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J. S. SPIRA ETAL

3,422,309

FLUORESCENT LIGHT DIMMING SYSTEM

Filed Sept. 21, 1966

Sheet 1 of 2

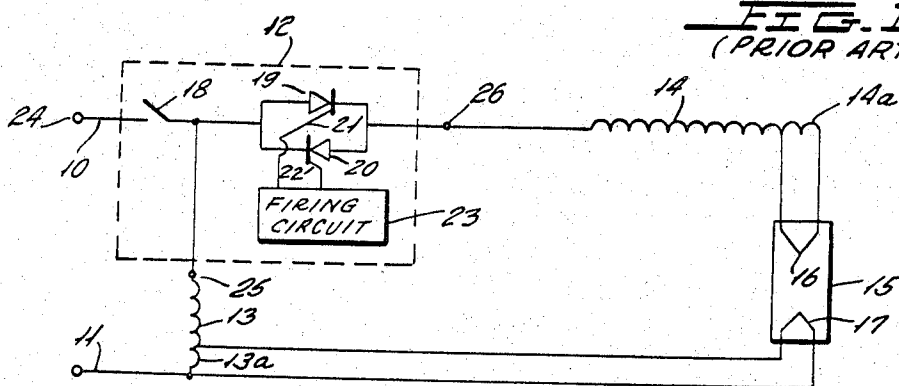
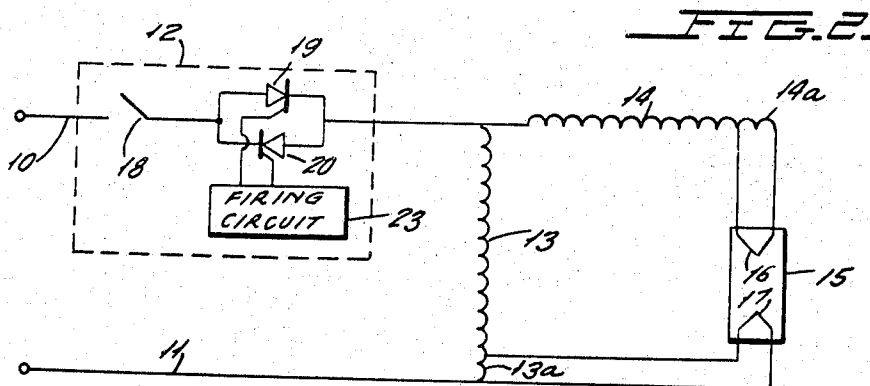
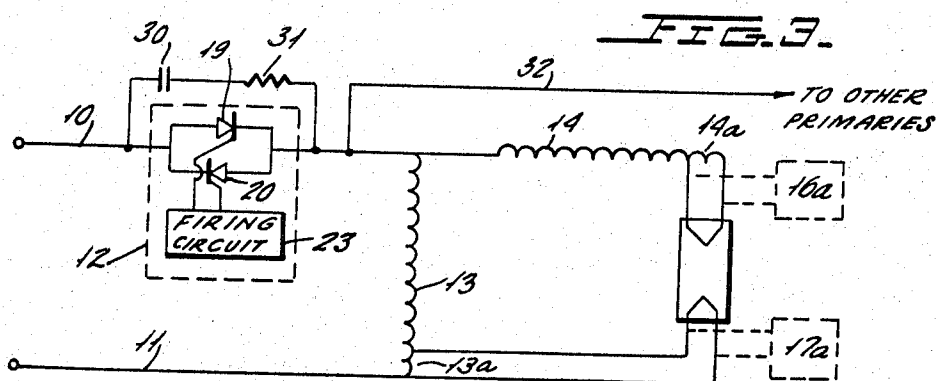
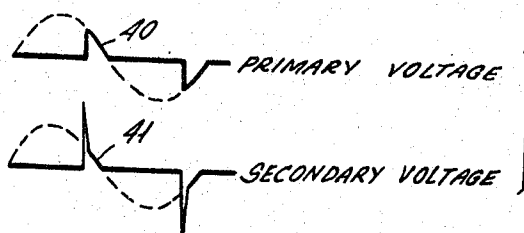


