

May 30, 1967

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3,323,006

BALLAST FOR OPERATING ELECTRIC DISCHARGE LAMPS
IN CONJUNCTION WITH A COMPANION BALLAST

Filed April 3, 1964

5 Sheets-Sheet 1

FIG. 1

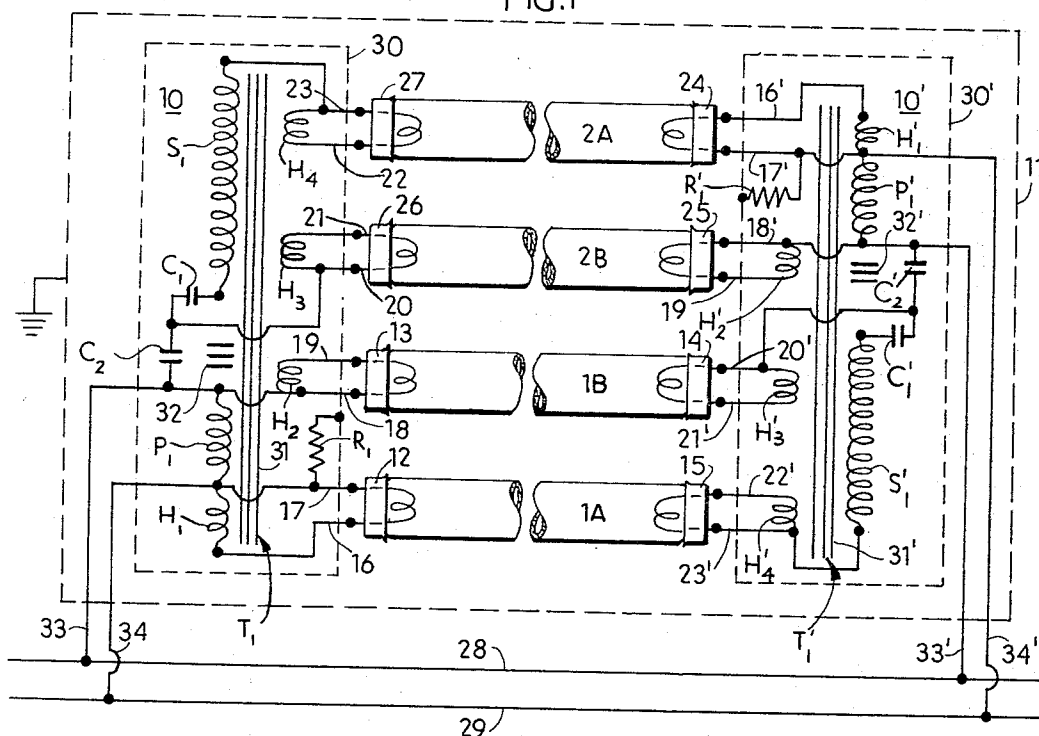
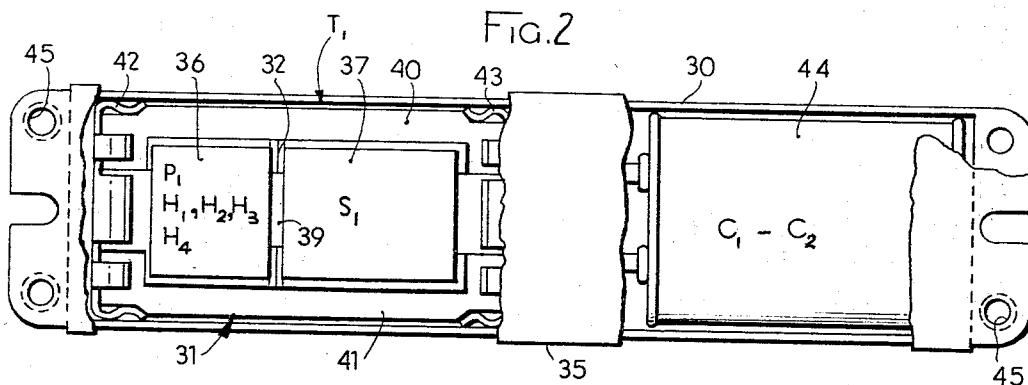


