United States Patent

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[54] **APPARATUS FOR MAINTAINING THE TEMPERATURE AND OPERATING A CALIBRATED LAMP IN A CONSTANT RESISTANCE MODE**
8 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** 315/255, 307/282, 307/297, 328/8, 315/257, 315/293, 315/311
[51] **Int. Cl.** H05b41/16, H05b 41/24
[50] **Field of Search** 307/282, 296, 297; 315/50, 57, 70, 86, 116, 194, 279, 282, 255, 257, 287, 291, 293, 297, 306, 308, 311; 328/8

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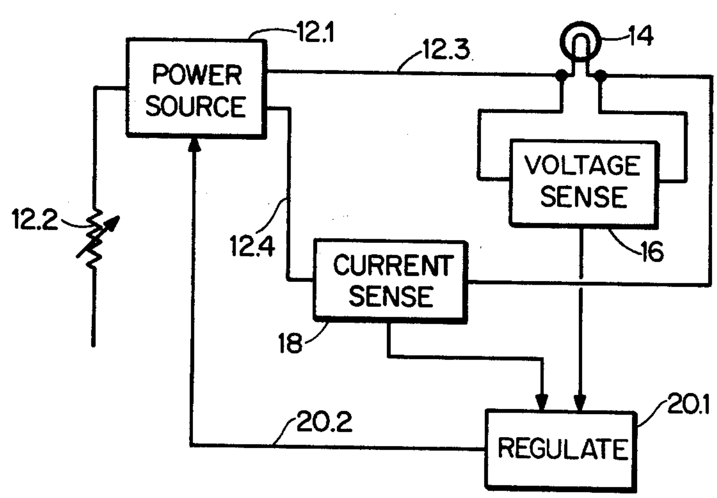
ABSTRACT: The resistance of an incandescent lamp filament, subject to ambient variations, is determined by sensing the current and voltage of the lamp filament. Since the resistance is a known function of the temperature of the filament, changes in the temperature of the filament are sensed to provide an output correction signal to a power supply which adjusts the input parameters of the lamp to maintain filament temperature constant.



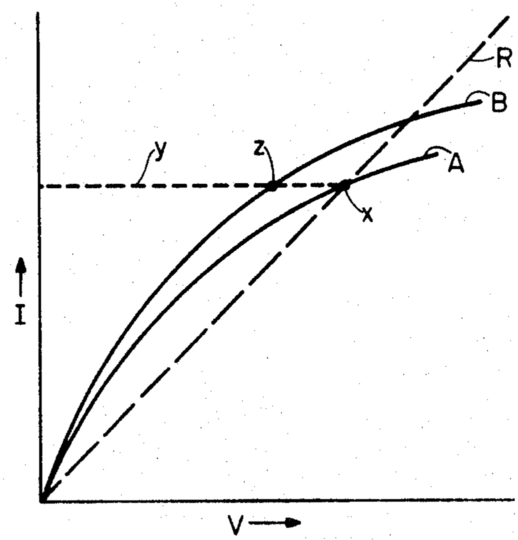


Fig. 1.

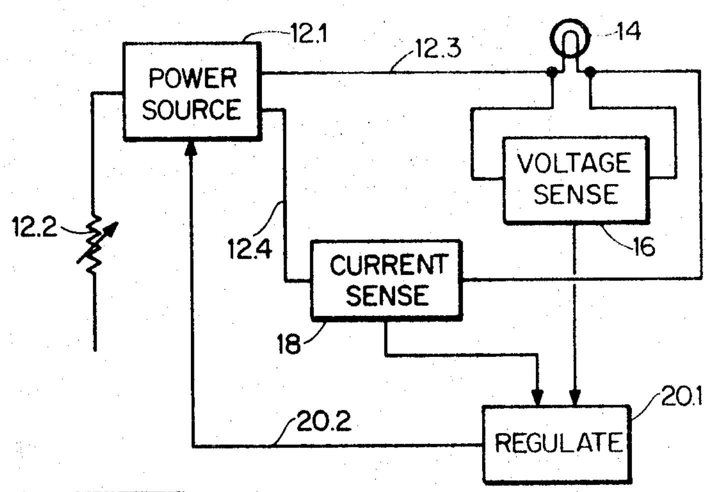


Fig. 2.