FIG. 4

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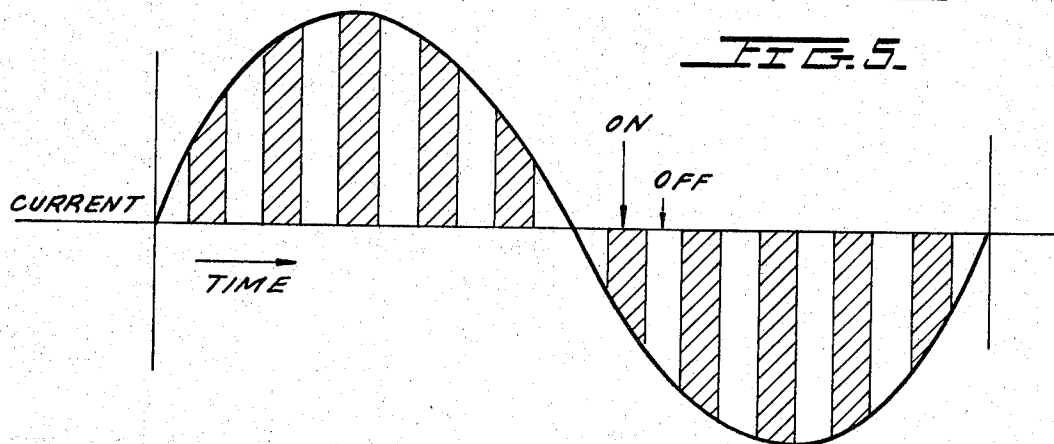


FIG. 6.

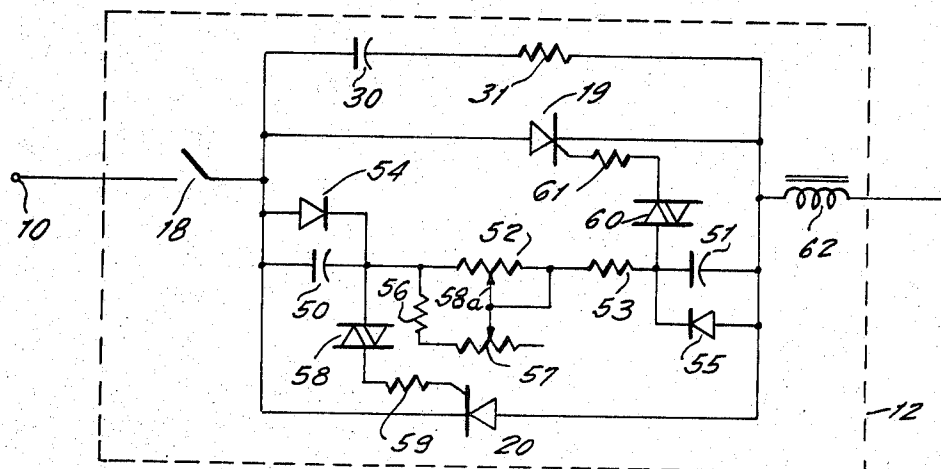
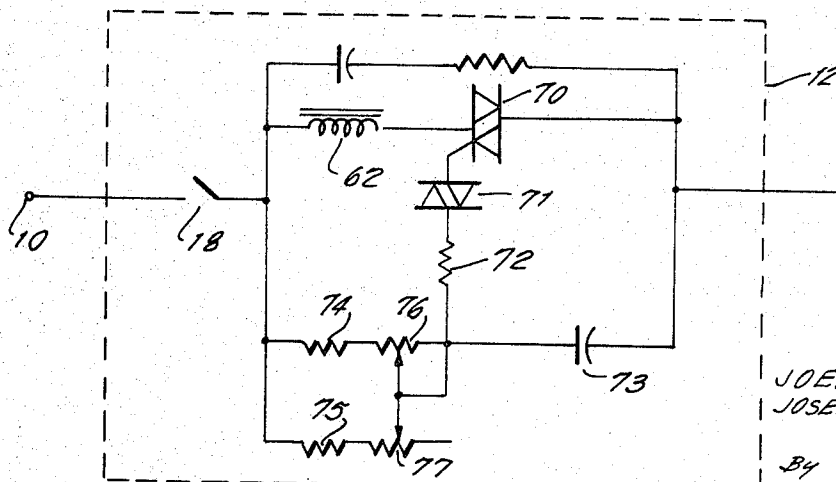


FIG. 7.