FIG. 2



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5 Sheets-Sheet 2

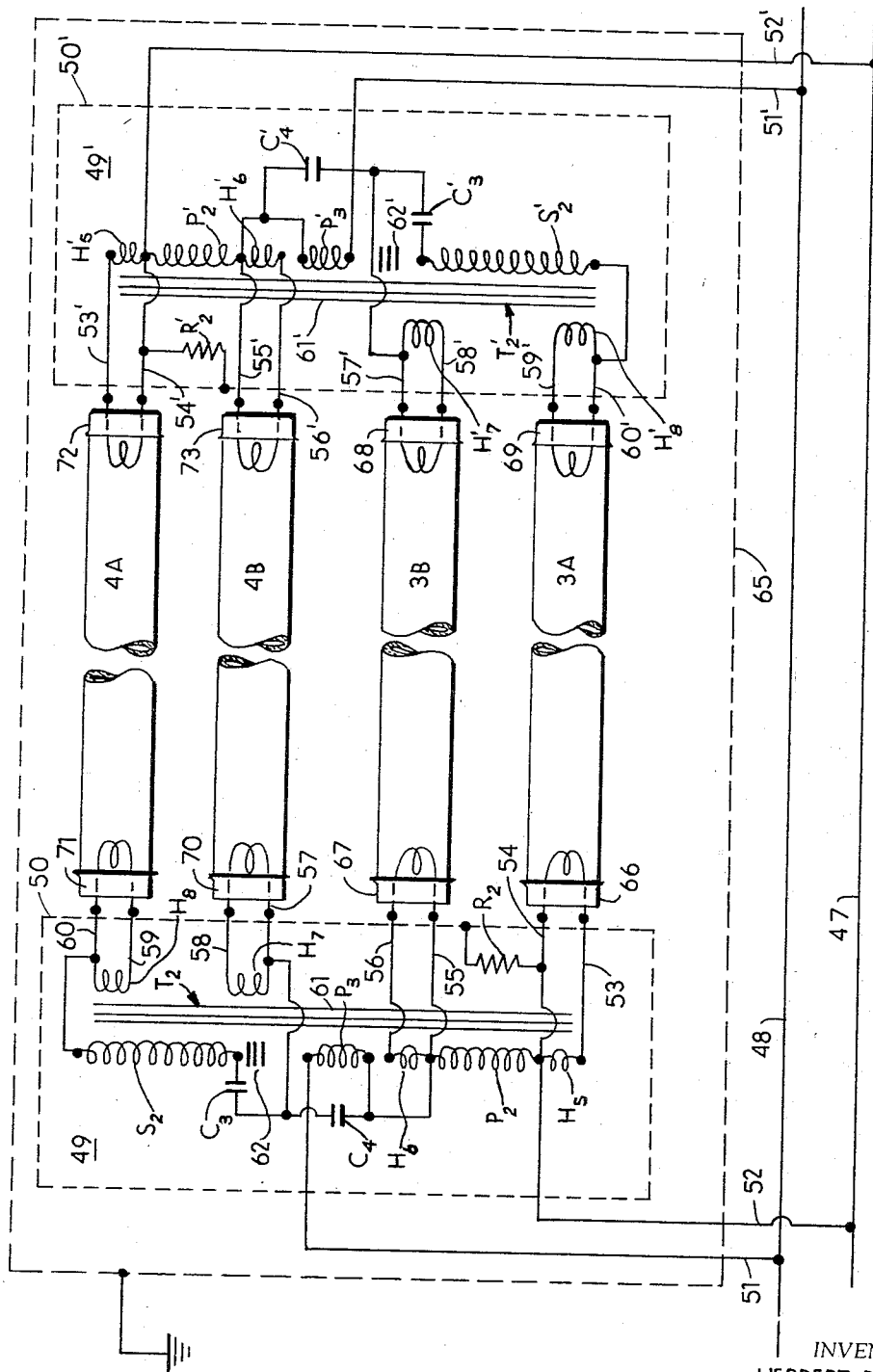


FIG. 3

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5 Sheets-Sheet 3

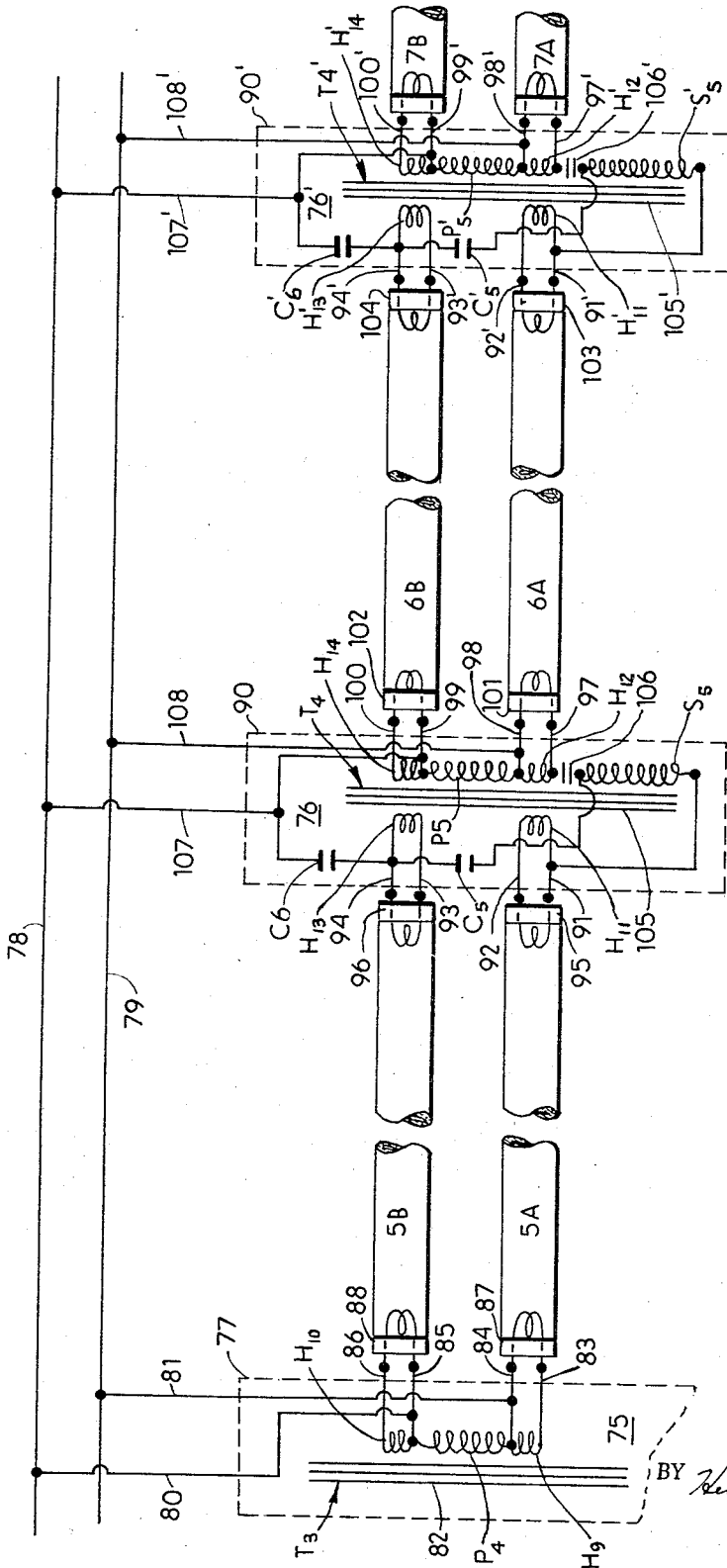


FIG. 4

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5 Sheets-Sheet 4

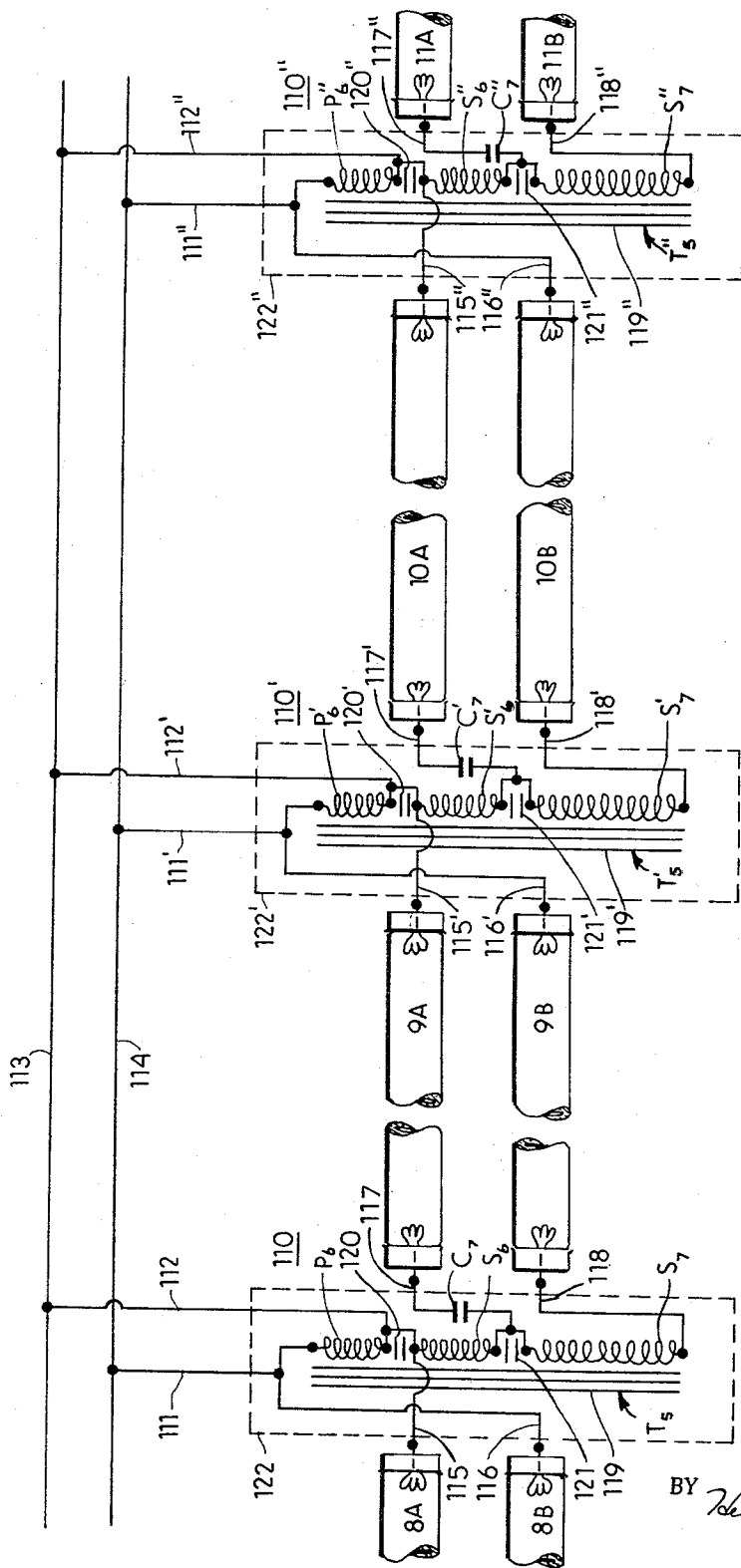


FIG. 5

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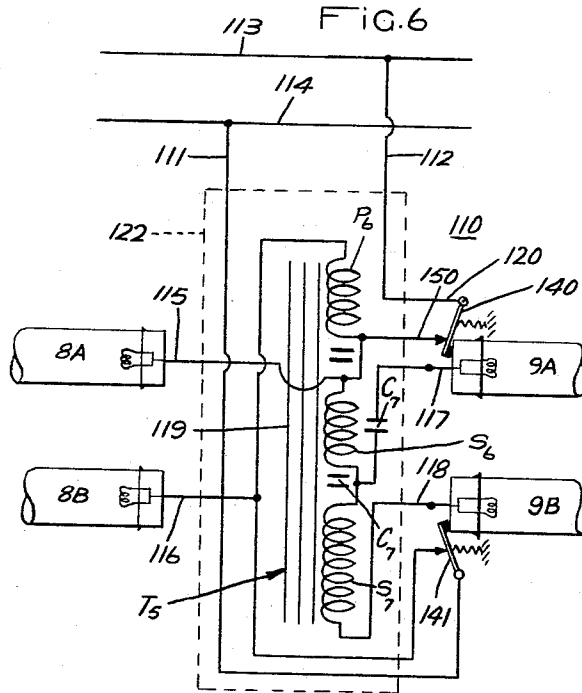
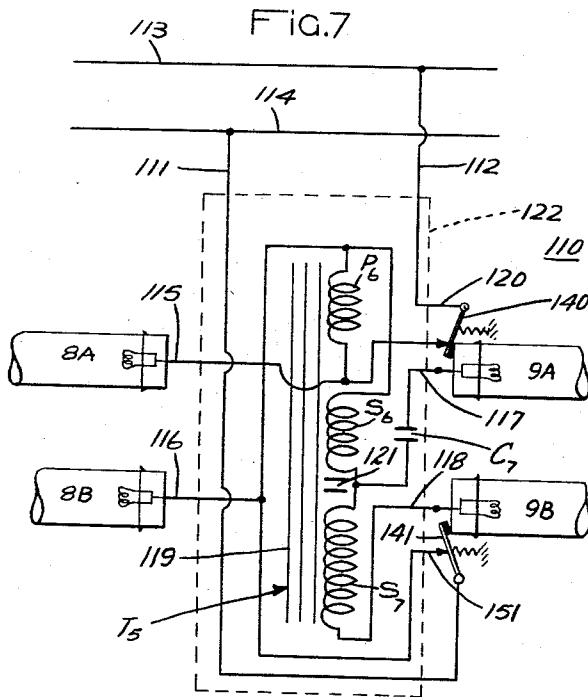
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BALLAST FOR OPERATING ELECTRIC DISCHARGE LAMPS
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Filed April 3, 1964

5 Sheets-Sheet 5



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BALLAST FOR OPERATING ELECTRIC DISCHARGE LAMPS IN CONJUNCTION WITH A COMPANION BALLAST

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Filed Apr. 3, 1964, Ser. No. 357,070
14 Claims. (Cl. 315-97)

This invention relates to ballasts for starting and operating electric discharge lamps such as fluorescent lamps.

In most fluorescent lighting applications the ballast for starting and operating the fluorescent lamps or lamp is mounted in the lamp fixture at a location intermediate between the ends of the lamp. Usually the ballast is secured in a channel provided in the upper portion of the fixture. The fluorescent lamps are generally supported by the lampholders at each end attached to the fixture. Electrical connections between the ballast and the lampholders are made by means of leads, which extend from each end of the ballast case which houses the components of the ballast. These leads are brought out through the fixture channel and connected to the lampholders at both ends of the