June 13, 1961 L. L. GENUIT 2,988,670

DIMMING CIRCUIT AND APPARATUS FOR GASEOUS DISCHARGE LAMPS

Filed Sept. 2, 1959 2 Sheets-Sheet 1

Fig. 5.

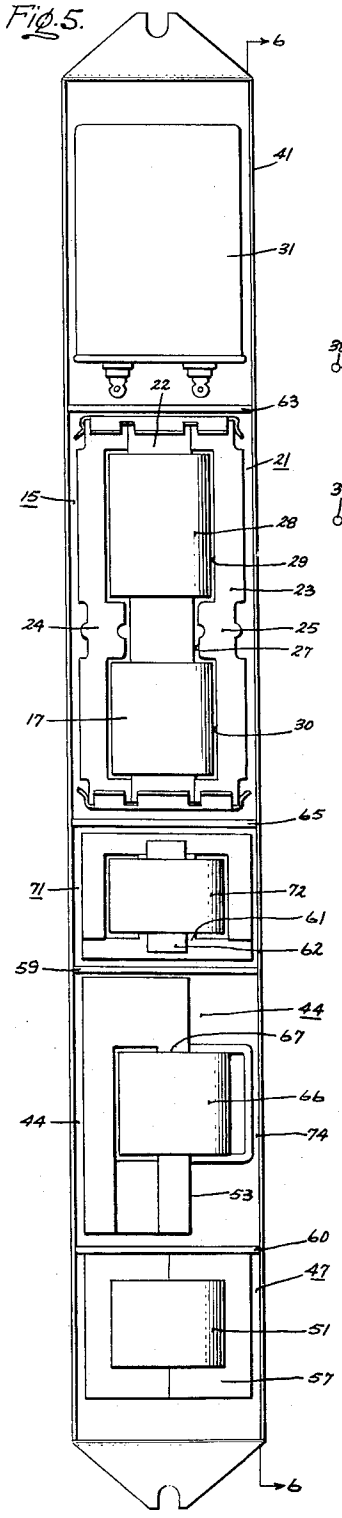


Fig. 1.

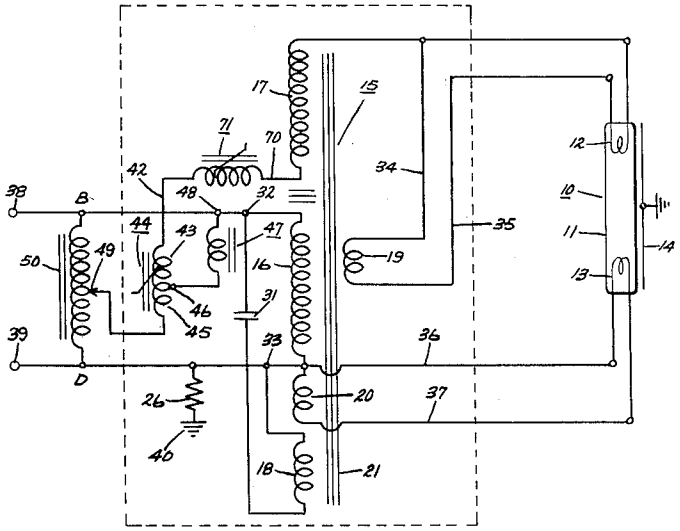
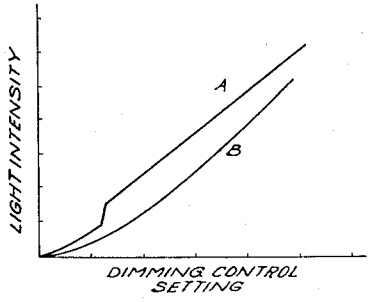


Fig. 2.



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DIMMING CIRCUIT AND APPARATUS FOR GASEOUS DISCHARGE LAMPS

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Fig. 6.

