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W. W. BROOKS ET AL
FLUORESCENT LAMP BALLAST

2,869,037

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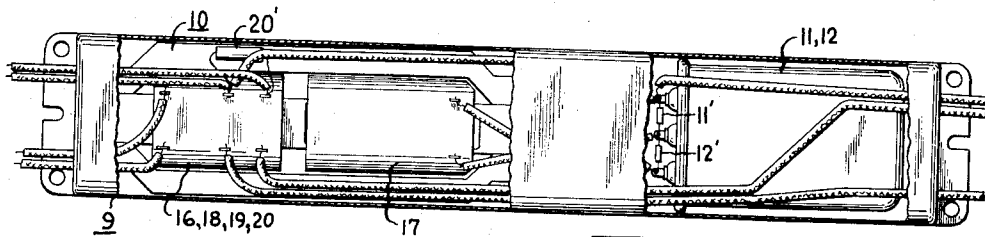


Fig. 1

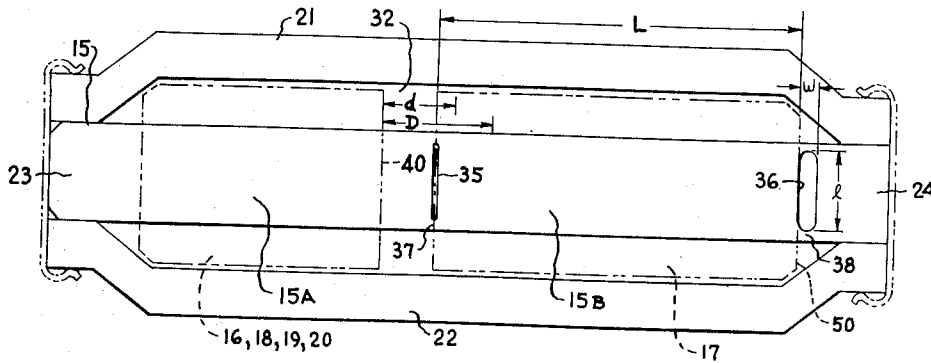


Fig. 2

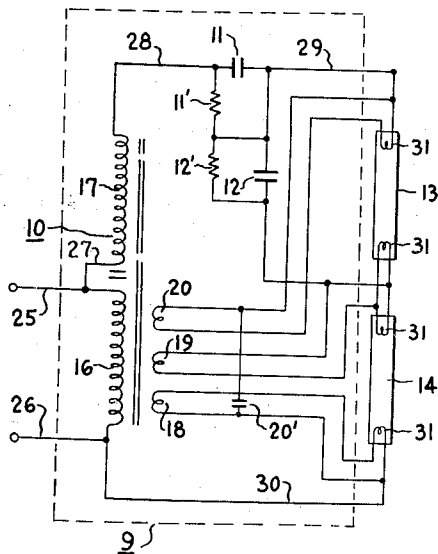


Fig. 3

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FLUORESCENT LAMP BALLAST

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11 Claims. (Cl. 315—97)

Our invention relates to reactor apparatus and circuits commonly known as "ballasts" for starting and operating fluorescent lamps and to high reactance transformers useful in such ballasts.

The advent of new hot-cathode grooved lamps known as "Power Groove" lamps which have unusually high wattage rating for a given starting voltage rating, has raised several difficult problems in providing suitable ballasts of desired small size and expense without sacrifice in lighting efficiency or ballast performance. For example, constructions and expedients conventionally used to obtain high lamp current output either result in the wrong starting or running voltage characteristics or in low lamp power factor operation or in unduly high primary winding current.

Accordingly, an object of the invention is to provide ballasts suitable for high wattage fluorescent lamps.

Another object is to provide high reactance transformers of small size and expense for use in ballasts capable of meeting the starting and operating requirements of high wattage lamps with good efficiency as evidenced by high light output.

In Patents 2,334,567—Lord and 2,334,587—Short, there are disclosed fluorescent lamp ballasts each employing a high reactance transformer having its secondary winding for connection in a series capacitive or "lead" circuit with the fluorescent lamps and having a narrow transverse slot forming a "bridged gap" in the core of the transformer in the magnetic circuit of the secondary winding. This type of construction has been widely used to provide ballasts for low or moderate wattage fluorescent lamps since it permits the achievement of a high secondary-to-primary winding coupling factor and good lamp current wave form for a given desired leakage reactance and starting voltage characteristic. When used with moderate wattage rated lamps, these ballasts provide optimum light output with only moderate primary winding currents, but when used with high wattage lamps, they result in inordinately high primary winding currents in order to obtain optimum light output. Our present invention is an improvement on this type of high reactance transformer construction, and has the further object of providing a high reactance bridged-gap transformer capable of providing optimum light output for both moderate and high wattage lamps with reduced or minimized primary winding currents.

