

3,305,697

BALLAST APPARATUS WITH AIR-CORE INDUCTOR

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This invention relates generally to ballast apparatus for starting and operating electric discharge devices such as fluorescent lamps. More particularly, it relates to such ballast apparatus in which an inductor is utilized in the ballast circuit.

Iron-core inductors have been widely used in the past and are presently being used as ballasts for low output fluorescent lamps. Also, they have been used in conjunction with high leakage reactance transformers as elements of peaking circuits in commercially available dimming ballasts. Likewise, iron-core inductors have been used as elements of tuned circuits in ballasts for starting and operating high output fluorescent lamps. These inductors almost universally employ laminated cores in 60 cycle applications since eddy current losses in a solid iron core would be relatively high. The number of laminations used is dependent upon the magnitude of the current that the coil of the inductor must handle before it is saturated. In ballasting applications where the frequency is above the audio frequency range, powdered-iron cores have been used.

In recent years in ballasts for operating high output lamps, a capacitor tuned to provide preselected harmonic components to aid in the starting of the lamps has been employed in the secondary circuit of the ballast transformer. With such an arrangement a higher root mean square open circuit voltage can be provided for a given number of turns in the secondary winding of the ballast transformer. In the application Serial Number 186,129, filed on April 9, 1962, in the name of Roger E. Hume, which issued December 21, 1965, as United States Patent No. 3,225,255 and which is assigned to the same assignee as the present invention, an improved arrangement is described and claimed in which an iron-core inductor is connected in series with the shunting capacitor in the secondary circuit of the ballast transformer for controlling the discharge of the capacitor in each half cycle.

A difficulty encountered in the application of iron-core inductors in ballast circuits is that the iron-core inductor contributes to the production of an audible sound radiation. Although the noise contributed by the iron-core inductor is not particularly objectionable, in many applications it is desirable that all audible radiations in the ballast be reduced.

Accordingly, a general object of the present invention is to provide an improved ballast apparatus for starting and operating electric discharge lamps, such as fluorescent lamps, characterized by improved sound characteristics.

It is a more specific object of the present invention to provide an improved inductor arrangement for use in conjunction with a tuned shunting capacitor to provide harmonic starting for fluorescent lamps.

In accordance with one form of the invention, I have provided a ballast apparatus for starting and operating one or more fluorescent lamps in which an air-core inductor is used in the secondary circuit of a ballast transformer. Preferably, the air-core inductor is connected in the discharge path of a tuned shunting capacitor connected in parallel circuit relation with the secondary winding of the ballast transformer. With the improved arrangement it is possible to appreciably reduce the audible noise radiations of the ballast apparatus.

The subject matter which I regard as my invention is set forth in the appended claims. The invention itself, how-

ever, together with further objects and advantages thereof, may be better understood by referring to the following description taken in connection with the accompanying drawing 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 without the electrical connections and with a portion of the case cut-away and potting material removed to show the disposition of the components, the electrical connections being made as shown in FIGURE 1; and

FIGURE 3 is a perspective view of the air-core inductor used in the exemplification of the invention illustrated in FIGURES 1 and 2.

Referring now more particularly to the drawings, the ballast apparatus embodying one form of the invention is generally identified by the reference numeral 10. As shown in FIGURE 1 the ballast apparatus 10 is enclosed in a dashed rectangle which schematically represents the case 11. The ballast apparatus 10 includes a high leakage reactance transformer 12 having a magnetic core 13, magnetic shunts 14, a primary winding P and a secondary winding S inductively coupled with the primary winding P. In order to supply heating current to the lamp filaments 15, 16, 17, 18, three cathode heating windings H₁, H₂, H₃ are inductively coupled with the primary winding P on the magnetic core 13. A pair of input terminal leads 19, 20 are provided for connection to a suitable alternating current supply such as a 60 cycle 115 volt supply. As shown in FIGURE 1, the fluorescent lamps 1 and 2, which are fluorescent lamps of the rapid start type, are preferably positioned in close proximity to a conductive fixture or plate 21 so that the lamps are disposed in capacitive relation with the plate 21. It will be seen that the plate 21 is connected by lead 22 to a suitable ground G.