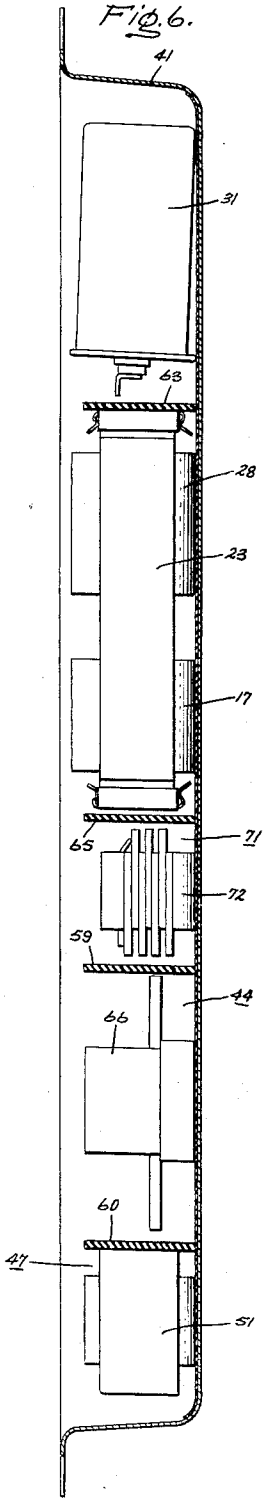


Fig. 3.

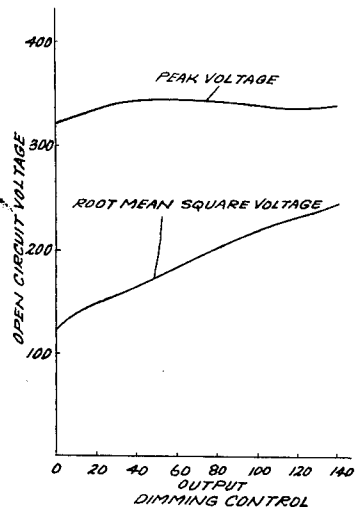


Fig. 4.

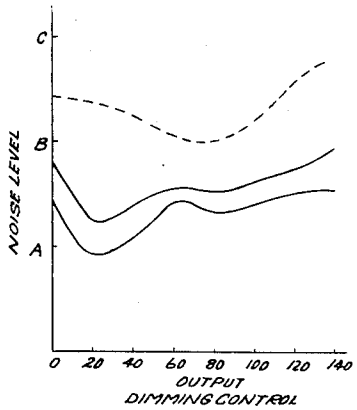
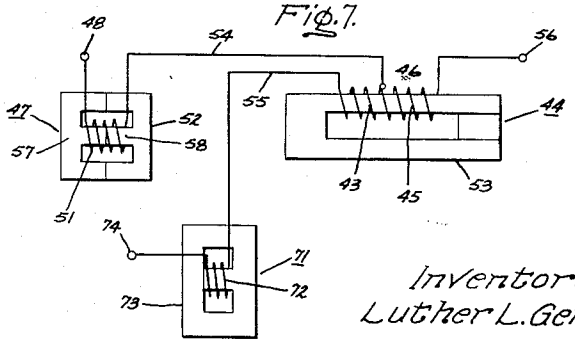


Fig. 7.



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2,988,670

DIMMING CIRCUIT AND APPARATUS FOR GASEOUS DISCHARGE LAMPS

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Filed Sept. 2, 1959, Ser. No. 837,624
10 Claims. (Cl. 315—98)

This invention relates to an electrical circuit and apparatus for regulating the luminous intensity of gaseous discharge lamps and more particularly to a dimming circuit and apparatus for operating at various levels of luminous intensity one or more fluorescent lamps from an alternating current source.

The invention is primarily intended for use in connection with gaseous discharge lamps having activated filamentary cathodes which are heated during the operation of the lamp by a constant supply of current. Since the cathodes are continuously heated in this manner, the cathodes can be brought to thermionic emission at voltages below the ionization voltage of the gas or vapor in the lamp. This characteristic makes it possible to operate such lamps at various levels of intensity. Commercially, lamps having heated cathodes are referred to as rapid start or hot cathode lamps.

Apparatus presently in commercial use for operating hot cathode lamps at various levels of luminous intensity are generally provided with some means for introducing a voltage spike into the lamp circuit for firing the lamp, particularly at the lower levels of luminous intensity. In a copending application filed in the name of Charles E. Strecker on the same date as this application and assigned to the assignee of the present application, a dimming circuit and apparatus is disclosed employing a peaking means to impress a voltage spike on the lamp circuit. This invention is concerned with an improvement of the apparatus and circuit disclosed in the aforementioned copending application.