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FLUORESCENT LIGHT DIMMING SYSTEM

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Continuation-in-part of application Ser. No. 281,974, May 21, 1963. This application Sept. 21, 1966, Ser. No. 581,089

U.S. Cl. 315-194
Int. Cl. G05f 1/02

5 Claims

ABSTRACT OF THE DISCLOSURE

A fluorescent light dimmer for use in a two-wire system in which the dimmer has two leads connected in series with one wire of the two-wire system, while the ends of the two wires of the two-wire system are connected across the primary winding of a ballast. The ballast primary winding is connected in closed series relationship with a series ballast winding and a fluorescent tube. Each of the ballast windings have small winding sections connected to the cathode heaters of the fluorescent tube.

This invention relates to a novel dimming circuit for fluorescent lights, and more specifically relates to a novel dimming circuit wherein a controlled rectifier-type control means is connected between the input source of power and the primary winding of the fluorescent light ballast. This application is a continuation-in-part of copending application Ser. No. 281,974, now abandoned, filed May 21, 1963, entitled "Fluorescent Light Dimming System," and assigned to the assignee of the present invention.

Dimmer circuits for dimming fluorescent lights are well known to the art. Generally, such dimming circuits consist of some type of control means such as adjustable resistors or autotransformers which vary the input voltage to the primary of the ballast. Such methods are subject to severe limitations of operation, since a small decrease in the voltage applied to the ballast will not provide a voltage high enough to permit the fluorescent tube to strike an arc. Therefore, only a relatively small range of dimming is available before the fluorescent tube drops out of illumination. Generally, the best dimming ratio obtainable with this type of variable input voltage to the ballast primary is of the order of from 2-to-1 to 5-to-1, and is impractical.

The use of controlled firing elements such as thyratrons or controlled rectifiers have also been used for dimming fluorescent lights. In all cases, however, the controlling devices are connected between the ballast secondary winding and the lamp. While this gives satisfactory operation and a wide range of dimming, these arrangements require the use of special dimming ballasts with elaborate auxiliary apparatus.

More important than this, however, the installation of such devices requires that three wires be connected from the dimming control structure as will be described more fully hereinafter. Therefore, when a dimmer is to be applied to a presently existing two wire installation, new wiring must be run to the fluorescent lamp fixtures.

The principle of the present invention recognizes the desirability of the latter controlled rectifier-type control which was always used between the ballast primary and tube, which gives wide range control, and further recognizes the desirability of having a dimming control struc-

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ture between the primary of the ballast and the voltage source, which eliminates the need for running additional wires in a two-wire installation. More specifically, and in accordance with the invention, the controlled rectifiers of the first mentioned species of units is used in the position of the latter mentioned species of units. Thus, in accordance with the invention, a controlled rectifier-type dimming control is connected between the ballast primary and the input voltage source.

When using this novel connection, applicant provides a system which has the advantage of simplified installation in presently existing two-wire systems, and moreover improves the dimming ratios made available by controlled rectifier-type operations wherein a high voltage pulse will be transmitted to the tube even though the applied voltage is low in view of the intermittent type current conduction experienced with a controlled rectifier-type device.

Accordingly, a primary object of this invention is to provide a novel dimming control structure for fluorescent lamps which gives smooth dimming down to a very low light intensity in a simple and inexpensive manner.

Another object of this invention is to provide a novel high ratio light dimming structure for fluorescent lamps which can be easily installed in presently existing two-wire installations.

A still further object of this invention is to provide a controlled rectifier-type device such as a controlled rectifier or thyatron or similar intermittently conductive device which is connected between the ballast primary and input A-C line, and does not require a special ballast construction.

These and other objects of this invention will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 illustrates a typical prior art dimming arrangement for a fluorescent light which requires the connection of three wires.

FIGURE 2 illustrates a fluorescent light dimming circuit construction in accordance with the invention wherein the dimmer structure has only two terminals, and will provide a wide dimming range.

FIGURE 3 illustrates the circuit of FIGURE 2 along with the provision of a by-pass circuit for the dimming control circuit and an extending lead which could go to other primary circuits of other ballasts.

FIGURE 4 shows the wave form of the ballast primary voltage and ballast secondary voltage in the circuit of FIGURE 3.

FIGURE 5 shows the wave form of tube current which flows intermittently under the control of a gate controlled switch.

FIGURE 6 illustrates a particular firing conduit which could be used in FIGURES 2 and 3 to fire the controlled rectifiers and which is energized from within the two terminals of the light dimmer structure.