In the embodiment of the invention illustrated schematically in FIGURE 1, a flux leakage path is provided by the magnetic shunts 14 between the primary winding P and the secondary winding S. The flux leakage path, if desired, may be formed through nonmagnetic material, such as air, or through magnetic material by the provision of projecting shunt legs formed on the magnetic core 13 or by inserting shunts between the primary winding P and the secondary winding S. It will be seen that one end of the secondary winding S is connected in circuit with the primary winding P by means of an autotransformer connection A. The other end of the secondary capacitor S is connected in circuit with a series capacitor C₁ which provides a net capacitive reactance in the lamp circuit. A starting capacitor C₂ is connected across lamp 2 so that the open circuit voltage is initially applied across lamp 1 during the starting condition. The resistors R₁ and R₂ which shunt the series capacitor C₁ and the starting capacitor C₂ are bleeder resistors and cause the charge on the capacitors C₁ and C₂ to be bled off when the circuit is de-energized.

Cathode heating winding H₁, which is wound as an extension of the primary winding P, is connected in circuit with filament 18 by electrical leads 23 and 24, cathode heating windings H₂ and H₃ are connected in circuit with the cathodes 15, 16, 17 by the electrical leads 25, 26, 27, 28 and 29. Preferably, cathode heating windings H₂ and H₃ are tightly coupled with the primary winding P and may be wound directly over the primary winding P.

In accordance with one form of the invention, an air-core inductor L is connected in the discharge path of a shunting capacitor C₃. In the illustrated exemplification of the invention the serially connected inductor L and capacitor C₃ were connected across the secondary winding S and the series capacitor C₁. Although in the exemplification of the invention the air-core inductor L was connected

in series with the shunting capacitor C_3 , it will be understood that the air-core inductor L can be placed at other locations in the circuit, for example, in the output lead 29 or the input lead 19.

As will be seen in FIGURE 3, the air-core inductor L consists of a plurality of turns of wire 31 wound on a paper spool 32. The outer layer of paper insulation 33 prevents the air-core inductor L from grounding against the case. The air-core inductor L may be precision wound without layer insulation or may be wound over paper layer insulation 34 as shown in FIGURE 3. The start and finish leads 35 and 36 are brought out from the air-core inductor L for connecting the inductor in the ballast circuit. In the illustrated exemplification of the invention the air-core inductor L was wound with 2026 turns of No. 28 wire to provide an inductance of approximately .022 of a henry at 1000 cycles. As is shown in FIGURE 2 the air-core inductor L is placed in the ballast case 11 between the end of the capacitor container C_1 , C_2 and the end wall of the case 11.

A secondary circuit arrangement which is tuned to provide preselected harmonic voltage components under open circuit conditions to aid in starting and which utilizes a serially connected impedance element and shunting capacitor is more fully described and claimed in the aforementioned Patent No. 3,225,255 assigned to the present assignee.

In FIGURE 2 I have shown a plan view of the ballast apparatus shown schematically in FIGURE 1 with the coverplate 37 cutaway and with the potting compound removed to show the arrangement of the principal components of the ballast apparatus 10. The circuit connections have been omitted in the interest of clarity. It will be seen that the magnetic core 13 has a central winding leg 38 and yoke sections 39, 40 which are firmly held in assembled relation with the central leg by the core clamps 41, 42. Primary winding P and the cathode heating windings H_1 , H_2 and H_3 are included in one coil assembly 43. Coil assembly 44 includes the secondary winding S and is disposed on the central winding leg 38 alongside of and separated from coil assembly 43 by magnetic shunts 14. The starting capacitor C_2 and the series capacitor C_1 are housed in a single metallic container 45. A cardboard strip 46 insulates the container 45 from the magnetic core 13.

The operation of the ballast circuit shown in FIGURE 1 will now be more fully described. When an alternating supply is applied across input terminal leads 19, 20, a voltage will be induced in the secondary winding S as determined by the respective turns ratio of the primary P and the secondary winding S . Voltages are, of course, immediately induced in the cathode heating windings H_1 , H_2 and H_3 , and cathode heating current is supplied to the cathodes of lamps 1 and 2. The open circuit voltage developed in the secondary circuit is initially applied across lamp 1 and is of sufficient magnitude to start lamp 1. After lamp 1 is started, the voltage across the starting capacitor C_2 is sufficient to cause lamp 2 to be ignited. The starting capacitor C_2 has sufficient impedance so that no appreciable current will flow through it after both lamps 1 and 2 are ignited. After the lamp 2 is ignited, both of the lamps 1 and 2 are operated in series circuit across the primary winding P and the secondary winding S of the ballast transformer 12.