Although the foregoing apparatus and circuit satisfactorily operates a rapid start lamp at a wide range of luminous intensity levels, it was found that a flutter or "jump" in light output occurs at a point in the low intensity region as the dimming control is advanced from the dim position to the bright position. This invention involves an improvement which eliminates the flutter in the light output and is applicable to the foregoing apparatus and circuit and generally to dimming control systems employing a peaking means to impress voltage spikes in a heated cathode lamp circuit.

Accordingly, a general object of the invention is to provide a new and improved circuit and apparatus for adjusting the luminous output of electric discharge lamps.

A specific object of the invention is to eliminate the flutter in the light output of a hot cathode lamp operated at varying levels of luminous intensity in dimming control circuits employing a means to impress a voltage spike in the lamp circuit.

Another object of the invention is to provide a peaking circuit having improved noise and structural characteristics.

Still, another object of the invention is to provide an improved peaking circuit, the components of which can be so arranged in a case with other components of the dimming control system along a longitudinal axis so that the transverse dimensions of the case are at a minimum to permit the case housing the components to be effectively concealed in a lighting fixture.

In accordance with the invention, a nonlinear reactor is included in series circuit relationship with the output terminals of an inductive device generating a voltage spike and the high leakage reactance secondary of a ballast transformer in a dimming control system. It was found

that the introduction of this nonlinear reactor in effect limits the lamp current when the luminous intensity is at the critical low levels where fluttering of luminous intensity may occur. Thus, the nonlinear reactor eliminates such fluttering in the region of low intensity levels. Further, it was found that the addition of the nonlinear reactor into the circuit in accord with the invention does not appreciably reduce the lamp current when the lamp is being operated at higher levels of luminous intensity. This condition is brought about because of the saturating characteristic of the reactor.

A dimming control, as referred to herein, is an apparatus, such as a variable transformer, which is used to vary the input voltage supplied to the lamp terminals and is usually at some remote location from the lighting fixture. The dimming control is used in conjunction with a dimming control system, which as a matter of commercial practice, is housed in a separate case and is generally located in or near the light fixture. A nonlinear transformer, as the term is used herein, is an inductive device and includes such devices as saturable reactors, transformers and autotransformers having saturating characteristics which for practical purposes are effective in the circuit only during the period their cores saturate and desaturate. A voltage spike is defined as a sharp voltage increment or impulse, in contradistinction to peak voltage, which is the maximum net open circuit voltage across the lamp and includes the voltage spike when the spike is superimposed on the lamp circuit.

The subject matter which I regard as my invention is set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may be understood by referring to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a schematic circuit diagram of a dimming control system in which the invention is embodied:

FIG. 2 illustrates two curves showing light intensity plotted against dimming control output, the letter "A" identifying the curve obtained when the nonlinear reactor of the invention is shorted out in the circuit shown in FIG. 1 and the letter "B" identifying the curve obtained with the nonlinear reactor of the invention in the circuit as shown in FIG. 1;

FIG. 3 illustrates the curves for the peak open circuit and the root mean square open circuit voltages at the lamp plotted against the dimming control output for the circuit shown in FIG. 1;

FIG. 4 shows the noise level versus dimming control output curves for a cold and hot condition of operation of the circuit shown in FIG. 1, the dashed line curve representing a hot condition of operation for a comparable circuit of the prior art;

FIG. 5 is a plan view of the dimming control system case with the cover plate removed to show the longitudinal arrangement of the component parts of the system;

FIG. 6 is a sectional view along line 6—6 of FIG. 5; and,

FIG. 7 is a diagrammatic illustration of the core and winding arrangement of the peaking circuit of the invention.

The rectangle formed by the dashed lines of FIG. 1 encloses the dimming control system of the invention. The illustrated dimming control system starts and maintains the luminous intensity of an electric discharge lamp **10** which is shown as a fluorescent lamp. In the illustrated circuit, the lamp **10** may be a 40-watt rapid start fluorescent lamp which comprises an elongated tubular cylindrical envelope **11** having sealed into the ends thereof the filamentary cathods **12** and **13**, which are illustrated in the form of a coil of tungsten wire. The filaments **12**, **13** are activated with oxides of alkaline earth

metals, such as mixtures of barium and strontium oxides. The envelope is filled with a starting gas, such as argon, at a pressure of a few millimeters and a small quantity of mercury. The interior of the envelope 11 is coated with a phosphor which converts the ultraviolet radiation produced by the discharge into visible light. The outside surface of the envelope 11 is coated with a water-repellent substance which makes it possible to start the lamp 10 under normal atmospheric conditions and low voltages when the lamp 10 is positioned close to a conducting means and a suitable potential difference is provided with respect to one of the cathodes 12, 13. The conducting plate 14 located in proximity to the lamp envelope 11 serves as such a conducting means and is connected to ground. In a commercial fixture, the metal reflector of the grounded fixture may perform the function of the conductive plate 14. The normal spacing of the plate 14 is approximately three-eighths (⅜) of an inch from the envelope 11.