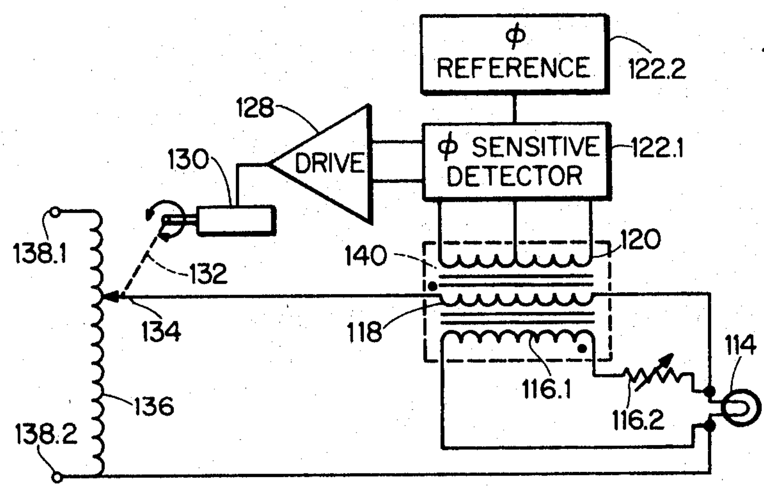


Fig. 4.

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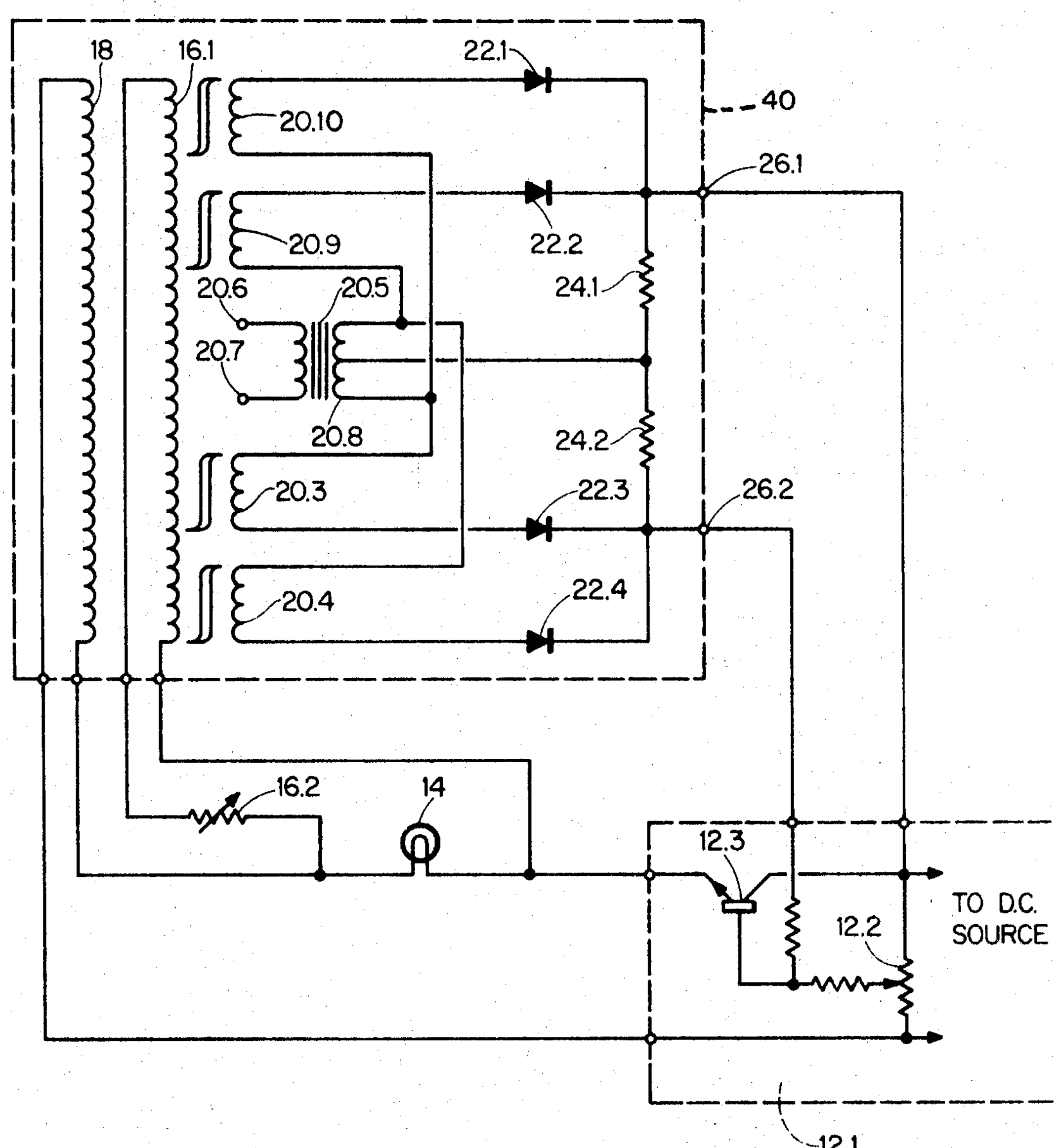

