This invention relates to electrical transformer ballasts and has for an object the provision of a novel, simple and economical high performance transformer ballast for a plurality of serially connected electric arc discharge devices such as fluorescent lamps.

The invention will be better understood from the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring now to the single figure of the accompanying drawing, which illustrates diagrammatically an embodiment of the invention, the high reactance transformer ballast is indicated generally at 1 and it is shown connected to two hot cathode fluorescent lamps 2 and 3, which are preferably of the so-called rapid start type as described and claimed in U.S. Patent 2,774,918 granted December 18, 1956, upon an application, Serial No. 250,106, filed Oct. 6, 1951, in the name of Eugene Lemmers and assigned to the same assignee. They are charge actinotronized by having cathodes which can be continuously heated to electron emission at voltages below the ionization voltage of the gas or vapor in the lamp. The transformer ballast is enclosed in a metal case which is indicated schematically at 4 and comprises essentially a shell-type transformer core and coil assembly 5 and associated electric circuit elements including a starting capacitor 6, a running capacitor 7 for providing leading current operation, and interconnecting circuit conductors.

The core of assembly 5 comprises a laminated magnetic core preferably of the general type described in U.S. Patent 2,734,176 granted February 7, 1956 upon an application, Serial No. 239,229, filed July 30, 1951, in the names of Herbert R. Gould and Andrew Schevitz and assigned to the same assignee. It has three laminations pieces or punchings per laminating layer, there being in each layer a central winding leg punching 8 and similar three-legged yoke punchings 9 disposed on opposite sides of the winding leg punching with the two end legs of each yoke punching in contact with the winding leg punching. Between the center part of the winding leg punching on opposite sides under the center legs of the yoke punchings 9 are non-magnetic gaps for high reluctance leakage flux paths or magnetic shunts of the transformer, which paths include the center legs of the yoke punchings 9. The term "magnetic shunt" is used herein to mean a high reluctance path for magnetic leakage flux whether through magnetic material or through non-magnetic material such as air. The right hand end legs of the yoke punchings 9, as viewed in the drawing, are notched so as to contact only the corners of the leg punchings 8 and provide gaps 10 and magnetic bridges 11 therefor which are buried in the core, i.e., separated from case 4 by the right hand end legs of yoke punchings 9. Also, the left-hand end legs are shorter than the right-hand end legs of the punchings for permitting economical nesting of these punchings when they are produced.

Mounted on the center leg punchings 8, on opposite sides of the center legs of the yoke punchings 9, are a primary winding 12 and a secondary winding 13, the primary winding having a tap 14. Also mounted on the winding leg 9 adjacent to or closely coupled to the primary winding 12 are a pair of cathode heater supply windings 15 and 16.

The circuit elements of the transformer ballast are connected to each other and to the lamps and to suitable input terminals 17 in the following manner. The primary winding 12 is connected directly between the input terminals by way of conductors 18, 19, tap 14, conductors 20 and 21. The secondary winding 13 has one terminal 22 thereof directly connected to the conductor 18 so that the primary winding and the secondary winding are connected in autotransformer relationship, and the polarity of the windings is such that the connection produces voltage step-up action. The other terminal 23 of the secondary winding 13 is the high voltage terminal of the step-up autotransformer and the high voltage terminal of conductor 23 is connected to one terminal or cathode heater of the lamp 3 by way of the running capacitor 7 and a conductor 24. The electrically adjacent electrodes or cathode heaters of the lamps 2 and 3 are directly interconnected as shown, and the lamp leg 2 is connected to the low voltage or normally grounded terminal of the transformer by a conductor 26 so that the full voltage of the windings 12 and 13 in series is impressed across the lamps 2 and 3 in series.

For insuring proper distribution of the sum of the open circuit output voltage of the windings 12 and 13 across the lamps 2 and 3, one of the lamps, for example the lamp 3 is permanently shunted by the starting capacitor 6. This is not in all cases essential, as the distributed inherent capacities of the circuit elements including the windings and the lamps themselves, will in certain cases provide proper distribution of voltage. However, for best and most reliable results, it is preferable to employ the starting capacitor 6, which may be connected across either lamp. For suppressing radio frequency disturbances produced by the arc discharges in the lamps 2 and 3, the two lamps may be shunted by a radio interference suppressing capacitor (not shown).