The reference character 15 designates generally the ballast auto-transformer which includes a primary 16, a high leakage reactance secondary 17, a second secondary 18, and the two cathode heating windings 19 and 20.

As shown in FIGS. 5 and 6, the magnetic core 21 of the ballast autotransformer 15 is comprised of a laminated central winding leg 22 and the E-shaped laminations 23 which abut the sides of the winding leg 22. The middle legs of the E-shaped laminations 23 form magnetic shunts 24, 25, the ends of which are spaced from the central winding leg 22 by an air gap 27.

The coil structure 28 includes the primary winding 16, the cathode heating windings 19, 20, and the second secondary 18. These windings are disposed about the central winding leg 22 in window 29. The secondary high leakage reactance winding 17 of the autotransformer 15 is disposed about the central winding leg 22 in window 30.

Referring again to FIG. 1, the cathode heating windings 19, 20 are tightly coupled with the primary 16 in order that the supply of cathode heating current is maintained at a constant value. The loose coupling between the primary 16 and secondary winding 17 is required in order to obtain the high leakage reactance which is necessary to limit the current flowing through the lamp 10 which has a negative resistance characteristic.

The second secondary winding 18 is connected in series with the power factor capacitor 31 across the power supply by terminal connections 32, 33. The purpose of the second secondary winding 18 is to increase the voltage across the capacitor 31 above the source voltage, thereby reducing the size of the capacitor required to correct the over-all power factor of the circuit. The capacitor 31 draws a leading current from the primary 16 which offsets the lagging magnetizing current.

It should be readily apparent that by the elimination of the capacitor 31 and the second secondary winding 18 that the circuit can be readily converted to a low power factor ballast arrangement. As will be hereinafter more fully described, such a ballast arrangement may be used with each lamp when more than one lamp is to be operated by a single peaking circuit in accordance with the invention.

The cathode heating windings 19, 20 are connected across the cathodes 12, 13 by means of conductors 34, 35 and 36, 37 respectively. The cathode heating winding 20 is shown in an autotransformer relationship with the primary 16, while the other cathode heating winding 19 is shown in an isolated secondary relationship with the primary 16. It should be evident that a circuit designer has a considerable amount of flexibility in locating the cathode heating windings, providing the windings will supply a constant heating current to the cathodes 12, 13.

The primary winding 16 is connected across a normal 120 volt, 60 cycle commercial power supply which is connected with the circuit at the terminals 38, 39, the terminal 38 being the high side and the terminal 39 being the low side of the supply. The low side is arranged so that it is at the same voltage potential as inductive plate 14 and is grounded through a resistor 26 to the ground 40, as shown.

One end of the high leakage reactance secondary 17 is connected by means of a conductor 70 to a nonlinear reactor 71. The nonlinear reactor 71 is also connected by means of a conductor 42 to a secondary winding 43 of a nonlinear transformer 44, which has a primary winding 45. Thus, the secondary winding 17 of the ballast transformer 15, the nonlinear reactor 71, and the secondary winding 43 are connected in series circuit relationship.

The primary 45 and secondary winding 43, as shown in FIG. 1, are in autotransformer relationship. A tap 46 of the nonlinear transformer 44 is connected with one end of a linear reactor 47, while the other end of the linear reactor 47 is connected to the high voltage side of the power supply at connection 48.

The primary winding 45 of the nonlinear transformer 44 is connected to a slider or variable tap 49 of a variable autotransformer or dimming control 50 connected across the power supply. In the practice of the invention, a stepdown or a step-up variable autotransformer may be used as required. In one commercial exemplification of the invention a variable autotransformer having a range from 0 to 130 volts alternating current was employed. In such an arrangement, a slight step-up in voltage is obtained when 120 volt power supply is used.