lamps. Connections are made from the ballast to both ends of the lamps because the lamps are usually connected in an operating loop which includes the lamp filaments at each end of the lamp and at least the high leakage reactance secondary winding of the ballast transformer.

By way of a specific illustration, in a commonly used ballast for starting and operating two 6 foot or 8 foot fluorescent lamps, two 46 inch red leads, two 65 inch blue leads extend from one end of the ballast for connection to the lampholders. Further, at the other end of the ballast, two 46 inch yellow leads are provided for connection with the lampholders, and two 18 inch black and white leads are provided for connection to a 120 volt alternating current supply. Thus, approximately 23 feet of insulated wire extends from the ballast for making the necessary electrical connections to the fluorescent lamps.

Although the leads are color coded, it is quite easy to confuse these leads, particularly when a ballast is being replaced. The running of these leads through the fixture imposes limitations on the design of the fixture. In process of manufacture and shipment the handling of the long leads presents a problem. It is therefore particularly desirable that the length of the external leads from a ballast be kept at a minimum.

Accordingly, it is a general object of my invention to provide a new and improved ballast apparatus for operating electric discharge lamps such as fluorescent lamps.

A more specific object of my invention is to provide an improved ballast for electric discharge lamps such as fluorescent lamps wherein the need for relatively long leads extending from the ballast for connection in electrical circuit with the lamps are effectively eliminated.

