

May 5, 1959

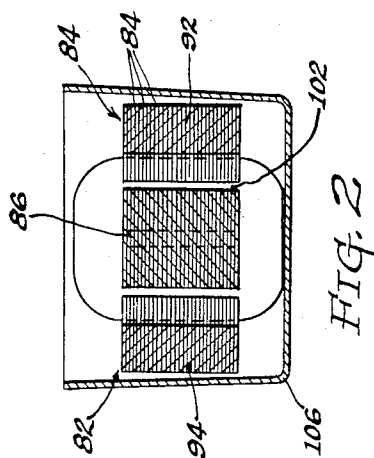
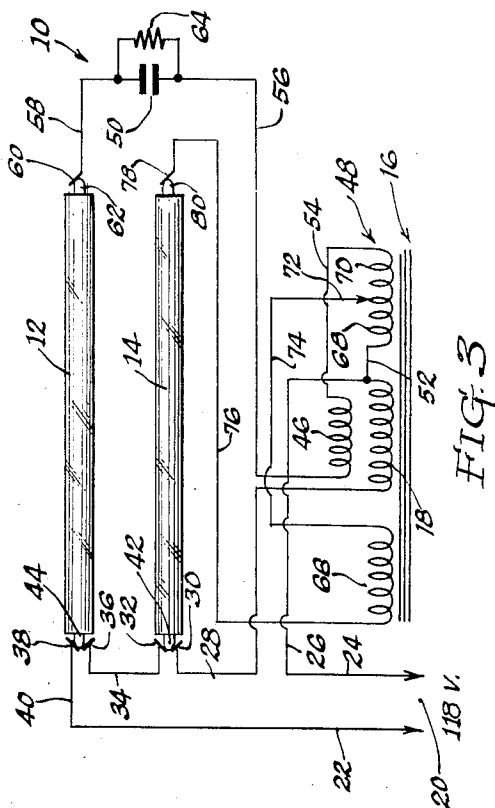
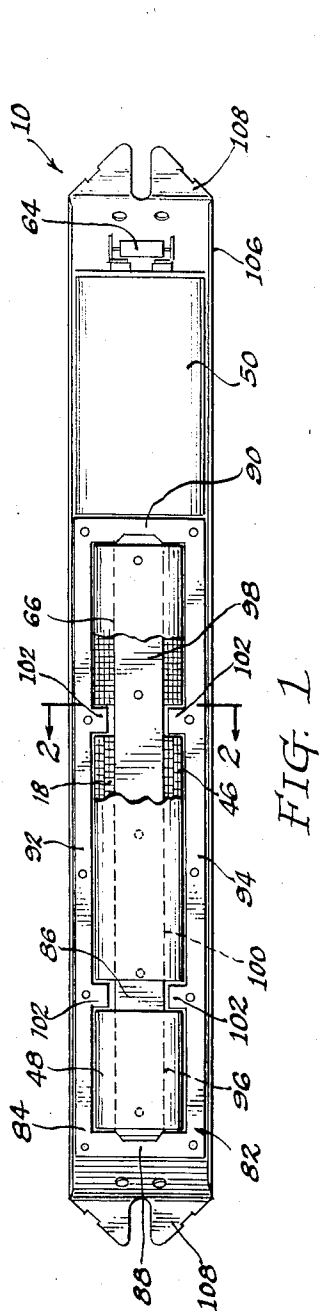
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BALLASTS FOR GASEOUS DISCHARGE LAMPS

Filed Oct. 10, 1956

5 Sheets-Sheet 1



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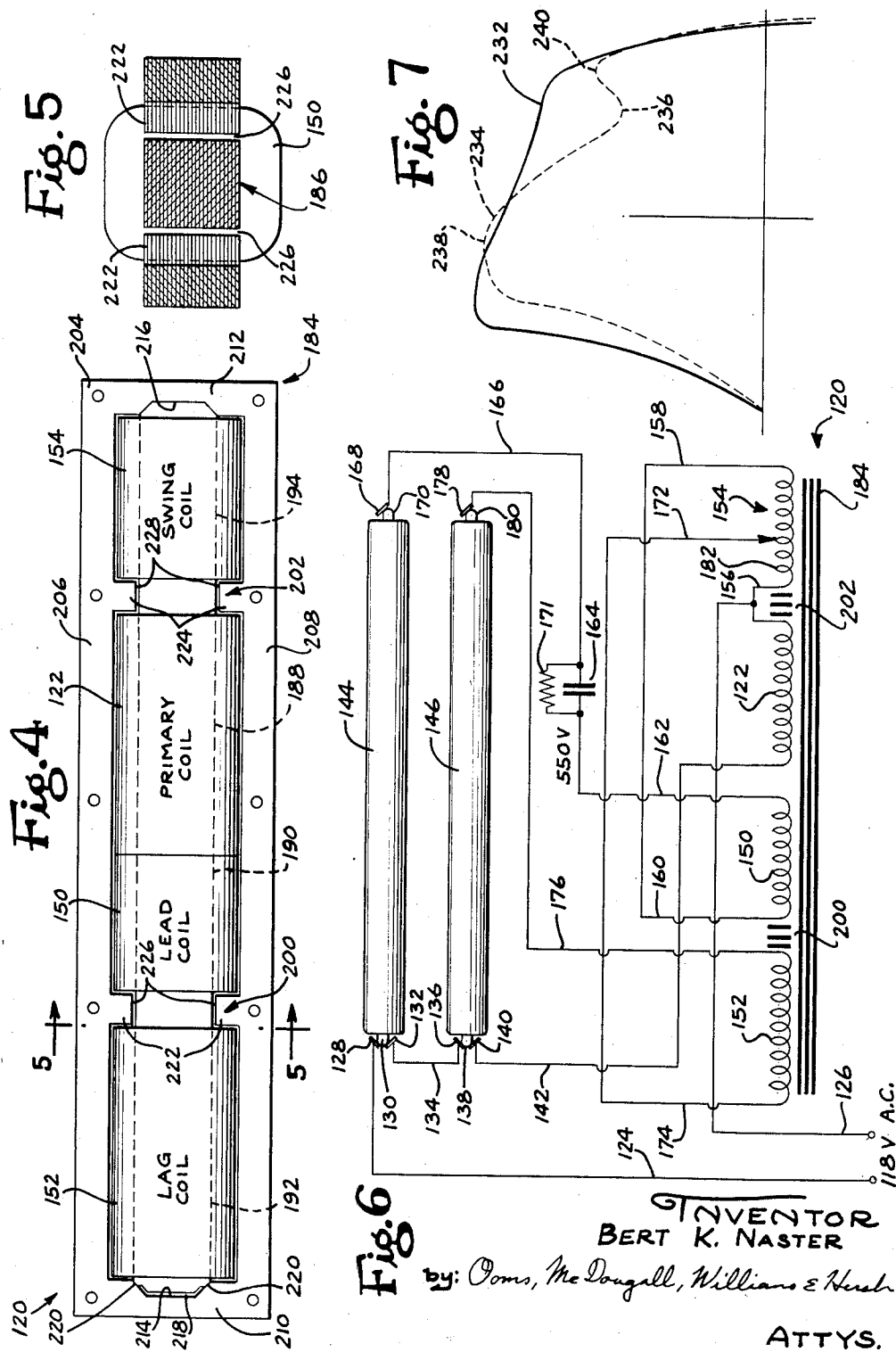
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BALLASTS FOR GASEOUS DISCHARGE LAMPS