The peaking circuit includes the nonlinear reactor 71, the linear reactor 47 and the nonlinear transformer 44, having the primary 45 and the secondary 43, as shown in FIG. 1, connected in autotransformer relationship. This permits the dimming control system to make maximum use of the voltage of the device.

In a dimming control system operating a 40-watt rapid start lamp, it is desirable that an open circuit peak voltage of approximately 325 volts be maintained at the lamp terminals over the widest range of dimming control settings. An advantage of the peaking circuit of the invention is that the voltage spike supplied by the secondary 43 of the nonlinear transformer 44 will progressively decrease as the setting of the dimming control is adjusted to increase the input voltage to the lamp 10 without a flutter in luminous intensity output.

In FIG. 7, a more detailed schematic illustration of the core structure and winding arrangement of the components of the peaking circuit of the invention is shown. The peaking circuit is comprised of the nonlinear reactor 71, the nonlinear transformer 44 and the linear reactor 47 connected as shown. The nonlinear reactor 71 includes a winding 72 and a magnetic core structure 73. The nonlinear transformer 44 includes the primary winding 45, the secondary winding 43, a tap 46, and a magnetic core structure 53. The linear reactor 47 includes a winding 51 and a magnetic core structure 52.

One end of the winding 51 of the linear reactor 47 is connected by means of a conductor 54 to the tap 46. The other end has a terminal 48 for connection to the high side of the power supply. A terminal 56 of the primary winding 45 provides a means for connecting to the adjustable tap 49 of the dimming control 50. A conductor 55 connects the secondary winding 43 of the nonlinear transformer 44 with the winding 72 of the nonlinear reactor 71, the windings 43 and 72 being in series circuit realtionship. The terminal 74 of the winding 72 provides a means for connecting the nonlinear reactor 71 in series circuit relationship with the high leakage reactance secondary 17.

The magnetic core structure 53 is built of a sufficient number of laminations to provide a relatively small cross-sectional area that makes the core readily saturable. In the illustrated exemplification of the invention, eight U-

shaped laminations are used, adjacent laminations being reversed to break the joints and being constructed of thin sections of grain oriented electrical steel.

The mangetic core structure **52** of the linear reactor **47** is built up of two adjacent stacks of E-shaped laminations **57** with the ends of their legs in an abutting relationship. The winding **51** is wound around a middle leg **58** formed by the juncture of the central legs of the laminations **57**.

In building up the magnetic core structure **73** of the nonlinear reactor **71**, small groupings of thin E-shaped laminations are stacked in an alternately staggered and inverted relationship. In the exemplification of the invention four laminations are used per grouping and a total of seven groupings are inverted and staggered as shown.

How the voltage spike is superimposed on the open circuit voltage across the lamp terminals will now be described. The total flux between the linear reactor **47** and the nonlinear transformer **44** is distributed between their respective cores **52, 53**. The variation of total flux is substantially sinusoidal and cycles at the frequency of the power supply. At the beginning of a cycle, saturation occurs very quickly in the legs of the core **53** of the nonlinear transformer **44**. The flux in the liear reactor **47**, however, increases slowly until the flux in the nonlinear transformer **44** passes the point of saturation at which time the flux in the linear reactor **47** undergoes a rapid increase. Since the flux in the core **53** of the nonlinear transformer **44** undergoes a very rapid change at the beginning of each half cycle, a voltage spike is generated in its secondary winding **43**. Since this voltage spike occurs approximately at the same time that the input lamp voltage from the dimming control **50** and ballast secondary **17** is at its maximum value and since the spike generated and the input lamp voltage are of the same polarity, the spike is superimposed on the sinusoidal input lamp voltage.

In view of the fact that the voltage across the primary winding **45** of the nonlinear transformer **44** increases as the slider **49** of the dimming control is moved away from a position of maximum brightness B, the spike generated in the secondary **43** will increase to maintain a fairly constant open circuit peak voltage at the lamp **10**. Thus, it is possible for the dimming control system to reliably operate the lamp **10** at a wide range of luminous intensity levels.

Referring now to FIGS. 5 and 6, the arrangement of the principal components in the dimming control system case **41** is shown. The power factor correcting capacitor **31** is located at one end of the case **41** and is separated from the ballast transformer **15** by an insulator **63**. As hereinbefore described, the core structure **21** is formed by the E-shaped laminations butting against the laminations of the central leg **22**. The coil structures **28** and **17** may be held against the central leg **22** by wedges (not shown).