In accordance with one form of my invention I have provided an improved ballast for use in conjunction with one or more other companion ballasts to start and operate electric discharge lamps, such as fluorescent lamps. The companion ballast includes a transformer having windings inductively coupled with a primary winding for supplying the heating current for the filaments at one end of the fluorescent lamps. The ballast for use in conjunction with the companion ballast includes a transformer with a primary winding for connection to an alternating current source and with a winding inductively coupled with primary winding for connection in electrical circuit with the filaments at other ends of the lamps for supplying heating current thereto. One of the last mentioned windings is also connected in circuit with the other ends of the lamps and conjointly with one of the windings of the

companion ballast provides the starting and operating potentials for the lamps.

The improved arrangement is also adapted for starting and operating instant start type of fluorescent lamps which do not require cathode preheat current. In such an application, the improved ballast is also used in conjunction with one or more companion ballasts to start and operate one or more instant start lamps and is connected only with one end of the lamps. All of the ballasts in the system include a transformer with a primary winding for connection with an alternating current source and at least one secondary winding loosely coupled therewith on a magnetic core. The loosely coupled secondary winding of one ballast cooperates with the primary winding of another ballast to provide the starting and operating potentials for the lamps.

By the provision of ballasts arranged for connection only with one end of the lamps in accordance with the improved arrangement of the invention, it is possible to eliminate the need for relatively long lamp leads extending from the individual ballasts.

Further aspects of the invention will be apparent from the more detailed description of the invention which follows. It will be understood that the specification concludes with claims which particularly point out and distinctly claim the subject matter which I regard as my invention. The invention, however, both as to organization and method of operation, may be best understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a schematic circuit diagram of a fluorescent lamp ballast embodying one form of my invention;

FIGURE 2 is a plan view of the ballast shown schematically in FIGURE 1 in which the circuit connections and the potting material have been omitted to show the arrangement of components;

FIGURE 3 is a schematic circuit diagram of an improved ballast embodying another form of the invention, the ballast being adapted for operation from an odd voltage alternating current supply, such as a 277 volt supply;

FIGURE 4 is a schematic circuit diagram illustrating a series of fluorescent lamps operating in pairs with the ballasts embodying another form of my invention;

FIGURE 5 is a schematic circuit diagram of the improved ballasts embodying another form of my invention for starting and operating pairs of instant start type of fluorescent lamps;

FIGURE 6 is a schematic circuit diagram of ballasts shown in FIGURE 5 modified for use with a pair of disconnect lampholders; and

FIGURE 7 illustrates another modification of the ballasts shown in FIGURE 5 wherein the primary winding of the ballast transformer is connected so that its voltage is included in the starting circuit.

Referring now more specifically to FIGURE 1 of the drawings, I have shown therein a schematic circuit diagram of ballast apparatuses or ballasts 10 and 10', which are disposed near the ends of four fluorescent lamps 1A, 1B, 2A and 2B mounted on a fixture 11 represented by the dashed rectangle 11. Lamps 1A and 1B are supported at their ends by the lampholders 12, 13, 14 and 15; and are connected in electrical circuit with the ballasts 10 and 10' by leads 16, 17, 18, 19, 20', 21', 22' and 23'. Similarly, the other pair of lamps 2A and 2B are supported in four similar lampholders 24, 25, 26 and 27 are connected with ballasts 10 and 10' by leads 16', 17', 18', 19', 20, 21, 22 and 23.

At the outset it should be noted that there are no interconnecting leads extending from any one of the ballasts 10, 10' to both ends of any one of the lamps. Since the ballasts 10, 10' as shown in FIGURE 1 are essentially the same except for the connections that are made to the ends

of the fluorescent lamps 1A, 1B, 2A and 2B, I have used the same reference numerals and letters to identify the corresponding parts thereof, the numerals and letters used to identify the parts of ballast 10' being primed.

In accordance with the present invention the relatively long leads required to connect the ends of a lamp or lamps with the ballast are eliminated. As will hereinafter be more fully explained, I have found that if the primary winding P_1 of one ballast 10 is electrically connected through the lamps 1A and 1B with the secondary winding S_1 of another companion ballast 10', the need for leads connecting both ends of the lamps 1A and 1B across a ballast is obviated. As is shown in FIGURE 1 the primary winding P_1 of ballast 10 is connected in circuit with the left ends of lamps 1A and 1B and the secondary winding S_1 of ballast 10' is connected with the right ends of lamps 1A and 1B to form a closed operating loop for lamps 1A and 1B. A second closed operating loop for fluorescent lamps 2A and 2B is provided by the connections of the lamps with the primary winding P'_1 with the right ends of lamps 2A and 2B and the connections of the secondary winding S'_1 with the left ends of the lamps 2A and 2B. Thus, a primary and a secondary winding which are not magnetically coupled with each other on the same magnetic core are connected electrically in circuit through the lamps to form lamp operating loops.

In the illustrated embodiment of the invention shown in FIGURE 1, the ballasts 10, 10' were adapted for operation from a standard commercial 120 volt, alternating source, represented by the supply lines 28 and 29. The ballasts 10, 10' respectively include a high leakage reactance transformer T_1 , T'_1 , a series capacitor C_1 , C'_1 , a starting capacitor C_2 , C'_2 , a grounding resistor R_1 , R'_1 and a ballast case 30, 30' represented schematically by a dashed rectangle. The lamps 1A, 1B, 2A and 2B are positioned in proximity usually to a conductive plate or the equivalent thereof so that the filaments of the lamps are capacitively coupled with the conductive plate during the starting condition. In most applications, as in the illustrated embodiment, the fixture 11 in which the lamps are mounted serves as the conductive plate.

The high leakage reactance transformers T_1 , T'_1 respectively include a magnetic core 31, 31' magnetic shunts 32, 32', a primary winding P_1 , P'_1 , a secondary winding S_1 , S'_1 , filament heating windings H_1 , H_2 , H_3 , H_4 and H'_1 , H'_2 , H'_3 and H'_4 and input terminal leads 33, 34 and 33' and 34'. Although in the illustrated exemplification of the invention the input leads 33, 34 and 33' and 34' are brought out externally from the ballasts 10, 10' for connection to the supply lines 28, 29, it will be appreciated the present arrangement is particularly adaptable to plug-in type of ballasts, in which the connections to the power may be made without external leads by the provision of male fittings insertable into a receptacle. Further, it will be appreciated that with the improved arrangement it is possible to make the lampholders 12, 13, 26 and 27 a part of the ballast 10 thereby eliminating the need for any external leads to be brought out externally from the ballast case 30.