Fig. 3.

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APPARATUS FOR MAINTAINING THE TEMPERATURE AND OPERATING A CALIBRATED LAMP IN A CONSTANT RESISTANCE MODE

BACKGROUND OF THE INVENTION

This invention relates to regulating systems and more particularly to a system for maintaining the filament temperature of a calibrated light source at a predetermined, constant value.

When standard incandescent lamps are calibrated by the National Bureau of Standards the Bureau provides the user of the lamps with a sheet of instructions and procedures detailing the conditions under which the lamp is to be operated, and typically may include a tabulation of the calibrated light output for various filament currents. In some instances values of spectral irradiance are tabulated as a function of wavelength at a distance of 50 centimeters, as measured from the center of the lamp to the receiver for a lamp current of 8.30 amperes.

The instructions cover the use of the particular filament lamp issued as standards of spectral irradiance for a particular wavelength range. The spectral irradiance from the lamp is based on the spectral radiance of blackbody as defined by Planck's equation and has been determined through comparison of a group of similar lamps with (1) the NBS standards of spectral radiance, (2) the NBS standards of luminous intensity, and (3) the NBS standards of total irradiance.

THe instructions provided are quite explicit and require that the lamp be mounted in a specific orientation in the supplied holder which is constructed in such a manner as to reflect a negligible amount of radiated flux in the direction of the receiver or spectrometer slit. A black shield must be placed at a distance of about 4 feet to the rear of the lamp to intercept stray radiant flux along the radiometric axis and adequate shielding must be provided to intercept stray flux from other directions. These procedures are intended to improve subsequent user reproducibility of calibrated output.

However, the lamp may be subject to environmental changes which influence such reproducibility. For example, variations in temperature of the atmosphere immediately surrounding the lamp envelope, or unpredictable minor movements of air will tend to produce a measurable and undesirable change in output of the lamp.

It is well known that when a lamp is being operated, a condition of overall thermal equilibrium is established. Both the filament and the envelope achieve such conditions wherein power input is equal to power output and the equilibrium is manifested in stable temperatures at any point of both elements.

In the filament, the electrical power is converted to thermal power causing filament temperature to increase until output power (radiated, convected, and conducted) is equal to input power. The envelope is heated primarily through radiation from the filament.

A condition of thermal equilibrium of the envelope is achieved when the power received is balanced by the power transferred to the surroundings, such condition is again manifested by stable temperatures.