In an adjacent portion of the case **41** and separated from the ballast transformer **15** by an insulator **65** is the nonlinear reactor **71**. The winding **72** is held securely against the central winding leg **61** by a wedge **62**.

The nonlinear reactor **71** is separated from the nonlinear transformer **44** by the insulator **59**. The coil structure **66**, which includes the primary winding **45** and secondary winding **43** is disposed around a leg **67** of the core structure **53** formed by alternately inverted U-shaped laminations. A U-shaped positioner **74** serves to firmly hold the coil **66** in a given location in the case **41**.

Separated from the nonlinear transformer **44** by an insulator **60** is the linear reactor **47**. The winding **51** is disposed about the middle leg **58** by two adjacent stacks of E-shaped laminations **57** as hereinbefore described. The linear reactor **47**, as well as the other components of the dimming control system, are embedded in a suitable potting compound, such as asphalt.

It is to be noted that none of the laminations employ any unusual configurations or have any narrow legs or bridged section. The laminations of the ballast transformer **15** are of the type commercially used for normal operation of fluorescent lamps. The core structures **21, 52, 53** and **73** are separate units. Thus, the dimming control system of this invention provides for the magnetic isolation, so far as is practically feasible, of all of the peaking and ballast elements of the system. It was found that such an arrangement results in an appreciable reduction in noise as compared to other dimming control systems of the electromagnetic type. The noise level versus dimming control output curves of FIG. 4 for the cold and hot condition of operation of the dimming control system of the invention indicate that the noise level does not appreciably rise over the entire dimming control output range. The dashed line curve is representative of the noise characteristic of a comparable electromagnetic dimming control system of the prior art. Therefore, the dimming control system of this invention is particularly suitable for many applications, such as, stage, auditorium, residential and funeral parlor lighting purposes where a low noise level is preferable.

The operation of the dimming control system of FIG. 1 will now be described in more detail. When the slider **49** of the dimming control **50** is at position B, the open circuit voltage across the primary and secondary voltages of the ballast transformer **15** are sufficient to fire the fluorescent lamp **10**. Once the lamp **10** ignites, the high leakage reactance of the secondary winding **17** of the ballast transformer **15** provides the necessary ballasting action required because of the negative resistance characteristic of the lamp **10**. The cathode heating windings **19, 20** are closely coupled to the primary winding **16** of the ballast transformer **15** and provide the filaments **12, 13** respectively with a substantially constant current for heating the cathodes of the lamp **10**.

It is to be noted, that when the slider **49** is in the position B, no voltage appears across the primary **45** of the nonlinear transformer **44** and the reactor **47** and no voltage spike is introduced by the secondary **43** into the lamp circuit. In effect, the primary **45** and the reactor **47** are by-passed and the lamp **10** operates in the normal manner.

As the slider **49** is moved away from the position of maximum brightness B, a progressively increasing voltage is being applied to the primary **45** of the nonlinear transformer **44** and the linear reactor **47**. Also, as the slider **49** is moved in this direction, the sinusoidal input voltage to the lamp **10** and the current being supplied to the lamp **10** correspondingly diminish. With a diminishing current supply to the lamp **10**, the energy emitted at the cathodes decreases and the fluorescent coating of the lamp receives a reduced amount of radiation with the result that the luminous intensity of the lamp declines.

Unless some means is provided in the dimming control system for firing the lamp **10**, it would normally stop discharging when the input voltage reaches a certain level. The peaking circuit provides the necessary voltage spike at each half cycle to refire the lamp. Since the voltage spike occurs at the frequency of 60 cycles per second, the operation of the lamp **10** is in effect continuous.

It is to be noted that as a decreasing input voltage appears across the lamp **10** to cause dimming, an increasing voltage is being applied across the primary **45** of the nonlinear transformer **44** and the linear reactor **47** to proportionately step up the voltage spike. Such an arrangement provides a substantially constant open circuit peak voltage for a wide range of the dimming control settings, and results in stable lamp operation at the selected levels of luminous intensity.

The stability of operation inherent in the dimming control system of the invention is evidenced by the open circuit voltage curves of FIG. 3. It is to be noted that open circuit peak voltage at the lamp terminals is substantially uniform over the entire range of dimmer control settings.