Having more specific reference now to FIGURE 2, I have shown therein an unpotted ballast 10 with the coverplate 35 broken away and without any circuit connections. It will be seen that the coil 36 which includes the primary winding P_1 and the heating windings H_1 , H_2 , H_3 and H_4 is separated from the coil 37 which includes the secondary windings S_1 by the magnetic shunts 32. It will be understood, of course, that the leakage reactance of a ballast transformer may be readily increased by the inclusion of a high reluctance leakage path or shunts of a magnetic material between the primary and the secondary windings of the ballast transformer. In the exemplification of the invention illustrated in FIGURES 1 and 2, the flux leakage path was formed of inserted shunts. Flux leakage paths may be formed either through nonmagnetic material, such as air, or through magnetic material by the provision of

projecting shunt legs integrally formed with the yoke section or by inserted shunts 32 such as are shown in FIGURE 2. A high leakage reactance transformer is normally used in a ballast since the fluorescent lamps have a negative resistance characteristic and a high leakage reactance transformer has a good current limiting characteristic.

As is shown in FIGURE 2, the magnetic core 31 has a central winding leg 39 and the yoke sections 40, 41 which are firmly held in assembled relation with the central leg 39, by means of clamps 42, 43. The three-terminal capacitor 44 includes the series and the starting capacitors C_1 , C_2 .

It will be noted that the coverplate 35 is attached at ends thereof to the ballast case 30 by means of the eyelet members 45. Since the ballast case 30 is usually secured to a grounded lamp fixture and further since the low potential side of the ballast transformer T_1 is connected to the case 30 through the isolating resistor R_1 , the low potential side of the ballast transformer T_1 is effectively grounded. It will be understood that if the low potential side of the distribution line is properly grounded and if the fixture is properly grounded, there would, of course, be no need in an autotransformer-connected ballast for the grounding connection to the ballast case 30. In the event that the distribution system is not effectively grounded or in the event that the lamp fixture 11 is not grounded, the starting aid resistor R_1 will provide a connection between the low potential side of the ballast circuit and the fixture to provide an auxiliary starting aid circuit.

Referring more specifically now to FIGURE 1, I will now more fully describe the operation of the ballasts 10 and 10' shown therein. When the high leakage reactance transformers T_1 and T'_1 are energized, voltages are induced in the secondary windings S_1 and S'_1 as is determined essentially by the respective turns ratio of the transformers T_1 , T'_1 . Also, voltages are immediately induced in the filament heating windings, and heating current is supplied to the filaments of lamps 1A, 1B, 2A and 2B. The open circuit voltage developed across the primary winding P_1 and the secondary winding S'_1 is applied across lamp 1A because of the shunting action of the starting capacitor C'_2 . It will be noted that the starting capacitor C'_2 is effectively connected across lamp 1B by circuit means which can be traced as follows: Starting at the right end of the lamp 1B, the circuit includes lead 20', the starting capacitor C'_2 , the input terminal lead 33', a portion of supply line 28, the input terminal lead 33 and lead 18 connected to the lamp-holder 13 at the left end of lamp 1B.

In a conventional ballast circuit, it will be appreciated that the starting capacitor is connected in circuit by means of leads brought from a ballast to both ends of the lamp. With the arrangement shown in FIGURE 1 the need for making such connections across the lamps is eliminated.

Continuing now with the description of the lamp operating circuit which includes lamps 1A and 1B, the combined voltages across the primary winding P_1 and across the secondary winding S'_1 are initially applied across lamp 1A. Also, during the starting condition, the combined potential across the primary winding P'_1 and the secondary winding S_1 is applied to the filament at the right end of lamp 1A, which is in capacitive relation with the conductive plate or fixture 11 so that a small current flows thereacross to aid in starting the lamp 1A.

After lamp 1A ignites, it conducts current and therefore a current flows through starting capacitor C'_2 , and the voltage across the starting capacitor C'_2 causes a breakdown of the gas contained in the lamp thereby causing the ignition of lamp 1B. The starting capacitor C'_2 presents sufficient impedance during operation so that it effectively isolates the lamp operating current for lamp 1A and 1B from the primary winding P'_1 . After both lamps 1A and 1B have ignited, there is only a negligible

5

amount of current flow between the lamp filaments and the fixture 11 because of the relatively high impedance presented by the capacitive coupling between the lamps and the fixture. Lamps 1A and 1B are operated in a closed loop or operating circuit which includes the primary winding P_1 of transformer T_1 , lead 19, the lamp 1B, lead 20', the series capacitor C'_1 , the secondary winding S'_1 , lead 23', lamp 1A and lead 17.

The other pair of lamps 2A and 2B are similarly started by the open circuit voltage across the primary winding P'_1 of transformer T'_1 and the voltage across the secondary winding S_1 of the transformer T_1 . The lamps 2A and 2B are operated in an operating circuit which includes the primary winding P'_1 , lead 18', lamp 2B, lead 20, the series capacitor C_1 , the secondary winding S_1 , lead 23, lamp 2A and lead 17'.

From the foregoing description, it will be apparent that I have provided an improved arrangement for operating a plurality of fluorescent lamps wherein the primary winding of one ballast transformer connected only with the left side of the fluorescent lamps is coupled with the secondary winding of another ballast transformer connected only with the right end of the fluorescent lamps to operate one pair of lamps in a closed operating loop thereby eliminating the need for external leads connecting both ends of the lamps with a ballast. Thus, the windings of one ballast complement the windings of the other ballast in providing the starting and operating voltages for the fluorescent lamps.

In FIGURE 3 I have illustrated a circuit diagram of a pair of ballasts 49 and 49', are shown enclosed in the cases 50, and 50' and are adapted for operation from an odd voltage supply, such as 277 volt alternating current supply represented by supply lines 47, 48. This embodiment of my invention generally differs from the FIGURE 1 embodiment in that a portion P_3 of the transformer primary is not included in the lamp operating circuit.

The high reactance transformers T_2 , T'_2 respectively include the input leads 51, 52, 51', 52', the output leads 53, 54, 55, 56, 57, 58, 59, 60 and 53', 54', 55', 56', 57', 58', 59', 60', a magnetic core 61, 61', a magnetic shunt 62, 62', primary winding portions P_2 , P_3 , P'_2 , P'_3 and secondary windings S_2 , S'_2 . The series capacitors C_3 , C'_3 respectively so that a leading current will flow in the lamp operating loop during operation. The starting capacitor C'_4 associated with the pair of lamps 3A, 3B is connected across lamp 3B by a circuit means which includes the primary winding portion P'_3 , the input terminal lead 51', a part of supply line 48, input lead 51, primary winding portion P_3 , output lead 55 and output lead 57' at the other end of lamp 3B. Similarly, the starting capacitor C_4 associated with lamp operating circuit for lamps 4A, 4B is connected across lamp 4B by a circuit which includes the primary winding portion P_3 , input terminal lead 51, a part of the supply line 48, the input terminal lead 51', the primary winding portion P'_3 , lead 55' and the lead 57 at the left end of lamp 4B. During the starting condition the series connection of the primary winding portions P'_3 and P_3 through the starting capacitor C'_4 is such that the voltages across the primary winding portions P'_3 and P_3 cancel out.