If now more convective power is transferred to the surroundings by the envelope (for example, by moving air or reduced ambient temperature), envelope temperature will decrease, and by the laws of radiation power transfer, more power will flow from filament to envelope. Under conditions of constant filament voltage or constant filament current, the resulting effect is reduced filament temperature. Since the optical output power is a function of the absolute temperature of the filament, any reduction in filament temperature produces a corresponding reduction of light output representing a departure from the calibrated condition.

It can be proven that a blackbody operating at 3000° K. must have its temperature maintained to an accuracy of $\pm\frac{1}{4}$° K. to maintain the spectral irradiance to $\pm$0.1 percent at 400 nanometers. This corresponds to about $\pm$0.01 percent of the resistance of a tungsten filament. It will therefore be obvious that to maintain a constant and repeatable light output, that the filament temperature must be held constant.

The electrical resistance of a filament is a well established function of its absolute temperature. Thus, a given filament temperature corresponds to a predictable and stable value of filament resistance. Therefore, reproducibility of light output is assured through operation at constant filament temperature which may be achieved by such electrical input adjustment as to maintain filament resistance constant.

It is well known that the resistance of a device is described by Ohms' law, namely: $R=E/I$ and that the resistance R is equal to the ratio of voltage-to-current used by the device. Therefore, one may determine filament resistance (R) through sensing filament voltage (E) and current (I).

It is, therefore, one object of the present invention to provide means for controlling the power emitted from a resistive impedance element by utilizing the relationship between the resistance of the element and the total emissive power therefrom.

Another object of the present invention is to provide a control circuit for controlling a standard, calibrated lamp utilizing the relationship between the total emissive power or lamp brightness and the lamp filament resistance.

Still another object of the present invention is to provide a control system for detecting subtle changes in resistive impedance of a calibrated lamp due to changes in surrounding conditions.

Yet another object of the present invention is to provide a control system for a standard calibrated lamp capable of detecting changes in ambient conditions in the vicinity of the lamp by detecting changes in the ratio of voltage-to-current (E/I) or resistance of the filament.

The features of my invention which I believe to be novel are set forth with particularlity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plot of current and voltage across the terminals of an incandescent, light standard;

FIG. 2 is a block diagram incorporating the features of my invention wherein a constant ratio of voltage to current is maintained in a calibrated lamp system;

FIG. 3 is a circuit diagram of one embodiment of a system incorporating the features of the invention for controlling the light from a calibrated light source by maintaining a constant ratio of voltage to current; and

FIG. 4 is a circuit diagram of another embodiment of a system incorporating the features of the invention for controlling the light from a calibrated light source by maintaining a constant ratio of voltage to current.

SUMMARY OF THE INVENTION

As will be hereinafter shown, my device senses the voltage applied to and the current passing through a high temperature resistive impedance, such as calibrated lamp, and treats the ratio of voltage to current sensed (E/I) as the parameter most indicative of the element temperature. This parameter, in the case of a lamp filament, represents a measure of the brightness of the lamp. By maintaining this ratio of E/I constant, in spite of variations in the lamp environment, I am able to achieve a constancy of light output far exceeding that resulting from the recommended method involving constant filament current.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a plot of current versus voltage wherein curve A may represent the current through the filament over a range of values of filament voltage under a set of constant lamp environmental conditions. It may be noted that as current (or voltage) is increased, filament resistance is increased as is evidenced by the curvature of the characteristic curve. At an opening point *x*, the filament is operating at a unique value of resistance as shown by dashed line *R*. This resistance in turn corresponds to a unique and particular filament temperature. The present invention provides circuitry for operating a lamp filament at the intersection of its characteristic *E—I* curve and line *R* of constant resistance.

Referring now to FIG. 2, there is shown, in block diagram form, power source **12.1** having leads **12.3** and **12.4** for supplying power to series connected lamp **14**. Voltage sensing means **16**, connected in parallel with lamp **14**, and current sensing means **18**, connected in series with lamp **14**, each is provided with an output which is applied as an input to regulator **20.1**. Regulator **20.1** produces a signal voltage at output lead **20.2** which is representative of the ratio of the voltage to the current (*E/I*) being used by lamp **14**. This correction or error signal voltage is fed to power source **12.1** as a means for varying a parameter of lamp **14**. A manual adjustment means **12.2** is provided in power source **12.1** to initially set the operating conditions of the power source while the error signal, appearing on lead **20.2** is the means for making a fine adjustment to maintain the *E/I* ratio or resistance of lamp **14** constant.