In general, in accord with the invention, a high reactance transformer is provided having a shell type core with a central elongated leg upon which side-by-side primary and secondary windings are located. This central winding core leg has at least two spaced bridged-gaps in the magnetic circuit of the secondary winding with one bridged-gap located remote from the primary winding to be essentially in the magnetic circuit of the secondary winding only, and with the other bridged-gap located proximate to, such as near or within, the primary winding to be in the magnetic circuits of both the primary and secondary windings.

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It has been found that the splitting of the bridged-gap into two properly apportioned bridged-gaps located in accord with the invention has the effect of giving optimum light output with a decrease in the usual primary winding current when used with moderate or high wattage lamps. Single bridged-gaps located in these or other positions usually result either in less favorable light output efficiency or higher primary winding currents regardless of variations in the size or shape of such single bridged gaps.

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may be easily understood by referring to the following description taken in connection with the accompanying drawing in which,

Figure 1 is a plan view of a ballast embodying the invention, with a portion of the cover removed, before the ballast components are embedded in a suitable potting compound;

Figure 2 is a plan view of a high reactance transformer employed in the ballast of Figure 1; and

Figure 3 is a schematic circuit diagram showing the ballast of Figure 1 connected in circuit with a pair of fluorescent lamps.

Referring to the drawing, one form of our invention is shown embodied in a ballast 9 comprising a high reactance transformer 10 and a pair of capacitors 11 and 12 for starting and operating a pair of fluorescent lamps 13 and 14 connected in series. Transformer 10 is of the "shell" type with an elongated central winding core leg 15 containing primary and secondary windings 16 and 17 on side-by-side portions 15A and 15B of central core leg 15, and three heating windings 18, 19 and 20 wound over or in the vicinity of the primary winding 16. A pair of elongated outer or "yoke" core legs 21 and 22 abut opposite sides of the ends 23 and 24 of central core leg 15 to complete the magnetic circuit of the core. The high reactance of the transformer is provided by the distributed leakage of the magnetic flux between the elongated central and yoke core legs 15, 21 and 22 along the length of the core. Alternatively, magnetic core members or "shunts" (not shown) may be extended between the central core leg 15 and the yoke core legs 21 and 22 in the region or space 32 intermediate the primary and secondary windings 16 and 17 to direct or augment the leakage of magnetic flux. Primary winding 16 contains input leads 25 and 26 for connection to a source of alternating electric voltage of power frequency, and is connected through conductor 27 in autotransformer relation with secondary winding 17. Capacitor 11 is connected in series with secondary winding 17 and with lamps 13 and 14 across the primary winding 16 through conductor 28 and ballast output leads 29 and 30. Capacitor 12 is provided as an aid in starting the lamps and is connected in parallel with lamp 13. Voltage for heating the cathodes 31 of the fluorescent lamps 13 and 14 is provided by means of the heating windings 18, 19 and 20. A capacitor 20' may be connected across the windings 18, 19, 20 as shown in order to reduce radio interference. Also, resistors 11' and 12' may be connected across capacitors 11 and 12 respectively to discharge these capacitors when the ballast is disconnected from the power source.

In accord with the invention, a pair of spaced transverse slots 35 and 36 are formed in the core of transformer 10 in the magnetic circuit of the secondary winding 17. These slots 35 and 36 are preferably formed in the central winding core leg 15. They do not extend across the entire width of the central winding core leg laminations, and thus form non-magnetic gaps bridged at their opposite ends by core sections 37 and 38 respec-

tively. These bridging core sections 37, 38 are generally known as "restricted" core sections and the transverse slots 35 and 36 thus form "bridged-gaps." One of these bridged-gaps 35, hereinafter referred to as the "proximate" bridged-gap, is located within or adjacent to the primary winding 16 so as to be in the magnetic circuit of both the primary and secondary windings. The other bridged-gap 36, hereinafter referred to as the "remote" bridged-gap, is located within or adjacent to the secondary winding and is spaced more remotely from the primary winding 16 than the proximate bridged-gap 35 thereby to be affected essentially by the magnetic flux of the secondary winding only. For most applications, proximate bridged-gap 35 is located no further than 20% of the length L of the secondary winding 17 from the end 40 of primary winding 16 as indicated by the dimension D, while remote bridged-gap 36 is located no closer than 30% of the length L of secondary winding 17 from the end 40 of the primary winding 16 as indicated by the dimension D. In the ballast transformer 10 illustrated in the drawings, the proximate bridged-gap 35 is located about 10% of the length of the secondary winding 17 away from the primary winding end 40, while the remote bridged-gap 36 is located a little more than the entire length L of the secondary winding 17 away from the primary winding end 40.