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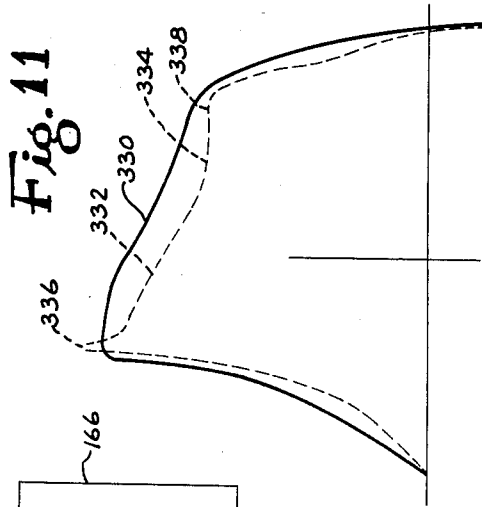
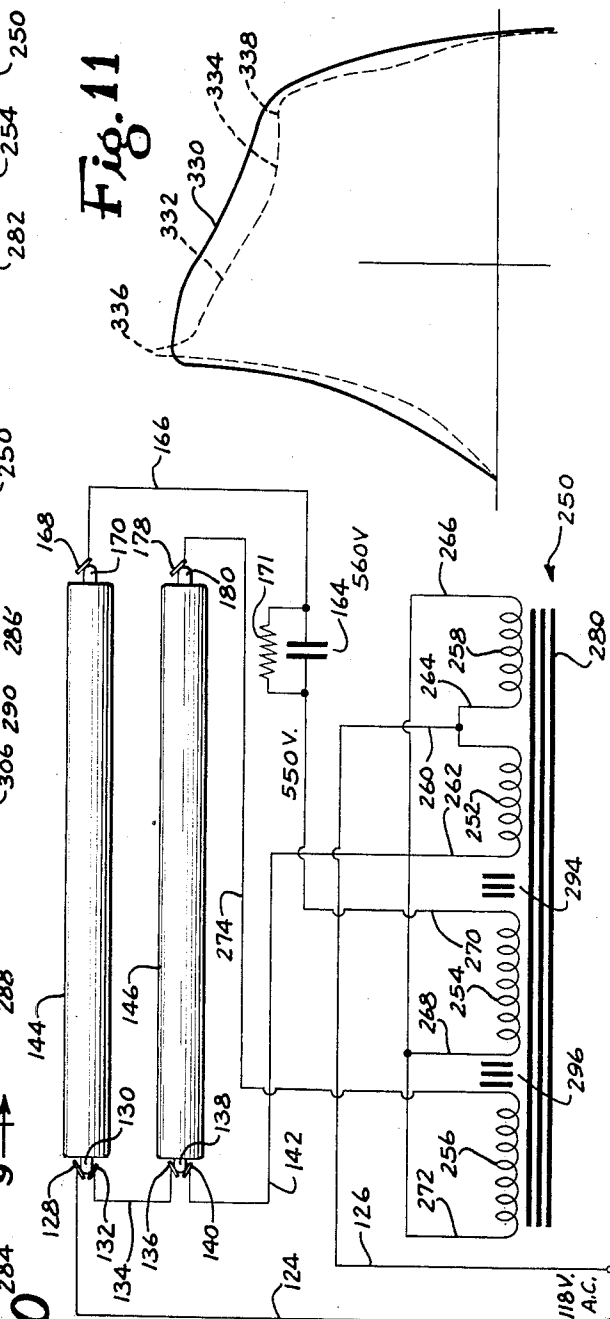
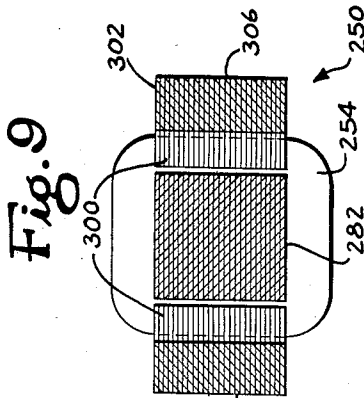
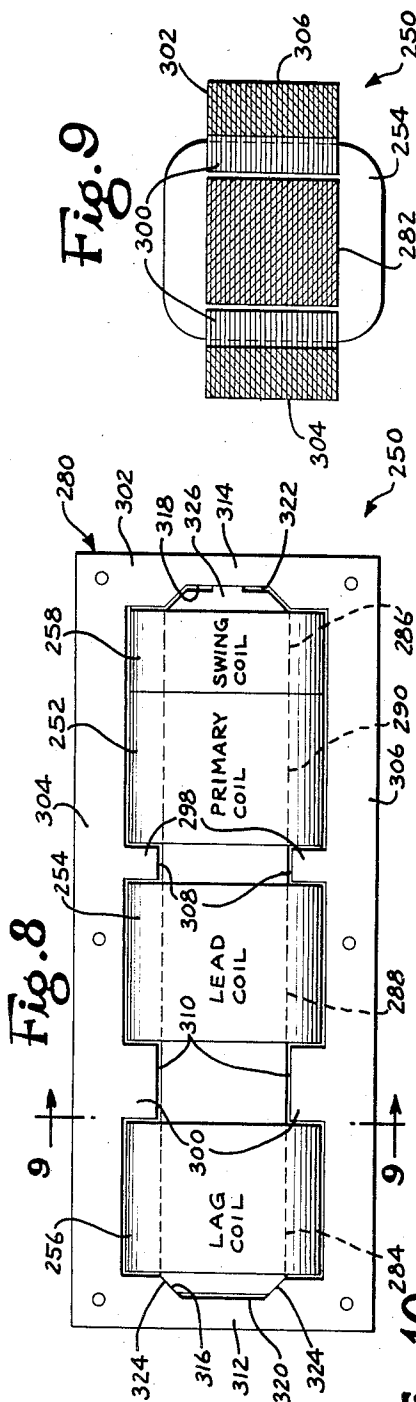
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BALLASTS FOR GASEOUS DISCHARGE LAMPS

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5 Sheets-Sheet 3



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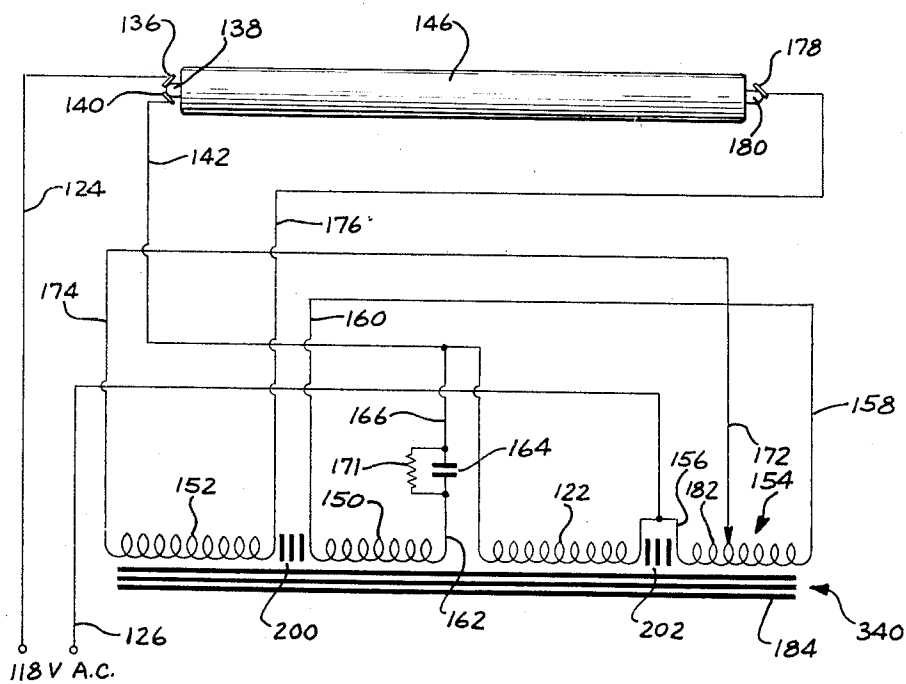
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BALLASTS FOR GASEOUS DISCHARGE LAMPS

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Fig. 12



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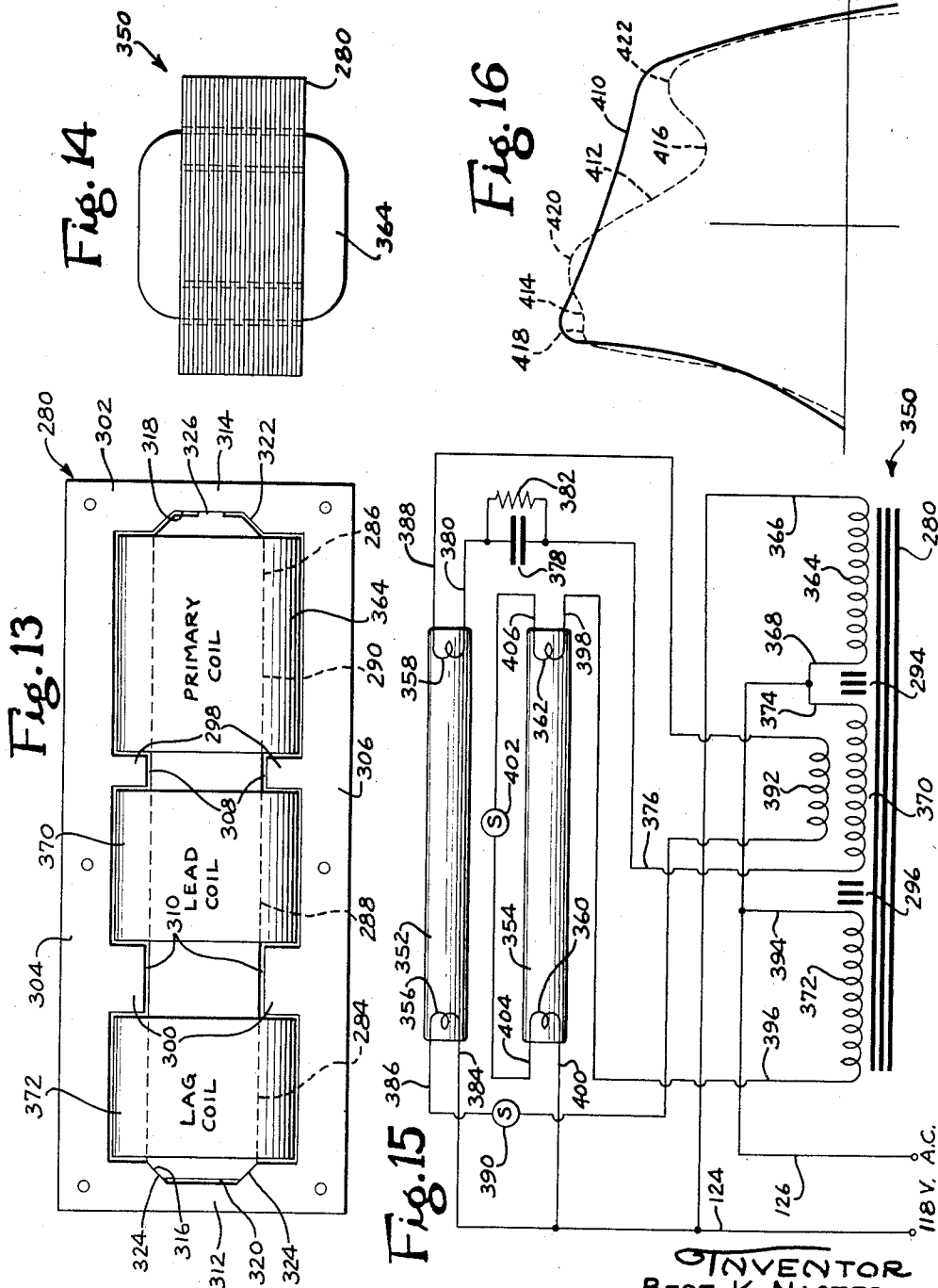
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BALLASTS FOR GASEOUS DISCHARGE LAMPS