FIGURE 7 illustrates another embodiment of a firing control circuit which could be used in FIGURES 2 and 3 where the function of the controlled rectifiers is replaced by a Triac type device and is energized from the two terminals of the dimmer structure.

Referring first to FIGURE 1 which illustrates a prior art arrangement, I have illustrated herein an input A-C line which includes wires 10 and 11 wherein a dimmer structure 12, shown as a dotted box, is in series with line 11.

The dimming ballast of FIGURE 1 is a conventional

dimming ballast having a primary winding 13 which is connected across the lines 10 and 11, and a series winding 14 which is connected in series with lines 10 and 11 and with the fluorescent tubes, schematically illustrated as tube 15.

The tube 15 is constructed in the usual manner, and is provided with cathodes 16 and 17. Cathode 16 is energized from winding portion 14a of winding 14, while cathode 17 is energized from winding portion 13a of winding 13.

The dimming circuit control structure 12 may include therein an "on-off" switch 18 and two controlled rectifiers 19 and 20 which are connected in "back-to-back" arrangement. The gate circuits 21 and 22 of controlled rectifiers 19 and 20 are then connected to an appropriate firing control circuit 23 which will determine the point in each cycle at which rectifiers 19 and 20 will fire.

Tube 15 fires because windings 13 and 14 constitute a step-up auto transformer. Because of the step-up voltage, tube 15 stays ignited even after the voltage is cut down by controlled rectifiers 19 and 20.

In such an arrangement, it is possible to have dimming ratios of the order of 20-to-1. The circuit, however, is subject to the severe disadvantage that the dimmer control unit 12 has three terminals 24, 25 and 26. Thus, if the dimmer is to be installed in a presently existing two-wire system, it becomes necessary to run an additional wire in the system.

Other dimming arrangements have been proposed and used in the past wherein the dimmer structure does not utilize controlled rectifier-type elements, but has used an autotransformer, or the like, wherein the voltage applied directly to lines 10 and 11 and thus, the primary winding 13 of the ballast, is lowered to control the application of voltage to tube 15 and, thus, control its intensity.

As previously indicated, these arrangements provide a relatively low range of regulation before the tube drops out of illumination.

The principle of the present invention is shown in FIGURE 2, and involves the recognition that the controlled rectifier-type scheme, well known to the art and shown in FIGURE 1, can be connected in the manner of the prior art input voltage varying devices for varying the voltage applied to the ballast primary. However, this novel combination of two prior art devices results in a device which will give an extremely wide range of dimming, while at the same time, can be directly connected in presently existing two-wire systems.

Referring to FIGURE 2 where components similar to those of FIGURE 1 have been given similar identifying numerals, it will be observed that the only difference is that the dimmer structure 12 is connected in front of the ballast primary winding 13. This apparently minor modification of circuit arrangement, however, leads to a highly desirable dimmer arrangement which can be directly placed in existing two-wire systems, and gives a dimming ratio heretofore impossible to achieve with the regulation type devices available for two-wire systems.

FIGURE 3 illustrates a further modification of the novel arrangement of FIGURE 2 wherein a radio frequency interference capacitor 30, and a damping resistor 31 are connected in parallel with the dimmer circuit 12. In addition, FIGURE 3 indicates that further conductor means 32 can be provided for other ballast primary windings with the single dimmer 12 serving to dim a plurality of individual fluorescent lamps.

In operation, and with the controlled rectifiers in series with the ballast primary, the sharp turn-on characteristic of controlled rectifiers, or equivalent devices, will cause a voltage peak to appear across the tube 15 to fire the tube. This inductive voltage peak will occur at all firing angles of the controlled rectifiers 19 and 20, but is especially important at low firing angles where the peak voltage without the added conductive peak is low.

This can be best understood by reference to FIGURE 4

wherein the wave shape 40 indicates the voltage applied to primary winding 13, while wave shape 41 having the peaks thereon indicates the voltage on secondary winding 14. At this point of firing adjustment, it can be presumed that the light intensity is at the lowest adjustment value which has been found to be consistently of the order of 1% of the full light intensity available from the tube 15.

If desired, controlled rectifiers 19 and 20 may be gate controlled switches which are inserted in series with the ballast. Gate controlled switches are devices that can be turned on and off by a suitable signal applied to the controlling element of a controlled rectifier. A gate controlled switch such as the Texas Instruments Type TIX-120AO can be turned on and off by a suitable signal applied to the gate whereas a conventional controlled rectifier is turned on with the gate and turned off by removing anode current. Such a device can also be bilateral as compared to the unilateral controlled rectifier.