In the FIGURE 3 embodiment an auxiliary starting aid potential is applied at the filament at the right end of lamp 3A that includes the voltage across the primary winding portion P'_2 , the voltage across the capacitors C'_4 and C'_3 , and the voltage across the secondary winding S'_2 . Similarly, a starting aid potential is applied at the filament at the left end of lamp 4A which includes the voltage across the primary winding portion P_2 , the voltage across the capacitors C_4 and C_3 , and the voltage across the secondary winding S_2 . It will be noted that the voltage across the primary winding portions P_3 and P'_3 does not appear in the auxiliary starting aid circuit and that the fluorescent lamps 3A, 3B, 4A, 4B are capacitively coupled with the

6

grounded fixture 65 due to the proximity of the lamps to the fixture 65. Preferably, the lamps 3A, 3B, 4A and 4B are supported within at least one inch from the metallic fixture 65 by the lampholders 66, 67, 68, 69, 70, 71, 72 and 73 to insure that the lamps are capacitively coupled with the grounded fixture.

Although the primary winding portion P'_2 and its inductively associated secondary winding S'_2 contribute voltage in the auxiliary starting aid circuit, once lamps 3A and 3B are ignited, the secondary winding S'_2 , in effect, disassociates itself with the primary winding portion P'_2 and contributes voltage in a lamp operating loop which includes the primary winding portion P_2 of the companion ballast 10. Starting at the left end of lamp 3A, this operating loop includes lead 54, the primary winding portion P_2 , output lead 55, lamp 3B, lead 57', the series capacitor C'_3 , the secondary winding S'_2 , lead 60' and lamp 3A. The voltage across secondary winding S_2 is utilized in conjunction with voltage primary winding portion P_2 only to aid in initiating the ignition of lamp 4A. During operation the secondary winding S_2 contributes voltage in conjunction with the primary winding portion P'_2 to operate lamps 4A and 4B. The operating loop for lamps 4A and 4B includes the primary portion P'_2 , output lead 55', lamp 4B, output lead 57, series capacitor C_3 , the secondary winding S_2 , the output lead 60, lamp 4A and output lead 54'.

In FIGURE 4 I have illustrated another form of the invention as applied to a fluorescent lamp lighting system in which the fluorescent lamps are operated in serially arranged fixtures such as is commonly found in large commercial buildings. The number of ballasts 75, 76, 76' which can be operated in this manner is, of course, limited by the current carrying capacity of the circuit branch. It will be noted that the first ballast 75 in the series consists essentially of a filament transformer T_3 enclosed in a case 77. The filament transformer T_3 is connected across the supply lines 78, 79 by input terminal leads 80, 81, includes a primary winding P_4 , filament heating windings H_9 , H_{10} , a magnetic core 82 and leads 83, 84, 85 and 86 connected with the lampholders 87, 88 supporting the left ends of the lamps 5A and 5B.

The other ballasts 76, 76' and including the last ballast (not shown) in the series are essentially the same. In the last ballast of the series the connections of filament heating windings H'_{12} , H'_{14} which are extensions of the primary winding are omitted. In all of the intermediate ballasts in the series, only two of which are shown in FIGURE 4, it will be noted that the lamp connections are made at opposite sides of the ballast cases 90 and 90'. It will be apparent that in some applications it may be advantageous to make the lampholders a part of the ballast case. When this is done, the ballasts themselves may serve as the lamp fixture.

As shown in FIGURE 4, leads 91, 92, 93, 94 from the left side of the ballast case 90 are connected to the lampholders 95 and 96 which support the right ends of lamps 5A and 5B. Also, four leads 97, 98, 99, 100 at the right side of the ballast case 90 are connected in electrical circuit with the lampholders 101, 102 which support the left ends of lamps 6A and 6B. The right ends of lamps 6A and 6B are supported by the lampholders 103 and 104 which are connected in circuit with leads 91', 92', 93' and 94' of ballast 76'. Since the parts of the ballasts 76 and 76' are essentially the same, the corresponding parts of ballast 76' are identified with the same reference letters and numerals but are primed so that these parts can be distinguished from its companion ballast 76. Although in the embodiment of the invention illustrated in FIGURE 4, only three ballasts 75, 76, 76' are shown, it will be understood, of course, that more units may be connected in the series, the actual number employed depending upon the branch circuit limitations is a particular installation.

Having more specific reference to ballast 76, it will be seen that the ballast 76 includes the high leakage reactance

transformer T_4 , a series capacitor C_5 and a starting capacitor C_6 . The high leakage reactance transformer T_4 is comprised of a primary winding P_5 , a secondary winding S_5 , filament heating windings H_{11} , H_{12} , H_{13} and H_{14} , a magnetic core 105, magnetic shunts 106, and a pair of input leads 107, 108 for connection to a suitable alternating current supply, such as for example a 120 volt commercial supply.

In the embodiment of the invention illustrated in FIGURE 4, the isolated filament heating windings H_{11} and H_{13} connected by the leads 91, 92, 93, 94 with adjacent lampholders 95, 96 and in electrical circuit with the right ends of the fluorescent lamps 5A and 5B. The filament heating windings H_{12} and H_{14} are connected by leads 97, 98, 99, 100 with lampholders 101, 102 and in electrical circuit with the filaments at the left ends of lamps 6A and 6B. In general, it will be noted that the left ends of the pairs of lamps are connected with a primary winding and the filament heating windings which are extensions of the primary winding and the right ends of the pairs of lamps are connected with a secondary winding and the isolated filament heating windings of a companion ballast. Thus, no external interconnections from a ballast to both ends of a lamp, other than those that occur through the supply lines, are required to start and operate each pair of lamps.

Referring again more specifically to the ballasts 75 and 76, it will be seen that the starting capacitor C_6 is connected in circuit across lamp 5B by a circuit that includes a portion of the supply line 78. Starting at the right end of lamp 5B, this circuit may be traced through the output lead 94, the capacitor C_6 , input terminal lead 107 the portion of the supply line 78 between input terminal lead 107 and input terminal lead 80 of ballast 75, and output lead 86 at the left end of lamp 5B.

With the supply lines 78, 79 energized, the primary windings P_4 , P_5 , P'_5 of the ballasts 75, 76, 76' etc. connected in circuit with the supply lines 78, 79 will be energized and a voltage will appear across the secondary windings and filament heating windings. The filaments of all of the fluorescent lamps 5A, 5B, 6A, 7A, 7B, etc. are heated for emission. Turning now more specifically to ballasts 76 and 76', the open circuit voltage across the secondary winding S'_5 of ballast transformer T'_4 and the open circuit voltage across the primary winding P_5 of ballast transformer T_4 will be initially applied across the lamp 6A. With the conduction through lamp 6A initiated, a voltage will build up across the starting capacitor C'_6 . Beginning at the right end of lamp 6B, the starting circuit includes output lead 94', the starting capacitor C'_6 input terminal lead 107', the portion of the supply line 78 between the input leads 107 and 107', input lead 107, and the output lead 99 at the left end of lamp 6B. The voltage developed across the starting capacitor C'_6 is sufficient to cause lamp 6B to ignite. With both lamps 6A and 6B ignited they are operated in a closed loop which includes lamp 6B, lead 94', the series capacitor C'_5 , the secondary winding S'_5 , output lead 91', lamp 6A, lead 98, the primary winding P_5 of ballast 76, and lead 99 at the left end of lamp 6B. The other pairs of lamps 5A, 5B and 7A, 7B in the system are started and operated in a similar manner.