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5 Sheets-Sheet 5



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BALLASTS FOR GASEOUS DISCHARGE LAMPS

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Application October 10, 1956, Serial No. 615,128

15 Claims. (Cl. 315-138)

This invention relates to new and improved ballasts for use in starting and operating fluorescent lamps or other gaseous discharge lamps. More specifically, the present invention relates to lead-lag ballasts adapted to operate one fluorescent lamp with leading current, while operating another lamp with lagging current. Thus the currents through the lead and lag lamps differ substantially in phase. The phase difference will approach 90°. With this type of arrangement, the phase difference in the lamp currents minimizes the combined stroboscopic effect of the lamps. Moreover, a lead-lag ballasting arrangement of this character will operate at a high power factor, approaching unity, rather than at the low power factors characteristic of inductive ballast arrangements. This application is a continuation in part of my co-pending application, Serial No. 543,069, filed October 27, 1955, and now abandoned.

One object of the present invention is to provide a new and improved lead-lag ballast which will operate at a substantially higher power factor than has heretofore been obtained with commercial lead-lag ballasts.

A further object is to provide a new and improved lead-lag ballast which will provide ample voltage for starting the lamps.

Another object is to provide a new and improved lead-lag ballast which tends to start the lead and lag lamps sequentially, the starting of the lead lamp being effective to increase the starting voltage applied to the lag lamp.

It is a further object to provide a new and improved lead-lag ballast which may readily be varied in construction to obtain the maximum possible power factor, simply by changing the position of a tap on one of the windings, without any necessity for changing the construction of the laminated core for the ballast.

Another object is to provide a new and improved lead-lag ballast whereby the waveform of the current through the lead lamp is improved, with the result that the ballast will operate with lower losses and at a higher power factor, and will operate the lead lamp with enhanced brilliance.

A further object is to provide a new and improved lead-lag ballast whereby the lamp currents and the power delivered to the lamps will remain nearly constant over an extremely wide range of input voltage.

Another object is to provide a new and improved lead-lag ballast which will achieve improved balance between the lead and lag lamps, with respect to lamp current, power consumption and brilliance.

It is another object to provide a new and improved lead-lag ballast capable of operating lamps with enhanced power input and brilliance, yet with reduced lamp current with resulting prolongation in lamp life.

A further object is to provide a new and improved lead-lag ballast which will operate the lamps with improved brilliance, yet with low input current to the ballast and low losses therein, with the result that the ballast will operate at a high power factor and with high efficiency,

but at a low operating temperature and with a minimum of noise and hum.

It is a further object to provide a new and improved lead-lag ballast capable of operating at high efficiency and with a high power factor and high lamp brilliance, while utilizing inexpensive grades of cold rolled steel in the core, rather than the expensive grades of silicon steel usually employed.

Further objects and advantages of the present invention will appear from the following description, taken with the accompanying drawings, in which:

Fig. 1 is a plan view of an exemplary ballast constituting a first illustrative embodiment of the invention.

Fig. 2 is an elevational sectional view taken generally along a line 2-2 in Fig. 1.

Fig. 3 is a schematic wiring diagram of the illustrative ballast of Fig. 1.

Fig. 4 is a plan view of another ballast, constituting a second illustrative embodiment of the invention.

Fig. 5 is an elevational sectional view taken generally along line 5-5 in Fig. 4.

Fig. 6 is a schematic wiring diagram of the ballast of Fig. 4.

Fig. 7 is a diagrammatic view showing the waveform of the lead lamp current for the ballast of Figs. 4-6.

Fig. 8 is a plan view of another ballast constituting a third illustrative embodiment of the present invention.

Fig. 9 is an elevational sectional view taken generally along a line 9-9 in Fig. 8.

Fig. 10 is a schematic wiring diagram of the ballast of Fig. 8.

Fig. 11 is a diagrammatic view showing the waveform of the lead lamp current for the ballast of Figs. 8-10.

Fig. 12 is a schematic wiring diagram of another modified ballast for operating only one lamp.

Fig. 13 is a plan view of still another ballast constituting another illustrative embodiment of the present invention.

Fig. 14 is an end elevational view of the ballast of Fig. 13.

Fig. 15 is a schematic wiring diagram of the ballast of Fig. 13.

Fig. 16 is a diagrammatic view showing the waveform of the lead lamp current for the ballast of Fig. 13.

If the drawings are considered in greater detail, it will be seen that Figs. 1-3 illustrate a ballast 10 adapted to start and operate two lamps 12 and 14, which may be fluorescent lamps or other gaseous discharge lamps. It will be understood that each of the two lamps may be replaced with two or more shorter lamps connected in series.

It will be seen from the schematic wiring diagram of Fig. 3 that the illustrative ballast 10 comprises a transformer 16 which preferably is arranged and connected as an auto-transformer. In this instance, the transformer 16 is provided with a primary winding 18, together with two secondary winding circuits adapted to operate the lamps 12 and 14.

The primary winding 18 may be energized from an ordinary alternating current power line 20 adapted to supply some suitable voltage, such as 118 volts. It will be realized that the transformer 16 may be arranged to operate on any other desired line voltage. The illustrated power line 20 includes a pair of line wires 22 and 24. It will be seen that a lead 26 extends directly between one end of the primary winding 18 and the line wire 24. A circuit may be traced from the other end of the primary 18 to the line wire 22 through a lead 28, contacts 30 and 32, a lead 34, contacts 36 and 38, and a lead 40. The contacts 30 and 32 are adapted to engage a terminal electrode 42 at one end of the lamp 14.

Likewise, the contacts 36 and 38 are arranged to engage an electrode 44 at one end of the lamp 12. It will be seen that the terminal electrodes 42 and 44 complete the energizing circuit to the primary winding 18 by establishing connections between the contacts 30 and 32, in the case of the electrode 42, and the contacts 36 and 38, in the case of the electrode 44. If either of the lamps 12 or 14 is removed, the energizing circuit to the primary winding 18 is automatically broken.

The illustrated secondary circuit to energize the lamp 12 comprises a lead circuit secondary winding 46 and a swing secondary winding 48. A capacitor 50 is also provided in the energizing circuit for the lamp 12, so that the lamp will operate on a leading current. The energizing circuit for the lamp 12 may be traced between the line wires 24 and 22 through the lead 26, a lead 52, the entire swing secondary winding 48, a lead 54, the lead secondary winding 46, a lead 56, the capacitor 50, a lead 58, a contact 60, a terminal electrode 62 on the lamp 12, the gaseous discharge in the lamp 12, the electrode 44, the contact 38, and the lead 40. It will be seen that a safety resistor 64 of high value is connected across the capacitor 50 to discharge the capacitor when the lamps are turned off. This arrangement largely eliminates the shock hazard that would be present if the capacitor were left charged.

It will be recognized that the leads 52, 54 and 56 connect the secondary windings 46 and 48 in series with the primary winding 18 and the capacitor 50 to define the energizing circuit for the lead lamp 12. In this instance, all of the windings 18, 48 and 46 are connected additively so that the total open circuit voltage of the three windings is the sum of the individual voltages.

The energizing circuit for the lamp 14 comprises a lag circuit secondary winding 66, together with a portion of the secondary circuit for the lead lamp 12. In this instance, the swing winding 48 is wound in two portions 68 and 70 with a tap 72 therebetween. The first portion 68 of the swing secondary winding 48 is utilized in the circuit for the lag lamp 14, as well as in the circuit for the lead lamp 12. The energizing circuit for the lag lamp 14 may be traced between the line wires 24 and 22 through the lead 26, the lead 52, the first portion 68 of the swing winding 48, the tap 72, a lead 74, the lag secondary winding 66, a lead 76, a contact 78, a terminal electrode 80 on the lamp 14, the gaseous discharge in the lamp 14, the electrode 42, the contact 32, the lead 34, the contact 36, the electrode 44, the contact 38 and the lead 40. Thus, the leads 52 and 72 connect the windings 18 and 66 and the winding portion 68 in series. In this instance, all three of the winding elements 18, 66 and 68 are polarized so that the windings are additive.