Referring now to FIG. 3 there is shown another embodiment employing the principles of my invention which utilizes direct current (DC) means for controlling the parameters of lamp **14** so that it will maintain its proper operating conditions. The components enclosed within dotted line **40** represent a magnetic amplifier wherein first control winding **18**, connected in series with lamp **14**, represents the current sensing means and second control winding **16.1**, together with variable resistor **16.2** is connected in parallel with lamp **14** and represents the voltage sensing means. As is well known in the art, magnetic amplifier **40** is provided with an excitation means **20.5** having a primary winding connected to terminals **20.6** and **20.7** to which is connected a suitable source of excitation (not shown). Center-tapped secondary **20.8** has one end thereof connected to the series connected load windings **20.2** and **20.3** and has its other end connected to the series load windings **20.1** and **20.4**. Each of the load windings **20.1**, **20.2**, **20.3** and **20.4** is connected to one end of respective diodes **22.1**, **22.2**, **22.3** and **22.4**. The other ends of diodes **22.1** and **22.2** are connected to one end of load resistor **24.1** and the common junction of the diodes and resistor is connected to output terminal **26.1**. Similarly, the other ends of diodes **22.3** and **22.4** are connected to one end of load resistor **24.2** with the junction common to these latter elements connected to output terminal **26.2**. To complete the circuit, the other ends of resistors **24.1** and **24.2** are connected together and to the center tap of excitation winding **20.8**.

In the operation of my device in this mode it will be seen that lamp **14** is provided with the appropriate value of current and voltage, from source **12.1**. Variable resistor **12.2** is provided in supply **12.1** for providing the initial settings of current and voltage to maintain the proper operating conditions. If, after the initial parameters are set, the ambient conditions change and the lamp is now subjected to a movement of air sufficient to reduce the temperature of the lamp envelope, the operating conditions will change. Assume for example, that as originally set up, the lamp is made to operate at a voltage and current that would correspond to point *x* of curve A (FIG 1). If now the ambient conditions change so that the lamp envelope temperature is lowered, the temperature of the filament would also change as the equilibria are upset. If now source **12.1** were a constant current source, it would be obvious that for the current to be maintained constant the operating point would be shifted along line *y* to curve B so that operation would be at point *z* corresponding to a different filament resistance and hence filament temperature. This would substantially alter the light output of lamp **14**, as there is a lower voltage appearing across the filament of the lamp and

indicating a change in filament resistance. However, the turns ratio of control windings **16.1** and **18** together with resistance **16.2** were appropriately selected so that any changes in sensed voltage to current ratio were manifested by the appearance of an error signal at the output terminals **26.1** and **26.2**. One may then use the error signal to maintain a constant ratio of *E/I* or resistance. The windings may be arranged so that if a positive going signal were to appear at terminals **26.1** with respect to **26.2** it would be indicative of a lamp load condition which indicates that the current passing through lamp **14** is too high. A negative voltage at the terminals would indicate that the current is too low while the amplitude of the signal would be proportional to the error. This error signal is then applied to the base of transistor **12.3** to regulate the current and voltage appearing at the output terminals of DC source **12.1** and thereby maintained the present *E/I* ratio so that lamp characteristic curve B (FIG. 1) will not be operated at point *w*.

It is known in the art that a magnetic amplifier of this type produces an output voltage proportional to the algebraic addition of the ampere-turns of the central windings. In the system configuration of FIG. 3, feedback control action tends to reduce the net ampere turns of control windings **16.1** and **18** toward zero. A null at output terminals **26.1** and **26.2** corresponds to a constant ratio of the *E* to *I* of lamp **14**.

Referring now to FIG. 4, there is shown another embodiment employing the principle of my invention and which operates the lamp in an alternating current (AC) mode. In this embodiment transformer **140**, indicated within dotted line is provided with winding **118** which represents the current sensing means and winding **116.1** which, together with resistor **116.2**, represents the voltage sensing means.