Having particular reference now to FIGURE 5, I have shown therein a schematic circuit diagram illustrating another embodiment of the invention as applied to fluorescent lamps 8A, 8B, 9A, 9B, 10A, 10B, 11A, 11B of the instant start type. Instant start fluorescent lamps differ from other types of fluorescent lamps in that the electrodes are not preheated in order to start the arc discharge. The instant start lamps require a relatively high voltage supplied across the electrodes to start the electric discharge. However, as soon as the lamps are ignited the electrodes heat up and a hot spot is developed providing the required electron omission at a relatively low cathode drop.

In FIGURE 5, I have shown three ballasts 110, 110'

and 110'' which cooperatively supply the starting and operating voltages for the lamps 9A, 9B, 10A and 10B. Also, these ballasts cooperate with other ballasts (not shown) to start and operate the fluorescent lamps 8A, 8B and 11A, 11B. The first ballast in the series may be provided by leaving the leads or terminals at the left side of a ballast unconnected. The last ballast in the series may be provided by leaving the leads or terminals at the right side disconnected. Since the ballasts 110, 110' and 110'' are identical in construction, I have identified the corresponding parts of the ballasts 110' and 110'' respectively with single primed and double-primed reference letters and numerals to identify the corresponding parts thereof. Further, to simplify the description of these ballasts, specific references will be made only to ballast 110.

Ballast 110 includes a ballast transformer T_5 , a capacitor C_7 , a pair of input terminals or leads 111, 112 provided for connection to an alternating current supply represented by supply lines 113, 114, a pair of output leads 115, 116 for connection in circuit with the right end of instant start lamps 8A, 8B, and output leads 117, 118 for connection in circuit with the ends of a second pair of instant start lamps 9A, 9B. The ballast transformer T_5 includes a primary winding P_6 , a loosely coupled secondary winding S_6 , a secondary winding S_7 , a magnetic core 119, and a pair of magnetic shunts 120, 121. All of the components of the ballast 110 are housed in a case 122.

The ballasts 110, 110' cooperate to ignite lamps 9A and 9B as follows: lamp 9A is initially ignited by the voltage which appears across the secondary winding S_6 of the ballast 110. It will be appreciated that the voltage across the capacitor C_7 is negligible before the conduction in lamp 9A is initiated. When lamp 9A ignites, current flows through the circuit which includes the input terminal lead 112', lead 115', lamp 9A, lead 117, capacitor C_7 , the loosely coupled secondary S_6 and input lead 112. The capacitor C_7 , in effect, produces a phase shift in the voltage across the secondary winding S_6 by lowering the net reactance of the circuit. This phase shift results in a voltage across the secondary winding S_6 that is in additive relative to the voltage across secondary winding S_7 . The combined effect of the voltage across primary winding P'_6 , the secondary winding S_6 and the secondary winding S_7 results in the ignition of lamp 9B. With current flowing through both of the lamps 9A and 9B the relatively high leakage reactance of secondary winding S_6 causes the winding S_6 to be effectively isolated from the operating circuit. Starting with the primary winding P'_6 , the operating circuit may be traced through lead 116', lamp 9B, lead 118, the secondary winding S_7 , the capacitor C_7 , lead 117, lamp 9A and lead 115'.

In FIGURE 6 I have illustrated a modification of the ballast 110 used in the system illustrated in FIGURE 5 in which the ballast 110 is adapted for use in conjunction with a pair of disconnect lampholders 140 and 141. The disconnect lampholders 140 and 141 include two contacts which are closed only when the lamp terminals of lamps 9A and 9B are inserted in the lampholders 140 and 141. When the left end lamp 9A is removed from the disconnect lampholder 140, it will be seen that the connection between the input lead 112 and the lead 150 connected to the junction between the primary winding P_6 and the secondary winding S_6 is opened thereby deenergizing the ballast 110. Further, it will be seen that when the left end of lamp 9B is removed from the disconnect lampholder 141, the connection between input terminal lead 111 and lead 151 connected to one end of the primary winding P_6 is open. Thus the ballast 110 is deenergized when either lamp is removed from its respective lampholder 140, 141. It will be understood, of course, that the left ends of the lamps 8A and 8B are similarly connected in disconnect lampholders associated with a companion ballast which is identical to the ballast 110 as shown in FIGURE 6.

Referring now to FIGURE 7 I have shown therein a ballast 110 incorporating an additional modification wherein the upper end secondary winding S_6 is connected to the upper end of the primary winding P_6 so that the voltage across the primary winding P_6 is included in the starting circuit for lamp 9A. With this starting connection it will be seen that the voltage across the secondary winding S_6 and also the voltage across the primary winding P_6 are included in the starting circuit loop. Starting at the left end of lamp 9A, this starting circuit loop includes the lead 117, the capacitor C_7 , the starting winding S_6 , the primary winding P_6 , lead 150, lead 112, part of the supply line 113, and the lead corresponding to lead 112 of the companion ballast which is connected in circuit with the right end of lamp 9A (not shown).

From the foregoing description of the various illustrated embodiments of my invention, it will be apparent that I have provided an improved ballasting arrangement for starting and operating electric discharge lamps such as fluorescent lamps, wherein the need for relatively long terminal leads for effecting electrical connection to both ends of the lamps has been eliminated. With the improved arrangements the handling of ballasts and the design of fluorescent lamp fixtures for these ballasts are greatly simplified.

Although several embodiments of the invention have been described in connection with ballasts for operating two or more lamps, it will be apparent that the ballasts are readily adapted for the operation of single lamps in a series system arrangement. Further, it will be apparent to those skilled in the art that other alterations and various modifications may be made without departing from the invention. It is therefore intended in the appended claims to cover all such alterations and 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. A ballast for use in conjunction with a companion ballast to start and operate at least one electric discharge lamp, said companion ballast including a high leakage reactance transformer having a primary winding for connection with an alternating current source and at least one secondary winding inductively coupled therewith on a magnetic core, and including circuit means for connection with one end of said electric discharge lamp to place said primary winding in circuit therewith, said ballast for use in conjunction with said companion ballast comprising: a high leakage reactance ballast transformer having a primary winding and at least one secondary winding inductively coupled therewith on a magnetic core, input means for connecting the primary winding of said ballast transformer in circuit with an alternating current source, and output means for connecting said last-mentioned secondary winding of said ballast transformer in circuit with the other end of the electric discharge lamp to place said last-mentioned secondary winding and the primary winding of the companion ballast in a lamp operating circuit for supplying the potential for operation of said lamp.