It is a fundamental property of fluorescent tubes that their light output is directly proportional to the arc current flowing through them. If for example the gate controlled switch were made to switch on and off in a manner indicated by FIGURE 5 the average current would be decreased and consequently the average light output would be decreased. Dimming is thereby obtained by varying the average current through the tubes. Again inductive voltage peaks are introduced at the leading edge of the conduction segment, thereby igniting the tube at low voltage levels. Further, fluorescent tubes increase in lumens/watt in direct proportion to frequency. Since turning the current on and off a few times during the cycle has the effect of increasing frequency, we employ the economic benefit of increased lumens/watt, i.e., more light for the same electricity.

Note that at this point there must be sufficient operating voltage for the heaters 16 and 17 of the tube, even though this is the point of minimum RMS voltage available. By way of example, there can be from 1 to 2 volts applied to the heaters by windings 13a and 14a at this point of minimum voltage regulation with the arc current being of the order of 0.05 to 2 milliamperes.

It should be further noted that the controlled rectifiers or equivalent controlled devices, must have a holding current which is less than the minimum current drawn by the ballast and tube.

In order to insure long life for the fluorescent tubes, the heater voltage should not increase excessively, nor should it be too low and preferably should be of the order of 2½ volts at striking. In accordance with the invention, however, the voltage applied to the heaters will vary as the dimmer regulates the applied voltage so that constant voltage means of any well known desired type should be provided for the heaters to prevent application of excessive voltages to the heaters. By way of example, well known saturable reactors can be connected in parallel with the heaters which will saturate after a given number of volt seconds have been applied thereto. Alternatively, and as shown in FIGURE 3 in dotted lines, auxiliary constant voltage sources 16a and 17a can be connected to filaments 16 and 17 respectively.

As indicated above, a capacitor 30 is provided for the suppression of radio frequency interference. A capacitor of this type can typically be of the order of 0.05 microfarad. However, since this capacitor may resonate with the inductance of the ballast causing an oscillation which would interfere with or destroy dimming action, the oscillation is preferably suppressed by connecting a small resistor 31 in series with capacitor 30 which could have resistance of the order of 100 ohms. Clearly, other oscillation damping means may be used.

Referring now to FIGURE 6, there is illustrated therein the details of the firing circuit 23 of FIGURES 2 or 3 which is contained in the dimmer structure 12 and is energized from the two terminals of the dimmer structure. In FIGURE 6, components identical to those components of

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FIGURES 2 and 3, are given identical identifying numerals. Thus, in FIGURE 6 the line 10 having the on-off switch 18 therein, as in FIGURE 2, is provided with the radio interference filter comprised of capacitor 30 and resistor 31.

FIGURE 6 additionally shows a specific firing circuit for the controlled rectifiers 19 and 20 which includes a series circuit composed of capacitors 50 and 51, variable resistor 52 and fixed resistor 53 which is connected in parallel with controlled rectifiers 19 and 20. Diodes 54 and 55 are connected in parallel with capacitors 50 and 51 respectively. Adjustable resistor 52 is provided with fixed parallel resistor 56 and adjustable resistor 57. Common wiper arms 58a, which are driven by any suitable adjustable knob, varies the resistance of adjustable resistor 52, the adjustable resistor 57 serving as a trimmer adjustment for adjustable resistor 52. The junction between capacitor 50 and resistor 52 is then connected to one end of trigger 58 which is connected in series with resistor 59 and the gate electrode of controlled rectifier 20. In a similar manner, the junction between resistor 52 and capacitor 51 is connected through the trigger 60 which is in series with resistor 61 and the gate of controlled rectifier 19. The complete assemblage of FIGURE 6 is then connected in series with reactor 62.

In operation capacitor 50 and adjustable resistor 52 serve as a phase control circuit for adjusting the firing point of controlled rectifier 20 by causing a pulse to be applied to the gate of controlled rectifier 20 once the voltage at the junction of capacitor 50 and adjustable resistor 52 reaches some predetermined value. The controlled rectifier 19 is triggered in an identical manner through the phase control circuit including capacitor 51 and trigger 60.