The actual dimensions of the slots 35 and 36 may be varied considerably depending upon the desired starting and operating electrical characteristics of the transformer 10. For most applications it has been found preferable to reduce the percentage of core restriction provided by proximate bridged-gap 35 over that provided by remote bridged-gap 36. This may be easily accomplished by making the width dimension W or the height dimension I, or both dimensions, of proximate bridged-gap 35 smaller than the corresponding dimensions of remote bridged-gap 36. In the embodiment illustrated, the height dimension 1 of both slots is kept equal while the width dimension W of slot 36 is made about four times that of proximate bridged-gap 35. The percentage of core restriction provided by proximate bridged-gap 35 is thus considerably less than the percentage of core restriction provided by remote bridged-gap 36.

In the operation of ballast 9 an input alternating voltage supplied between input terminals 25 and 26 of primary winding 16 causes a greater voltage to be developed across autotransformer 10 which is supplied through power factor correcting capacitor 11 and starting capacitor 12 first across lamp 14 and then across both lamps 13 and 14 thereby to start these lamps. Heating voltage is also supplied to the cathodes of these lamps through the heating windings 18, 19 and 20. The inductive reactance of transformer 10 and particularly of secondary winding 17 together with the capacitive reactance of capacitor 11 perform the ballasting function of the circuit, compensating for the negative resistance characteristic of the fluorescent lamps.

The size, shape and location of the bridged-gaps 35 and 36 affect both the starting and operating characteristics of the ballast 9 as well as the lamp current wave form. In general, the bridged-gaps 35, 36 tend to prevent saturation of the secondary winding magnetic circuit thereby reducing core losses and improving the lamp current wave form. The bridging of the gaps by the restricted sections 37 and 38 improves the mechanical stability of the slotted core and has the further advantage of permitting this improvement in lamp current wave form and transformer efficiency with only a small reduction in open circuit voltage.

The location of the bridged-gaps 35 and 36 in accord with the invention greatly improves lamp light output with only a small increase over the primary winding current which would occur without the presence of these bridged-gaps. We have found that a change in the location of a bridged-gap in the central core leg 15 closer to the primary winding 16 beyond a point less than 20% of

the length of the secondary winding 17 away from the primary winding causes the lamp light output to increase and reach a maximum, but that the primary winding current also increases. A single bridged-gap located proximate to the primary winding 16 and dimensioned to provide the desired starting, operating and leakage reactance characteristics for the transformer 10 has been found, however, to result in an economically intolerable increase in primary winding current when the ballast is used to supply current to moderate or high wattage lamps. On the other hand, a single bridged-gap located in the region of remote bridged-gap 36 and dimensioned to provide the desired starting, operating, and leakage reactance characteristics cannot economically be made to provide the desired optimum light output from the fluorescent lamps. By splitting the single gap into two bridged-gaps, one located proximate to and the other located remote from the primary winding, it has been found possible to derive the benefit of increased lamp light output and yet maintain all the other advantages of a larger total bridged-gap with only a minor increase in primary winding current.

In a typical ballast 9 constructed for starting and operating two 48" power-groove lamps rated at 107 watts, capacitor 11 had a capacitance of 11.0 microfarads, capacitor 12 had a capacitance of .075 microfarad. Discharge resistors 11' and 12' had a resistance of 4.0 megohms each. The high reactance transformer 10 included a central winding core leg made up of a stack of high permeability magnetic laminations 8.5 inches long, .968 inch wide and stacked to a height of 1.375 inches, and the yoke core legs were made up of stacks of high permeability magnetic laminations .484 inch wide and stacked to a height of 1.375 inches. The various transformer windings were all made of number 20 copper wire with the primary winding having 394 turns, the secondary winding 17 having 804 turns, the heater windings 18 and 20 each having 14 turns and the heater winding 19 having 15 turns. Radio interference suppressing capacitor 20' had a capacitance of .01 microfarad. The primary winding extended 3.434 inches along the length of the core and the secondary winding 17 extended 7.5 inches. The primary winding was 2.5 inches long and the secondary winding was 3.828 inches long. The proximate bridged-gap 35 was located .316 inches away from the end 40 of the primary winding while the remote bridged-gap 36 was located immediately adjacent the opposite end 50 of the secondary winding. Both bridged-gaps had a height of .766 inch. Proximate bridged-gap 35 had a width of .047 inch while remote bridged-gap 36 had a width of .188 inch. The transformer 9 developed an open circuit voltage of 278 volts across both the primary and secondary winding in series. Output lamp current at optimum light output was 1.5 amperes with a primary winding current of 1.31 amperes.

