to the ballast case **53** which is itself grounded to the fixture **5** through the case ground **44** and the fixture ground **6**. Normally, of course, the grounding connection between the case and the fixture is accomplished simply through the bolting of the case to the fixture. Since the upper end of winding **8** is at ground potential, the full voltage of the windings **8** and **9** thereby appears between the cathode **37** and the fixture **5** through the case ground **44** and the fixture ground **6**. Normally, of course, the grounding connection between the case and the fixture is accomplished simply through the bolting of the case to the fixture. Since the upper end of winding **8** is at ground potential, the full voltage of the windings **8** and **9** thereby appears between the cathode **37** and the fixture **5** at the same voltage as it is initially applied across the cathodes 36 and 37. With this voltage between the cathode **37** and the fixture, a small current thereby flows from the cathode **37** to the fixture through the distributed capacitance between them. This small current ionizes the gas around the cathode **37**, and this ionization together with the potential applied between the cathodes is effective to ignite lamp **4**. After the lamp starts, the current flowing through the auxiliary circuit is very minor compared to that between the lamp cathodes, whereby its effect on lamp operation is negligible.

Referring next to the lead circuit, it will be seen that with lead **14** connected to the grounded side **15** of the power supply, the voltage of the lead secondary **7** will be applied between cathode **22** of lamp **51** and the fixture through capacitor **32** when power is first applied to the ballast. This will cause a small current to flow between the cathode **22** and the fixture ionizing the gas around the cathode. This, together with the voltage across the lamp cathodes causes it to ignite, and once the lamp **51** is ignited, the auxiliary current is negligible relative to the lamp circuit current between the cathodes. The same effect also occurs with regard to cathodes of lamp **50** to aid it in igniting once lamp **51** has fired.

Now, however, suppose that the ballast is to operate from an ungrounded power supply, in this instance the resistor **42** appears in the starting aid circuit for the lead circuit lamps. The resistor **42**, as shown, ties the primary lead **14***a* to the lag circuit heating winding **38** and the resistor **43** in turn ties the winding **38** to the ballast case **53** and thereby to the fixture **5**. Thus, when power is first placed on the ballast, the combined voltages of the primary **6** and the secondary **7** appear between cathode **22** of lamp **51** and the conductive fixture **5**. The same starting aid effect is again secured, i.e., the gas around cathode **22** is ionized by a small current flow between the cathode and the fixture to ionize the gas around the cathode. After lamp **51** is started, the gas around the cathodes of lamp **50** is likewise ionized by this circuit to aid in starting lamp **50**.

It will be understood that due to the very high resistance of resistors **42** and **43**, no shock hazard is introduced into the ballast due to the provision of the starting aid circuits.

While in accordance with the patent statutes I have described what at present is considered to be the preferred embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is therefore intended in the appended claims to cover all such modifications as fall within the true spirit and scope of the invention:

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Ballast apparatus for starting and operating three fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in series circuit relation and to said primary winding in autotransformer relation to form a lead circuit for operating two of said lamps with leading current, said lag circuit secondary windings being electrically isolated from said primary winding and being serially interconnected to form a lag circuit for operating the other of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary winding, and said winding leg having a bridged gap beneath said other lag secondary winding, whereby said windings are effective to operate said lamps in said lead and lag circuits with a good current balance therebetween.

2. The combinaton of claim 1 in which said yoke member has a flux leakage leg projecting toward said winding leg between said primary winding and said other lag circuit secondary winding.

3. Ballast apparatus for starting and operating three fluorescent lamps of the heated cathode type, comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in series circuit relation and to said primary winding in autotransformer relation to form a lead circuit for operating two of said lamps with leading current, said lag circuit secondary windings being electrically isolated from said primary winding and being serially interconnected to form a lag circuit for operating the other of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary winding, and said winding leg having a restricted portion in the region of said other lag secondary winding, whereby said windings are effective to operate said lamps in said lead and lag circuits with a good current balance therebetween, and means for heating the cathodes of said lamps comprising a plurality of heating windings located on said winding leg in the region of said primary winding for heating the cathodes of the two lamps connected in said lead circuit, and a pair of heating windings located on said winding leg in the region of said other lag secondary for heating the cathodes of the lamp connected in said lag circuit.

4. Ballast apparatus for starting and operating a plurality of fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in

series circuit relation to form a lead circuit for operating at least one of said lamps with leading current, said lag circuit secondary windings being serially interconnected to form a lag circuit for operating at least a second of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary winding, and said winding leg having a restricted portion in the region of said other lag secondary winding, whereby said windings are effective to operate said lamps in said lead and lag circuits with a good current balance therebetween.

5. Ballast apparatus for starting and operating a plurality of fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a first lag circuit secondary winding, a primary winding, a second lag circuit secondary winding and a lead circuit secondary winding arranged on said winding leg in the order named, a capacitive reactor, said lead circuit secondary being connected to said capacitor reactor in series circuit relation to form a lead circuit for operating at least one of said lamps with leading current, said lag circuit secondary windings being serially interconnected to form a lag circuit for operating at least a second of said lamps with lagging current, said winding leg having a restricted portion in the region of said first lag circuit secondary winding and being otherwise of substantially the same cross-section throughout its length.