In order to demonstrate the advantages achieved by the improved air-core inductor arrangement, sound measurements were made on a group of four identical ballast Nos. 1, 2, 3 and 4 utilizing iron-core inductors and a second group of four identical ballast Nos. 5, 6, 7 and 8 using the air-core reactors in accordance with the invention. To make the sound measurements the ballasts were mounted in a test fixture and hung in an anechoic chamber at a distance of approximately 4 feet above a Universal collecting horn. The ballasts were run over night to allow them to come to an operating temperature.

Overall decibel readings were taken using the Universal collecting horn and a General Radio 1551A sound level meter. The octave band data for the operating ballasts was obtained with a General Radio 1551B sound level meter and a Herman-Holser-Scott sound analyzer. The sound measurements obtained are summarized in Table I below:

TABLE I
WITH IRON-CORE INDUCTOR

Ballasts Tested	Overall Decibel Reading	Decibels Measured in Octave Band of 1,200-2,400 cycles per second	Decibels Measured in Octave Band of 2,400-4,800 cycles per second
#1.....	26.7	20.8	14.0
#2.....	24.2	21.0	16.0
#3.....	26.8	22.0	16.0
#4.....	28.5	22.0	14.1

WITH AIR-CORE INDUCTOR

#5.....	22.2	16.5	11.8
#6.....	20.7	16.0	11.8
#7.....	24.7	17.5	11.0
#8.....	20.0	14.0	10.8

From the data presented in Table I, it will be apparent that significant improvements have been achieved in the sound characteristics of the ballasts using air-core inductors. In particular, it will be noted that in the 1200-1400 and 2400-4800 cycle per second frequency bands it is possible with an air-core inductor to achieve significant reductions in the sound level of the ballasts.

It will be appreciated that the specific embodiment of the invention which I have described herein by way of illustration may be changed and modified without departing from the principle of the invention. The improved air-core inductor arrangement can be advantageously employed in other ballast circuits which utilize an inductor as a component. It is to be understood, therefore, that I intend by the appended claims to cover all such changes and modifications that 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. In a ballast apparatus for starting and operating at least one electric discharge lamp from an alternating source, said ballast apparatus including a high leakage reactance transformer having a magnetic core, a primary winding and a secondary winding inductively coupled with said primary winding on the magnetic core, said primary winding having a pair of leads for connection to said alternating source, a series capacitor connected in series circuit relation with said secondary winding to provide a net capacitive reactance in the secondary circuit of said high leakage reactance transformer, a shunting capacitor connected in parallel circuit relation with said secondary winding, circuit means including a plurality of output leads for supplying the output current of the apparatus to the lamp, the improvement comprising an air-core inductor connected in series circuit relation with said shunting capacitor and across said secondary winding of said high leakage transformer and said series capacitor.

2. In a ballast apparatus for starting and operating at least one electric discharge lamp from an alternating source, said ballast apparatus including a high leakage reactance transformer having at least one primary winding and at least one secondary winding, a capacitor connected in parallel circuit relation with at least said secondary winding, a secondary circuit including at least said secondary winding and said capacitor, said secondary circuit tuned to provide a preselected harmonic voltage component under open circuit conditions to aid in starting said electric discharge lamp, said primary winding connected across a pair of input leads for connection to the alternating source, output means including a plurality

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of output leads for applying the combined output of said transformer and secondary circuit across the output leads, the improvement comprising an air-core inductor connected in the discharge path of said capacitor.

3. A ballast apparatus for starting and operating at least one fluorescent lamp, said ballast apparatus including a high leakage reactance transformer means for supplying the starting and operating voltages across said lamp, said means including input leads for connection to an alternating supply and output leads for applying said voltages across said lamp, and an air-core inductor connected in circuit with one of said leads of the ballast apparatus, said air-core inductor producing a negligible amount of audible sound radiation.

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4. The ballast apparatus set forth in claim 3 wherein said air-core inductor is comprised of layers of conductor wire interleaved between layers of paper insulation.

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