The windings on the transformer 16 may be arranged in various ways, but in this instance, the lag winding 66 is loosely coupled to the primary winding 18 so that there will be considerable leakage flux between the windings. Accordingly, the winding 66 has a fairly high leakage reactance so as to limit the operating current through the lamp 14. Due to the inductive reactance of the winding 66, the lamp 14 draws a lagging circuit.

The lead winding 46 is preferably coupled more closely than the lag winding 66 to the primary winding 18. In this way, the leakage reactance of the lead winding 46 will be relatively low. Moreover, the voltage induced from the primary winding 18 will be close to the maximum possible value. The coupling between the swing winding 48 and the primary winding 18 may be varied to a considerable extent, but in this instance is somewhat closer than that between the lag winding 66 and the primary winding 18. At the same time, the swing winding 48 is coupled somewhat less closely than the lead winding 46 to the primary winding 18. Thus, the swing winding 48 has a fairly high leakage reactance, all of which is in the lead circuit and part of which is in the lag circuit. In the energizing circuit for the lead lamp

12, the reactance of the capacitor 50 exceeds that of the windings 46 and 48. Thus, the lamp 12 draws a leading current which is limited by the capacitor 50.

The coupling relationships among the windings 18, 46, 48 and 66 on the transformer 16 might be secured in various ways. However, one suitable and advantageous arrangement for the transformer 16 is shown in Figs. 1 and 2. It will be seen that the transformer 16 includes a magnetic core 82 composed of a stack of laminations 84. The illustrated core 82 has an outer, generally rectangular ring-shaped member 84 and a central leg member 86. It will be seen that the central leg 86 extends between opposite end legs 88 and 90 on the outer core member 84. Elongated side legs 92 and 94 are formed on the outer member 84 between the end legs 88 and 90. In this instance, the side legs 92 and 94 are considerably elongated relative to the end legs 88 and 90. This construction increases the leakage flux in the transformer 16. The joints between the center member 86 and the outer member 84 also increase the leakage flux.

The illustrated central leg 86 may be considered to have two end portions 96 and 98 and an intermediate portion 100. In this embodiment, the primary winding 18 is mounted on the intermediate portion 100. The lead winding 46 is wound directly over the primary winding 18 to obtain close coupling between these windings. It will be seen that the swing winding 48 and the lag winding 66 are mounted on the end portions 96 and 98, respectively, of the central leg 86. The end portion 98 is longer than the end portion 96 and hence is effectively spaced farther from the primary winding 18. Thus, the coupling between the lag winding 66 and the primary winding 18 is even looser than that between the swing winding 48 and the primary.

In the illustrated transformer 16, the leakage flux is increased by magnetic shunt elements acting between the central leg 86 and the side legs 92 and 94 adjacent opposite ends of the primary winding 18. While the shunts might take various forms, they are illustrated as projections 102 extending inwardly from the side legs 92 and 94 toward the central leg 86. Two such projections 102 are provided at each end of the primary winding 18 and are interposed between the primary and the adjacent secondary windings. The shunts 102 are effective to increase the leakage reactance of the lag winding 66 and the swing winding 48. It will be seen that gaps 104 are provided between the magnetic shunts 102 and the central leg 86.

The entire transformer 16 and the capacitor 50 may be mounted in a housing 106, which may assume various forms but is illustrated as an elongated sheet metal pan with slotted mounting flanges 108 at its opposite ends.

It will be understood that the number of turns in the various coils of the transformer 16 may be varied over a wide range to suit different conditions and requirements. Likewise, the arrangement of the coils, the shape of the core, and the number and thickness of the laminations in the core may be varied. Nevertheless, it may be helpful to give these particular details of a specific ballast which has been tested and found to operate in a highly advantageous manner. These details are given purely by way of example and are not intended to limit the scope of the invention.

In this specific ballast, the primary winding has 800 turns of No. 23 gauge wire. The lead winding 46 has 1700 turns of No. 29 gauge wire. Likewise, 1700 turns of No. 29 gauge wire are employed in the swing coil. The portion 68 between the tap 72 and the end lead 52 has 1000 turns which are connected into the lag circuit. The lag secondary 66 has 2550 turns of No. 28 gauge wire.

In the specific example, the magnetic core 82 is approximately 10 inches long and 2 inches wide. Thirty-three of the laminations 84 are employed and each lamination is .025 of an inch thick.

In the specific exemplary ballast, the value of the capacitor 50 is about 1.45 microfarads. The leak resistor 64 may have a value of 6 megohms.

The specific ballast, described by way of example, is adapted to be operated at a nominal primary voltage of 118 volts. Under open circuit conditions, the total voltage across the lead lamp 12 is 565 volts and is entirely adequate to start the lead lamp. This voltage represents the total of the voltages across the primary 18, the swing coil 48 and the lead coil 46.

Under open circuit conditions, the total voltage developed in the lag circuit and applied across the lag lamp 14 is about 540 volts. Thus, the starting voltage across the lag lamp 14 initially is somewhat less than that across the lead lamp 12. However, as soon as the lead lamp 12 is started, the starting voltage across the lag lamp 14 is automatically increased to about 565 volts so that the lag lamp will be fired. This increase of voltage in the lag circuit is brought about by the leading current drawn by the lead lamp and passing through the portion 68 of the swing coil 48. It will be recalled that the portion 68 is also in the lag circuit. The current through the lead lamp 12 causes a voltage drop in the swing coil 48 due to the leakage reactance of the coil. Because of the leading character of the current, however, the voltage drop is so phased that it actually augments the voltage induced in the swing coil 48 by the primary winding 18. A portion of this augmented voltage is developed in the winding portion 68 and thereby is applied to the lag lamp 14 so as to increase the starting voltage and insure the firing of the lag lamp.

Under operating conditions with both of the lamps 12 and 14 lighted, the lead lamp 12 draws leading current, due to the reactance of the capacitor 50, while the lag lamp 14 draws lagging current due to the inductive reactance of the lag secondary 66. The out-of-phase components of the leading and lagging currents tend to neutralize each other, with the result that the power factor of the ballast is improved and may closely approach unity. The position of the tap 72 on the swing coil 48 affects the balance between the leading and lagging currents. Thus, the position of the tap may be preselected to obtain the maximum possible power factor. With this construction, a power factor between 95 and 100 percent can readily be obtained.

The utilization of a portion of the lead circuit in the lag circuit results in a considerable saving in material and a reduction in the weight and size of the ballast. Since the lead and lag currents are considerably out-of-phase, the resultant current in the common portion 68 of the lead and lag circuits is considerably less than the arithmetic sum of the currents. In other words, the lead and lag lamps draw their peak currents at different times, with the result that the current in the common portion of the lead and lag circuits is minimized. This action permits the use of relatively small wire in the swing coil 48.

The illustrated construction considerably reduces the number of turns of wire required to develop the necessary starting voltage for the lamps. Accordingly, the overall size of the ballast can be made small. The saving in the total number of turns results largely from the utilization of the swing coil to energize both the lead and the lag lamps.

Due to the precise balance between the lead and lag currents, the out-of-phase components are substantially neutralized. This action reduces the total current in the swing coil and also reduces the leakage flux in the core.

Accordingly, the size of the core and the amount of copper employed in the windings may be reduced to a minimum. The reduction in total current and in leakage flux reduces the losses in the ballast, with the result that less heat is generated. Thus, the amount of copper and iron in the ballast can be reduced without causing the

ballast to rise in operating temperature above established limits.

The voltage in the lead and lag circuits is relatively low since the voltage need only be sufficient to start a single lamp. The relatively low voltage is an advantage from a safety standpoint. Moreover, the low voltage requirements obviate any need for employing extremely fine wire in the secondary windings. Such wire is expensive and leads to increased winding cost. Moreover, the low voltage employed in the ballast virtually eliminates any danger of breakdown in the insulation.

The illustrated ballast of Figs. 1-3 operates the two lamps 12 and 14 in such a manner that the combined stroboscopic effect is minimized. Due to the provision of the capacitor 50, the lamp 12 draws leading current. On the other hand, the lamp 14 draws lagging current because of the inductive reactance of the windings 66 and 68 in the lag circuit. Thus, the currents in the lead and lag lamps 12 and 14 are substantially 90 degrees out-of-phase. Accordingly, the current in one lamp 12 is at or near its maximum point when the current in the other lamp is passing through its zero point. With the currents thus staggered, the stroboscopic effect is largely eliminated.

The connection of the lag circuit to the tap 72 on the swing coil 48 has the effect of matching the impedances in the lead and lag circuits so as to provide maximum power factor and efficiency. If the discharge in one lamp is extinguished due to a fault in the lamp or some other cause, the other lamp remains in operation. In other words, the continued operation of each lamp is independent of that of the other lamp.