6. Ballast apparatus for starting and operating three fluorescent lamps of the heated cathode type comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a first lag circuit secondary winding, a primary winding, a second lag circuit secondary winding and a lead circuit secondary winding arranged on said winding leg in the order named, a capacitive reactor, said lead circuit secondary being connected to said primary winding in autotransformer relation and to capacitor reactor in series circuit relation to form a lead circuit for operating two of said lamps with leading current, said lag circuit secondary winding being serially interconnected to form a lag circuit for operating the other of said lamps with lagging current, said winding leg having a bridged gap in the region of said first lag circuit secondary winding and being otherwise of substantially the same cross-section throughout its length, and means for heating the cathodes of said lamps comprising a plurality of heating windings located on said winding leg in the region of said primary winding for heating the cathodes of the two lamps connected in said lead circuit, and a pair of heating windings located on said winding leg in the region of said other lag secondary for heating the cathodes of the lamp connected in said lag circuit.

7. Ballast apparatus for starting and operating a plurality of fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a first lag circuit secondary winding, a primary winding, a second lag circuit secondary winding and a lead circuit secondary winding arranged on said winding leg in the order named, a capacitive reactor, said lead circuit secondary being connected to said capacitor reactor in series circuit relation to form a lead circuit for operating at least one of said lamps with leading current, said lag circuit secondary winding being serially interconnected to form a lag circuit for operating at least a second of said lamps with lagging current, said winding leg having a restricted portion in the region of said first lag circuit secondary winding and being otherwise of substantially the same cross-section throughout its length, a conductive casing enclosing said high reactance transformer and said capacitive reactor, and a pair of high ohmage resistors respectively connecting one end of one of the lag circuit secondary windings to said casing and to one end of said primary winding.

8. Ballast apparatus for starting and operating three fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in series circuit relation and to said primary winding in autotransformer relation to form a lead circuit for operating two of said lamps with leading current, said lag circuit secondary windings being electrically isolated from said primary winding and being serially interconnected to form a lag circuit for operating the other of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary, and means for heating the cathode of said lamp comprising a plurality of heating windings located on said winding leg in the region of said primary for heating the cathode of the lamps connected in said lead circuit, and a pair of heating windings located on said winding leg in the region of said other lag circuit secondary winding for heating the cathodes of the lamp connected in said lag circuit.

9. Ballast appartus for starting and operating a plurality of fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a first lag circuit secondary winding, a primary winding, a second lag circuit secondary winding and a lead circuit secondary winding arranged on said winding leg in the order named, a leakage leg on said core located between said first lag secondary winding and said primary winding, a capacitive reactor, said lead circuit secondary being connected to said capacitor reactor in series circuit relation to form a lead circuit for operating at least one of said lamps with leading current, said lag circuit secondary winding being serially interconnected to form a lag circuit for operating at least a second of said lamps with lagging current, said winding leg having a restricted portion in the region of said first lag circuit secondary winding and being otherwise of substantially the same cross-section throughout its length.

10. Ballast apparatus for starting and operating a plurality of fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a first lag circuit secondary winding, a primary winding, a second lag circuit secondary winding and a lead circuit secondary winding arranged on said winding leg in the order named, a capacitive reactor, said lead circuit secondary being connected to said capacitor reactor in series circuit relation to form a lead circuit for operating at least one of said lamps with leading current, said lag circuit secondary winding being serially inter-connected to form a lag circuit for operating at least a second of said lamps with lagging current, and a leakage leg on said core located between said first lag circuit secondary winding and said primary winding.

11. Ballast apparatus for starting and operating three fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in series cir-

cuit relation and to said primary winding in autotransformer relation to form a lead circuit for operating two of said lamps with leading current, said lag circuit secondary windings being electrically isolated from said primary winding and being serially interconnected to form a lag circuit for operating the other of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary winding, and said winding leg having a restricted portion in the region of said other lag secondary winding, and said core having a leakage leg between said primary winding and said one secondary windings, whereby said windings are effective to operate said lamps in said lead and lag circuits with a good current balance therebetween.

12. Ballast apparatus for starting and operating three fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in series circuit relation and to said primary winding in autotransformer relation to form a lead circuit for operating two of said lamps with leading current, said lag circuit secondary windings being electrically isolated from said primary winding and being serially interconnected to form a lag circuit for operating the other of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary, whereby said windings are effective to operate said lamps in said lead and lag circuits with a good current balance therebetween.

13. Ballast apparatus for starting and operating a plurality of fluorescent lamps comprising a high reactance transformer having a magnetic core with an elongated winding leg and an outer yoke member, a plurality of windings disposed on said winding leg in side by side relationship, said windings including a primary winding for connection to an alternating current source, a lead circuit secondary winding and a pair of lag circuit secondary windings, a capacitive reactor, said lead circuit secondary winding being connected to said capacitive reactor in series circuit relation to form a lead circuit for operating at least one of said lamps with leading current, said lag circuit secondary windings being serially interconnected to form a lag circuit for operating at least a second of said lamps with lagging current, one of said lag circuit secondaries being located on said winding leg between said primary winding and said lead circuit secondary winding and the other of said lag circuit secondary windings being located on the opposite side of said primary winding, and said winding leg having a restricted portion in the region of said other lag secondary winding, whereby said windings are effective to operate said lamps in said lead and lag circuits with a good current balance therebetween, and a conductive casing enclosing said high reactance transformer and said capacitive reactor, and a pair of high ohmage resistors respectively connecting one end of one of the lag circuit secondary windings to said casing and to one end of said primary winding.

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