Although we have described above a particular embodiment of the invention, many modifications may be made, and it is to be understood, therefore, that we intend to cover by the appended claims all such modifications as fall within the true spirit and scope of the invention.

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

1. A high reactance ballast transformer comprising a shell type magnetic core having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps in the magnetic circuit of said secondary winding, one of said bridged-gaps being proximate to said primary winding and affecting the current thereof.

2. The high reactance ballast transformer of claim 1 wherein the other bridged-gap is located remote from

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said primary winding to have relatively little effect upon the current thereof.

3. The high reactance ballast transformer of claim 2 wherein the percentage of core restriction provided by said proximate bridge-gap is less than the core restriction provided by said remote bridged-gap.

4. A high reactance ballast transformer comprising a shell type magnetic core, having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps in the magnetic circuit of said secondary winding, one of said bridge-gaps being no more than 20% of the length of the secondary winding away from said primary winding, and the other bridged-gap being no less than 30% of the length of said secondary winding away from said primary winding.

5. The high reactance ballast transformer of claim 4 wherein said primary and secondary windings are connected in autotransformer relationship.

6. The high reactance ballast transformer of claim 4 wherein the percentage of core restriction provided by said bridged-gap closer to said primary winding is less than the percentage of core restriction provided by said bridged-gap more remote from said primary winding.

7. A high reactance ballast transformer comprising a shell type magnetic core having an elongated central core leg and a pair of yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, said central core leg having a pair of spaced transverse slots forming bridged-gaps therein, one of said slots being located essentially in the magnetic circuit of said secondary winding only and the other of said bridged-gaps being located in the magnetic circuit of both said primary and secondary windings.

8. Ballast apparatus for starting and operating fluorescent lamps comprising a high reactance transformer including a shell type magnetic core having an elongated central core leg and a pair of elongated yoke core legs defining coil receiving windows with said central core legs, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, a capacitor connected in series with said secondary winding for connection in series with a

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fluorescent lamp across said primary winding, and said central core leg having a pair of spaced transverse slots forming bridged-gaps therein, one of said bridged-gaps being located essentially in the magnetic circuit of said secondary winding only, and the other bridged-gap being located in the magnetic circuit of both said primary and said secondary windings.

9. The ballast apparatus of claim 8 in which the bridged-gap in the secondary winding magnetic circuit is located no less than 30% of the length of said secondary winding away from said primary winding, and the bridged-gap in both the primary and secondary winding magnetic circuits is located no more than 20% of the length of the secondary winding away from said primary winding.

10. Ballast apparatus for starting and operating high wattage fluorescent lamps comprising a high reactance transformer including a shell type magnetic core having an elongated central core leg and a pair of elongated yoke core legs defining coil receiving windows with said central core leg, a primary winding and a secondary winding arranged on side-by-side portions of said central core leg within said windows, a capacitor connected in series with said secondary winding for connection in series with a fluorescent lamp across said primary winding, a plurality of heating windings arranged on said central core leg in the region of said primary winding for supplying voltage to the cathodes of a fluorescent lamp, and said central core leg having a pair of spaced transverse slots forming bridged-gaps in the magnetic circuit of said secondary winding, one of said bridged-gaps being no more than 20% of the length of said secondary winding away from said primary winding and the other bridged-gap being no less than 30% of the length of said secondary winding away from said primary winding.

11. The ballast apparatus of claim 10 wherein the percentage of core restriction provided by the bridged-gap closer to the primary winding is less than the percentage of core restriction provided by the bridged-gap more remote from the primary winding.

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Notice of Adverse Decision in Interference

In Interference No. 90,178 involving Patent No. 2,869,037, W. W. Brooks and C. E. Strecker, Fluorescent lamp ballast, final decision adverse to the patentees was rendered July 12, 1963, as to claims 1, 2, 3, 4, 5, 6, 7, 8 and 9.
[*Official Gazette September 3, 1963.*]

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In Interference No. 90,178 involving Patent No. 2,869,037, W. W. Brooks and C. E. Strecker, Fluorescent lamp ballast, final decision adverse to the patentees was rendered July 12, 1963, as to claims 1, 2, 3, 4, 5, 6, 7, 8 and 9.

[Official Gazette September 3, 1963.]