Figs. 4-7 illustrate a second ballast 120 which in many respects is quite similar to the ballast 10 of Figs. 1-3 but in other respects represents a significant improvement over the ballast of Figs. 1-3. Thus, the ballast 120 comprises a primary winding 122 which is connected across line wires 124 and 126 by a circuit which may be traced through a contact 128, a lamp terminal 130, a contact 132, a lead 134, a contact 136, a lamp terminal 138, a contact 140, and a lead 142. It will be seen that the line wire 124 is connected to the contact 128, while the line wire 126 is connected to one side of the primary winding 122. The other side of the primary winding 122 is connected to the lead 142. The lamp terminals 130 and 138 are on fluorescent lamps 144 and 146. The lamp 144 is the lead lamp, while the lamp 146 is the lag lamp. When the lamps 144 and 146 are in their normal operating positions, the lamp terminals 130 and 138 close the primary circuit so that the primary winding 122 will be energized from the line wires 124 and 126. If either of the lamps 144 and 146 is removed, the primary winding 122 will be disconnected from the line wires 124 and 126. It will be understood that the line wires 124 and 126 may be connected to a suitable source of alternating current which may be at 118 volts and 60 cycles, or some other suitable voltage and frequency.

The ballast 120 is of the auto-transformer type and thus includes a lead circuit winding 150, a lag circuit winding 152, and a swing winding 154. The lead and lag windings 150 and 152 are arranged in lead and lag circuits to energize the lead and lag lamps 144 and 146, which the swing winding is common to both circuits. Thus, one primary lead 156 on the swing winding 154 is connected to the line wire 126, and thence to one side of the primary winding 122. The other primary lead 158 of the swing winding 154 is connected to one terminal lead 160 of the lead winding 150. The other primary lead 162 of the swing winding 150 is connected to one side of a capacitor 164. It will be seen that a lead 166 is connected between the other side of the capacitor 164 and a contact 168 which engages a terminal or electrode 170 on the lead lamp 144. A leak resistor 171 is connected across the capacitor 164 to insure that

the capacitor will be discharged when the lamps 144 and 146 are turned off.

In this case, the swing winding 154 is provided with a tap 172 which is connected to one terminal lead 174 on the lag winding 152. The other terminal lead 176 of the lag winding 152 is connected to a contact 178 which engages a terminal or electrode 180 on the lag lamp 146.

The swing winding 154 and the lead winding 150 are so connected that the voltages developed by these windings are additively related to the voltage across the primary winding 122. Likewise, the voltage developed by the lag winding 152 is additively related to the primary voltages and the portion of the swing coil voltage developed between the lead 156 and tap 172. This portion 182 of the swing coil 154 is in series with the lag coil 152.

In this case, the transformer windings 122, 150, 152 and 154 are arranged in an improved manner on a core 184 made of iron, steel or other highly permeable material. It will be seen that the core 184 has a straight, elongated central leg 186 which supports the four windings 122, 150, 152 and 154. The leg 186 may be considered to have two adjacent central portions, 188 and 190 and two end portions 192 and 194. It will be seen that the primary and lead coils 122 and 150 are arranged end to end on the central portions 188 and 190, while the lag and swing coil 152 and 154 are mounted on the end portions 192 and 194. The lead coil 190 is positioned between the primary 188 and the lag coil 192, on one end of the primary coil 188, while the swing coil 194 is on the other end of the primary coil.

In the ballast of Figs. 4-7 all of the secondary windings, 150, 152 and 154 have substantial leakage reactances. These reactances are due to several factors, including the elongated configuration of the central leg 186 and the end to end disposition of the coils and the spacing between the coils. Thus there is a substantial leakage flux between the lead coil 150 and the primary winding 122, due to the elongated character of these coils and the arrangement of the coils in end to end relation. The lag coil 152 is spaced farther from the primary winding 122 than the lead coil 190, and hence has a higher leakage reactance. Likewise, the swing coil 154 is spaced from the primary 122 and hence has a relatively high leakage reactance.

The leakage reactances of the lag coil 152 and the swing coil 154 are increased by the interposition of magnetic shunts 200 and 202 between the primary coil 122 and the coils 152 and 154. More specifically, the shunt 200 is interposed between the lag coil 152 and the lead coil 150, while shunt 202 is interposed between the swing coil 154 and the primary winding 122. While the shunts 200 and 202 might be formed in various ways, they are shown as projections on an elongated, rectangular, generally box shaped core member 204 which extends around the central member 186. The rectangular member 204 has side legs 206 and 208 which are substantially parallel to the central member 186, together with relatively short end legs 210 and 212 which extend at right angles to the central leg 186. In this case, the end legs 210 and 212 have notches 214 and 216 therein which receive the ends of the central leg 186. A partial gap 220 of air or other non-permeable material may be provided between one end of the central leg 186 and the end members 210, to define saturable portions 220 on the end of the central leg 186. It will be seen that the shunt 200 is in the form of a pair of projections 222 extending inwardly from the members 206 and 208 toward the central leg 186. Likewise, the shunt 202 takes the form of a pair of projections 224 on the legs 206 and 208, extending inwardly toward the central leg 186. Gaps 226 and 228 of air or other non-magnetic material may be provided between the projections 222 and the central leg 186. In like manner, gaps 228 may be provided between the central leg 186 and the projections 224.

While the number of turns in the windings 122, 150, 152 and 154 may be varied, it may be of interest to give the coil data for an actual example of a successful ballast of the type shown in Figs. 4-6. In the example, the primary winding had 700 turns of #22 gauge wire, while the lead coil 150 had 1560 turns of #29 gauge wire. The lag coil had 2450 turns of #29 gauge wire, while the swing winding 154 had 1660 turns of #29 gauge wire. The portion 182 between the end lead 156 and the tap 172 had 940 turns.

This exemplary ballast developed a lead lamp starting voltage of about 550 volts with a primary voltage of about 118 volts. This voltage was sufficient to effect instant starting of the lead lamp 144. Initially, the lag lamp starting voltage was somewhat less than the lead lamp voltage, but as soon as the lead lamp was started, the lag lamp voltage increased to 570 volts, sufficient to effect the instant starting of the lag lamp. The increase in the starting voltage for the lag lamp is due to the leading current drawn by the lead lamp 144 through the swing winding 154. Due to the leakage reactance of the swing winding 154 the leading current causes the voltage at the tap 172 to increase. This voltage is applied to the lag lamp 146, and is so phased that it enhances the starting voltage for the lag lamp 146.

With the ballast 120 of Figs. 4-6 there is a significant amount of inductive reactance in series with both the lead lamp 144 and the lag lamp 146. In the circuit for the lead lamp 144, the lead winding 150 has a considerable inductive reactance due to its arrangement in end to end relation to the primary winding 122, along the elongated central leg 186 of the core. In addition the swing coil 154 has a fairly high inductive reactance, due to the spacing between the swing coil 154 and the primary 122, and the provision of shunt 202 between the coils.

In the circuit for the lag lamp 146, the lag winding 152 has a high inductive reactance, due to the very considerable space between the lag winding 152 and the primary winding 122, the provision of the shunt 200 between the windings. Moreover, a portion of the inductive reactance on the swing coil 154 is in series with the lag coil 152 due to the connection of the lag coil to the tap 172.

It will be understood that there is also a high capacitive reactance in the circuit for the lead lamp 144 due to the provision of the capacitor 164. It is the capacitor 164 which causes the lamp 144 to draw a leading current.

The waveform of the current in the lead lamp 144 is greatly improved due to the high inductive reactances in the circuit for the lamp. Fig. 7 shows an oscillogram 232 representing the improved waveform of the lead lamp current for the ballast of Figs. 4-6. It will be seen that the waveform is quite flat topped and smooth and is free from any dips or sharp peaks. The waveform indicates that only a relatively small amount of harmonic content is present in the lead lamp current. By way of comparison, Fig. 7 also shows an oscillogram 234 representing the lead lamp current in a prior ballast, not having high inductive reactance in the circuit for the lead lamp. It will be seen that the oscillogram 234 has a sharp dip 235 between two relatively sharp peaks 238 and 240. These irregularities in the waveform indicate that a relatively large amount of harmonic content is present in the lead lamp current.

The improved waveform of the lead lamp current increases the power consumption in the lead lamp and the brilliance of the lamp, while reducing the lamp current. Accordingly, the life of the lamp is prolonged. The improved lead lamp waveform also improves the waveform of the lag lamp current, with resulting increase in lag lamp power consumption and brilliance.

As a result of the improved lamp current waveform and reduced lamp current, the ballast operates with reduced losses and hence at a lower temperature. Moreover, the ballast generates a minimum of noise and hum.

The improvement in the waveform raises the power factor of the ballast substantially and also effects a substantial increase in the efficiency of the ballast. With silicon steel or other high grade magnetic material in the core 184, a power factor of 96 to 98% may be obtained. This is higher than is commercially required, with the result that inexpensive cold rolled steel may be substituted for the expensive silicon steel, while still achieving a power factor of 90%, which is fully acceptable commercially. Thus, the improved ballast makes possible a choice between a design that will give practically unity power factor and a much less expensive design that will still give a commercially acceptable power factor.

Due to the reduced lead lamp current, the voltage across the capacitor 164 is substantially reduced, with the result that a less expensive capacitor may be employed without danger of voltage breakdown.

With the high inductive reactance in the lead and lag circuits, the ballast of Figs. 4-6 gives an improved balance between the lead and lag lamps 144 and 146 with regard to lamp current, power consumption and brilliance. Moreover, the self-regulating action of the ballast is greatly improved. Thus, the lamp currents remain nearly constant over a wide range of primary voltage. It has been observed that there is only an insignificant change in the lamp currents and the primary current when the primary voltage is varied between 105 and 125 volts. The lamps will start with only 85 volts impressed across the primary.