2. The ballast for use in conjunction with a companion ballast as set forth in claim 1 wherein a capacitor is connected in series circuit relation with the secondary winding to cause a leading current to flow in the lamp operating circuit and wherein windings inductively coupled on said magnetic core with the primary winding are provided for connection in circuit with the filament at said other end of the electric discharge lamp.

3. A fluorescent lamp ballast for use in conjunction with a companion ballast to operate at least two fluorescent lamps, said companion ballast including a transformer having a primary winding and at least one secondary winding inductively coupled therewith on a magnetic core, and also including circuit means for connecting said primary winding with one end of the fluorescent lamps, said ballast for use in conjunction with said companion

ballast comprising: a high leakage reactance transformer having a primary winding and at least one secondary winding inductively coupled therewith on a magnetic core, input means connected with said primary winding for connection in circuit with alternating current supply lines, and means for connecting the secondary winding of said high leakage reactance transformer in circuit with the other ends of the fluorescent lamps to place the secondary winding of the high leakage reactance transformer and the primary winding of the companion ballast in a lamp operating circuit to conjointly provide the operating voltage for said lamps without need for connections from one of said ballasts to both ends of said fluorescent lamps.

4. The ballast for use in conjunction with a companion ballast as set forth in claim 3 wherein a starting capacitor is connected in electrical circuit with the primary and secondary windings of said ballast for use in conjunction with a companion ballast to cause a starting voltage to be initially across one of the lamps, said starting capacitor during starting being electrically in parallel circuit relation with one of said lamps through the connections of said ballasts with the alternating current supply lines.

5. The ballast for use in conjunction with a companion ballast as set forth in claim 3 wherein a capacitor is connected in series circuit relation with the secondary winding to cause a leading current to flow to said lamps; and wherein windings inductively coupled with the primary winding on said core are provided for connection in circuit with the filaments at said other ends of said fluorescent lamps for supplying heating current to said filaments.

6. A fluorescent lamp ballast for use in conjunction with at least one companion ballast to start and operate a plurality of fluorescent lamps, said companion ballast including a transformer with a primary winding for connection with an alternating source and having windings inductively coupled therewith on a magnetic core for supplying at least the filament heating current for the filament at one end of said fluorescent lamps, said ballast for use in conjunction with said companion ballast comprising: a transformer having a primary winding for connection with an alternating current source and windings inductively coupled with said primary winding on a magnetic core, and circuit means for connecting said windings with the other ends of said fluorescent lamps for supplying at least the heating current for the filaments at the other ends of said fluorescent lamps, said last mentioned transformer conjointly with said companion ballast limiting the current supplied to the lamps during operation and providing the potential required for starting and operating said fluorescent lamps without need for connections from said ballasts to both ends of the lamps.

7. A fluorescent lamp ballast for operating four fluorescent lamps in conjunction with a companion ballast that includes a high leakage reactance transformer having a primary winding for connection with alternating supply lines and a secondary winding inductively coupled therewith on a magnetic core, said companion ballast including means for connection with one end of the first pair of said fluorescent lamps to place said primary winding in circuit therewith, and for connection with one end of the second pair of said lamps to place said secondary winding in circuit with second pair of lamps, said ballast for use in conjunction with said companion ballast comprising: a high leakage reactance transformer having a primary winding for connection with the alternating current supply lines and having a secondary winding inductively coupled with said primary winding on a magnetic core, means for connection with the other ends of the first pair of fluorescent lamps to place said last mentioned secondary winding in a first lamp operating circuit with the primary winding of the companion ballast to operate said first pair of lamps, and means for connection with the other ends of said second pair of lamps to place the primary winding of said ballast for use in conjunction with said companion ballast in a second lamp operating

11

circuit with the secondary winding of the companion ballast to operate said second pair of lamps.

8. The ballast for use in conjunction with a companion ballast as set forth in claim 7 wherein a starting capacitor is connected in electrical circuit with the primary and secondary winding to cause a starting voltage to be initially applied across one of the lamps of said second pair of lamps, said starting capacitor during starting being in parallel circuit relation with the other of said second pair of lamps by the connection of said ballasts with the alternating supply lines, and during operation said starting capacitor presenting a relatively high impedance to isolate the last mentioned secondary winding from said second lamp operating circuit.

9. The fluorescent lamp ballast for use in conjunction with a companion ballast as set forth in claim 7 wherein a capacitor is connected in series circuit relation with the secondary winding to cause a leading current to flow in said second lamp operating circuit.

10. A ballast for use in conjunction with at least one companion ballast to start and operate a plurality of electric discharge lamps, said companion ballast including at least a means for supplying the heating current for the filaments at one end of said electric discharge lamps and including terminals for connection with an alternating current source, said ballast for use in conjunction with said companion ballast comprising: potential supply means including current limiting means for connection with an alternating source, circuit means for connection of said potential supply means in circuit with the other ends of the electric discharge lamps for supplying lamp operating current and heating current for the filaments at said other ends of said lamps, and said potential supply means of said last mentioned ballast with the companion ballast conjointly ballasting and providing the operating potential for said lamps without need for electrical connections to be brought out from any one of said ballasts to both ends of an electric discharge lamp.

11. The ballast for use in conjunction with a companion ballast as set forth in claim 10 wherein a starting capacitor is connected in electrical circuit with the potential supply means to cause a starting voltage to be initially applied across one of said lamps, said capacitor during starting being in parallel circuit relation through the connection of said ballast with the alternating current source.

12. A system for starting and operating at least a pair

12

of electric discharge lamps including a first and second ballast, each comprising a transformer having a primary winding for connection with an alternating current source and a secondary winding inductively coupled with the primary winding, said system comprising at least two lamp operating circuits with the primary winding of one transformer and the secondary winding of the other transformer in each of the lamp operating circuits, whereby the windings in each lamp operating circuit conjointly supply the operating and starting potential for said electric discharge lamps without need for leads to be brought out from one of said ballasts for connection to both ends of said lamps.

13. The system of claim 12 wherein a capacitor is connected in each of said lamp operating circuits to cause a leading current to flow to the lamps during operation.

14. A fluorescent lamp ballast for use in conjunction with companion ballasts to start and operate fluorescent lamps, said companion ballast including a transformer having a primary winding for connection with an alternating current source, at least one secondary winding inductively coupled with the primary winding on a magnetic core, means for supplying at least heating current to one end of at least one of the fluorescent lamps, said ballast for use in conjunction with the companion ballasts comprising: a ballast transformer having a primary winding for connection with an alternating source and also having at least one secondary winding inductively coupled with the primary winding on a magnetic core, and including means for supplying heating current to the other end of at least one of the fluorescent lamps, and circuit means for connecting one of the windings of said last mentioned transformer in circuit with said other end of at least one of the fluorescent lamps, the primary winding of one of the transformers and the secondary winding of the other transformer conjointly providing the electrical potential for operating said at least one of said fluorescent lamps.

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