Operating potential is derived from autotransformer **136** which may be of the type known commercially as a "Variac." A source of AC potential (not shown) is applied to terminals **138.1** and **138.2** so that the AC potential appearing thereacross may be picked, at any suitable value, by moveable arm **134**. This potential is then applied through current sensing winding **118** which is in series with lamp load **114**. Transformer **140** is further provided with a center tapped sensing winding **120** for detecting changes in the sensed current and voltage used by lamp **114**. When slight changes in the operating parameters occur, the change will be marked by the appearance of an AC error voltage in winding **120**. The amplitude is proportional to the degree of unbalance. The voltage will be in phase or 180° out of phase with the line according to the sense of the unbalance. The resulting error signal is then applied to a phase sensitive detector **122.1**, the output of which is a DC signal which may have, for example, a positive value when conditions indicate a high current through lamp **114** and the negative value for low current through lamp **114**. As in the previous embodiment, the amplitude of the signal from detector **122.1** will be proportional to the error. This output error signal is then applied as an input to a drive on amplifier means **128** which, in turn, provides a signal at its output, suitable to operate servo or motor means **130**. The shaft of servo means **130** is coupled to the moveable arm **134** of autotransformer **136**, as indicated by dotted lines **132**, so that rotation of the shaft of servo means **130** will, with the appearance of an error signal at the output of detector **122.1**, appropriately vary the input parameters to lamp **114** and thereby reduce the error signal to zero and hence maintain the required constant *E/I* ratio.

While there has been described what is presently considered the preferred embodiment of my invention, it would now be obvious to all those skilled in the art that various other changes and modifications may be made therein without departing from the inventive concept contained herein and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim is:

1. Apparatus for maintaining the temperature of a lamp filament constant, comprising:

a source of potential connected to the filament for providing operating parameters of a given ratio thereto;

a plurality of sensing means connected in series and in parallel with the filament;

each sensing means detecting an operating parameter of the filament, and each deriving respective signal voltages therefrom representative of the sensed parameter;

means connecting the respective signal voltages to detecting means for sensing and for deriving an error signal in response to changes in the ratio of sensed parameters; and

means connecting the error signal to the source of potential to vary the operating parameters and maintain the ratio constant.

2. The apparatus of claim **1**, wherein:

the potential connected to the lamp filament is direct current; and

the operating parameters are filament voltage and filament current.

3. The apparatus of claim **2**, wherein;

the means sensing the voltage operating parameter and the means sensing the current operating parameter are a pair of magnetic amplifier control windings; and

output windings coupled to the control windings for generating a signal voltage representative of changes in the ratio of the sensed voltage and sensed current of the lamp filament.

4. The apparatus of claim **3**, further comprising:

a constant current power supply providing the voltage and current parameters; and

a series passing stage in series with the power supply output for detecting the changes in the ratio of sensed voltage to sensed current.

5. The apparatus of claim **1**, wherein:

the potential connected to the lamp filament is alternating current; and

the operating parameters are filament voltage and filament current.

6. The apparatus of claim **5**, wherein:

the means sensing the voltage operating parameter and the means sensing the current operating parameter are a pair of electromagnetically coupled transformer windings; and

an output winding coupled to the pair of windings for generating a signal voltage representative of the ratio of the sensed voltage to the sensed current of the lamp filament.

7. The apparatus of claim **6**, further comprising:

a variable output autotransformer, the input of which is connected to the source of alternating current the output of which is connected to one pair of windings; and

drive means connected to the output of the autotransformer for varying the operating parameters to the transformer.

8. THe apparatus of claim **7**, further comprising:

a phase sensitive detector connected to the output winding:

a source of reference phase voltage connected to the phase detector;

the phase detector combining the signal voltage and the reference phase voltage to derive an error signal responsive to the change in the ratio of sensed parameters; and

means connecting the output of the phase sensitive detector to the drive means to vary the operating parameters of the lamp filament.