The nonlinear reactor **71** in series circuit relationship with the secondary **43** of the nonlinear transformer **44**

serves the purpose of eliminating a fluttering in the luminous intensity of the lamp which may occur. This flutter is illustrated by the sharp rise in curve A of FIG. 2. Such fluttering may occur at a point in the region of low power input to the lamp. The nonlinear reactor 71 functions to limit the lamp current when the power input is at critical low levels. As shown by the curve B of FIG. 2, the introduction of the nonlinear reactor 71 does not have an appreciable effect on the intensity levels but has the effect of "smoothing out" the curve. This is due to the fact that the lamp current is not appreciably reduced when the lamp is operated at the higher levels of luminous intensity because of the saturating characteristic of the reactor 71.

From the foregoing description, it should be apparent that a single peaking circuit of the invention and a single dimming control can be used to operate a plurality of lamps as well as a single lamp. In the embodiment illustrated in FIG. 1, a second secondary 18 is used in conjunction with the power factor correcting capacitor 31 for the purpose of reducing the size of the capacitor. As is well-known in the art, the power factor can be corrected by other methods without coupling the winding 18 with a ballast transformer.

While I have described above a particular embodiment of the invention, many modifications may be made. It is to be understood, therefore, that I intend by the appended claims to cover all such 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. Apparatus for operating a hot cathode fluorescent lamp at various light intensity levels regulated by a dimming control energized by an alternating current supply and having an adjustable tap, said apparatus comprising a ballast means having a primary energized by said alternating current supply and a high leakage reactance secondary, a peaking means including a linear reactor and a first nonlinear inductive device connected in series for producing a voltage spike in said nonlinear device variable in magnitude as the dimming control is regulated, a second nonlinear inductive device for eliminating flutter in light intensity at low dimming control settings, circuit means for applying a voltage across said serially connected linear reactor and first nonlinear inductive device, said first nonlinear device having a pair of output terminals for applying said voltage spike to said lamp and circuit means connecting said output terminals, said second nonlinear inductive device, said high leakage reactance secondary and said lamp in series circuit relationship with said adjustable tap.

2. Apparatus for operating a hot cathode fluorescent lamp at various light intensity levels regulated by a dimming control energized by an alternating current supply including a high and a low side and having an adjustable tap, said apparatus comprising a ballast means having a primary energized by said alternating current supply and a high leakage reactance secondary, a peaking means including a linear reactor and a nonlinear transformer having a primary and a secondary, a nonlinear reactor for eliminating flutter in light intensity at low dimming control settings, circuit means for connecting said adjustable tap, said primary of the nonlinear transformer, said linear reactor and the high side of the alternating current supply in series circuit relationship and circuit means for connecting said secondary of said nonlinear transformer, said nonlinear reactor, said high leakage reactance secondary, said lamp and said low side of said alternating current supply in series circuit relationship.

3. A peaking circuit for superimposing a voltage spike on an input voltage supplied to a hot cathode fluorescent lamp from an alternating current source and regulated by a dimming control having an adjustable tap, said lamp being connected across a ballast transformer having a primary and a high leakage reactance secondary, said peaking circuit comprising a nonlinear transformer including a primary, a secondary and a tap between said secondary and primary; said primary having a terminal for connecting with said adjustable tap; a nonlinear reactor connected in series with said secondary of the nonlinear transformer and having a terminal for connecting said serially connected nonlinear reactor and said secondary in series circuit relationship with said high leakage reactance secondary; and a linear reactor connected to said tap of the nonlinear transformer and having a terminal for connecting to said alternating current source.

4. A dimming control system for operating a hot cathode fluorescent lamp at various light intensity levels regulated by a dimming control energized by an alternating power supply including a low and a high side and having an adjustable tap, said system comprising a high leakage reactance transformer having a primary connected across said power source and a high leakage reactance secondary; a linear reactor; a nonlinear transformer having a primary and secondary, said linear reactor and said primary of the nonlinear transformer being connected in series across said adjustable tap and said high side of the power source; a nonlinear reactor for eliminating flutter in the light intensity for low dimming control settings; and circuit means for connecting said secondary of the nonlinear transformer, said nonlinear reactor, said high leakage reactance secondary, said lamp and said low side of the power source in series circuit relationship.