It is to be especially noted that the firing circuit shown in FIGURE 6 is connected within the two terminals available within the dimmer structure since the various components receive line voltage until the time that their respective rectifiers are fired. After their respective components have fired, the firing control circuit does not need voltage for the rest of the half cycle. Once the half cycle is completed for their respective control rectifiers, voltage will again appear across the phase components for the new half cycle to prepare it for its next firing duty.

Satisfactory results had been obtained with the circuit of FIGURE 6 using the following component values:

Capacitor 30	0.05 microfarad, 200 volts.
Capacitor 50	0.1 microfarad, 200 volts.
Capacitor 51	0.1 microfarad, 200 volts.
Resistor 31	150 ohms.
Resistor 52	700 kilohms.
Resistor 53	2.2 kilohms.
Resistor 56	220 kilohms.
Resistor 57	2 megohms.
Resistor 59	150 ohms.
Resistor 60	150 ohms.
Diode 54	Type 1N485.
Diode 55	Type 1N485.
Trigger diode 58	Type (G.E.) ST2X5.
Trigger diode 60	Type (G.E.) ST2X5.
Controlled rectifier 19	Type (G.E.) C22B.
Controlled rectifier 20	Type (G.E.) C22B.
Reactor 62	25 microhenries, 5 amperes.

FIGURE 7 illustrates a circuit similar to FIGURE 6 in which a triac device 70 replaces the function of the back-to-back connected controlled rectifiers 19 and 20 of FIGURE 7. In FIGURE 7, numerals identifying components similar to those of FIGURES 2, 3 and 6 are given the similar identifying numerals whereby the circuit is connected in series with switch 18 and has the parallel connected resistance-capacitance circuits 30-31.

In FIGURE 7, triac 70 is connected in series with the

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reactor 62 of FIGURE 6 while a symmetric firing circuit for triac 70 is composed of trigger diode 71 which is connected through resistor 72 to the phase control circuit composed of capacitor 73, resistors 74 and 75 and potentiometers 76 and 77. The operation of the circuit of FIGURE 7 is such that the adjustment of the main adjustment resistor 76 will cause a phase shift in the voltage appearing at the junction between resistor 76 and capacitor 73 so that a firing pulse will be transmitted through trigger diode 71 every half cycle dependent upon the amount of phase control which is desired in the firing of triac 70 to obtain the desired dimming operation.

The following values can be satisfactorily used for the circuit of FIGURE 7:

Capacitor 73	0.05 microfarad, 200 volts.
Resistor 72	150 ohms.
Resistor 74	1 kilohm.
Resistor 75	100 kilohms.
Potentiometer 76	115 kilohms.
Trimmer potentiometer 77	1 megohm.
Trigger diode 71	Type (G.E.) ST 2X5
Triac 70	Type (G.E.) 2J257/285
Reactor 62	25 microhenries, 5 amperes.

Although this invention has been described with respect to preferred embodiments thereof, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred therefore that the scope of this invention be limited not by the specific disclosure herein but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. In combination for a two-wire power system:
 - (a) first and second elongated conductors connected to an A-C source and constituting the sole electrical power distributing conductors of said system;
 - (b) a ballast transformer having first and second terminals for connection to a power source and having secondary heating winding means;
 - (c) a fluorescent tube having cathode filament means; said fluorescent tube connected to said ballast transformer; said cathode filament means connected to said secondary heating winding means;
 - (d) and a light dimming device having controllable conductive means therein for controlling the length of time current can flow therethrough in any half cycle of said A-C source having a first and second lead extending therefrom forming its sole electrical connection to a power source; said first lead of said light dimming device connected in series with one end of said first elongated conductor; said second lead of said light dimming device connected to said first terminal of said ballast transformer; said second terminal of said ballast transformer connected to one end of said second elongated conductor; whereby said light dimming device is connectable in a two-wire system without requiring installation of a third power conducting conductor connected to one of said first and second elongated conductors.
2. The combination of claim 1 wherein said controllable conductive means comprises a triac.
3. The combination of claim 1 wherein said ballast transformer contains a first winding portion and a second winding portion; the ends of said first winding portion defining said first and second terminals; said first winding portion, second winding portion and fluorescent tube connected in closed series relation.
4. The device substantially as set forth in claim 1

directly across said controllable conductive means; said radio filter means including a series connected capacitor and damping resistor.

5. The combination as set forth in claim 3 wherein said second heating winding means comprises winding portions of said first and second winding portions, respectively.

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U.S. Cl. X.R.

307—252; 315—199