In the ballast of Figs. 4-7 the swing coil 154 supplies starting voltage and inductive reactance for both the lead and the lag circuits. This arrangement brings about a substantial saving in material and space. In other words, this arrangement makes the ballast more economical and more compact.

Figs. 8-11 illustrate another ballast 250 which is also highly advantageous but is somewhat different in construction than the ballast 120. However, the circuit for connecting the ballast 250 between the power line wires 124 and 126 and the lamps 144 and 146 is much the same as in the case of the ballast 120. Accordingly, the same reference characters have been employed in Fig. 10 as in Fig. 6 for the various circuit components which remain the same.

It will be seen that the ballast 250 of Figs. 8-11 comprises a primary winding 252, a lead winding or coil 254, a lag coil 256, and a swing coil 258. As in the arrangement of Fig. 6, one terminal lead 260 of the primary winding 252 is connected to the line wire 126, while the other terminal lead 262 is connected to the lead 142. Thus, the voltage across the line wires 124 and 126 is impressed across the primary winding 252.

The swing coil 258 and the lead coil 254 are connected in series with the primary voltage to energize the lead lamp 144. Thus, one terminal lead 264 of the swing coil 258 is connected to the terminal lead 260 of the primary winding 252. The other terminal lead 266 of the swing coil 258 is connected to one terminal lead 268 on the lead coil 254. The other terminal lead 270 of the lead coil 254 extends to the capacitor 164 and thence to the lead lamp 144.

In the exemplary ballast 250 the entire swing coil 258 is also in the lag circuit, along with the lag coil 256. Thus, one terminal lead 272 of the lag coil 256 is connected to the terminal lead 266 of the swing coil 258. The other terminal lead 274 of the lag coil 256 extends to the contact 178 and thence to the lag lamp 146.

In the ballast 250 of Figs. 8-11, the windings 252, 254, 256 and 258 are provided with a core 280 made of iron, steel or other highly permeable material. It will be seen from Fig. 8 that the core 280 has a central leg 282 on which the coils 252-258 are mounted. The central leg 282 may be considered to have two end portions 284 and 286 and two intermediate portions 288 and 290. In this case the lag coil 256 and the swing coil 258 are on the end portions 284 and 286, while the lead coil

254 and the primary coil 252 are on the intermediate portions 288 and 290, much as in the ballast 148 of Figs. 4-7. However, in the case of the ballast 250, the swing coil 258 is in end to end relation to the primary coil 252. The lead coil 254 and the lag coil 256 are spaced from the opposite end of the primary coil 252. It will be seen that the lead coil 254 is between the coil 252 and the lag coil 256 as in the ballast 120 of Figs. 4-7.

Due to the arrangement of the coils, the lead, lag and swing coils 254, 256 and 258 have significant inductive reactances. The lag coil 256 being most distant from the primary coil 252, has a high inductive reactance, while the lead and swing coils 254 and 258 have smaller inductive reactances.

The inductive reactances of the lead and lag coils 254 and 256 are enhanced by shunts 294 and 296. It will be seen that the shunt 294 is between the primary coil 252 and the lead coil 254, while the shunt 296 is between the lead coil 254 and the lag coil 256. Thus both of the shunts 294 and 296 are between the primary and the lag coils 252 and 256.

From Fig. 8 it will be seen that the shunts 294 and 296 take the form of two pairs of inward projections 298 and 300 on a rectangular boxlike core member 302 extending around the central leg 282 of the core 280. The projections 298 and 300 extend inwardly toward the central leg 282 from longitudinal legs 304 and 306 of the rectangular core member 302. As already indicated, the projections 298 are between the primary and lead coils 252 and 254, while the projections 300 are between the lead and lag coils 254 and 256. The projections 300 are somewhat wider than the projections 298 and thus have a greater shunting action. Gaps 308 and 310 are provided between the central leg 282 and the projections 298 and 300.

The central leg 282 extends between relatively short end legs 312 and 314 of the rectangular core member 302. Notches 316 and 318 are formed in the end legs 312 and 314 to receive the ends of the central leg 282. Partial gaps 320 and 322 of non-magnetic material are defined between the ends of the central leg 282 and the end legs 312 and 314. However, reduced portions 324 and 326 of the ends of the central leg 282 directly engage the end legs 312 and 314 to define saturable elements in the magnetic circuit, whereby the leakage flux will be greater under operating conditions than under starting conditions.

As already indicated, all of the secondary windings 254, 256 and 258 have significant inductive reactances. Thus there is considerable inductive reactance in the circuits for both the lead and lag lamps 144 and 146. The inductive reactances of the lead and swing coils 254 and 258 are in series with the lead lamp 144, along with the capacitive reactances of the capacitor 164. The inductive reactances of the lag and swing coils 256 and 258 are in series with the lag lamp 146. The reactances in series with the lead and lag lamps 144 and 146 define and limit the normal operating currents of the lamps.

While the number of turns in the windings 252-258 may be varied, it will be of interest to give the coil data for an exemplary ballast. In an exemplary ballast the primary coil 252 had 450 turns of No. 23 gauge wire, the lead coil 254 had 1200 turns of No. 29 gauge wire, the lag coil 256 had 1300 turns of No. 29 gauge wire and the swing coil had 580 turns of No. 29 gauge wire.

It will be noted that in both of the ballasts 120 and 250, the lead coil is between the primary coil and the lag coil. This arrangement results in improved balance between the lead and lag lamps 144 and 146 with regard to current, power consumption and brilliance. Moreover, this arrangement improves the waveform of the lamp currents, particularly the lead lamp current. The inductive reactance in the lead lamp circuit also improves the lead lamp waveform. Fig. 11 illustrates an oscillogram 330 which represents the waveform of the lead lamp current

for the ballast 250 of Figs. 8-10. It will be seen that the waveform is relatively smooth, flat topped and free from irregularities. These characteristics indicate that the harmonic content of the current is low. By way of comparison, Fig. 11 also illustrates an oscillogram 332 representing the lead lamp current for a prior ballast in which the lead and lag coils were on opposite ends of the primary. It will be seen that the oscillogram 332 has a dip 334 between two peaks 336 and 338. These irregularities indicate the presence of undesirably great harmonic content in the lead lamp waveform.

The improved lamp current waveform results in high power factor and efficiency, along with high lamp brilliance. The lamp current is actually reduced, with the result that lamp life is prolonged. Moreover, the ballast runs cooler and with a minimum of noise and hum.

As in the case of the ballast 120, the ballast 250 offers a choice between extremely high power factor, from 96 to 98%, obtainable by using silicon steel in the core, and a somewhat lower but commercially acceptable power factor of about 90% with the use of ordinary inexpensive cold rolled steel in the core. The use of an inexpensive grade of steel brings about a great saving in the cost of the ballasts.

Like the ballast 120, the ballast 250 provides nearly constant lamp and primary currents over a wide range of primary voltages.

In all of the ballasts thus far described, the swing winding or coil is inductively reactive and hence provides a high impedance source of voltage for both the lead and the lag circuits. The high impedance of the swing winding results in a greatly improved balance in the lamp currents of the lead and lag lamps.

In addition, the high impedance provided by the swing winding results in excellent current wave form in both the lead and lag circuits. In this way, maximum lamp wattage and brilliance are obtained at normal operating current.

In the ballasts of Figs. 1-7, the lag circuit is connected to the tap on the swing coil, and the tap is precisely adjusted so as to match the impedances and lamp currents in the lead and lag circuits. The precisely adjusted tap provides maximum efficiency with maximum lamp currents and lamp brilliance. As a result of the high impedance swing coil, the precisely adjusted tap connected to the lag circuit, and the improved arrangement of the coils on the core, each of these ballasts provides excellent regulation, in that the lamp currents and the primary input current remain nearly constant over an extremely wide range of input voltage to the primary winding. The provision of the precisely adjusted swing coil tap also achieves the maximum level of power factor correction. Accordingly, the operating losses are reduced to a minimum and the efficiency is increased to a maximum. Furthermore, quieter operation of the ballast is obtained. The high impedance lead and lag circuits reduce the losses in both the core and the windings.

In the ballast of Figs. 8-11, no tap is necessary on the swing coil, because the entire swing coil is in the lag circuit. The swing coil is so arranged and so related to the core and the other coils that the entire coil gives the ideal impedance in the lag circuit.

In the ballasts of Figs. 4-11, the swing coil is located at the opposite end of the primary coil from the lead coil. Thus, the lead circuit is split into two coils on opposite ends of the primary coil. This arrangement provides a more compact arrangement of the magnetic flux in the core. In other words, the extent of the magnetic field is reduced. As a result, the mechanical hum and noise produced by the ballast are greatly reduced so that the ballast operates with greatly improved quietness. Furthermore, the core losses are considerably reduced and the efficiency is improved.