5. A peaking circuit for superimposing a voltage spike on an input voltage supplied to a hot cathode fluorescent lamp from an alternating current source and regulated by a dimming control having an adjustable tap, said lamp being connected across a ballast transformer having a primary and a high leakage reactance secondary, said peaking circuit comprising a nonlinear transformer having a core structure formed of alternately inverted U-shaped laminations including a primary and a secondary winding disposed on said core structure in autotransformer relationship and a tap disposed between primary and secondary windings, said primary having a terminal for connecting with said adjustable tap; a nonlinear reactor being connected in series with said secondary winding and having a terminal for connecting said secondary winding with said high leakage reactance in series circuit relationship; and a linear reactor connected to said tap of the nonlinear transformer and having a terminal for connecting to said alternating current source.

6. A peaking circuit for superimposing a voltage spike on an input voltage supplied to a hot cathode fluorescent lamp from an alternating current source and regulated by a dimming control having an adjustable tap, said lamp being connected across a ballast transformer having a primary and a high leakage reactance secondary, said peaking circuit comprising a nonlinear transformer including a primary, a secondary and tap between said secondary and primary, said primary having a terminal for connecting with said adjustable tap; a nonlinear reactor having a core structure formed of alternately inverted and staggered groupings of E-shaped laminations and a winding disposed on said core structure, said nonlinear reactor being connected in series with said secondary of the nonlinear transformer and having a terminal for connecting said serially connected nonlinear reactor and said secondary in series circuit relationship with said high leakage reactance secondary; and a linear reactor connected to said tap of the nonlinear transformer and having a terminal for connecting to said alternating current source.

7. Apparatus for operating a hot cathode fluorescent lamp at various brightness levels regulated by a dimming control energized by an alternating voltage supply including a high side and a low side and having an adjustable tap, said apparatus comprising a ballast means

having a primary energized by said alternating voltage supply and having a high leakage reactance secondary; a peaking means including a linear reactor, a nonlinear reactor and a nonlinear transformer having a primary and a secondary; circuit means for connecting said primary of said nonlinear transformer and said linear reactor in series circuit relationship between said adjustable tap and said high side of the alternating voltage supply; and circuit means connecting said secondary of the nonlinear transformer, said nonlinear reactor, said high leakage reactance secondary, said lamp and said low side of the alternating voltage supply in series circuit relationship.

8. Apparatus for operating a hot cathode fluorescent lamp at various brightness levels regulated by a dimming control energized by an alternating current supply including a high and a low side and having an adjustable tap, said apparatus comprising a ballast autotransformer having a primary energized by said alternating current supply and having a high leakage reactance secondary; a linear reactor; a nonlinear reactor; a nonlinear transformer having a primary, a secondary in autotransformer relationship with said primary and a tap between said primary and secondary; circuit means connecting said secondary of the nonlinear transformer, said nonlinear reactor, said high leakage reactance secondary, said lamp and said low side of the alternating current supply in series circuit relationship; and circuit means connecting said adjustable tap, said primary of the nonlinear transformer and said linear reactor and said high side of the alternating current supply in series circuit relationship, said ballast autotransformer, said linear reactor, said nonlinear reactor, and said nonlinear transformer being magnetically isolated from each other.

9. Apparatus for operating a hot cathode fluorescent lamp at various light intensity levels regulated by a dimming control energized by an alternating current supply, said apparatus comprising a ballast means for limiting the current supplied to said lamp and having a pair of terminals, a nonlinear reactor for eliminating flutter in light intensity at low dimming control settings, a peaking means for providing said lamp with a voltage spike to aid in firing said lamp and having a pair of output terminals, and circuit means for connecting said terminals of said ballast means, said nonlinear reactor, said output terminals of said peaking means and said lamp in series circuit relationship.

10. Apparatus for operating a hot cathode fluorescent lamp at various light intensity levels regulated by a dimming control energized by an alternating current supply and having an adjustable tap, said apparatus comprising a ballast means having a pair of current limiting terminals, a peaking means including a linear reactor and a first nonlinear inductive device connected in series for producing a voltage spike in said nonlinear device variable in magnitude as the dimming control is regulated, a second nonlinear inductive device for eliminating flutter in light intensity at low dimming control settings, circuit means for applying a voltage across said serial connected linear reactor and said first nonlinear inductive device, said nonlinear device having a pair of output terminals for applying said voltage spike to said lamp and circuit means connecting said output terminals, said second nonlinear inductive device, said pair of current limiting terminals and said lamp in series circuit relationship with said adjustable tap.

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