For supplying heating current to a cathode 28 of lamp 2 this cathode is connected by way of a conductor 29 to the remaining terminal of the primary winding and hence by way of the tap 14 back to the other side of the cathode 28 through conductors 20, 21 and 26. One side of cathode 30 of the lamp 3 is connected by way of a conductor 31 to the winding 16 and then by way of conductors 32 and 24 back to the other side of the cathode 30.

The electrically adjacent ends of cathodes 33 (of lamp 2) and 34 (of lamp 3) are preferably energized in parallel from the winding 15, the circuit connections being from the left hand end of winding 15 through a conductor 27, the cathodes 33 and 34 in parallel, conductor 25 and back to winding 15. Winding 15 has as many turns as winding 16 and as many turns as there are between tap 14 and terminal conductor 29 of the primary winding 12.

The operation of the illustrated embodiment of the invention is as follows.

When the input terminals 17 are connected to a suitable source of supply (not shown) the full open circuit voltage, which is the sum of the voltages of the primary winding 12 and secondary winding 13, is impressed across the lamps 2 and 3 in series. However, the capacitance of starting capacitor 6 is very much greater than the inherent capacitance of the lamps 2 and 3 so that practically all of the output voltage and very little of this voltage is at first impressed across the lamps 2 and 3 and the capacitor 6 in parallel. At the same time the cathode 28 is energized by the voltage of the winding 12 between tap 14 and terminal 29, the cathode 30 is ener-
gized by the voltage of the winding 16 and the cathodes 33 and 34 are energized in parallel by the voltage of the winding 15 so that the cathodes are quickly heated to electron emitting temperature. As soon as the cathodes of the lamp 2 emit electrons the starting voltage of the lamp 2 is reduced very much below the voltage which would be required to start it or cause an arc discharge between its electrodes 28 and 33 if they were cold. Therefore, the secondary winding 13 can have a very much lower voltage, and consequently a fewer number of turns than would be required if the lamps were to be started by means of a cold cathode discharge, and the combined voltages of the windings 12 and 13 need only be a little more than sufficient to start the lamp 2 with its cathodes 30 and 34 hot and emitting electrons. As soon as the lamp 2 starts, the discharge current in the lamp 2 flows through the starting capacitor 6, thus producing a relatively high voltage drop in the capacitor 6, which voltage drop is impressed across the lamp 3 and causes the lamp 3 to form an arc discharge between its heated terminal electrodes or cathodes 30 and 34. After the lamp 3 starts, the arc drop in the lamp 3 falls to a relatively low value, so that the capacitor 6 is effectively short circuited by the lamp 3.

The ballasting action, so as to limit the operating current of the lamps to the proper value, is obtained by means of the running capacitor 7 and the leakage reactance of the transformer 5 which is produced by the center legs of the yoke members 9, which act as part of the magnetic shunts in the core between the primary winding 12 and the secondary winding 13. In other words, when the lamps are in operation the leading phase of the lamp current, resulting from capacitor 7, in flowing through the secondary winding 13 produces a magnetizing effect in the core, and the resulting excess flux over the magnetizing flux produced by the primary winding 12 flows largely through the magnetic shunts in a local magnetic circuit which causes the main secondary winding section 13 to act as a current limiting reactor to a large extent. The bridged gaps 10—11 serve to limit the excess leading leakage flux of the secondary winding so as to prevent magnetic saturation of the part of the core occupied by the secondary winding. As they are buried in the core, i.e. formed in the internal portion of the core and not on the outside, they have very little stray flux which gets outside the core to cause noise and heating in the usual surrounding metal case.

As an example of a specific transformer ballast in accordance with this invention which is suitable for operating two 40-watt fluorescent lamps in series, the core may be 45% inches long and 25% inches wide with a stack height of 50% inch of laminations of 19 to 25 mils thickness. The winding leg 8 may be one inch wide, the length of the primary winding section of the core may be 15% inches and the length of the secondary winding section of the core may be 2 inches. The primary winding 12 may consist of 549 turns with the tap 14 located at 532 turns, the secondary winding 13 may consist of 1222 turns, the winding 15 may consist of 17 turns and the winding 16 may have 17 turns. The starting capacitor 6 may have 0.05 microfarads capacity and the running capacitor 7 may have 2.85 microfarads capacity. The power factor with both lamps operating is about 96% leading.