Fig. 12 illustrates another modified ballast 340 which is an example of the manner in which the ballasts thus

far described may be modified so as to operate a single lamp. It will be seen that the ballast 340 of Fig. 12 is the same as the ballast 120 of Figs. 4-7, except that the ballast 340 is arranged to operate only one lamp. In this case, the lag lamp 146 remains and is operated by the ballast 340, while the lead lamp is not employed. The line wire 124 is connected directly to the contact 136 which is engageable with the terminal 138 on the lamp 146. The lead circuit of the ballast 340 is employed to effect power factor correction. Thus, the lead or wire 166 is connected directly to the primary wire 142 rather than being connected to the lead lamp. In the lead circuit for the ballast 340, the primary coil 122, the swing coil 154, and the lead coil 150 are connected in series as before. The capacitor 164 is connected across the three coils so as to draw leading current and afford power factor correction.

The ballast 340 operates in much the same manner as the ballast 120, except that the input current is reduced considerably inasmuch as only one lamp is drawing power from the ballast. As before, the ballast 340 operates with high inductive impedance in both the lead and lag circuits. Furthermore, the ballast 340 provides high efficiency, high power factor, maximum lamp brilliance, quiet operation, and greatly improved regulation of lamp brilliance with variations in the input voltage. In other words, the single lamp ballast 340 has all of the advantages of the ballasts previously described.

It will be understood that any of the previously described ballasts may be converted into a single lamp ballast simply by connecting the capacitor to the primary return lead rather than to the lead lamp. In other words, the lead circuit is closed so that the capacitor is directly across the series-connected coils in the lead circuit.

Still another illustrative ballast 350 is shown in Figs. 13-16. The ballast 350 is somewhat similar to the ballast 250 in that both ballasts may employ the same or substantially the same core 280. Accordingly the same reference characters have been applied to the core 280 in Figs. 13-15 as in Figs. 8-10.

However, the arrangement and connection of the ballast windings are somewhat different in Figs. 13-15 than they are in Figs. 8-10. More specifically, the ballast 350 is adapted to operate fluorescent lamps 352 and 354 of the type having filamentary electrodes which may be heated electrically to start the lamps. Thus, the lamp 352 has filaments 356 and 358 while the lamp 354 has filaments 360 and 362.

It will be seen that the illustrative ballast 350 has a primary winding 364 having terminal leads 366 and 368 which are connected directly to the power line wires 124 and 126. In this case, there is no swing coil but there are lead and lag coils 370 and 372. One terminal lead 374 of the lead coil 370 is connected to the terminal lead 368, while the other terminal lead 376 on the lead coil 370 is connected to one side of a capacitor 378. The other side of the capacitor is connected to one terminal 380 of the filament 358 of the lead lamp 352. A leak resistor 382 is connected across the capacitor 378.

To complete the circuit for the lead lamp 352, one terminal 384, of the other lead lamp filament 356 is connected to the power line 124. The other terminal 386 of the filament 356 is adapted to be connected to the other terminal 388 of the filament 358 by a starting circuit that includes an automatic starter switch 390, which may be of any suitable construction, so as to close the starting circuit momentarily, when the lead lamp 352 is first energized. When the starting circuit is closed, current flows through the filaments 356 and 358, with the result that they are heated sufficiently to emit electrons. After a brief interval, the starter 390 opens the starting circuit, with the result that an arc discharge is established in the lead lamp 352.

The starting circuit for the lead lamp 352 may also

include a compensating winding 392 which may be connected in series with the starter 390 between the filament terminals 386 and 388. The compensating winding 392 is coupled to the primary winding 370 and is adapted to provide additional voltage to heat the lead lamp filaments 356 and 358 so as to increase the speed with which the lead lamp 352 is started.

In the circuit for the lag lamp 354, one terminal 394 of the lag winding 372 is connected to the terminal 368 of the primary winding 364, while the other terminal 396 of the lag winding 372 is connected to one terminal 398 of the lag lamp filament 362. One terminal 400 of the other lag lamp filament 360 is connected to the line wire 124. To start the lag lamp 354, a conventional or suitable automatic starter 402 is connected between the other terminals 404 and 406 of the filaments 360 and 362. The starter 402 is adapted to close momentarily to heat the filaments 360 and 362 and then open to establish an arc discharge in the lamp 354.

As already indicated, the core 280 of the ballast 350 may be the same as for the ballast 250 of Figs. 8-10. In the case of the ballast 350, however, the primary coil 370 occupies the entire space occupied by the primary and swing coils 252 and 258 in the ballast 250. In other words, the primary coil 370 occupies the portions 286 and 290 of the central leg 282.

As in all of the previously described ballasts, the primary coil 364 is adjacent one end of the core 280 and is at the opposite end of the core from the lag coil 372. The lead coil 370 is between the primary and lag coils 364 and 372. Due to the arrangement of the coils and the provision of the shunts 294 and 296, the lead and lag coils 370 and 372 have considerable leakage reactances.

The compensating winding 392 may be arranged in various ways with regard to the core 280. As shown the compensating winding 392 is wound over the lead coil 370.

The number of turns in the various coils may be varied but it may be of interest to give the coil data for an exemplary coil. In this coil, the primary winding 364 had 650 turns of No. 26 gauge wire, the lead coil 370 had 900 turns of No. 28 gauge wire, the lag coil had 770 turns of No. 28 gauge wire, and the compensating winding 392 had 145 turns of No. 28 gauge wire.

As in the case of all of the previously described ballasts, the ballast 350 provides considerable leakage or inductive reactance in both the lead and lag circuits. Thus, the reactive lead and lag windings 370 and 372 provide the inductive reactances in the circuits for the lead and lag lamps 352 and 354. Due to the inductive reactances in the lead circuit and the interposition of the lead coil between the primary coil and the lag coil, the lead coil waveform is greatly improved. Thus, Fig. 16 illustrates an oscillogram 410 representing the lead lamp current for the ballast 350. It will be noted that the waveform of the lead lamp current is smooth, flat topped and free from irregularities. By way of comparison, Fig. 16 also illustrates an oscillogram 412 representing the lead lamp waveform for a prior ballast in which the lead and lag coils were on opposite sides of the primary coil. It will be noted that the oscillogram 412 has two dips 414 and 416 interspersed between three peaks 418, 420 and 422. The irregularities in the waveform 412 cause loss of lamp brilliance and increased losses in the ballast. Thus, the improved waveform 410 for the ballast 350 results in greater lamp brilliance with less lamp current and lower losses. The ballast 350 operates at high efficiency and with a high power factor. The operating temperature and the noise produced by the ballast are low. Moreover, as in the case of the other ballasts, ballast 350 maintains nearly constant lamp and primary currents with wide variations of the primary voltage.

As already indicated, the high impedance lead and lag circuits in each of the ballasts reduces the lamp currents

and improves the wave form thereof, while actually increasing the lamp brilliance. At the same time, the voltage across the capacitor in the lead circuit is reduced considerably, with the result that there is less chance that the capacitor will fail due to voltage breakdown. The reduction in capacitor voltage also makes it possible to reduce the cost of the capacitor.

Various other modifications, alternative constructions and equivalents may be employed without departing from the true spirit and scope of the invention as exemplified in the foregoing description and defined in the following claims.

I claim:

1. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core, a primary winding thereon, a separate highly reactive lag secondary winding spaced on said core from said primary winding, a separate secondary winding on said core, a separate reactive swing secondary winding on said core and including first and second portions with a tap therebetween, a lead circuit including a capacitor and leads connecting said primary winding, said swing winding and said lead winding in an additive series with said capacitor, and a lag circuit including leads connecting said primary winding, said first portion of said swing winding, said tap and said lag secondary winding in an additive series, said primary winding being connected in the same direction in both said lead and lag circuits.

2. In a discharge-lamp ballast, the combination comprising a magnetic core, a primary winding mounted thereon, a separate reactive lead secondary winding mounted on said core on one end of said primary winding, a separate highly reactive lag secondary winding spaced on said core from said primary winding and beyond said lead secondary winding, said lead secondary winding thereby being disposed on said core between said primary, and said lag secondary windings, a separate reactive swing secondary winding mounted on said core on the opposite end of said primary winding, said primary winding thereby being disposed on said core between said lead and swing secondary windings, a capacitor, a lead circuit connecting said capacitor in series with said primary, lead and swing windings with said primary, lead and swing windings additively related, and a lag circuit connecting said primary winding and said lag secondary winding in an additive series with at least a portion of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

3. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core, a primary winding mounted thereon, a separate reactive lead secondary winding mounted on said core on one end of said primary winding, a separate highly reactive lag secondary winding spaced on said core from said primary winding and beyond said lead secondary winding, said lead secondary winding thereby being disposed on said core between said primary and said lag secondary windings, a separate reactive swing secondary winding mounted on said core on the opposite end of said primary winding, said primary winding thereby being disposed on said core between said lead and swing secondary windings, a magnetic shunt disposed between said lead and lag secondary windings, a capacitor, a lead circuit connecting said capacitor in series with said primary, lead and swing windings with said primary, lead and swing windings additively related, and a lag circuit connecting said primary winding and said lag secondary winding in an additive series with at least a portion of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

4. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core, a primary winding mounted thereon, a separate reactive lead secondary winding mounted on said core on one end of said primary

winding, a separate highly reactive lag secondary winding spaced on said core from said primary winding and beyond said lead secondary winding, said lead secondary winding thereby being disposed on said core between said primary and said lag secondary windings, a separate reactive swing secondary winding mounted on said core on the opposite end of said primary winding, said primary winding thereby being disposed on said core between said lead and swing secondary windings, a first magnetic shunt between said lead and lag secondary windings, a second magnetic shunt between said primary and swing secondary windings, a capacitor, a lead circuit connecting said capacitor in series with said primary, lead and swing windings with said primary, lead and swing windings additively related, and a lag circuit connecting said primary winding and said lag secondary winding in an additive series with at least a portion of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

5. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core, a primary winding mounted thereon, a separate reactive lead secondary winding mounted on said core on one end of said primary winding, a separate highly reactive lag secondary winding spaced on said core from said primary winding and beyond said lead secondary winding, said lead secondary winding thereby being disposed on said core between said primary and said lag secondary windings, a separate reactive swing secondary winding mounted on said core on the opposite end of said primary winding, said primary winding thereby being disposed on said core between said lead and swing secondary windings, a first magnetic shunt between said lead and lag secondary windings, a second magnetic shunt between said primary and lead secondary windings, a capacitor, a lead circuit connecting said capacitor in series with said primary, lead and swing windings with said primary, lead and swing windings additively related, and a lag circuit connecting said primary winding and said lag secondary winding in an additive series with at least a portion of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

6. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core, a primary winding thereon, separate first and second secondary windings on said core, a separate third secondary winding on said core and including first and second portions with a tap therebetween, at least said second and third secondary windings being highly reactive, a first circuit including a capacitor and leads connecting said primary winding, said third winding and said first winding in an additive series with said capacitor, and a second circuit including leads connecting said primary winding, said first portion of said third winding, said tap and said secondary winding in an additive series, said primary winding being connected in the same direction in both said first and second circuits.

7. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core having an elongated generally rectangular ring portion with a pair of opposite side legs and a pair of opposite end legs, said core having a central longitudinal leg extending between said end legs, said central leg having first and second end portions and an intermediate portion therebetween, said second portion being longer than said first portion, magnetic shunt elements projecting from said side legs toward said central leg adjacent opposite ends of said intermediate portion, a primary winding on said intermediate portion, a separate lead secondary winding wound over said primary winding on said intermediate portion, a separate highly reactive lag secondary winding on said second end portion, a separate reactive swing secondary winding on said first end portion and having first and second winding portions with a tap therebetween, a capacitor, a lead circuit having leads connecting said primary winding, said swing winding, and said lead winding in a first additive

series with said capacitor, and a lag circuit including leads connecting said primary winding, said first winding portion of said swing winding, and said lag winding in a second additive series, said lead circuit having a higher open circuit voltage than said lag circuit, said swing winding being effective to induce an increased voltage in said lag circuit in response to current in said lead circuit.

8. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core having an elongated generally rectangular ring portion with a pair of opposite side legs and a pair of opposite end legs, said core having a central longitudinal leg extending between said end legs, said central leg having first and second end portions and an intermediate portion therebetween, a primary winding on said intermediate portion, a first separate secondary winding wound over said primary winding on said intermediate portion, a second separate secondary winding on said second end portion and having first and second winding portions with a tap therebetween, a capacitor, a first circuit having leads connecting said primary winding, said third winding, and said first winding in a first additive series with said capacitor, and a second circuit including leads connecting said primary winding, said first winding portion of said third winding and said second winding in a second additive series, said first circuit having a higher open circuit voltage than said second circuit, said third winding being effective to induce an increased voltage in said second circuit in response to current in said first circuits.

9. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core having an elongated generally rectangular ring portion with a pair of opposite side legs and a pair of opposite end legs, said core having a central leg extending between said end legs, a primary winding on said central leg, a separate reactive swing secondary winding on one end of said central leg and at one end of said primary winding, a lag secondary winding on the opposite end of said central leg and spaced thereon from the opposite end of said primary winding, a separate lead secondary winding disposed on said central leg adjacent said primary winding, a capacitor, a lead circuit connecting said capacitor in series with said primary, swing secondary and lead secondary windings, and a lag circuit connecting said primary and lag windings in series with at least part of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

10. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core having an elongated generally rectangular ring portion with a pair of opposite side legs and a pair of opposite end legs, said core having a central leg extending between said end legs, a primary winding on said central leg, a separate reactive swing secondary winding on one end of said central leg and at one end of said primary winding, a lag secondary winding on the opposite end of said central leg and spaced thereon from the opposite end of said primary winding, a separate lead secondary winding disposed on said central leg between said primary and said lag secondary windings, magnetic shunt means disposed between said lead and lag secondary windings and extending between said central leg and said ring portion, a capacitor, a lead circuit connecting said capacitor in series with said primary, swing secondary and lead secondary windings, and a lag circuit connecting said primary and lag windings in series with at least part of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

11. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core having an elongated generally rectangular ring portion with a pair of opposite side legs and a pair of opposite end legs, said core having a central leg extending between said end

legs, a primary winding on said central leg, a separate reactive swing secondary winding on one end of said central leg and at one end of said primary winding, a lag secondary winding on the opposite end of said central leg and spaced thereon from the opposite end of said primary winding, a lead secondary winding disposed on said central leg between said primary and said lag secondary windings, first magnetic shunt means disposed between said lead and lag secondary windings and extending between said central leg and said ring portion, second magnetic shunt means disposed between said primary and swing secondary windings and extending between said central leg and said ring portion, a capacitor, a lead circuit connecting said capacitor in series with said primary, swing secondary and lead secondary windings, and a lag circuit connecting said primary and lag windings in series with at least part of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

12. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core having an elongated generally rectangular ring portion with a pair of opposite side legs and a pair of opposite end legs, said core having a central leg extending between said end legs, a primary winding on said central leg, a separate reactive swing secondary winding on one end of said central leg and at one end of said primary winding, a separate lag secondary winding on the opposite end of said central leg and spaced thereon from the opposite end of said primary winding, a separate lead secondary winding disposed on said central leg between said primary and said lag secondary windings, first magnetic shunt means disposed between said lead and lag secondary windings and extending between said central leg and said ring portion, second magnetic shunt means disposed between said primary and lead secondary windings and extending between said central leg and said ring portion, a capacitor, a lead circuit connecting said capacitor in series with said primary, swing secondary and lead secondary windings, and a lag circuit connecting said primary and lag windings in series with at least part of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

13. In a ballast for gaseous discharge lamps, the combination comprising a magnetic core, a primary winding mounted thereon, a separate reactive lead secondary winding mounted on said core adjacent one end of said primary winding, a separate reactive swing secondary winding mounted on said core on the opposite end of said primary winding, a capacitor, a lead circuit connecting said capacitor in series with said primary, lead and swing

windings with said windings additively related, said lead circuit thereby being divided between said lead and swing windings on opposite ends of said primary winding, a separate highly reactive lag secondary winding mounted on said core on the opposite end of said lead winding from said primary winding, said lead winding thereby being disposed between said primary winding and said lag winding, and a lag circuit connecting said primary winding and said lag secondary winding in an additive series with at least a portion of said swing secondary winding.

14. In a ballast for operating a gaseous discharge lamp, the combination comprising a magnetic core, a primary winding mounted thereon, a highly reactive lag secondary winding spaced on said core from one end of said primary winding, a separate reactive swing secondary winding mounted on said core on the opposite end of said primary winding, a lag circuit connecting said primary winding and said lag secondary winding in an additive series with at least a portion of said swing secondary winding for operating the lamp, a separate reactive power factor correcting lead secondary winding mounted on said core between said lag secondary winding and said primary winding, said lead and swing secondary windings thereby being disposed on opposite ends of said primary winding, a capacitor, and a closed lead circuit connecting said capacitor in series with said primary, lead and swing windings in a closed loop with said windings additively related.

15. In a discharge lamp ballast, the combination comprising a magnetic core, a primary winding on said core, a separate reactive swing secondary winding on said core and adjacent one end of said primary winding, a separate lag secondary winding on said core and spaced thereon from the opposite end of said primary winding, a separate lead secondary winding disposed on said core adjacent said primary winding, a capacitor, a lead circuit connecting said capacitor in series with said primary, swing secondary and lead secondary windings, and a lag circuit connecting said primary and lag windings in series with at least part of said swing secondary winding, said primary winding being connected in the same direction in both said lead and lag circuits.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,885,597

May 5, 1959

Bert K. Naster

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 35, for "drags" read -- draws --; column 6, line 64, for "primary" read -- terminal --; line 66, for "primary", second occurrence, read -- terminal --; lines 68 and 69, for "primary" read -- terminal --; line 69, for "swing" read -- lead --; column 7, line 42, for "190" read -- 150 --; line 63, for "220" read -- 218 --; line 72, strike out "228"; column 8, line 61, for "235" read -- 236 --; column 10, line 2, for "148" read -- 120 --; column 13, line 23, for "370" read -- 364 --; line 25, for "370" read -- 364 --; line 41, for "coil" read -- ballast --, both occurrences; line 57, for "samooth" read -- smooth --.

Signed and sealed this 6th day of October 1959.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE
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