While there has been shown and described a particular embodiment of the invention, it will be obvious to those skilled in the art that changes and modifications can be made without departing from the 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 high reactance transformer ballast for a plurality of serially connected arc discharge devices comprising, in combination, a substantially closed magnetic core having a primary winding section and a secondary winding section separated by a magnetic shunt for leakage flux from said sections, a buried bridged gap in said core adjacent said secondary winding section, a primary winding on the primary core section and a secondary winding on the secondary core section, said primary winding and said main secondary winding being connected in voltage step-up autotransformer relation for supplying starting voltage and operating current to a plurality of arc discharge devices in series, and a plurality of cathode heating supply windings mounted on said primary core section only.

2. A high reactance transformer ballast for starting and operating with leading current a pair of serially connected hot cathode fluorescent lamps comprising, in combination, a shell-type transformer core having a central winding leg and oppositely disposed three-legged yoke members with the outer legs of the yoke members in contact with opposite sides of the winding leg member and with the intermediate legs of the yoke members spaced from the winding leg so as to constitute relatively high reluctance magnetic shunts which divide the winding leg into a primary winding section and a secondary winding section, the end legs of the yoke members which contact said secondary winding section of the winding leg being notched so as to produce buried bridged gaps therebetween, a primary winding comprising a main primary section separated from said secondary winding section by an integral extended cathode heating supply section on the primary winding section of the core winding leg, a secondary winding on the secondary winding portion of the core winding leg, a pair of cathode heating supply windings mounted on the primary winding section of the core winding leg, a running capacitor, a main primary winding section and said secondary winding being connected in voltage step-up autotransformer relation in series with said running capacitor for supplying starting voltage and leading operating current to a pair of serially connected hot cathode fluorescent lamps, a starting capacitor for connection in shunt circuit relation with one of said lamps, said starting capacitor having a substantially greater capacitance than the lamp across which it is adapted to be connected, one cathode heater supply winding on the primary winding section of the core winding leg being connected for supplying heating current to the adjacent cathodes of different ones of said lamps, said starting capacitor having one terminal connected to one side of said one cathode heating winding and having its other terminal adapted to be connected to the other cathode of one of said lamps the extended primary winding section of said primary winding being connected for supplying heating current to the other cathode of the lamp which is adapted to be connected to the main primary winding, the remaining cathode heating supply winding on the primary winding section of the core winding leg being connected for supplying cathode heating current to the remaining cathode of the other lamp which is for connection directly to the main secondary winding.

3. A high reactance transformer ballast for a pair of serially connected rapid start fluorescent lamps comprising, in combination, a substantially closed magnetic core having a primary winding section and a secondary winding section which are separated by a magnetic shunt, said core also having a series buried bridged gap adjacent said secondary winding section, a primary winding on said primary section and a secondary winding on said secondary winding section, a running capacitor, said primary winding and said secondary winding being connected in voltage step-up autotransformer relationship in series with said running capacitor for supplying starting voltage and leading operating current to a pair of serially connected soft start fluorescent lamps, a starting capacitor for connection across one of said lamps, a metal case enclosing said transformer and capacitors, and three cathode heating...
supply windings on said primary winding core section, one of the cathode heating supply windings which supplies the cathode for the lamp electrode which is for connection to the primary winding being integral with said primary winding, one of the other cathode heating supply windings having the same number of turns as said supply winding which is integral with said primary winding and being for the cathode of the other lamp which is connected to said secondary winding, and the remaining cathode heating supply winding having as many turns as the others and being for energizing the remaining two cathodes in parallel, said starting capacitor having one terminal connected to one side of said remaining cathode heating supply winding and its other terminal adapted to be connected to one of said first two lamp cathodes.

4. The high reactance transformer ballast of claim 1 comprising a running capacitor connected in series with said secondary winding.

5. The high reactance transformer ballast of claim 4 comprising a starting capacitor connected between two of said cathode heating supply windings for connection across one of said arc discharge devices.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,496,981</td>
<td>Boucher</td>
<td>Feb. 7, 1950</td>
</tr>
<tr>
<td>2,504,549</td>
<td>Lemmers</td>
<td>Apr. 18, 1950</td>
</tr>
<tr>
<td>2,558,293</td>
<td>Feinberg</td>
<td>June 26, 1951</td>
</tr>
</tbody>
</table>